Smartphone use during breastfeeding and its impact on mother-infant interaction and maternal responsiveness: Within-subject design

Running title: Smartphone use during breastfeeding

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Abstract

This study investigated the association between maternal smartphone use during breastfeeding and the quality of mother-infant interactions and maternal visual responsiveness to the infant's bids for attention. We observed 13 mother-infant dyads and video-recorded breastfeeding under the experimental (smartphone use) and control (no smartphone use) conditions on separate days. To evaluate the quality of mother-infant interactions between the two conditions, we used the Japanese revised version of the Assessment of Mother-Infant Sensitivity (AMIS) scale. The mothers' visual responses to their infants' bids for attention were categorized into two groups. In this study, although smartphone use clearly increased distracted feeding times, we found no significant associations between maternal smartphone use and the quality of mother-infant interactions or bonding during breastfeeding. However, smartphone use during breastfeeding was found to interfere with the mother's ability to respond visually to the infant's bid for her attention.

The results of this study can be applied while developing resources regarding smartphone use for nursing mothers.

Key words: breastfeeding, eye-tracking technology, mother-infant interactions, smartphone

KEY POINTS

- Smartphone use during breastfeeding significantly increased distracted feeding times.
- Protracted instances of smartphone use during breastfeeding may hamper the mother's visual responsiveness to the infant's bids for her attention.
- Smartphone use during breastfeeding was not associated with poor quality of mother-infant interactions.

1 INTRODUCTION

As smartphones have become an indispensable part of daily life, mothers frequently use them during breastfeeding (Tomfohrde & Reinke, 2016). In Japan, approximately 60%–67% of mothers use smartphones or other devices while breastfeeding one month after giving birth (Inoue et al., 2015; Inoue et al., 2019). According to Klaus et al. (2001), breastfeeding during the period shortly after birth is a crucial opportunity for mother-infant interaction. Although infants have the innate ability to form attachments with their parents, mothers' sensitivity to their children's mental and physical states as well as their ability to respond appropriately to their child's needs strengthens mother-infant interactions (Bowlby, 1982, 1991a). Thus, maternal smartphone use while breastfeeding could potentially impact mother-infant bonding.

1-1 Background

In a study with infants aged below six months, Golen and Ventura (2015a) found that maternal distraction (i.e., looking away from the infant) during bottle-feeding reduced mothers' sensitivity to the infant's cues. Moreover, maternal use of digital media decreased the quality of mother-infant interactions during feeding (Golen & Ventura, 2015b). Additionally, Ventura et al. (2019) suggested that maternal use of digital media during breastfeeding might reduce mothers' interest in or capacity to interact with their children socially. McDaniel and Coyne (2016a, 2016b) coined the term "technoference" to highlight the daily disruptions in interpersonal relationships caused by digital and mobile technologies. Moreover, studies report an association between technoference and behavioral problems among children (McDaniel & Radesky, 2018a) and parenting stress (McDaniel & Radesky, 2018b). Further, in their study with older children, Radesky et al. (2014) found that maternal mobile device use reduced verbal and nonverbal mother-infant interactions in eating tasks. Other studies have suggested that parental use of mobile devices may cause them to miss

their child's bids for attention (Kiefner-Burmeister et al., 2020; Kildare & Middlemiss, 2017). A longitudinal study by Inoue et al. (2021) found no association between habitual smartphone use during breastfeeding and issues with mothers' emotions toward their children or with mother-infant bonding. The authors attributed this result to the mothers' ability to observe their children while simultaneously using their smartphones; however, no actual data were presented to support this claim. Thus, although using digital media while breastfeeding could negatively impact mother-infant interactions' quality, the relationship between habitual smartphone use and mothers' feelings toward their children is unclear. Moreover, digital media use's impact on mother-infant bonding is undetermined. As only few studies have focused on infants, evidence-based explanations on the effect of maternal use of digital media such as smartphones on mother-infant interactions and bonding are needed, preferably using experimental observation.

Although several experimental studies explored maternal digital media use during breastfeeding and mother-infant interactions (Golen & Ventura, 2015a; Ventura et al., 2019), Ventura et al. (2019) conducted a within-subject experiment to compare the quality of mother-infant interactions between a digital media use condition (i.e., watching a television program on a tablet) and a control condition. Although Ventura et al.'s (2019) experiment was well controlled, it did not directly measure the participating mothers' digital media use; moreover, the digital media use measured in the experiment was not based on the mothers' daily use. To address this limitation, we ensured that maternal smartphone use in this study represented participants' daily use. Additionally, we used an observation log to record the dyad's behaviors and the mother's gaze to determine mother-infant interactions' quality as well as maternal visual responsiveness toward infants.

1-2 Aim of the study

This study aimed to explore maternal smartphone use during breastfeeding. Moreover, we aimed to examine maternal smartphone use's impact on mother-infant interactions' quality. Our study had the following two hypotheses:

1) Maternal smartphone use during breastfeeding negatively impacts mother-infant interactions' quality.
2) Maternal smartphone use during breastfeeding hampers their visual responsiveness to the infant's bids for attention.

2 THEORETICAL FRAMEWORK

Mother-infant bonding is created by continual mother-infant interactions post birth. The quality of mother-infant interactions is strengthened by the child's ability to form attachments with the parents as well as the mother's ability to respond appropriately to the child's needs. Breastfeeding during the period shortly after birth is a crucial opportunity for mother-infant interactions. Thus, maternal smartphone use while breastfeeding could affect the attention the mother pays to child and the mother's ability to respond appropriately to the child's needs. Therefore, there is concern that repeated mother-smartphone interactions during feeding might have deleterious effects on the formation of the mother-infant bonding

2-1 Methodology framework

In this study, we measured the quality of mother-infant interactions during breastfeeding, through the observation of mother-infant behavior and mother's gaze. Mother-infant behavior was observed and evaluated using the Mother-Infant Sensitivity (AMIS) scale's. The mother's gaze was used to understand smartphone use's effect on mother-infant interactions, that is, the hindrance to the attention the mother pays to child and the mother's ability to respond appropriately to the child's needs. We evaluated interference with mothers' attention

to their children by measuring the amount of time that mothers' gaze redirected away from their child. We evaluated interference with mother's sensitivity and production of appropriate responses by assessing the frequency of maternal visual re-direction elicited by the child's attention-seeking behaviors. The formation of the mother-infant bond was evaluated using a scale that evaluates the mother's emotional bonding.

3 METHODS

3-1 Design

The study employed a within-subject experimental design, in which each mother-infant dyad was observed during breastfeeding under experimental and control conditions in a laboratory setting that simulated the dyad's daily environment.

3-2 Participants

Data collection was conducted from October 2018 to July 2019 in Japan. Of the 15 mother-infant dyads who applied to participate in the study, we accepted 13 dyads who met the following eligibility criteria: 1) full-term pregnancy; 2) post-birth, both mother and child were healthy and did not require additional hospitalization for medical treatment; 3) the mother had no depressive symptoms; 4) the infant was between 2–6 months old (i.e., 8–30 weeks); 5) the mother breastfed the infant directly during the day; and 6) the mother habitually used her smartphone during breastfeeding. The eligible age for participating infants was the attachment stage of development at which they spontaneously exhibited social response behaviors, such as following the mother's gaze, reaching out, grabbing, smiling, and babbling (Bowlby 1982, 1991b). Based on Kikuchi et al.'s (2017) study of the gaze behaviors of breastfeeding mothers, the minimum sample size was set at 10–15 dyads.

We sought participants through open recruitment and network sampling. Recruitment forms were distributed in a mother-infant class. To control for behavioral bias, candidates were not informed of the study's analytical perspective. They were informed that the study aimed to examine the characteristics of mother-infant interactions during breastfeeding using different perspectives.

3-3 Ethical considerations

The study was granted ethical approval from the University of Shimane, Nursing Research Ethics Review Board, application number: 266. Participants were provided thorough verbal and written explanations about the research contents and protection of personal information, prior to obtaining their informed consent. The mothers' consent was obtained to collect their child's data. The mothers received a gift certificate worth 2,000 yen as compensation for their participation.

3-4 Measures

3-4-1 *Logging mother-infant behaviors and tracking the mother's gaze*

The video-recording from the gaze tracking camera displayed gaze movements and the length of time the gaze was held; the screen included a counter at the bottom showing the number of recorded seconds, according to the time displayed on the counter. When the mother was gazing in a different direction, the child could not be seen in the gaze-tracking camera. In such cases, the observation log for the mother-infant behavior was completed using the video recording of that moment from the fixed camera. The observation log entries recorded what the mother was looking at (e.g., the child's face, hands, feet, body, or the smartphone), what the mother was doing (e.g., gestures to help the baby to nurse, utterances and their meaning, prodding to get the infant to nurse, touching the baby's face, head, hands, or feet, or using the

smartphone), and what the baby was doing (e.g., utterances, sounds, significant limb movements, facial movements, opening their eyes, making eye contact with the mother, smiling, sucking, squirming, crying, or bending backward). Two researchers confirmed that they agreed on the number of seconds, the content of the entries, the child's bids for the mother's attention, and maternal visual responses.

3-4-2 *Assessing the quality of mother-infant interactions*

To evaluate mother-infant interactions' quality, we used the Assessment of Mother-Infant Sensitivity (AMIS) scale's revised Japanese version. The videos were evaluated by two trained individuals who were not participants of the experiment and were not informed about the study's hypotheses. They were trained by researchers with prior experience with the AMIS scale assessment; moreover, they were given detailed explanations of the evaluation criteria assessment training. All videos were independently evaluated by both evaluators, and Spearman's correlation coefficients showed good inter-rater reliability (r=.980 and r=.988 for the control smartphone use conditions, respectively).

The AMIS scale was developed by Price (1983) to assess the quality of early mother-infant interactions in a feeding context. The scale was translated into Japanese (Katori & Takahashi, 2004). Further, the revised Japanese version, created by Katori and Takahashi (2008), comprises 27 items, each with a possible score of 1–5 points, with total scores ranging from 27–135. Higher scores indicate greater sensitivity, suggesting that the mother is better able to sense and respond to the child's mental and physical needs. Of the 27 items, 15 items evaluate maternal behaviors, 7 evaluate infant behaviors, and 5 evaluate dyadic interactions.

The AMIS scale's revised Japanese version was used after due permission from its authors for research purposes.

3-4-3 *Distracted breastfeeding*

Distracted breastfeeding refers to the loss of mothers' full attention while breastfeeding. We measured this occurrence based on the amount of time the mothers' gaze redirected away from their children.

3-4-4 *The mother's visual response to the child's bids for attention*

According to Lamb and Easterbrooks (1981), the mother goes through a four-stage response process as follows: 1) she perceives the infant's signal or need, 2) interprets it accurately, 3) selects an appropriate response, and 4) implements it effectively. A deficiency in any of these stages could result in a response that could likely be insensitive to the child. The mother's sensitivity and appropriate response were evaluated based on the maternal visual response to the child's bids for attention, and are defined as follows. In this study, we focused on the mother's perception of the infant's signals and needs as well as the infant's bids for the mother's attention when she turned her gaze away (e.g., vocalizations and eye contact). Further, the mother's reactions of turning her gaze back to the child were classified as either "non-simultaneously responsive" or "simultaneously responsive."

3-4-5 *Mother-to-Infant Bonding Scale Japanese version (MIBS-J)*

To evaluate the mother's feelings toward her baby, we used the Japanese version of the Mother-to-Infant Bonding Scale (MIBS-J; Yoshida et al., 2012), which was translated from the original MIBS (Taylor et al., 2005). The clinical utility and validity of the MIBS-J was confirmed in a study by Yoshida et al. (2012). The scale comprises 10 items, each of which are rated from 0–3 points. Moreover, higher total scores indicate stronger negative feelings

toward the infant. The scale was used after due permission from the translators for research purposes.

3-5 Research process

Each mother brought her child to the laboratory to breastfeed under observation on two separate days. To control for the variation in children's growth, the interval between the two observations was within two weeks. On average, the interval was seven days. The participants completed a survey including information on the mother's age and number of children, the child's sex and age (in weeks), feeding method, and breastfeeding behaviors during the day in terms of smartphone use and mothers' observation of the infant. Further, they also completed the MIBS-J.

For our observations, the mothers were required to breastfeed twice, once following the experimental condition and once following the control condition. After completing breastfeeding observations of the dyad under the control condition, we provided mothers with an explanation of the experimental condition for the next session, in which they could use their smartphones during breastfeeding. For the control condition, participants were instructed to breastfeed the infant as if they were at home; however, smartphone use was restricted. During the experimental condition, participants were instructed to use their own smartphone while breastfeeding the infant as they would at home. We performed a simulation of the experiment to create circumstances that resembled everyday use to determine a realistic number of observations that could be performed, and to order the control and experimental conditions. The timing of the observations was adjusted to match the infants' feeding times. The mothers were required to arrive at the laboratory at least 30 minutes before the scheduled time for breastfeeding and to begin and end feeding when the child indicated readiness. Start and finish times were recorded on the mother's signal.

The observations were video-recorded using two cameras, in addition to the researcher's note-taking. One camera was the Universal Serial Bus (USB) version of a Japanese gaze tracking device (Talk Eye Lite, TKK2950) that could record what the mother was seeing from her perspective (e.g., what the baby looked like to her and what she was doing on her smartphone). The device was mounted on lightweight goggles. As it could be adjusted quickly, it could be used by participants who wore spectacles or contact lenses. The images were recorded in units of a millisecond and uploaded to a personal computer for display using the USB connection. The second camera was arranged on a tripod in an unobtrusive corner of the room to record breastfeeding. An observer from the research team kept a written record of the time, sights, and sounds during the mother-infant interactions. The researcher sat behind the mother and child; they were out of their line of sight and took special care not to affect their interactions.

The laboratory was not insulated from external sounds; it was open to noises such as people walking in the hallway, but no other sounds were present (Figure 1). We decided not to play music, because music unfamiliar to the participants could be distracting (Ventura, 2019).

The protocol for the experiment was developed following the steps below to ensure participant safety and high-quality results.

1) Testing with dolls: Dolls representing newborns were used for test runs to determine the presentation of the experimental condition as well as the frequency, number, and times for observations.

2) Simulations: Six simulations of the experiment were run using three dyads with infants aged below 12 months.

3) Participants in the simulations were interviewed for their feedback. Further, advice from experts was sought for their perspective on measuring the mother's

gaze during breastfeeding.

3-6 Analysis

Using the logs of mother and infant behaviors and maternal gaze behaviors, we calculated the time (in seconds) mothers spent breastfeeding using their smartphones and looking elsewhere than at their child (including the time they were using their smartphones). We identified the longest durations mothers spent continuously looking at their smartphones without turning their gaze back to the infant. Smartphone use time was calculated after assessing the type of activity mothers performed on their smartphones. The proportion of smartphone use time was calculated using the following formula: (total smartphone usage time/total breastfeeding time) * 100. Similarly, a distracted feeding rate was calculated using the formula: (time spent looking elsewhere/total breastfeeding time) * 100.

For the AMIS Scale, positive Spearman's rank correlations between the subscale scores and the total score were found. Correlation coefficients were also calculated for the relationships between AMIS scale scores, the proportion of feeding time on smartphones, and the distracted feeding rate for each condition. A sign test was performed for within-subject comparisons. Using this definition, the mother's visual response was categorized as either 1) simultaneous or 2) non-simultaneous. Using the median feeding time spent on a smartphone (70 seconds), the sample was split into two groups, including 1) briefer use and 2) more extensive use. The two groups' AMIS Scale scores and MIBS-J scores were compared using the Mann−Whitney U test. Statistical analyses were performed using the Statistical package for the social sciences (SPSS) version 26, and a two-tailed significance level of 5% was considered significant.

4 RESULTS

4-1 Participant characteristics

The sample comprised 13 mother-infant dyads. The mean age ± standard deviation for the mothers was 35.9 ± 3.8 years (range: 31–41). Of the 13 mothers, 2 mothers (13.3%) had one child, 10 (66.6%) had two children, and 1 (6.6%) had three children. The mean age for the infants in the sample was 13.1 ± 3.5 weeks (range: 10–20). Of the 13 infants, 7 (53.8%) were boys and 6 (46.2%) were girls. Ten (76.9%) infants were entirely breastfed and three (23.1%) were both breastfed and bottle-fed; however, all were breastfed during the day. The mean maternal smartphone usage time was 1.1 hours (range 0.5–4). The mean score on the MIBS-J was 0.6 ± 0.7 (range 0–2), indicating that none of the dyads experienced any difficulty with mother-infant bonding.

4-2 *Distracted breastfeeding rate*

Comparison of statistics between the smartphone and control conditions (Table 1) showed that distracted breastfeeding times were significantly longer ($p<0.001$, sign test) and the distracted breastfeeding rate were likely to be higher ($p<0.001$, sign test) in the smartphone condition. This was because mothers rarely took their eyes off of their infants while breastfeeding; moreover, even when they did, it was almost always to use their smartphones. Overall and subscale scores for the AMIS Scale, indicators of the quality of mother-infant interactions, showed no significant condition-related differences (overall $p=0.388$, subscale $p=0.754$–1.000, sign test). Correlations between the conditions ranged from medium to high for feeding time, AMIS Scale overall score, and the maternal item and dyadic item subscale scores ($rs=0.572$–0.853, Spearman's rank correlation coefficient).

4-3 *Length of time on smartphone during feeding*

To compare results on the length of time on a smartphone during feeding, the median time (70 seconds) was used to split the sample into two groups: 1) briefer use and 2) more extensive use (Table 2). The infants in the more extensive use group were likely to be older ($p=0.022$, Mann−Whitney U). Moreover, no significant differences were found in the AMIS overall, subscale scores, or MIBS-J scores.

4-4 *Maternal visual responsiveness*

To compare results by maternal responsiveness, mothers were categorized as simultaneously responsive if their gaze never left their infant or if they visually responded to the child at virtually the same time that the infant bid for their attention, or non-simultaneously responsive when they turned their gaze away (e.g., to look at their smartphone). Table 3 shows that no significant differences were found by comparing the AMIS overall and subscale scores between the two groups of mothers. Similar results were found after comparing the MIBS-J scores between these two groups.

4-5 *Purposes of smartphone use/mother's visual response*

Based on the behaviors and gaze tracking in the observation logs of the 13 dyads, Table 4 shows the dyads listed in order of each mother's longest duration of continual smartphone use, in ascending order. These durations ranged from 2–249 seconds. Each incident was listed along with the mother's purpose of smartphone use and placement of smartphone during use. Three mothers used their smartphone to check the time or screen, ten used it to check their email or read articles, etc., and three mothers used it to send messages. Further, the smartphone's placement varied; while four mothers placed it on the side table (Figure 2) or the floor, the rest placed it between themselves and their infants or behind the infant, next to their head (Figure 3). Table 4 also shows the children's bids for attention during the mother's

smartphone use (opening their eyes, making sounds, moving a hand or foot, making eye contact, ceasing nursing, etc.) as well as descriptions of maternal visual responses to the child.

In some cases, the child made no bid for their mother's attention because her smartphone use was extremely brief. However, in eight cases, the child did try to draw the mother's attention. As shown in the table, as the smartphone use time prolonged, the children made more bids for their mothers' attention. In Case K, the child pushed at the mother's hand to prevent her from using her smartphone. Of the eight cases in which the child bid for the mother's attention, the mother simultaneously turned her gaze back to the child in two cases. In six cases, the mother did not simultaneously look at the child.

Table 4 shows a clear difference between the simultaneous and non-simultaneous responses when the duration of an instance of continuous smartphone use reached 28 seconds. In cases of brief smartphone use, the responses could be considered simultaneous; however, if the mother was composing or reading messages, her responses were considered non-simultaneous. The details of each case are listed in Table 4.

5 DISCUSSION

This study investigated the association between maternal smartphone use during breastfeeding and the quality of mother-infant interactions and the mother's visual responsiveness to the infant's bids for her attention. However, the results supported only one of the study's hypotheses; no association was found between smartphone use during breastfeeding and poor quality mother-infant interactions. Nevertheless, the results revealed that continuous smartphone use while breastfeeding could hamper maternal response to the infant's bids for her attention.

In the absence of distractions in the study's breastfeeding environment, the mothers focused virtually all (99%) of their attention on their infants. However, once they were able to use their smartphones, there was a marked increase in distracted feeding time. Nevertheless, no significant difference in the mother-infant interaction quality was found in the smartphone use condition. This finding is inconsistent with those of previous studies, which reported an association between a decline in mother-infant interaction and digital media use. In other words, watching a 22-minute program on the iPad (Ventura et al., 2019) was associated with maternal distraction (Golen & Ventura, 2015a). According to Golen and Ventura (2015b), "maternal distraction" referred to "mothers engaging in distracting activities during the infant's feeding for more than 75% of the time." In our study, even when mothers used their smartphones, they focused their attention on their infants for a majority of the breastfeeding time; overall, approximately 90% of the mothers' time was infant-focused, and they were distracted only 10% of the time. Thus, unlike prior studies, everyday smartphone use in our study was not considered a "maternal distraction." It is also possible that the conditions used in previous studies to represent "digital media use" were different from participants' daily digital media use. Moreover, to evaluate its effect on the formation of the mother-infant bond, we investigated the emotional bond between a mother and her child. Our study found no association between smartphone use and mother-infant bonding, a finding consistent with the results of previous studies (Ali et al., 2020; Inoue et al., 2021). This suggests that the time maternal time mothers' spent on smartphones and the purpose of usage during breastfeeding is unlikely to have any effect on emotional bonding.

Our results indicated that when mothers spent a long time on their smartphone or were sending messages using the smartphone, they were slower to respond visually to their infant's bids for attention. This finding was consistent with Golen and Ventura's (2015a) study that reported that mothers who used social media were likely to be less sensitive to their infant's

cues. Moreover, the longest smartphone use duration and total smartphone use time were both significantly longer in the non-simultaneously responsive group, compared with the simultaneously responsive group. There was a clear difference between response types when smartphone use time lasted 28 seconds, as all cases of long-duration smartphone use were found in the non-simultaneous group. Thus, protracted use, more than the total time spent on a smartphone, could hamper a mother's responsiveness to her infant. In cases where the mother only glanced at the screen, her responses could still be considered simultaneous; however, if she was composing a message, she was unable to respond to the baby, simultaneously. Previous studies on smartphone use during breastfeeding found that, most commonly, mothers browsed the internet, made selections (e.g., shopped online), checked screens (e.g., for the time or blinded reference), and used social media (Tomfohrde & Reinke, 2016) on their smartphones. While searching, browsing, selecting, or checking a screen requires brief attention and can be easily be interrupted, composing a message on social media can take the mother's attention away from the child long enough for her to miss her infants' bids for attention.

However, contrary to some previous findings, our results also confirmed that some infants tried to interact with their mothers during their smartphone use. In contrast, Ventura et al. (2019) revealed a decline in infant responsiveness. Additionally, although only in one case, the infant tried to prevent the mother from using the smartphone and ultimately succeeded. Thus, we found that children actively bid for their mothers' attention when they used their smartphones. A child's bid for the caregiver's attention increases daily after birth; moreover, this behavior directed at the mother may sustain the quality of mother-infant interactions throughout breastfeeding, thus contributing to healthy bonding.

The mother indicated in the case above, however, avoided the baby's hand and continued using her smartphone. Although she was aware of the baby's bid for her attention,

she did not visually respond to him; thus, to an external observer it appeared as if she ignored the baby's bid. Although a child's signals become clearer with age, our results show that the occurrences of these signals increase with the increase in time spent using the smartphone. Moreover, smartphone use during breastfeeding could potentially lead to the mother ignoring her child's bids for attention, albeit unintentionally. In this study, the mother returning her gaze to the child was considered responsive; however, in mother-infant interactions, an appropriate response requires a mother to perceive and interpret the child's needs and select an appropriate response from her repertoire (Lamb & Easterbrooks, 1981). However, investigating the effect of smartphone on the quality of mother-infant interactions also requires an appreciation of the mother's introspective experience and her responsiveness, including examining whether she was aware of the child's bid for her attention and, if so, what were the reasons for not responding to their bid for attention. It is important to be aware of this, as inappropriate maternal responses can be a major stressor for an infant (Provenzi et al., 2015), while subsequently impacting the mother-infant relationship.

5-1 Limitations

This study's limitations should be considered when interpreting the results. To observe daily smartphone use by mothers during breastfeeding, the protocol for the experiment purposefully attempted to replicate everyday use to the extent possible. However, as a result, the experimental conditions' order could not be randomized, we were unable to uniformly control the position in which the mothers held their smartphones or their purposes for using them. To operate the smartphone while breastfeeding, mothers almost always held it close to the child. Some positions made it impossible for us to view the mother's visual response to the child. Although we did not find it difficult to see the child's face in any of the cases because the smartphone was placed on the side table or on the floor; moreover, in each of

these cases, the usage time was brief; however, we were unable to confirm if it interfered with the mother's visual responsiveness to their child. Thus, the experiment should be performed using smartphones in fixed positions for conclusive findings.

Moreover, breastfeeding in a laboratory is not the same as breastfeeding at home. Participants were aware that they were being observed by the camera. Thus, psychological biases could affect how and for what purpose the mothers used their smartphones. Although younger individuals may have increased smartphone use, the participants in this sample were generally older. We did not differentiate in the analysis between *primigravida* mothers and mothers who already had other children. Further, as participants were required to come to the laboratory, the sample was geographically biased. Moreover, the sample was socioeconomically biased because the participants were required to own and afford a smartphone. Furthermore, to verify the quality of the mother-infant interaction, investigating the mother's subjectivity is also necessary. A study with a larger, more diverse sample is warranted to verify the results of this study more conclusively.

6 CONCLUSION

In this study, although smartphone use clearly increased the distracted feeding time, no significant associations were found between maternal smartphone use and the quality of mother-infant interactions or bonding during breastfeeding. However, smartphone use during breastfeeding interfered with the mother's ability to respond visually to the infant's bids for her attention. Despite the fact that some infants attempted to interact with their mothers while they used their smartphones, the mothers' responses were hampered due to prolonged smartphone use or sending messages.

As time passes after childbirth, mothers tend to spend more time on their smartphones; further, their smartphone use during breastfeeding might continually affect

maternal responsiveness. Therefore, smartphone use during breastfeeding remains a concern that is worth exploring. As a result, smartphone use during breastfeeding may result in the mother ignoring the child's bids for her attention.

RELEVANCE FOR CLINICAL PRACTICE

Mothers and nurses, midwives, lactation consultants, and childbirth educators in hospital and birthing centers need to consider that protracted smartphone use for some purposes could hamper the mother's responsiveness to her child's bids for her attention. Although we hypothesized that being distracted during breastfeeding due to smartphone use would affect mother-infant interactions and bonding, our results indicated that the probability was, in fact, low. Further studies are required to elucidate these effects. The results of this study can be used while developing resources for nursing mothers regarding smartphone use. Nurses, midwives, and other supporters of breastfeeding should inform mothers regarding the potential effects of smartphone use during breastfeeding on the quality of mother-infant interactions and their responsiveness to the infant's bids for attention. Moreover, future studies should confirm how and for what purposes mothers use their smartphones, as it will contribute to improvements in mother-infant interactions.

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CONFLICTS OF INTERESTS

The authors declare that there are no conflicts of interest

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FIGURE LEGENDS

Figure 1. The laboratory environment

Figure 2. Smartphone placement: On the side table or floor

Figure 3. Positioning the smartphone for use: Behind the baby, near the head

Table 1. Distracted breastfeeding rates and AMIS scale scores for the smartphone and control conditions

	Smartphone use condition		Control condition		p[1)]	rs[2)]
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)		
Feeding time (s)	904.2 (305.8)	845.0 (769.5–1062.5)	806.8 (266.8)	805.0 (569.0–1002.0)	0.092	.853**
Time on smartphone (s)	163.8 (232.1)	70.0 (20.5–198.5)	2.7 (9.7)	0 (0–0)	0.001**	0.463
Proportion of time on smartphone (%)	19.5 (8.3)	8.3 (2.6–31.2)	0.2 (0.8)	0 (0–0)	0.001**	0.463
Distracted feeding time (s)	170.6 (228.5)	83.0 (37.5–198.5)	5.7 (10.8)	3.0 (0–6.5)	0.001**	0.077
Distracted feeding rate (%)	19.5 (22.2)	9.9 (4.3–29.5)	0.5 (0.9)	.10 (0–0.9)	0.001**	0.217
AMIS Scale overall score	111.5 (6.7)	115.0 (105.0–117.0)	109.9 (6.1)	111.0 (104.5–115.0)	0.388	.572*
AMIS Subscale scores						
Maternal items	63.2 (4.1)	63.0 (60.5–67.0)	62.6 (3.9)	63.0 (60.5–65.5)	0.754	.573*
Infant items	28.2 (2.8)	27.0 (26.0–30.5)	27.3 (2.8)	27.0 (26.5–28.5)	1.000	0.314
Dyadic items	20.1 (1.6)	20.0 (19.0–21.5)	20.0 (1.0)	20.0 (19.5–20.5)	1.000	.588*

Abbreviations: IQR, Interquartile range; SD, Standard deviation; AMIS, Assessment of Mother-Infant Scale Japanese revised version

1) Comparison of the smartphone use and control conditions: sign test

2) Correlation between the smartphone use and control conditions: Spearman's rank correlation coefficient

* $p<0.05$; ** $p<0.01$

Table 2. Comparison of AMIS scores by length of time on smartphone during breastfeeding

	Briefer use (n=6)		More extensive use (n=7)		p[1)]
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
Mother's age	37.0 (3.3)	37.0 (33.8–39.8)	34.9 (4.1)	33.0 (32.0–39.0)	0.234
Infant's age (weeks)	10.8 (1.0)	10.5 (10.0–12.0)	15.0 (3.7)	14.0 (11.0–19.0)	0.022*
Feeding time (s)	1013.8 (302.6)	881.5 (799.5–1264.0)	801.1 (297.3)	840.0 (639.0–961.0)	0.366
MIBS-J	0.5 (0.5)	0.5 (0–1.0)	0.7 (0.8)	1.0 (0–1.0)	0.731
AMIS overall score	110.5 (7.9)	112.5 (102.3–117.3)	112.4 (5.9)	115.0 (107.0–117.0)	1.000
AMIS subscale scores					
Maternal items	63.2 (5.0)	64.0 (58.3–68.0)	63.3 (3.6)	63.0 (62.0–65.0)	0.945
Infant items	27.2 (1.6)	26.5 (26.0–28.5)	29.1 (3.5)	27.0 (26.0–33.0)	0.366
Dyadic items	20.1 (2.0)	20.0 (18.0–22.3)	20.0 (1.2)	20.0 (19.0–21.0)	0.945

Abbreviations: IQR, Interquartile range; SD, Standard deviation; MIBS-J, Mother-to-infant Bonding Scale: Japanese version; AMIS, Assessment of Mother-Infant Scale Japanese revised version. 1) Comparison of briefer and more extensive smartphone use groups: Mann−Whitney U test. Sample was split into 1) briefer use and 2) more extensive use groups using the median time (70 seconds) spent on a smartphone during feeding. * $p<0.05$; ** $p<0.01$

Table 3. Comparison of AMIS scores by maternal visual responsiveness

	Simultaneously responsive (n=7)		Non-simultaneously responsive (n=6)		p
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
Mother's age	36.4 (3.4)	36.0 (33.0–39.0)	35.2 (4.4)	33.5 (31.8–39.8)	0.445
Infant's age (weeks)	11.3 (1.5)	11.0 (10.0–12.0)	15.7 (4.0)	15.0 (11.0–19.3)	0.073
Feeding time (s)	1006.3 (277.0)	91.08 (803–1164.0)	785.0 (317.4)	795.0 (562.0–961.0)	0.181
MIBS-J	0.7 (0.6)	1.0 (0.0–1.0)	0.5 (0.5)	0.5 (0.0–1.0)	0.731
AMIS overall score	111.4 (7.6)	117.0 (10.3–117.0)	111.7 (6.1)	113.5 (105.8–117.0)	0.731
AMIS subscale scores					
Maternal items	63.1 (4.6)	63.0 (59.0–68.0)	63.3 (3.9)	63.5 (60.8–66.0)	0.945
Infant items	28.1 (3.0)	27.0 (26.0–30.0)	28.3 (2.9)	27.0 (26.0–31.5)	0.945
Dyadic items	20.1 (1.9)	20.0 (18.0–22.0)	20.0 (1.3)	19.5 (19.0–21.3)	0.945

Abbreviations: IQR, Interquartile range; SD, Standard deviation; MIBS-J, Mother-to-infant Bonding Scale: Japanese version; AMIS, Assessment of Mother-Infant Scale Japanese revised version

1) Comparison of simultaneously responsive and non-simultaneously responsive mothers: Mann-Whitney U test

Mothers were classified as “simultaneously responsive” based on whether they never took their eyes off the child and, if they did, whether they returned their gaze to the child virtually at the same time as soon as the child began bidding for their attention.

Table 4. Purposes of smartphone use during breastfeeding/mother's visual response to the child's bid for attention

Case ID	Phone use purpose/Placement during use						Child's bid for attention during mother's smartphone use							Mother's visual response to bids for her attention	
	Where phone was placed during operation (For the longest instance of continual use)	Duration of longest instance of phone use (secs)	Time on phone (s)	Purpose Checking time/home screen (s)	Reading email/articles, etc. (s)	Texting, etc. (s)	Opened eyes[1)]	Made sounds[1)2)]	Body movements[1)2)]	Made eye contact[1)]	Stopped sucking[1)2)]	Other[1)2)]	Not observed	Response[1)2)]	Observation logged[1)2)]
A	Side table or floor	2	5	5	0	0							○	Simultaneous	Gaze virtually never left the child
B	Side table or floor	3	8	8	0	0	[-]			[-]			○	Simultaneous	Gaze virtually never left the child

C	Side table or floor	6	6	6	0	0	[-]			[-]			Simultaneous	Gaze virtually never left the child
D	Far side of child near waist/buttocks	11	38	3	35	0	○				Uttered a sound		Simultaneous	Responded to child's vocalizations
E	Near side of child, between them	16	33	17	16	0	○					○	Simultaneous	Gaze virtually never left the child
F	Side table or floor	17	49	32	17	0	○					○	Simultaneous	Gaze virtually never left the child
G	Far side of child near head	22	205	0	205	0	○			○			Simultaneous	Responded to child making eye contact
H	Far side of child near waist/buttocks	28	158	59	99	0	Partially[-]		○	○			Non-simultaneous	Did not respond to child's movements or eye contact
I	Far side of child near head	42	70	6	22	42	○	○	○				Non-simultaneous	Did not respond to child's movements or vocalizations

J	Far side of child near head	44	403	0	80	323	○	○	○			Non-simultaneous	Did not respond to movements. Sometimes responded to vocalizations, sometimes did not
K	Near side of child, also sometimes on child's abdomen	54	122	0	122	0	○	○	○	○	Pushed away the hand the mother used to hold her	Non-simultaneous	Did not respond to eye contact or body movements. Although the child pushed away the hand the mother used to hold her phone, she did not respond did not look at the child) and continued to avoid the baby's hand. Responded to

											phone		the child voicing their unhappiness and stopped using her phone.
L	Far side of child near waist/buttocks	97	192	8	13	171	○	○		○	Choked	Non-simultaneous	Did not respond to child's eye contact, vocalizations or even when the child was choking
M	Far side of child, at a bit of a distance	249	838	47	791	0	[-]		○	[-]	○	Non-simultaneous	Did not respond to body movements. Did respond when child stopped nursing.

*1） Confirmed from gaze tracker camera data.

*2） Confirmed from tripod camera recorded images.

*"Responded" refers to the mother turning her gaze to the child in response to bids for her attention.

*"Simultaneous" responses included both the mother not taking her eyes off the baby and looking at the baby in response to bids for attention when she did look away. "Non-simultaneous" refers to lack of response to the child's bids.

*○ indicates the observation was confirmed.

*[-] indicates that the baby's face could not be observed in the recording when the mother was using her phone.

Figure 1. The laboratory environment

Figure 2. Smartphone placement: On the side table or floor

Figure 3. Positioning the smartphone for use: Behind the baby, near the head