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Maternal Mobile Phone Use During Mother–Child Interactions Interferes With the Process of Establishing Joint Attention

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Parental mobile device use while parenting has been associated with reduced parental responsiveness and increased negative affect among children. However, it remains unclear whether it can interfere with the process of acquiring social communication skills. Thus, this study sought to experimentally examine whether maternal mobile phone use while interacting with the child has an immediate effect on the frequency of mothers' and infants' joint attention (JA) behaviors, the likelihood that these behaviors will lead to JA episodes, and the duration of established JA episodes. Participants were a community sample of 114 (M_{age} = 11.36 months; 50% male) Israeli typically developing infants, in which most mothers were highly educated and living in two-parent families. Mother–infant dyads completed a modified still-face paradigm and were randomly assigned to one of three experimental conditions during the still-face phase: (a) mobile phone disruptions, (b) social disruptions, and (c) undisrupted play. Mother–infant interactions were coded for frequency of JA behaviors and duration of JA episodes. In dyads assigned to the mobile phone disruptions condition, infants produced more JA initiations, mothers were less likely to contingently respond to infant initiations, JA behaviors were less likely to result in established JA, and JA episodes were shorter compared to dyads in the two control conditions and the baseline free play phase. Findings suggest that maternal mobile phone use during face-to-face interactions with the infant can disrupt the process of establishing JA in ongoing mother–child interactions. Possible implications from this line of work for family digital media use are discussed.

Keywords: joint attention, mobile phone use, parent–child interaction, digital media

Parental mobile device use while parenting (PMU) has become deeply embedded in children's daily experiences, raising concerns about the potential impact of this phenomenon on children's development (McDaniel, 2019). A growing body of research suggests that PMU is associated with fewer verbal and nonverbal interactions and lower parental responsiveness to children's bids for attention (Davidovitch et al., 2018; Hiniker et al., 2015; Radesky et al., 2014; Vanden Abeele et al., 2020; Wolfers et al., 2020). In social communication development, reciprocal social exchanges with caregivers serve as a primary socialization mechanism that supports children's social skills (D'Entremont & Seamans, 2007). Together, parent–infant dyads establish shared attentional states by initiating and responding to their partner's cues, enabling infants to practice their emerging joint attention (JA) abilities. JA develops rapidly toward the end of the first year, when children are increasingly able to join their social partner's focus of attention and direct the attention of another to an object/event of interest (Carpenter et al., 1998; Mundy & Gomes, 1998). Thus, studying the effects of PMU on 12-month-old infants' JA abilities offers a test of how mobile disruptions can interfere with the emergence of a core developmental milestone.

The Development of JA

JA refers to shared attentional states between two people focused on an object/event of interest (i.e., JA episodes), as well as nonverbal social communication behaviors that precede these shared attentional states (i.e., JA behaviors; Tasker & Schmidt, 2008). JA behaviors are often categorized into two types (Mundy et al., 2007): *responding to JA* (RJA; following the gaze shift/head turn or pointing gestures of another to locate an object/event of interest) and *initiating JA* (IJA; making eye contact and gesturing to

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direct the attention of another to an object/event of interest). RJA behaviors emerge in the first months of life when infants share eye-to-eye gazes with their caregivers (Butterworth & Jarrett, 1991). By age 12 months, most infants begin to exhibit IJA behaviors (using gaze and/or pointing/showing gestures), but the developmental course is quite variable until the consolidation of JA skills at around 18 months of age (Carpenter et al., 1998). Tasker and Schmidt (2008) suggested that JA is best conceptualized as a process involving a sequence of complementary actions that occur during caregiver–child interactions. Specifically, JA is operationalized in terms of a sequence of three antecedent communicative acts (initiation act, response, response to the response) that may result in a JA episode (established JA; EJA). This approach goes beyond the examination of discrete JA behaviors as it focuses on how effective these behaviors are in achieving and sustaining JA episodes (Tasker & Schmidt, 2008).

JA is considered a hallmark of social communication skills and has been related to later receptive and expressive language abilities, as well as to multiple aspects of social cognition, such as the understanding of others' mental states (Brooks & Meltzoff, 2015; Toth et al., 2006). Deficits in JA are often seen among individuals with autism spectrum disorder, but individual differences in JA contribute to variability in outcomes among both high-risk and typically developing infants (Meindl & Cannella-Malone, 2011). Thus, there is considerable impetus for identifying environmental factors that can support or impede the development of children's JA.

During infancy, shared attentional states between infants and their caregivers support the maturation and consolidation of infants' JA behaviors (Bakeman & Adamson, 1984). Infant–caregiver interactions that are characterized by sensitivity to the infant's focus of attention, affect, and developmental stage serve as an ideal platform on which infants can practice and elaborate on their emerging JA abilities (D'Entremont & Seamans, 2007). For example, maternal sensitivity toward the infant (i.e., warm and responsive interactions) has been positively related to infants' concurrent and subsequent JA behaviors (Gaffan et al., 2010; Hobson et al., 2004). Conversely, mother–child interactions that are characterized by low responsiveness to infants' social cues have been related to less time spent in JA with the caregiver (Schechter et al., 2010; Raver & Leadbeater, 1995).

Parental Mobile Phone Use During Parent–Child Interactions

There is ample evidence that most parents in Western societies frequently use their mobile phones while caring for their children (Wolfers et al., 2020). For example, a recent observational study conducted in the United States and Israel reported that most parents in both countries (74%–79%) used their smartphones while spending time at the playground with their children, with approximately a third of parents using their phones for prolonged periods (40% to 100% of the time; Elias et al., 2020). A survey study conducted in Germany and Switzerland further showed that 60% of parents reported using their smartphones while caring for their children (Wolfers et al., 2020). These findings have motivated a growing body of research regarding the repercussions that PMU may have on both parents and children.

PMU and Parental Behavior

Overall, findings from observational studies consistently show that PMU is associated with reduced verbal and nonverbal communication with children, slow responses to children's engagement attempts, and less sensitive eventual responses (Abels et al., 2018; Davidovitch et al., 2018; Elias et al., 2020; Hiniker et al., 2015; Radesky et al., 2014; Wolfers et al., 2020). McDaniel (2020) suggested that there are two main ways by which PMU can impact parents' behavior. The first is the *distraction* caused by mobile device use, which hinders parents' ability to identify their children's cues and respond promptly (Abels et al., 2018; Radesky et al., 2014). PMU can also cause continuous *disruptions* to the flow of the parent–child interaction. This phenomenon, which has been termed "technoference," refers to the interruptions in interpersonal interactions that occur due to the use of mobile technology devices (McDaniel, 2015). Mobile phone use occurs in brief, intermittent bursts (Radesky et al., 2020) that can create unexpected "breaks" in parent–child interactions during which the child is abruptly excluded from the interaction and the parent is less able to appropriately respond to the child's cues (Kildare & Middlemiss, 2017).

PMU and Children's Behavior

Observational studies examining the immediate effect of PMU on children's behavior show that young children exhibit negative emotions such as frustration, anger, and withdrawal while their caregivers are absorbed with their mobile devices in playgrounds and restaurants (e.g., Elias, 2020; Radesky, 2014). Recently, researchers have adapted the classic still-face paradigm (SFP; Tronick et al., 1978), which simulates an extreme case of maternal unresponsiveness, to experimentally examine the effects of PMU on children's behavior (Myruski et al., 2018; Rozenblatt-Perkal et al., 2022; Stockdale et al., 2020). The classic SFP includes three phases: parent–child free play, still face (the parent becomes completely unresponsive with a flat expressionless face), and a reunion phase in which play is resumed (Tronick et al., 1978). In the modified SFP, parents are asked to be fully absorbed in a mobile device during the still-face phase of the paradigm and become unresponsive to their children. The findings from these studies mirror the classic still-face effect, with young children expressing increased negative affect, decreased positive affect and toy exploration, and more social bids toward the caregiver during the modified still-face phase (Myruski et al., 2018; Stockdale et al., 2020). Some of these effects were carried over to the reunion phase. In a recent study, we used a modified version of this task to compare infants' changes in heart rate and negative affect between the three phases and between three conditions: mobile phone disruption (PMU), social disruptions, and undisrupted play (Rozenblatt-Perkal et al., 2022). Results showed that infants in the mobile disruptions condition exhibited increases in heart rate and negative affect during the disruption phase, followed by a decrease in the resume play phase. Infants in the social disruptions and undisrupted play conditions showed significantly less physiological and behavioral reactivity (Rozenblatt-Perkal et al., 2022). These findings demonstrate that young children are highly sensitive to the disruptions to the flow of social interactions that occur during PMU. Experimental work further shows that these disruptions can inhibit children's language learning. In this regard, Reed et al. (2017) demonstrated that 2-year-old children failed to learn new words that were taught by parents during segments that were interrupted by a mobile phone call. Conversely, Konrad et al. (2021) found that experimentally induced text interruption to the parent–child interaction did not affect imitation learning in toddlers, although higher reported maternal mobile-phone reliance was associated with poorer overall imitation abilities. Thus, PMU may have cascading effects on children's ability to acquire social communication skills within the parent–child context.

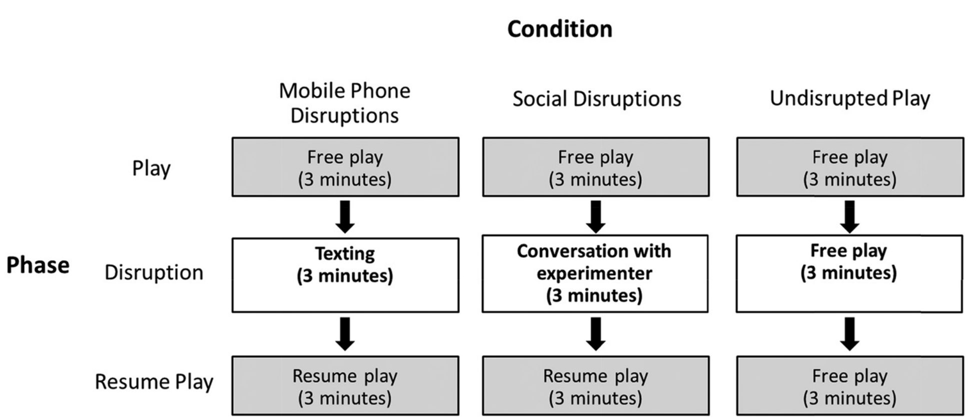
Although the results from the studies above confirm that PMU can impact children's social-emotional functioning, it is possible that the effect of PMU is similar to other types of disruptions that occur during parent–child interactions. Previous research has noted that parents tend to be involved in several other non-child-directed activities while caring for their children, such as reading, eating, and social interaction (Abels et al., 2018). However, PMU may be associated with larger decreases in parental responsiveness than these other activities as it demands higher concentration and is often prolonged (Vanden Abeele et al., 2020). Being engaged in a social conversation, for example, may enable parents to flexibly alternate their attention between the infant and the conversation and continue responding to the infants' social bids (Vanden Abeele et al., 2020). Additionally, by age 12 months, infants are able to perceive and understand certain aspects of a social conversation and even learn from third-party conversations (e.g., Oshima-Takane et al., 1996). For example, by 12 months of age, infants selectively attend to the speaker of social conversations (von Hofsten et al., 2009), make gaze shifts between the actors based on the flow of a social conversation (Augusti et al., 2010), and expect communicative actions to be directed at a third-party listener (Thorgrimsson et al., 2015). Conversely, when a social partner is engaged with the mobile device, the context may be less clear for infants and more excluding, plausibly leading to elevated distress. Indeed, in a recent study, we showed that infants demonstrate higher increases in heart rate and negative affect when exposed to PMU than when exposed to a social disruption in which a research assistant engaged the mother in a conversation (Rozenblatt-Perkal et al., 2022). However, to better understand the mechanism that underlies infants' responses to PMU, it is important to further examine how dyadic social processes unfold during PMU.

The Current Study

Although there is clear evidence that PMU is associated with reduced parental responsiveness and increased negative affect among children, it remains unclear whether it can interfere with the process of acquiring early social communication skills. By applying a process approach to conceptualizing and measuring JA (Tasker & Schmidt, 2008), we examined whether PMU has immediate effects on the frequency of infants' and mothers' JA behaviors (i.e., IJA and RJA) and the duration of JA episodes (EJA). We also examined whether JA behaviors are less likely to result in JA episodes during PMU.

Using a cross-sectional research design, we utilized a modified SFP that was recently validated in a paper using data collected in the current study (Rozenblatt-Perkal et al., 2022). Specifically, we made two main modifications to Myruski et al. (2018). First, instead of asking mothers to interact only with the mobile device and become unresponsive to the infant during the modified still-face phase, we sent them text messages and asked them to reply with no further instructions regarding the interaction with the infant. We argue that repeated disruptions in parent–child interactions in which mothers go "in and out" of the interaction intermittently more closely mirror infants' daily experiences with PMU (Konrad et al., 2021). This also enabled us to examine whether and how mothers continue to be involved in the process of establishing and maintaining JA despite the mobile phone disruptions. Second, we added a between-groups control condition in which the mobile phone disruptions phase was swapped by a phase in which a research assistant posed similar questions to the mothers in a verbal manner (i.e., social disruptions condition). Finally, we added a between-groups control condition of undisrupted mother–-child free play, as in Konrad et al. (2021), to account for changes that occur in social interactions through time (i.e., undisrupted play condition). Figure 1 presents a schematic description of the three experimental conditions and phases. Our hypotheses were as follows.

Figure 1
Schematic Description of the Three Experimental Conditions and Phases



Note: Adapted from "Infants' physiological and behavioral reactivity to maternal mobile phone use–An experimental study," by Y. Rozenblatt-Perkal, M. Davidovitch, and N. Gueron-Sela, 2022, *Computers in Human Behavior, 127*, pp. 107038. Copyright 2022 by Elsevier. Adapted with permission.

Hypothesis 1

Based on previous research showing that infants display increased social bids toward the caregiver during mobile device disruptions (Myruski et al., 2018; Stockdale et al., 2020), we hypothesized that infants assigned to the mobile phone disruptions condition would exhibit an increase in IJA behaviors during the disruption phase compared to the free play phase, as well as in comparison with infants assigned to the social disruptions and undisrupted play conditions in this phase of the experimental paradigm.

Hypothesis 2

Observational studies have shown that mothers exhibit reduced verbal and nonverbal communication with their children while using their mobile phones (Abels et al., 2018; Radesky et al., 2014). Therefore, we predicted that mothers assigned to the mobile phone disruptions condition would exhibit a decrease in IJA behaviors during the disruption phase compared to the free play phase, as well as in comparison with mothers assigned to the social disruptions and undisrupted play conditions in this phase of the experimental paradigm.

Hypothesis 3

Previous research has also shown that mobile device use is associated with slow responses to children's engagement attempts and less sensitive eventual responses (Abels et al., 2018; Hiniker et al., 2015; Wolfers et al., 2020). Thus, we predicted that mothers assigned to the mobile phone disruptions condition would be less likely to contingently respond (produce RJA behaviors) to their infants' IJA behaviors during the disruption phase compared to the free play phase, as well as in comparison with mothers assigned to the social disruptions and undisrupted play conditions in this phase of the experimental paradigm.

Hypothesis 4

As mentioned above, previous research using the modified SFP found increases in children's social bids toward the caregiver (Myruski et al., 2018; Stockdale et al., 2020). Therefore, we predicted that infants would continue to be vigilant to their mothers' behavior during all phases and conditions and that there will be no differences in infants' contingent responses to maternal IJA behaviors between the experimental phases and conditions.

Hypotheses 5 and 6

Findings from naturalistic observational studies have noted that when parents used their mobile phones, their responses to their children's bids were slower, showed less affect, and were less likely to prioritize the child over other activities (Vanden Abeele et al., 2020). In addition, parents were more likely to merely show awareness rather than to interact following their children's bids when using a phone than when not using a phone (Abels et al., 2018). Based on these findings, we suggest that the process of establishing and sustaining JA will be compromised in the mobile disruption condition. Specifically, mother–child dyads assigned to the mobile phone disruptions condition will exhibit lower JA success rates (i.e., infant and mother IJA behaviors will be less likely to lead to JA episodes) in the disruption phase compared to the free play phase and to dyads in the social disruptions and undisrupted play conditions in this phase of the experimental paradigm (Hypothesis 5). In addition, mother–infant dyads assigned to the mobile phone disruptions condition will exhibit a decrease in the length of JA episodes during the disruption phase compared to the free play phase, as well as in comparison with dyads assigned to the social disruptions and undisrupted play conditions in this phase of the experimental paradigm (Hypothesis 6).

Method

Participants

The study protocol was reviewed and approved by the Human Subjects Research Committee at Maccabi Health Care Services (study title: "Exploring the Behavioral and Physiological Implications of Parental Mobile Use for Mother–Child Interactions"; protocol no. 0012–19-MHS). One hundred twenty-two mothers and their infants (61 male) were recruited to participate in the study through advertisements on 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 children diagnosed with neurodevelopmental disorders. Data from eight participants were excluded from the analysis because of (a) belated maternal reporting of diagnosed psychiatric conditions (n = 5), (b) equipment failure (n = 2), and (c) excessive infant crying during the test session (n = 1). There were no differences in exclusion frequency between experimental conditions. Thus, the final sample for the current analysis included 114 mother–child dyads.

The demographic characteristics of the study participants are presented in Table 1. Mean child age was 11.36 months (SD = 1.55), and the mean maternal age was 32.49 years (SD = 3.78). Most of the mothers in the sample were born in Israel (75.4%) and had a college degree (76.2%). No significant differences were found between the groups in terms of demographic characteristics.

Design

Data were collected during a laboratory assessment. Participants were randomly assigned to one of three experimental conditions: mobile phone disruptions (n = 38), social disruptions (n = 35), and undisrupted play (n = 41). All three conditions started and ended with a 3-min mother–child free play, and the manipulation occurred in between them: (a) mobile phone disruptions: an experimenter sent mothers text messages and mothers were instructed to reply with no further instructions regarding the interaction with the infant; (b) social disruptions: an experimenter entered the room and presented the same questions verbally; and (c) undisrupted play: mother–child free play (see Figure 1). A detailed description of the task can be found in Rozenblatt-Perkal et al. (2022).

Measures

Coding JA Behaviors and Episodes

Mother and infant behaviors were coded using the Noldus Observer XT 14.0 software, guided by a coding protocol developed by Tasker and Schmidt (2008). The following measures were

Table 1
Sample Demographic Characteristics by Group

Variable	Mobile phone disruptions (n = 38)	Social disruptions (n = 35)	Undisrupted play (n = 41)	Total (N = 114)	Test statistics
Infant age, months, M (SD)	11.02 (1.51)	11.4 (1.58	11.65 (1.5)	11.36 (1.55)	F = 2.236
Infant gender, male, n (%)	19 (50)	17 (48.6)	21 (50)	57 (50)	χ^2 = .421
Mother characteristics					
Age, M (SD)	32.75 (3.96)	32.43 (3.25)	32.31 (4)	32.49 (3.78)	F = 3.833
Married, n (%)	32 (86.5)	32 (91.4)	38 (90.5)	102 (89.4)	χ^2 = 4.19
Country of origin					χ^2 = 1.75
Israel	27 (73)	29 (82.9)	30 (71.4)	86 (75.4)	
Other	9 (24.3)	5 (14.3)	11 (26.2)	25 (21.9)	
Education level, n (%)					F = 8.666
High school or less	2 (5.4)	3 (8.6)	7 (16.7)	12 (10.5)	
Professional training	2 (5.4)	3 (8.6)	7 (16.7)	12 (10.5)	
Undergraduate degree	20 (54.1)	17 (48.6)	17 (40.5)	54 (47.3)	
Graduate degree	12 (32.4)	11 (31.5)	10 (23.8)	33 (28.9)	
Income, n (%)					F = .58
Low	3 (8.1)	4 (11.4)	3 (7)	10 (8.7)	
Below average	13 (35.1)	12 (34.3)	18 (42.8)	43 (37.7)	
Average	11 (29.7)	11 (31.4)	13 (31)	35 (30.7)	
Above average	8 (21.6)	7 (20)	7 (16.7)	22 (19.2)	

calculated and used in the current analysis: mother and child total IJA behaviors, mother and child contingent RJA, JA success rate, and total duration of JA episodes.

JA Behaviors.

IJA Behaviors. Initiation acts were defined as communicative behaviors (verbal and nonverbal) that were not part of the current focus of the interaction and were directed at a social partner to draw and direct their attention to an object/event of interest. IJA behaviors included gesture functions to invite or elicit a social partner's attention, such as showing, pointing, or alternating eye contact between an object and the social partner. If more than one IJA behavior focused on the same object/event occurred within a 5-s interval, this was recorded as one IJA behavior. Two types of initiation acts were coded: acts performed by the mother (MIA) and acts performed by the child (CIA). The occurrence of each of these behaviors was recorded throughout the experimental task. MIA and CIA total scores were created by calculating the total IJA behaviors that occurred in each phase in the experimental paradigm. To control for slight variability among dyads in the length of the second experimental phase, we created relative frequencies for each of the IJA variables by multiplying the absolute frequency of IJA behaviors by 3 (the total number of minutes the dyads were supposed to be observed for in the second phase) and dividing by the total number of actual minutes observed (Tasker et al., 2010).

Contingent RJA. The contingent RJA measure refers to the likelihood that one partner's IJA would be followed by the other partner's RJA within 5 s. The computation of this measure included two steps. First, we recorded the occurrence of RJA behaviors of any type within 5 s from the IJA behavior, separately for mothers and children. Responses to JA were defined as behavioral or communicative actions that served to acknowledge the initiation act within 5 s of its occurrence. The recipient's response reflects recognition—or the lack thereof—of the initiation action directed at them. Examples of RJA behaviors included gaze orienting (i.e., shifting gaze toward the initiation act), imitation (i.e., acts that match or repeat the social partner's vocal, facial, gestural, or motor behavior, e.g., the child places the ball on their head while looking at the mother, the mother then places the ball on her head), elaboration and expansion of the interpersonal topic such as simple comments and commentary (e.g., child shows mother a ball and mother replies, "Yes, this is a ball"), affective information (e.g., child points at a picture of a dog in the book and mother replies, "The doggy is sad"), describing behaviors or actions (e.g., child blows soap bubble and makes eye contact with mother and mother replies, "You blew a bubble!"). Two types of responses were coded: responses performed by the mother (MR^1) and responses performed by the child (CR^1). Additionally, third-order child and maternal responses were coded (CR^2 and MR^2, respectively), that is, responses produced by the social partner who initiated communication within 5 s from the social partner response. The occurrence of each of these behaviors was recorded throughout the experimental task.

In the second step, measures of maternal and infant contingent RJA behaviors were calculated using transitional probabilities, calculated via state-lag sequential analysis using the Noldus Observer program. A transitional probability was calculated based on the likelihood that one partner's RJA behavior was the next behavior to directly follow the other partner's IJA behavior. In other words, this measure reflects the probability that a partner's IJA will be successful in eliciting a response from the other partner. These probabilities were then averaged for each phase to produce two separate maternal and infant contingent RJA scores.

JA Episodes. JA was considered established when the following sequence of communication exchanges occurred: (a) performance of initiation act by the mother or the child, (b) response by the social partner within 5 s, (c) response by the social partner who initiated communication within 5 s to indicate awareness of the partner's shared attention, and (d) the social partners remain visually and/or communicatively focused on the object, activity, or event for at least 3 s. At this point, the social partners are considered to have EJA. JA was considered terminated when one of the social partners performed a termination act and remained off topic for more than 5 s. Termination acts were any behavioral and communicative acts resulting in threatened or actual termination of the JA episode and included disinterest in the current focus of attention or the initiation of a new object, activity, or event. Notably, if the social partner's attention was regained to the current focus of attention within 5 s of the performance of the termination act, the JA episode was continued and not considered terminated. Two types of termination acts were coded: termination acts performed by the mother and termination acts performed by the child. The termination codes were used to define the end of JA episodes.

JA Success Rate. JA success rate refers to the probability that IJA behaviors will eventually result in a JA episode, reflecting how effective the JA behaviors were in achieving JA episodes (Tasker & Schmidt, 2008). A measure of JA success rate was calculated via time lag sequential analysis based on the likelihood that one partner's IJA behavior will lead to EJA within 13 s (the time frame defined for the sequence that precedes EJA, as described above). Two separate mother and infant JA success rate scores were calculated for each phase.

Total Duration of JA Episodes. This measure reflects the total time that the dyad was able to sustain JA. We calculated the proportional duration of JA episodes for each phase by dividing the total duration of EJA at each phase by the total minutes of the phase.

Reliability. All videotaped interactions were coded independently by two trained coders. To assess interrater reliability, 20% of the videotapes were randomly selected and coded by both coders. Intercoder reliability was calculated for each JA measure, and all reported behavioral domains showed good interrater agreement (Cohen's kappa ranged from .81 to .87).

Covariates

Technoference in Mother–Child Activities. Overall technoference in mother–child activities was included as a covariate based on previous studies demonstrating associations between maternal reported technoference behaviors 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) TV, (c) computer, (d) tablet, (e) iPod, and (f) video game console. Mothers responded to each item on a 7-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, 2018).

Infant Negative Emotionality. Based on previous studies suggesting that infant negative emotionality may influence infants' response to the SFP (Braungart-Rieker et al., 2014; Myruski et al., 2018), infants' negative emotionality was also included as a covariate. Mothers completed the Infant Behavior Questionnaire Revised—Very Short Form (Putnam et al., 2014), a caregiver report of infant temperament measuring positive affectivity, negative emotionality, and orienting and regulatory capacity. For the purposes of the current study, the Negative Emotionality scale was used ($\alpha = .75$).

Analytic Strategy

An a priori power analysis based on 5,000 Monte Carlo simulations was conducted using the powerCurve function (Green & Macleod, 2016). The results indicated that a sample size of 105 participants provides sufficient power ($\beta = .8$) to detect a medium effect size ($\eta_p^2 = .6$), with a corrected α level of .0125.

First, we evaluated bivariate correlations between the main study variables and the covariates. To test the study hypotheses, a series of three factorial repeated-measures analyses of variance (ANOVAs) were conducted separately for each outcome. Condition was treated as a between-participants factor (i.e., mobile phone disruptions, social disruptions, and undisrupted play) and phase as a within-participants factor (free play, disruption, resume play). The dependent variables were infant and mother IJA behaviors and established JA duration. The main effect for phase could not be examined for some of the dependent variables due to small percentages of these behaviors in the free play and resume play phases. Therefore, four additional one-way ANOVAs were conducted to test the effect of condition (between-participants factor) on infant and mother contingent RJA behaviors and JA success rate (dependent variables) during the disruption phase. If models revealed significant main effects or interactions, pairwise comparisons were conducted using the Holm's sequential Bonferroni and Tukey's honestly significant difference methods to adjust for multiple comparisons.

This study was not preregistered. Data, study materials, and analysis code from this study are not publicly available. Access to this information is restricted for ethical reasons, in order to protect participants' privacy and confidentiality. Furthermore, the informed consent procedure did not include a statement regarding public availability of anonymized data.

Results

Preliminary Analysis

Bivariate correlations between the primary study variables and the covariates were estimated (see Table 2). No significant correlations were found between infant negative emotionality and technoference in mother–child activities and the study variables. In addition, one-way ANOVA analyses indicated that there were no significant differences in infant negative emotionality and technoference between the three experimental conditions, $F(2, 103) = 1.416$, $p = .247$; $F(2, 103) = .154$, $p = .857$, respectively. Therefore, technoference and negative emotionality were not included in the primary analysis.

IJA Behaviors

Infant IJA Behaviors (Hypothesis 1)

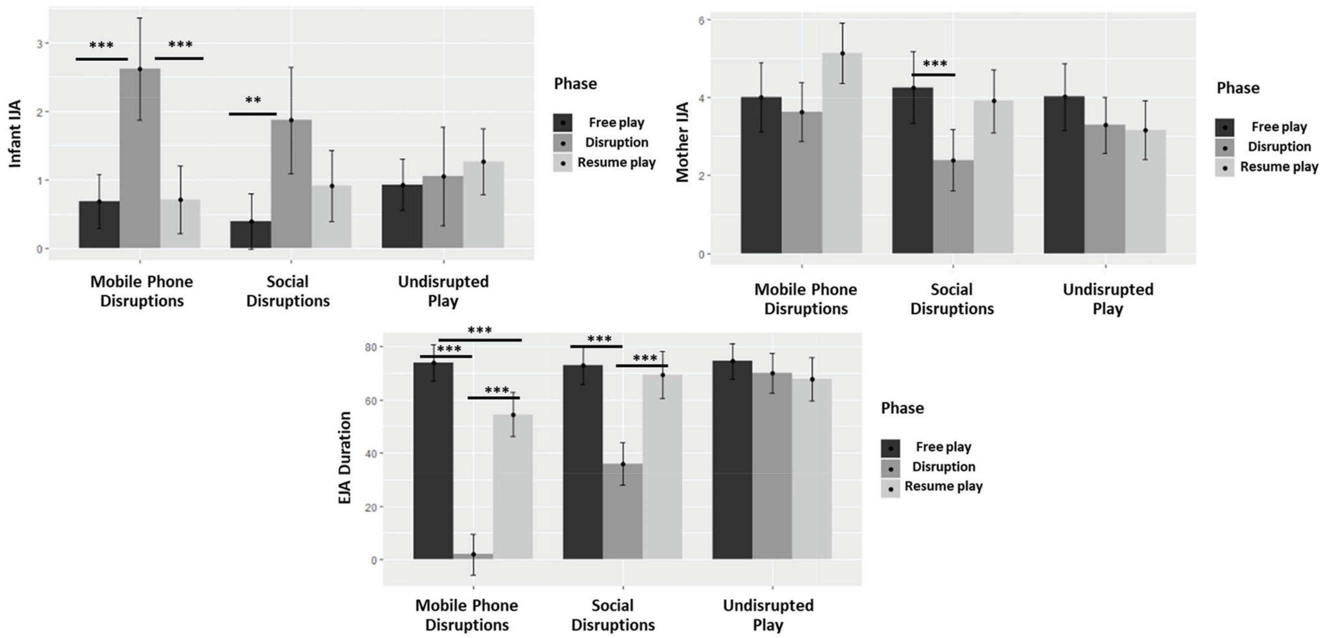
There was a significant main effect for phase, $F(2, 222) = 19.097$, $p = .000$, $\eta_p^2 = .147$, such that there were more infant IJA behaviors in the disruption phase of the experiment compared to the free play phase, $t(111) = -5.492$, $p < .001$, $\eta_p^2 = .213$, and the resume play phase, $t(111) = -1.77$, $p < .001$, $\eta_p^2 = .137$. There was no significant main effect for condition, $F(2, 111) = .555$, $p = .575$, $\eta_p^2 = .010$, indicating no differences in overall infant IJA behaviors between experimental conditions. However, there was a significant interaction between condition and phase, $F(4, 222) = 6.160$, $p = .000$, $\eta_p^2 = .100$.

Table 2
Means, Standard Deviations, and Correlations Among the Study Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Household income	—																			
2. Education level	.346**	—																		
3. Infant gender	.037	−.007	—																	
4. Infant age (months)	.016	−.056	−.068	—																
5. Mother age (years)	.315**	.280**	−.122	−.067	—															
6. Infant negative emotionality	−.032	−.005	.061	−.072	−.228*	—														
7. Technoference	−.090	.009	.172	−.037	.071	.043	—													
8. EJA_P1	−.101	.074	.026	.049	.206*	.190	.078	—												
9. EJA_P2	.104	−.088	.130	.088	.026	.121	.020	.022	—											
10. EJA_P3	.154	−.022	−.001	−.020	−.063	.081	.074	−.013	.409**	—										
11. MIJA_P1	−.067	−.027	−.022	.075	.017	.028	−.092	.065	−.159	.285**	—									
12. MIJA_P2	.077	−.025	.007	.123	−.018	.050	.008	.034	−.232*	−.152	.290**	—								
13. MIJA_P3	−.073	−.051	.043	.055	.059	−.026	−.091	.717	−.417*	−.638	.258**	.077	—							
14. CIJA_P1	−.067	.083	−.005	.071	.099	−.195	.039	.079	.042	−.071	.091	−.070	−.038	—						
15. CIJA_P2	.085	.104	.021	.048	.043	−.097	.112	.089	−.300**	.021	−.150	−.085	.063	.256**	—					
16. CIJA_P3	.098	.161	−.002	.162	.091	−.166	.047	−.029	.000	−.099	−.083	.151	−.092	.199*	.327**	—				
17. CCRJA_P2	−.010	−.062	−.120	.052	−.035	.151	.065	.252*	.346**	.398**	−.244*	−.304**	.335**	.117	.115	.110	—			
18. MCRJA_P2	−.183	−.183	−.016	−.031	−.079	−.064	−.086	−.065	.283*	.094	−.238*	−.146	−.190	.007	.023	.062	.145	—		
19. CJASR_P2	−.082	−.149	.127	−.142	.117	−.008	−.032	−.238*	.442**	.136	−.296*	−.154	−.091	−.049	−.136	.033	.229	.451**	—	
20. MJASR_P2	.044	−.106	.062	.138	.089	.078	−.019	.152	.676**	.367**	−.120	−.224*	−.313**	.070	−.118	−.007	.277**	.199	.406**	—
M	4.34	3.97	—	11.36	32.49	4.22	1.65	74.95	36.85	63.77	4.09	3.12	4.05	0.68	1.82	0.97	0.8	0.46	0.06	0.13
SD	1.29	.910	—	1.55	3.78	1.03	0.54	19.57	36.96	26.76	2.74	2.36	2.54	1.21	2.39	1.54	0.25	0.42	0.11	0.13

Note. EJA = established joint attention; MIJA/CIJA = maternal/child initiating joint attention; MCRJA/CCRJA = maternal/child contingent response to initiating joint attention; MJASR/CJASR = maternal/child joint attention success rate. P1 = play phase, P2 = disruption phase, P3 = resume play phase.
$^*p < .05$. $^{**}p < .01$.

Figure 2
Mean Levels of IJA Behaviors and Duration of EJA by Experimental Condition and Phase



Note. IJA = initiating joint attention behaviors; EJA= established joint attention.
$^{**}p < .01$. $^{***}p < .001$.

Post hoc paired comparisons (see Figure 2) indicated that at the within-participant level, in the mobile phone disruptions condition, there were more infant IJA behaviors in the disruption phase compared to the free play phase, $t(111) = -5.221$, $p < .001$, and the resume play phase, $t(111) = 5.252$, $p < .001$. A similar pattern was found in the social disruptions condition, with more infant IJA behaviors in the disruption phase compared to the free play phase, $t(111) = -3.818$, $p = .007$. In the undisrupted play condition, no differences in infant IJA behaviors were found between phases. At the between-participants level, infants in the mobile phone disruptions condition showed slightly more IJA behaviors in the disruption phase compared to infants in the undisrupted play condition; however, this difference did not reach significance level after correcting for multiple comparisons, $t(111) = 2.99$, $p = .099$. No significant differences were found in IJA behaviors in the disruption phase between the mobile phone disruptions and social disruptions conditions, $t(111) = 1.366$, $p = .100$.

Maternal IJA Behaviors (Hypothesis 2)

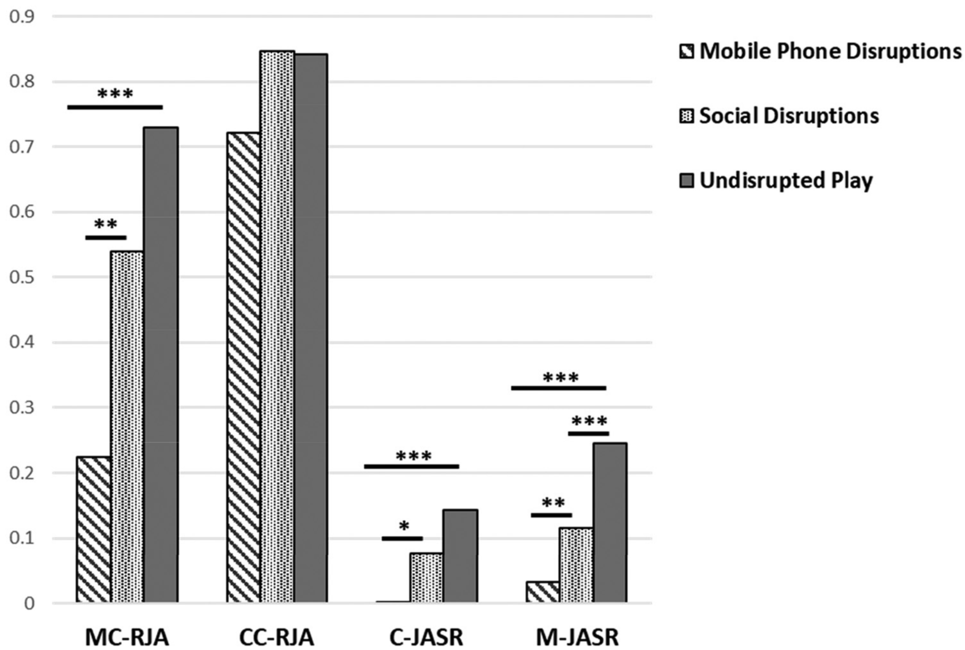
There was a significant main effect for phase, $F(2, 222) = 7.33$, $p < .001$, $\eta_p^2 = .062$, such that there were fewer maternal IJA behaviors in the disruption phase compared to the free play phase, $t(111) = 3.488$, $p = .002$, and the resume play phase, $t(111) = -3.152$, $p = .004$. There was no significant main effect for condition, $F(2, 111) = 2.32$, $p = .103$, $\eta_p^2 = .040$, indicating no differences in overall maternal IJA behaviors between conditions. However, there was a significant interaction between phase and condition, $F(4, 222) = 3.31$, $p = .012$, $\eta_p^2 = .056$.

Post hoc paired comparisons (see Figure 2) indicated that at the within-participant level, in the social disruptions condition, there were fewer maternal IJA behaviors in the disruption phase compared to the free play phase, $t(111) = 3.646$, $p = .014$. In the mobile disruptions and undisrupted play conditions, there were no differences in maternal IJA behaviors between phases. At the between-participants level, mothers in the mobile disruptions condition showed more IJA behaviors compared to mothers in the undisrupted play condition, $t(111) = 3.590$, $p = .017$.

Contingent RJA Behaviors (Hypotheses 3 & 4)

Due to the small percentage of infant IJA behaviors in the free play and resume play phases (37% and 46%, respectively), mothers' and infants' likelihood to produce contingent RJA behaviors in response to their partners' IJA behaviors were not considered in these phases. Therefore, a one-way ANOVA was conducted to examine the effect of condition on mothers' likelihood to produce contingent RJA behaviors in response to infant IJA behaviors in the disruption phase (see Figure 3). A significant effect for condition was found, $F(2, 67) = 10.239$, $p < .001$, $\eta_p^2 = .234$. Post hoc paired comparisons indicated that mothers assigned to the mobile phone disruptions condition were significantly less likely to contingently respond to their infants' IJA behaviors in comparison with mothers assigned to the social disruptions, $t(67) = -3.00$, $p = .011$, and undisrupted play conditions, $t(67) = -4.36$, $p < .001$. No significant differences were found between mothers assigned to the social disruptions and undisrupted play conditions ($p = .251$). There were no significant differences in infants' likelihood to produce contingent RJA behaviors in response to maternal IJA behaviors between experimental conditions in the disruption phase, $F(2, 63) = 2.74$, $p = .069$, $\eta_p^2 = .054$.

Figure 3
Mean Levels of Mother and Child Contingent RJA Behaviors and JA Success Rates in the Disruption Phase by Experimental Condition



Note. MC-RJA/CC-RJA = maternal/child contingent response to joint attention; M-JASR/C-JASR = maternal/child joint attention success rate.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

JA Success Rate (Hypothesis 5)

Again, due to the small percentage of infant IJA behaviors in the free play and resume play phases, JA success rates were not considered in these phases. There was a significant effect for condition on child JA success rate in the disruption phase, $F(2, 67) = 9.983$, $p < .001$, $\eta_p^2 = .23$. Post hoc paired comparisons (see Figure 3) indicated that infants assigned to the mobile phone disruptions condition had lower JA success rates compared to infants assigned to the social disruptions, $t(67) = -2.54$, $p = .036$, and undisrupted play conditions, $t(67) = -4.42$, $p < .001$. No differences were found between infants in the social disruptions condition and infants in the undisrupted play condition in JA success rates, $t(67) = -2.07$, $p = .104$. A similar pattern was found for the mother JA success rate, with a significant effect for condition, $F(2, 96) = 36.026$, $p < .001$, $\eta_p^2 = .429$, indicating that mothers assigned to the mobile phone disruptions condition had lower JA success rates compared to mothers assigned to the social disruptions, $t(96) = -3.08$, $p = .007$, and undisrupted play conditions, $t(96) = -8.42$, $p < .001$. Mothers assigned to the social disruptions condition had lower JA success rates compared to mothers in the undisrupted play condition, $t(96) = -4.83$, $p < .001$.

EJA Duration (Hypothesis 6)

There was a significant main effect for condition, $F(2, 111) = 23.21$, $p < .001$, $\eta_p^2 = .295$, such that the EJA duration was shorter in the mobile phone disruptions condition compared to the social disruptions, $t(111) = -3.824$, and the undisrupted play conditions, $t(111) = -6.794$, $p < .001$. The EJA duration was also shorter in the social disruptions condition compared to the undisrupted play condition, $t(111) = -2.755$, $p = .007$. There was also a significant main effect for phase, $F(2, 222) = 116.64$, $p < .001$, $\eta_p^2 = .512$, such that in the disruption phase, the EJA duration was shorter compared to the free play phase, $t(111) = 14.317$, $p < .001$, and the resume play phase, $t(111) = -10.895$, $p < .001$. The EJA duration was also shorter in the resume play phase compared to the free play phase, $t(111) = 3.987$, $p < .001$.

There was also a significant interaction between condition and phase, $F(4, 222) = 34.87$, $p < .001$, $\eta_p^2 = .386$. Post hoc paired comparisons (see Figure 2) indicated that at the within-participant level, EJA duration was shorter in the mobile phone disruptions condition in the disruption phase compared to the free play phase, $t(111) = 15.755$, $p < .001$, and the resume play phase, $t(111) = -11.9$, $p < .001$. The EJA duration was also shorter in the resume play phase compared to the free play phase, $t(111) = 4.479$, $p < .001$. In the social disruptions condition, the EJA duration was also shorter in the disruption phase compared to the free play phase, $t(111) = 7.794$, $p < .001$, and the resume play phase, $t(111) = -7.236$, but no significant difference was found between the free play and resume play phases, $t(111) = .837$, $p = .100$. In the undisrupted play condition, no differences in the EJA duration were found between phases. At the between-participants level, the EJA duration in the disruption phase was shorter in the mobile phone disruptions condition compared to the social disruptions condition, $t(111) = -6.103$, $p < .001$, and the undisrupted play conditions, $t(111) = -12.707$, $p < .001$. Finally, the EJA duration in the disruption phase was shorter in the social disruptions condition compared to the undisrupted play condition, $t(111) = -6.221$, $p < .001$.

Discussion

The goal of this study was to examine the immediate effects of maternal mobile phone use on early social communication behaviors. Specifically, we examined whether maternal mobile phone use while interacting with the child concurrently affects the frequency of mothers' and infants' JA behaviors (i.e., IJA and contingent RJA), the likelihood that these behaviors will lead to JA episodes (success rate), and the duration of established JA episodes. To test our research questions, we used a modified SFP (Rozenblatt-Perkal et al., 2022) in a cross-sectional research design and applied a process approach to conceptualizing and measuring JA (Tasker & Schmidt, 2008). Overall, we found that PMU immediately affects both child and maternal JA behaviors and interferes with the process of establishing JA. Our findings, together with previous work (Elias et al., 2020; McDaniel, 2019; Myruski et al., 2018; Stockdale et al., 2020), highlight the repercussions that PMU may have on parent–child interactions and children's social communication skills.

There is ample evidence from both observational and experimental studies that PMU is associated with lower caregiver responsiveness and elevated child negative affect (e.g., Elias et al., 2020; Myruski et al., 2018; Radesky et al., 2014; Rozenblatt-Perkal et al., 2022; Wolfers et al., 2020). However, these findings are limited in three main ways. First, many studies have used observational research methods and based their studies on field notes (e.g., Abels et al., 2018; Hiniker et al., 2015; Radesky et al., 2014). Those studies are limited in their ability to infer causality and directionality. Second, experimental studies that operationalized PMU did not include other disruption control conditions. One exception is a recently published study in which we used the experimental task described in this study (Rozenblatt-Perkal et al., 2022). Finally, most previous relevant studies, including a study published from the current data set (Rozenblatt-Perkal et al., 2022), have focused on the effects of PMU on children and parents separately; therefore, little is known about how PMU impacts dyadic social processes, such as establishing JA. To the best of our knowledge, this is the first study to address these limitations by using an experimental research design to examine the immediate effects of mobile phone disruptions/social disruptions/no disruptions on mother–infant JA behaviors and episodes.

Initiating JA Behaviors

Consistent with previous research demonstrating that while parents are engaged with a mobile device, children display increased bids for parental attention (Myruski et al., 2018; Stockdale et al., 2020), we found that infants assigned to the mobile phone disruptions condition exhibited more IJA behaviors in the disruption phase compared to the play phases. However, no differences in IJA were found between the mobile phone and the social disruptions conditions, which may indicate that disruptions (not only by mobile phones) in the parent–child interaction elicit greater efforts to regain parents' attention. This finding is consistent with that of Vanden Abeele et al. (2020), who suggested that the decrease in interaction quality during disruptions is not solely a feature of digital media use itself. Infants in the mobile phone disruptions condition showed slightly more IJA behaviors in the disruption phase compared to infants in the undisrupted play condition; however, this difference did not reach significance level after correcting for multiple comparisons.

Contrary to our hypothesis and previous studies suggesting that mothers engage in fewer verbal and nonverbal interactions with their children when using a mobile phone (Radesky et al., 2015), we found that mothers assigned to the mobile phone disruptions condition did not show a significant reduction in IJA in the disruption phase compared to the free play phase and did not show fewer IJA behaviors in this phase compared to the two control conditions. However, mothers assigned to the social disruptions condition showed a significant reduction in IJA behaviors during the disruption phase compared to the initial free play phase. One explanation for these findings might be that in the mobile phone disruptions condition, mothers felt guilty about disengaging from the interaction and accordingly made many attempts to initiate interactions with their infants. They could have also been affected by potential demand characteristics associated with the study design and tried to be highly responsive to both the phone and the infant, which may be portrayed as more socially accepted. It is also possible that PMU in naturalistic contexts, such as restaurants and playgrounds (Abels et al., 2018; Elias et al., 2020; Radesky et al., 2014), involves higher levels of emotional and attentional engagement than the PMU operationalization in the current study (i.e., answering neutral text messages), resulting in reduced ability to initiate interactions with their children.

Contingent Response to Initiating Behaviors

Consistent with our hypothesis, despite the increase in infants' IJA behaviors in the disruption phase, mothers assigned to the mobile phone disruptions condition were less likely to contingently respond to the child's IJA behavior compared to mothers assigned to the social disruptions and undisrupted play conditions. This finding is consistent with observational studies that showed that when caregivers are engaged with a mobile phone, the odds of responding to their children's bids for attention are low, and when they do respond, their responses are less coordinated and less timely (Davidovitch et al., 2018; Hiniker et al., 2015; Radesky et al., 2014). Moreover, compared to other non-child-related activities, mobile phone use appeared to be more engaging and exclusive. Therefore, mobile phone use may have a greater impact on the amount and timing of caregivers' responses than other distractive activities, such as talking to another person (Abels et al., 2018; Vanden Abeele et al., 2020).

Our findings also indicate that there were no differences in infants' likelihood of contingently responding to their mothers' IJA behaviors between the three conditions. This suggests that infants remain vigilant to their mothers' IJA behaviors and display contingent responses due to their expectation of social exchanges with their mothers.

Established JA

In addition to assessing JA behaviors, we also examined measures of JA success rate and the duration of EJA episodes. These measures are distinct from the IJA and contingent RJA measures as they reflect different aspects of the JA process. JA success rate reflects the probability that IJA behaviors will eventually result in a JA episode (i.e., how effective JA behaviors are in achieving JA episodes; Tasker & Schmidt, 2008). JA duration reflect the total time that the dyad was able to sustain, not just establish, JA. As previous research demonstrated that the duration of dyadic JA is predictive of children's self-regulation abilities and Executive Functions (Morales et al., 2005; Raver, 1996; Rozenblatt-Perkal et al., 2022; Vaughan Van Hecke et al., 2012), this is a critical aspect of JA to consider. In the current study, the IJA and contingent RJA measures were mostly unrelated or moderately related to the JA success rate and the JA duration, highlighting the importance of differentiating between these measures and conceptualizing JA as a process.

JA Success Rate

In the mobile phone disruptions condition, it was less likely that both mothers' and infants' IJA behaviors would lead to JA episodes in the disruption phase compared to the social disruptions and undisrupted play conditions. That is, even though mothers and infants produced IJA behaviors, these dyads failed to establish JA. These findings raise the question about the effect that PMU may have on the process of acquiring JA abilities. For social communication skills to develop, infants must learn that communicative bids such as pointing, showing, or following the social partner's line of regard lead to specific outcomes and can affect the course of the social interaction in predictable ways (Goldstein et al., 2009; Gros-Louis et al., 2014). Research indeed shows that infants are sensitive to violations of social communication maxims. For example, using the classic SFP, Goldstein et al. (2009) showed that during the still-face episode, infants showed an extinction burst (i.e., an increase in their vocalizations), suggesting that they had learned the efficacy of their vocalizations on caregivers' behavior. When IJA and RJA behaviors repeatedly fail to establish JA, the temporal contingency of the JA process is violated, potentially affecting infants' ability to effectively use communicative bids in social interactions.

Dyads assigned to the social disruptions condition had higher JA success rates in the disruption condition than dyads in the mobile disruptions condition, suggesting that these dyads still had some ability to produce effective reciprocal social exchanges. A social disruption can be considered a joint interruption (Reed et al., 2017) that draws the attention of both the mother and the child. In this case, the partners in the dyad still share their focus of attention, although the infant is not an active participant in the mother's interaction with the third party. Therefore, a shared disruption may be less disruptive in the process of establishing JA.

JA Duration

Finally, our results indicate that PMU affects the mother–infant dyad's ability to sustain JA episodes. The length of mother–infant JA episodes under the mobile phone disruptions conditions was shorter in the disruption phase compared to both play phases. In addition, in the resume play phase, the JA length was still shorter compared to the first free play phase. These findings are consistent with previous research showing that some of the effects of PMU were still evident during the resume play phase (Myruski et al., 2018; Stockdale et al., 2020). On the other hand, in the social disruptions condition, there was a moderate decrease in the disruption phase and a return to the initial levels of JA in the resume play phase. That is, although both disruptions caused a reduction in the length of JA episodes, there was a more substantial decline in the mobile phone disruptions condition.

Limitations

The findings of this study should be interpreted considering several limitations. First, this study examined immediate reactions to a short, controlled episode of parental mobile device use. Therefore, the findings of this study cannot speak to the long-term effects of continuous, prolonged exposure to PMU on infants' JA and high-order social communication skills. Recent research suggests that JA involves a whole-brain system that contributes to the functional development of neural systems that underlie social cognition abilities, such as mentalizing (Mundy, 2018). Thus, future research should examine the long-term effects of exposure to PMU on both social behavior and social–cognitive brain systems, such as the dorsal and medial frontal cortex, the amygdala, and the striatum (Eggebrecht et al., 2017; Elison et al., 2013; Oberwelland et al., 2016). It is also important to characterize the associations between PMU exposure and children's long-term outcomes. For example, do these associations follow a linear form with higher exposure predicting lower social-emotional functioning, or is there a cutoff for PMU exposure that places children at increased risk for future social-emotional difficulties? An additional limitation, which stems from the experimental nature of this study, is the social desirability effect. It is possible that mothers in the mobile phone disruptions condition showed more IJA in the lab compared to their daily interactions with their infants, which may explain the gap between the results of the current study and observational studies that found a decrease in mothers' initiation behaviors while using mobile phones (e.g., Abels et al., 2018; Elias et al., 2020; Radesky et al., 2014). This is consistent with the finding that mobile phone use was less disruptive to parent–child interactions when parents agreed to participate in an observational study than when observed in a public setting (Vanden Abeele et al., 2020). Finally, we used a community sample of typically developing infants, in which most mothers were highly educated and living in two-parent families. Therefore, our findings cannot be generalized to high-risk populations, such as infants at risk for deficits in JA (e.g., children at risk of developing autism spectrum disorder). Future studies employing high-risk samples can shed light on the differential effects that PMU may have on infants with social communication difficulties.

Conclusions

Our results suggest that PMU disrupts the immediate process of establishing mother–infant JA. By adding a social disruptions control condition, we showed that social disruptions are less disruptive than mobile phone use. Our work adds to the extant literature by demonstrating that PMU has an impact not only on discrete parent or child behaviors but also on the dyadic process of establishing contingent social interactions. Although our findings cannot speak to the long-term effects of PMU on the development of JA skills, it is possible that repeated exposure to PMU can alter the development of adaptive social-communication skills. When the temporal contingency of the JA process is inconsistent and unexpected, children may not learn how to use social cues in an adaptive manner. Moreover, PMU can displace opportunities for face-to-face interactions with the caregiver that are necessary for the development of social-communication skills (McDaniel & Radesky, 2018). For example, previous research demonstrated that the duration of dyadic JA positively predicted toddlers' use of efficient regulatory strategies when coping with distress and better inhibitory control and Executive Function abilities (Morales et al., 2005; Raver, 1996; Rozenblatt-Perkal et al., 2022; Vaughan Van Hecke et al., 2012). Thus, the reduced duration of dyadic JA associated with PMU can possibly affect the development of children's self-regulatory skills.

The findings from this study can inform initiatives designed to promote balanced family media use plans and highlight the need to designate screen-free time periods for parent–child interactions to support children's social skill development. An important next step will be to experimentally test whether controlled manipulation of PMU will result in improvements in dyadic JA and children's social-communication skills over time.

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