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Exploring the Relationship Between Maternal Wellbeing, Infant Development, Smartphone Use, and Mother-Infant Responsiveness

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ABSTRACT

Emerging evidence suggests smartphone use has adverse effects on mother-infant relationships. However, while research suggests that maternal responsiveness is reduced when using a smartphone, little research has been undertaken with infants. This study used cross-sectional data to explore associations between infant social-emotional development, maternal mental health outcomes, smartphone use, and mother-infant responsiveness. We recruited 450 mothers with infants aged 3–9 months, in the UK. Data were collected between October 2021 and April 2022, during the COVID-19 pandemic. Validated self-report scales measured predictor variables and an outcome variable of mother-infant responsiveness. Hierarchical linear multiple regression identified a final model ($R^2 = 0.385$, $F\,(3,432) = 17.33$, $p < 0.001$), with four significant predictors for mother-infant responsiveness: infant social-emotional development, birth parity, perceived social support in the form of appraisal, and likelihood of maternal smartphone use when the infant may be perceived as passive. These results suggest that within this sample, suboptimal infant social-emotional development, additional children in the family, lack of appraisal support for mothers, as well as maternal smartphone use during critical periods of parenting all demonstrate a negative association with mother-infant responsiveness. The results have implications for planning early support for mothers in the first months of their infant's life.

1 | Introduction

Dyadic behavioral synchrony is a critical interactive process that develops between mother and infant starting at around 3 months of age (Beebe et al. 2016; R. Feldman 2007) and is implicated in the development of cognitive and social emotional processes such as mentalization (Atzil, Hendler, and Feldman 2014) and attachment security (Bernard, Meade, and Dozier 2016). Dyadic synchrony has been operationalized as a "dynamic and reciprocal adaptation of the temporal structure of behaviors and shared affect between interactive partners (Leclère et al. 2014, 2). It is also often referred to as a 'dynamic dance' between mother and infant (Leclère et al. 2014; Provenzi et al. 2018), and as such relies on the bidirectional responsiveness of both mother and infant to effectively notice, respond to, and influence, one another's behavior and affect. A number of risk factors have been identified as posing a risk to the development of dyadic synchrony in mother-infant dyads when the infant is aged between 3 and 9 months, including maternal depression and anxiety (Lotzin et al. 2016; Moore et al. 2016) and infant physiological development (de Graag et al. 2012; R. Feldman 2006; for a full review of identified risk factors see Golds et al. 2022).

One risk factor more recently implicated in the underdevelopment of parent-infant interactions is the caregiver's use of a smartphone in the presence of the infant. As smartphones become more

essential to our everyday lives, the ubiquity of smartphone use has been predicted to have a consequential impact on individuals' interpersonal interactions and relationships (McDaniel 2019). For example, the desire that many individuals feel to maintain a physical proximity to one's mobile phone and to feel connected to the wider world has led to the phenomenon of 'technoference' (McDaniel and Coyne 2016a), whereby interruptions to everyday interpersonal interactions occur due to the use of digital and mobile technology. Technoference between a caregiver and their child may take place as caregivers attempt to multitask and can occur several times throughout the day, creating interruptions to caregiving routines such as feeding, mealtimes, or playtime (McDaniel and Radesky 2018a).

Importantly, extant research with parents and their children aged 0–3 years suggests technoference may be a risk factor for infants' emotional, social, and cognitive development (Myruski et al. 2019; Tidemann and Melinder 2022). Maternal technology use, across a number of devices, in the presence of an infant has been found to be significantly associated with greater infant negative affect as well as reduced mother-to-infant attachment quality, as reported by the mother (Alvarez Gutierrez and Ventura 2021). Additionally, measuring the likelihood of maternal smartphone use, rather than actual daily usage, across a small number of parenting domains, has been found to be associated with lower vocabulary development in 2-year-olds (Sundqvist et al. 2021).

Concerning the risks to parental responsiveness while using a smartphone, a number of studies have been undertaken. Using naturalistic playground observations, Wolfers et al. (2020) found that mothers of children under 3 years who displayed more habitual phone use (measured via self-reports of smartphone use each day) were likely to demonstrate less maternal sensitivity—the mother's ability to notice and accurately interpret her child's behaviors and needs (Ainsworth, Bell, and Stayton 1971) —than mothers who used their phones less often. Cross-sectional studies have suggested that longer durations of maternal smartphone use in the presence of the infant are associated with lower maternal sensitivity (Tharner et al. 2022). Additionally, Ventura, Levy, and Sheeper (2019) found that mothers who used their devices while feeding their infant failed to respond to satiety cues, while infants also showed decreased levels of responsiveness to the mother when she used a smartphone. Further, smartphone use has been reported to compromise maternal responsiveness in a small number of experimental studies (albeit with slightly older infants), whereby the mother's responsiveness to their child's bids for attention were seen to decrease (Konrad et al. 2021; Lederer, Artzi, and Borodkin 2021; Rothstein 2018). While it has been suggested that engagement with a smartphone is often only slightly more distracting for caregivers of children under 5 years than other similarly non-child-directed activities such as reading a magazine or conversing with other adults, it has also been argued that incidences of total immersion in phone use happen more often than these other activities (Konrad et al. 2021; Lederer, Artzi, and Borodkin 2021; Vanden Abeele, Avels, and Hendrickson 2020).

However, the full body of research to date provides somewhat contradictory results regarding the impact of smartphone use on caregiver responsiveness. Longitudinal findings suggested that mothers in Japan who used their smartphones during breastfeeding did not perceive any negative implications in how they responded to, or bonded with, their infant (Inoue, Hashimoto, and Ohira 2021). Similarly, Coyne et al. (2022) reported that maternal smartphone use while feeding an infant was not associated with longitudinal impacts on the mother-infant attachment bond and can in fact provide benefits to the mother who may use the phone to connect with others and increase her own feelings of mental wellbeing. Taken together, these contradictory findings suggest that additional research examining the associations between maternal smartphone use across a wide number of parenting domains and perceptions of mother-infant synchrony and responsiveness would make a notable contribution to the discourse surrounding maternal smartphone use in the presence of an infant.

While mothers report an awareness that smartphone use is not always beneficial to the developing relationship with their child (Radesky et al. 2016), the risk of overusing a smartphone, often termed problematic smartphone use (Billieux 2012), may be a cause for concern as mothers are presented with a number of risk factors that may exacerbate habitual device use. While taking care of an infant, there is a risk that primary caregivers, typically women, can feel isolation and loneliness (McDaniel 2019). During times of loneliness, many people are more likely to use social media platforms in an attempt to feel engaged with others, however this can lead to problematic levels of device use (Baerg MacDonald and Aitken Schermer 2021; Kim, LaRose, and Peng 2009). Particularly during the COVID-19 pandemic, mothers may have felt heightened levels of isolation, causing them to turn to their smartphone to maintain contact with friends and family, relying on online support to an even greater extent (David and Roberts 2021). However, some studies have suggested that levels of smartphone usage have not diminished to pre-COVID baselines in populations of young adults, suggesting that increased smartphone use behaviors may have become habitual even after pandemic-related social restrictions were eased (Massar et al. 2022).

Maternal depression has also been associated with higher levels of phone use, as mothers may turn to social media in a bid to 'escape' from their negative feelings (Newsham, Drouin, and McDaniel 2018). While mothers may feel short term benefits in using their phones to 'disconnect' from their caregiving responsibilities as well as their own negative feelings, using a smartphone for passive consumption of social media and/or entertainment purposes has been linked to further decreased feelings of wellbeing (Stevic et al. 2021). Additionally, non-social use such as passive consumption of entertainment on a smartphone has also been associated with higher levels of depressive symptoms, smartphone addiction, and problematic habitual use (Elhai et al. 2017). One of the reasons for this may be that mothers are likely to engage in social comparison behaviors which decrease their feelings of wellbeing and efficacy as a mother, and that this may be particularly problematic for mothers with infants (Coyne, McDaniel, and Stockdale 2017). The combined results from these studies suggests that there may be a bidirectional association between higher levels of smartphone use and maternal depression. Similarly, in parents of children aged 0–7 years, Uzundağ et al. (2022) found that mothers who reported feeling more stressed also reported

problematic levels of smartphone use, which was linked to more interruptions within mother-child interactions. It would seem then, that mothers who are experiencing poorer mental health outcomes, such as stress, depression, or feelings of isolation are further at risk for problematic smartphone use behaviors.

While a growing body of research aims to understand the influence of parental smartphone use on caregiver-child interactions and responsiveness (for a review of the research on parents and children aged 0–5 years see Braune-Krickau et al. 2021), minimal research has focused specifically on infants under 12 months old. This is particularly important given that 3–9 months is an important stage of development for infants to acquire interactive processes, such as dyadic synchrony, with their primary caregivers (R. Feldman 2007; Harrist and Waugh 2002). Whilst dyadic behaviors such as synchrony are more regularly measured through observational paradigms, some related behavioral concepts, such as perceived mutual responsiveness (Harrist and Waugh 2002; Mesman 2010) can be measured through self-report scales (Amankwaa and Pickler 2007) and can proxy for bidirectional processes (Harrist and Waugh 2002; Mesman 2010), such as dyadic behavioral synchrony, observed in the mother-infant dyad. Mutual responsiveness occurs when the mother and infant display contingent affective behaviors during interaction (Van Egeren, Barratt, and Roach 2001), and is considered as being an interactional component of dyadic behaviors such as behavioral synchrony (McDaniel, Ventura, and Drouin 2024). Self-report scales such as the Mother-Infant Responsiveness Instrument (MIRI; Amankwaa and Pickler 2007) may effectively proxy the bidirectional relationship by assessing the mother's perception of both her own responsiveness to the infant, as well as the infant's responsiveness to her.

However, in considering self-report measurement of smartphone use, it is important to recognize most users underestimate how much time they spend on their phone each day (Andrews et al. 2015), partially due to the increasingly passive nature of social media consumption (Stevic et al. 2021). While many individuals would report that their smartphone use functions as a way to communicate with others, and provide more social connection, it has been suggested that most smartphone use is more passive, such as scrolling through photos and videos on social media platforms (Elhai et al. 2017). Due to the unreliable nature of smartphone use reporting, numerous scales have been developed in order to capture this data (Andrews et al. 2015; McDaniel and Coyne 2016b). Additionally, passive data trackers can be used to measure the exact amount of time an individual has used their phone, including checking behaviors (when the individual picks up their phone to check for notifications). Whilst self-report scales should be interpreted with caution, Andrews et al. (2015) suggest that asking participants how often they use their phone each day should return adequate estimations of smartphone use.

To our knowledge, no large-scale studies to date have explored whether maternal smartphone use across a number of parenting domains is associated with levels of perceived mother-infant synchrony within the dyad, in the first year of the infant's life. Accordingly, this cross-sectional study aimed to identify associations between previously identified risk factors in the development of dyadic synchrony (i.e., Golds et al. 2022; Leclère et al. 2014), with the addition of maternal smartphone use during different parenting tasks, and perceptions of mother-infant mutual responsiveness in infants aged 3–9 months. Since it is not known whether specific patterns of behavior of smartphone use during different parenting tasks are more likely to associate with reduced mother-infant responsiveness, the current study will explore patterns of use using EFA analysis (see Methods section). Due to the somewhat contradictory nature of the data in the extant literature, we will use an exploratory approach to understand how perceived mother-infant responsiveness associates with identified risk factors, including the addition of a previously unknown factor: maternal smartphone use in the presence of the infant. Due to the exploratory approach, no directional results are hypothesized a priori. However, the study aims to answer the following research questions: (i) do infant social-emotional issues associate with maternal-infant responsiveness, (ii) do maternal mental health outcomes, including ill health, wellbeing and social support associate with maternal-infant responsiveness, and (iii) are specific patterns of behavior of maternal smartphone use associated with mother-infant responsiveness?

2 | Methods

2.1 | Design

An online cross-sectional survey design was employed to maximize the participant pool. The survey recruited mothers of infants born between January 2021 and January 2022, who were living in the UK. Both potential risk and protective factors of mother-infant responsiveness were measured as predictor variables in the survey. Potential risk factors included perceived infant social-emotional developmental issues, maternal poor mental health outcomes (i.e., depressive, anxiety, and stress symptoms), and maternal smartphone use. Potential protective factors included feelings of positive wellbeing and perceived social support. The outcome variable was mother-infant responsiveness. The present study was conducted according to guidelines laid down in the Declaration of Helsinki, with written informed consent obtained from each participant before any assessment or data collection. All procedures involving human subjects in this study were approved by the Clinical Psychology Ethics Committee at the University of Edinburgh.

2.2 | Recruitment Procedure

The survey recruitment poster was shared with 56 parent support groups online, predominantly through Facebook and Twitter. The recruitment poster was also shared on MQMentalHealth.org, a research recruitment website. Additionally, a promoted advert was also shared on Facebook in the week 25 March–1 April 2022. This advert was targeted to women aged 18–65, living in the UK, and contained the same recruitment poster as was sent to the online support groups. The recruitment poster/flyer included a QR code and hyperlink to the study which was housed on the Qualtrics platform. After reading the participant information sheet and providing consent, participants were then able to access the survey. Participants were reminded that they did not have to answer any questions that made them feel uncomfortable. The

questionnaires were completed in the following order: (i) demographic information, (ii) COVID-19 information, (iii) ASQ:SE-2, (iv) DASS-21, (v) WHO-5, (vi) ISEL-12, (vii) TIPS, (viii) MIRI. The survey took approximately 20 min to complete and after completion, participants were linked to a debrief sheet which again signposted useful information and support organisations. Participants were also offered the opportunity to enter a prize draw with one winner of a £50 Amazon voucher as an incentive. The study remained open for 6 months, between October 2021 and April 2022.

2.3 | Participants

Mothers were eligible for inclusion in the study if they were (i) older than 16 years old, (ii) lived in the UK and (iii) had a baby aged between 3 and 9 months old. No exclusion criteria were used. In accordance with the British Psychological Society (BPS) guidelines, any participant in the UK aged over 16 years is considered acceptable for sole informed consent and so no additional parental consent was needed for participants under the age of 18 years. A total of 450 participants' responses were analyzed as part of the study. The mean scores for maternal mental health outcomes all fell within the 'normal' range on the DASS-21 (depression $M = 3.32$, SD = 3.22; anxiety $M = 2.71$, SD = 2.76; stress $M = 6.43$, SD = 3.56; for cut off ranges see Measures section), indicating a non-clinical sample. The mean scores for infant social emotional development also fell within the 'no to low risk' range ($M = 26.83$, SD = 16.42; for cut off ranges see Measures section), indicating a non-clinical sample. As a significant correlation was found between infant age and ASQ score ($r = -0.101$, $p = 0.016$), an independent samples t-test was conducted to explore differences between 'younger' (3–6 months) and 'older' (6–9 months) infants. While there was a significant difference between infant social emotional development mean scores between these two groups ($p = 0.007$), both group's mean scores were still falling within the 'no to low risk' range (younger infants $M = 28.91$, SD = 16.54; older infants $M = 24.77$, SD = 16.07). This indicates that while mothers of younger infants were scoring their infants as slightly higher in perceived social emotional difficulties, this was still predominantly within the normal range of behavior for this age group. For full demographic data, see Table 1.

2.4 | Measures

2.4.1 | Demographic Questionnaire

Demographic data consisted of eight questions concerning maternal age, ethnicity, country of residence, level of education, employment status, and whether the mother was on maternity leave. Household composition was requested pertaining to how many caregivers were in residence as well as any other children.

2.4.2 | COVID-19 Questionnaire

Further demographic data relating specifically to the COVID-19 pandemic was requested through four questions, to understand what degree of lockdown had been experienced (if any) with the baby, whether anyone in the household was a frontline worker, whether there had been changes to employment status due to COVID-19, and whether anyone in the household had received a COVID-19 positive diagnosis.

2.4.3 | Infant Social and Emotional Development

The Ages and Stages Questionnaire: Social-Emotional (ASQ:SE-2; Squires, Bricker, and Twombly 2015) 6 Month Questionnaire is a 23-item measure for use with infants aged 3–9 months. The scale is filled out by parents and measures social and emotional development of the infant with ratings presented on a 3-point scale as 0 (Often or always), 5 (Sometimes), 10 (Rarely or never), with reverse scoring attributed to some items. An additional 5 points can be added for any items which are highlighted as a particular concern for parents. Scores below 30 are deemed no or low risk, scores between 30 and 45 are considered close to cutoff, and scores above 45 are considered at risk of social emotional developmental issues. The scale records infant age, infant gestational age at birth (preterm or full-term), and infant sex. The scale also includes three open-ended questions which ask (i) if the parent has concerns about the baby's eating or sleeping, (ii) if the parent has concerns in general about the baby, and (iii) what the parent enjoys most about their baby. The ASQ:SE-2 is a well validated scale with internal reliability, measured by Cronbach's coefficient alpha, reported as ranging from 0.71–0.91 (Squires, Bricker, and Twombly 2015). Cronbach's alpha in the current sample was 0.63. While this is lower than some previously reported alphas, reliability values of 0.60–0.70 may be deemed acceptable in exploratory research (Nunnally and Bernstein 1994). Due to the low alpha score, confirmatory factor analysis (CFA) was performed on the one-factor model. The results indicated a relatively poor fit ($\chi^2 = 768.912$, $df = 230$, $p \leq 0.001$, RMSEA = 0.072, CFI = 0.51). Previous item response theory modeling has indicated that the scale can be classified into two dimensions, categorized as Emotional Competence and Social Competence (Chen, Squires, and Scalise 2020). A subsequent CFA using these proposed dimensions indicated a marginally better fit ($\chi^2 = 543.728$, $df = 208$, $p \leq 0.001$, RMSEA = 0.060, CFI = 0.70). While the model fit was slightly better, the alpha scores remained low, particularly for the emotional competence dimension (emotional competence $\alpha = 0.52$; social competence $\alpha = 0.70$). As there was little improvement in the model with additional dimensions, and as social-emotional development was the focus of the original measure, the total score was therefore used as it was felt that the higher overall internal consistency of 'social-emotional development' as a latent construct was more informative when considering perceived infant development by the mother.

2.4.4 | Maternal Mental Health

The Depression, Anxiety, and Stress Scale with 21 items (DASS-21; Lovibond and Lovibond 1995) is a shortened version of the DASS, a well-validated measure of depressive symptoms, anxiety, and stress. The scale invites participants to answer how each statement applies to them over a timeframe of the past week and the ratings are presented as a 4-point scale as 0 (Never), 1

TABLE 1 | Demographic and COVID-19 information for all participants.

Maternal age (years)	***N***
	450
(Mean)	32.38
(SD)	4.55
(Range)	18–44
Ethnicity	***N* (%)**
African, Caribbean, or Black British	1 (0.2)
Asian or Asian British	9 (2)
White	429 (95.4)
Mixed/multiple ethnicity	7 (1.6)
Another ethnic group	4 (0.8)
Country of residence	***N* (%)**
England	291 (64.7)
Scotland	125 (27.7)
Wales	18 (4)
Northern Ireland	16 (3.6)
Level of education	***N* (%)**
Secondary school	16 (3.6)
College/Vocational	66 (14.7)
Undergraduate degree	177 (39.3)
Postgraduate degree	179 (39.7)
Other	12 (2.7)
Employment status	***N* (%)**
Full-time employee	287 (63.8)
Part-time employee	84 (18.7)
Self-employed	24 (5.4)
Student	5 (1.1)
Stay-at-home mother	47 (10.4)
Other	3 (0.6)
On maternity leave	***N* (%)**
Yes	376 (83.6)
No	54 (12)
NA	20 (4.4)
Household composition	***N* (%)**
Lone parent household	20 (4.5)
Couple household	428 (95.1)
Other	2 (0.4)
Any other children	***N* (%)**
No	282 (62.7)
Yes	168 (37.3)
Infant age (months)	***N***
	450
(Mean)	5.86
(SD)	1.69
(Range)	3–9
Infant sex	***N* (%)**
Male	214 (47.6)
Female	236 (52.4)
Premature	***N* (%)**
No	400 (88.9)
Yes	50 (11.1)
Concerns eating/sleeping	***N* (%)**
No	370 (82.2)
Yes	73 (16.2)
Concerns in general	***N* (%)**
No	378 (84)
Yes	64 (14.2)
Lockdown with infant	***N* (%)**
No	331 (73.6)
Yes	119 (26.4)
Frontline worker in household	***N* (%)**
No	219 (48.7)
Yes	231 (51.3)
Changes in employment	***N* (%)**
No	324 (72)
Yes	126 (28)
COVID-19 diagnosis	***N* (%)**
No	265 (58.9)
Yes	185 (41.1)

(Sometimes), 2 (Often), 3 (Almost always). Cutoff scores are different for each subscale but comprise of 'normal' (depression = 0–4; anxiety = 0–3; stress = 0–7), 'mild' (depression = 5–6; anxiety = 4–5; stress = 8–9), 'moderate' (depression = 7–10;

anxiety = 6–7; stress = 10–12), 'severe' (depression = 11–13; anxiety = 8–9; stress = 13–16), and 'extremely severe' (depression = 14+; anxiety = 10+; stress = 17+). The overall Cronbach's alpha for this scale was 0.92, indicating high internal consistency. For individual subscales, Cronbach's alpha was 0.87 for the depression subscale, 0.77 for the anxiety subscale, and 0.84 for the stress subscale. Confirmatory factor analysis indicated that the traditional three-factor model was a good fit for this sample ($\chi^2 = 528.401$, $df = 186$, $p \leq 0.001$, RMSEA = 0.064, CFI = 0.91).

The WHO (Five) Well-Being Index (WHO-5; World Health Organisation 1998) is a 5-item measure reporting feelings of well-being over a timeframe of the past 2 weeks. The scale invites participants to answer how each statement applies to them and the ratings are presented as a 6-point scale as 0 (At no time), 1 (Some of the time), 2 (Less than half of the time), 3 (More than half of the time, 4 (Most of the time), 5 (All the time). A score is calculated by totaling the five answers. Scores range from 0 to 25, with 0 representing lowest feelings of well-being and 25 representing highest feelings of well-being. A score below 13 indicates poor well-being and is used as a cutoff, indicating depressive symptoms. Cronbach's alpha was 0.86, indicating high levels of internal consistency. Confirmatory factor analysis suggested that a one-factor model was a good fit ($\chi^2 = 32.379$, $df = 5$, $p \leq 0.001$, RMSEA = 0.07, CFI = 0.97).

2.4.5 | Social Support

The Interpersonal Support Evaluation List—shortened version 12 items (ISEL-12; Cohen et al. 1985) is a 12-item measure of perceived social support. Within the scale are three subscales, "appraisal support" (i.e., feeling as though you have someone to talk to about your problems and receiving constructive feedback), "belonging support" (feeling as though you have someone to spend time with), and "tangible support" (feeling as though you have someone who will help with physical tasks/material aid if necessary). Each subscale contains 4 measured items, rated on a 4-point scale as 1 (Definitely False), 2 (Probably False), 3 (Probably True), 4 (Definitely True) with reverse scoring attributed to some items. No cutoffs are reported for this scale, however higher scores on the scale indicate that participants perceive themselves to have higher levels of social support in each of the three subscales. The overall Cronbach's alpha for this scale was 0.89. For individual subscales, Cronbach's alpha was 0.80 for the appraisal subscale, 0.81 for the belonging subscale, and 0.71 for the tangible subscale, indicating high internal consistency for overall scale and subscales. Confirmatory factor analysis suggested that the three-factor model was an appropriate fit ($\chi^2 = 208.745$, $df = 51$, $p \leq 0.001$, RMSEA = 0.08, CFI = 0.93).

2.4.6 | Maternal Smartphone Use in the Presence of the Infant

The Technology Interference with Parenting Scale (TIPS; McDaniel and Coyne 2016b) was employed to understand how mothers are likely to engage with their smartphone in the presence of their infant. An adapted TIPS (Sundqvist et al. 2021) was introduced through a question stem that reads, "There are often times when parents have to use their smartphone when spending time with their child. How likely are you to use your phone (e.g., to make calls, text, check email, check social media, watch a video)?" Participants were then given a list of different parenting domains, for example, bedtime, playtime, mealtimes, bathtime etc., and are asked to rate how likely they are to use their phone at those times. The ratings are presented as a 5-point scale as 0 (Never), 1 (Rarely), 2 (Sometimes), 3 (Often), 4 (Very Often). Higher scores would indicate that parents are more likely to use their smartphone more often in the presence of their infant. In the current sample, Cronbach's alpha was 0.80. Confirmatory factor analysis showed relatively poor fit with a one-factor model for this scale ($\chi^2 = 527.720$, $df = 44$, $p \leq 0.001$, RMSEA = 0.114, CFI = 0.72). Therefore, exploratory factor analysis (EFA) was performed, where a visual inspection of the scree plot and rotated component matrix indicated a three-factor model, with the three factors translating to (i) infant is asleep ($\alpha = 0.61$), (ii) infant could be perceived as an active partner in the dyad ($\alpha = 0.67$), and (iii) infant could be perceived as a passive partner in the dyad ($\alpha = 0.80$), with two items not loading onto any factor (using 0.4 as a cutoff; see Figure S1 for more detail). The CFA was re-run to test this three-factor model which reported better fit ($\chi^2 = 282.767$, $df = 51$, $p = < 0.001$, RMSEA = 0.089, CFI = 0.84). While two factors reported lower alphas than the total score alpha (infant asleep, infant active), due to the better model fit, it was decided that a three-factor model would be employed for further analysis as one focus of the study was to better understand if specific patterns of behavior of maternal smartphone use associated with mother-infant responsiveness.

2.4.7 | Mother-Infant Responsiveness

To measure the outcome variable, mother-infant responsiveness, the Maternal Infant Responsiveness Instrument (MIRI; Amankwaa and Pickler 2007) was used. This is a 22-item measure used to proxy representations of the mother-infant relationship and has been validated for use with both preterm and full-term infants, and previously used in studies with infants ranging between 28 weeks of gestational age up to 3 years old (Spurlock et al. 2023). The scale invites participants to reflect on their own behavior as well as that of their infant and answer how each statement relates to the responsiveness within the dyadic relationship with a rating scale of 5 (Strongly agree), 4 (Agree), 3 (Somewhat agree), 2 (Disagree), 1 (Strongly disagree) with reverse scoring attributed to some items. While there are no cutoff scores reported for this measure, higher scores indicate that the mother perceives the dyad as more responsive to one another. A systematic review of studies employing the MIRI to measure mother-infant responsiveness reported moderate to high internal consistency across studies, with alphas ranging from 0.76 to 0.89 (Spurlock et al. 2023). In the current sample, Cronbach's alpha was 0.85 indicating a high internal consistency for the scale. For this sample, CFA indicated a moderate fit with a one-factor model for this scale ($\chi^2 = 1262.574$, $df = 209$, $p \leq 0.001$, RMSEA = 0.106, CFI = 0.71). Therefore, exploratory factor analysis (EFA) was performed, where a visual inspection of the scree plot indicated a two-factor model, with the two factors translating to (i) mother responsiveness ($\alpha = 0.85$), and (ii) infant responsiveness ($\alpha = 0.84$), with four items not loading onto either factor. The CFA was re-run to test this two-factor

model which reported better fit, (χ^2 = 659.093, df = 186, $p \leq 0.001$, RMSEA = 0.093, CFI = 0.83). However, the two factors were highly correlated (r = 0.714, $p < 0.001$). Due to significant correlation between the two factors, and given the study's focus on bidirectional dyadic responsiveness, it was decided that the total score for mother-infant responsiveness using a one-factor model would be used.

2.5 | Data Analysis

2.5.1 | Data Cleaning

An a priori power analysis for linear regression was calculated using G*Power 3.1 (Faul et al. 2009). Based on this, a sample size of 280 participants was identified to be adequate to ensure a small effect size at the recommended power of 0.80 for $\alpha = 0.05$. Responses were initially received from 615 participants. Data cleaning took place to ensure survey responses fitted the inclusion criteria. While applying inclusion criteria, it became clear that some survey responses were not genuine responses and were likely to have been submitted by bots. Bot responses have become an increasingly common issue in online surveys (Pozzar et al. 2020). To effectively identify bot responses, triangulation methods were applied. A response was identified as a potential bot if it contained two or more of the following 'red flags': (i) completing the survey in under 10 min; (ii) timestamps very close together (e.g., multiple surveys filled out with the exact same start time); (iii) repetitive open-ended responses (e.g., multiple survey responses in a row with the exact same response to open-ended questions); (iv) repetitive IP addresses; (v) IP addresses connected to geographical locations outside of the UK; (vi) inconsistent responses to "sensitive" questions (e.g., "how often do you use your phone during bathtime?—Often/Very often"); and (vii) responses outside of inclusion criteria. One hundred and two responses were identified as potential bot responses and were removed from the final data set. An additional 63 responses were excluded from the final data set due to no infant age recorded, or an infant age recorded that was outside of the exclusion criteria. This process led to a final data set comprising 450 participants.

Incomplete responses were identified for potential data imputation. Across the variables used within the analysis, missing data ranged between 3.6% and 12.9% (see Table 2 for missing data rates for each variable). A visual inspection of patterns of missingness suggested that missing data was due to participant drop out rather than specific responses missing not at random (MNAR). A t-test of missingness reported similar means in present and missing cases for all variables where more than 5% of values were missing. Additionally, Little's Missing Completely at Random (MCAR) Test was used, which reported that all missing data was MCAR (χ^2 = 41,789.37, df = 47,525, p = 1.00). Multiple imputation was therefore identified as an appropriate method of dealing with missing data (Madley-Dowd et al. 2019). Multiple imputation was carried out in SPSS v28 and 10 multiply imputed datasets were generated. The imputation process included all variables that were subsequently used in regression analysis, as well as three auxiliary variables (country of residence, employment status, and employment changes due to Covid-19). Linear regression models were then fitted to each imputed dataset and Rubin's rules (1987) were applied to pool parameter estimates and standard errors.

Following this, data were transformed to numerical form, including applying scoring schemes to survey measures, with total and subtotal scores calculated. Dummy coding was applied to nominal data, with the group representing the majority coded as 0. Some answers relating to demographic and COVID-19 data were transformed into binary categories (these comprised the questions, (i) Are you currently on maternity leave?, (ii) Do you have any other children? (iii) Is anyone in your household a frontline worker?, and (iv) Has anyone in your household experienced changes in employment status due to COVID-19?). Additionally, mean substitution methods were used when, e.g., multiple answers were sometimes recorded for the ASQ:SE-2. In this instance, a participant may have recorded that their infant showed certain behaviors both "Sometimes"

TABLE 2 | Description of study variables (N = 450).

Study variable (measure used)	*M* (*SD*)	Missing data %	Possible range	Observed range
Mother responsiveness (MIRI)	98.29 (7.76)	12.9	22–110	72–110
Infant social emotional development (ASQ:SE-2)	27.40 (17.97)	8.0	0–230	0–115
Depressive symptoms (DASS-21)	3.27 (3.18)	6.2	0–21	0–20
Anxiety symptoms (DASS-21)	2.66 (2.74)	7.6	0–21	0–15
Stress symptoms (DASS-21)	6.32 (3.50)	3.8	0–21	0–19
Wellbeing (WHO-5)	13.63 (4.38)	3.6	0–25	2–24
Social support—appraisal (ISEL-12)	12.87 (2.77)	5.6	4–16	4–16
Social support—belonging (ISEL-12)	11.42 (2.90)	5.1	4–16	4–16
Social support—tangible (ISEL-12)	12.71 (2.62)	5.1	4–16	4–16
Maternal smartphone use [infant active] (TIPS)	7.34 (1.86)	9.8	3 – 15	3–14
Maternal smartphone use [infant passive] (TIPS)	9.79 (3.33)	11.3	6 – 30	6–28
Maternal smartphone use [infant asleep] (TIPS)	8.46 (2.79)	10.2	3–15	3–15

Abbreviations: ASQ:SE-2, ages and stages social emotional; DASS-21, depression, anxiety and stress scale; ISEL-12, interpersonal support evaluation list; MIRI, mother-infant responsiveness instrument; TIPS, technology interference with parenting scale; WHO-5, WHO (five) well-being index.

and "Often or always"/"Rarely or never". In these cases, an average score was calculated (i.e., Sometimes). Data were analyzed in SPSS v28.

2.5.2 | Statistical Analysis

Descriptive statistics were reported, including mean and standard deviation for continuous variables and frequencies and percentages for categorical variables. Correlational analyses were used to identify significant associations between all measured variables (Pearson's *r*). Due to the high degree of correlation among measured variables, tests for multicollinearity were undertaken. Both VIF and tolerance scores reported no suggestion of multicollinearity. As no collinearity was identified between measured variables, all variables were retained in the statistical analysis. Finally, a two-block hierarchical linear regression was conducted using measured variables that were significantly correlated to mother-infant responsiveness.

3 | Results

3.1 | Descriptive Statistics

Descriptive statistics for all measures are reported in Table 2.

3.2 | Correlational Analyses

Table 3 displays the correlations between the variables for mother-infant responsiveness (MIRI), infant social and emotional development (ASQ:SE-2), depressive symptoms, anxiety symptoms, stress symptoms (as measured by DASS-21), feelings of well-being (WHO-5), perceived social support in the forms of appraisal, belonging, and tangible support (as measured by ISEL-12), and maternal smartphone use in the presence of the infant (TIPS) across three different dimensions (infant may be perceived as passive, active, and asleep). All measured variables had significant associations with mother-infant responsiveness. Correlational analysis was also performed on the identified covariates (i.e., maternal age, maternal education, birth parity, infant sex, premature birth, infant age) with the outcome variable mother-infant responsiveness. No significant correlation was reported between mother-infant responsiveness and any of the identified covariates.

3.3 | Regression Analyses

A two-block hierarchical linear multiple regression analysis was performed using the measured variables with mother-infant responsiveness as the outcome variable. In block one, identified predictors were infant social emotional development (ASQ:SE-2), maternal mental health measured through depressive symptoms, stress symptoms, and anxiety symptoms (DASS-21), feelings of

TABLE 3 | Pearson correlations for survey measures.

	ASQ: SE-2	DASS-21 (D)	DASS-21 (A)	DASS-21 (S)	WHO-5	ISEL-12 (A)	ISEL-12 (B)	ISEL-12 (T)	TIPS (active)	TIPS (passive)	TIPS (asleep)
MIRI	−0.495**	−0.244**	−0.206**	−0.197**	0.213**	0.320**	0.268**	0.244**	−0.194**	−0.396**	−0.134**
ASQ:SE-2		0.181**	0.159**	0.218**	−0.216**	−0.235**	−0.199**	−0.164*	0.134**	0.218**	0.125*
DASS-21 (D)			0.606**	0.722**	−0.642**	−0.445**	−0.376**	−0.285**	0.209**	0.198**	0.114*
DASS-21 (A)				0.695**	−0.414**	−0.437**	−0.338**	−0.332**	0.152*	0.204**	0.164**
DASS-21 (S)					−0.583**	−0.408**	−0.313**	−0.299**	0.192**	0.146**	0.154**
WHO-5						0.407**	0.380**	0.286**	−0.129*	−0.052	−0.076
ISEL-12 (A)							0.659**	0.633**	−0.188**	−0.265**	−0.160**
ISEL-12 (B)								0.618**	−0.139**	−0.216**	−0.165**
ISEL-12 (T)									−0.229**	−0.316**	−0.220**
TIPS (active)										0.509**	0.238**
TIPS (passive)											0.293**

Abbreviations: ASQ-SE:2, ages and stages questionnaire; DASS-21 (A), depression, anxiety and stress scale anxiety subscale; DASS-21 (D), depression, anxiety and stress scale depression subscale; DASS-21 (S), depression, anxiety and stress scale stress subscale; ISEL (T), interpersonal support evaluation list tangible subscale; ISEL-12 (A), interpersonal support evaluation list appraisal subscale; ISEL-12 (B), interpersonal support evaluation list belonging subscale; MIRI, mother-infant responsiveness instrument; TIPS, technology interference with parenting scale; WHO-5, WHO (five) well-being index.
*$p \leq 0.05$, **$p < 0.001$.

wellbeing (WHO-5), social support measured through perceived appraisal support, perceived belonging support, and perceived tangible support (ISEL-12). Due to their potential associations with maternal wellbeing, and mother-infant dyadic interactions, as well as potential risk factors for problematic smartphone use covariates of maternal age, maternal education, premature birth, parity, and infant sex (R. Feldman et al. 2003; Golds et al. 2022; McDaniel and Radesky 2018b; Porter, van Heugten, and Champion 2020; Stevic et al. 2021), were also added to the model at this stage. In block two, additional predictors of maternal smartphone use in the presence of the infant (TIPS) across three different dimensions (infant may be perceived as active, passive, and asleep) were also added to the linear regression model. Block one provided a model ($R^2 = 0.310$, F (13,435) = 14.00, $p < 0.001$), containing three significant predictors: infant social emotional development ($b = -0.192$, $p < 0.001$), maternal depression ($b = -0.413$, $p = 0.012$), and perceived appraisal support ($b = 0.450$, $p = 0.011$). The addition of maternal smartphone use in block two significantly improved the model fit ($R^2 = 0.385$, F (3,432) = 17.33, $p < 0.001$), and contained four significant predictors: infant social emotional development ($b = -0.166$, $p < 0.001$), birth parity ($b = 1.091$, $p = 0.019$), perceived appraisal support ($b = 0.382$, $p = 0.024$), and maternal smartphone use in the presence of the infant, specifically when the mother may perceive the infant as a passive partner in the dyad ($b = -0.689$, $p < 0.001$). This change accounted for an additional 7.5% of the variance in the outcome variable of mother-infant responsiveness. For full regression results, see Table 4.

4 | Discussion

Our findings provide a unique contribution to the literature on maternal smartphone use and mother-infant interactions. To our knowledge, this is the first study to explore perceptions of bidirectional responsiveness in this age group (which can be used as a proxy for mother-infant dyadic synchrony—a crucial interactional process for developing a secure attachment bond), and its associations with infant social-emotional development, and maternal mental health outcomes, maternal wellbeing, and social support, as well as investigating patterns of behavior of maternal smartphone use across a wide range of parenting domains while the infant is aged between 3 and 9 months. The findings of this study can be used to answer the research questions, namely, (i) do infant social-emotional issues associate with maternal-infant responsiveness, (ii) do maternal mental health outcomes, including ill health, wellbeing and social support associate with maternal-infant responsiveness, and (iii) are specific patterns of behavior of maternal smartphone use associated with mother-infant responsiveness?. The results of these explorations, and the implications of the results are highlighted below.

TABLE 4 | Two-block hierarchical linear regression model of predictors of mother-infant responsiveness.

	Model 1					Model 2				
Variables	***b***	***SE***	***β***	***t***	***p***	***B***	***SE B***	***β***	***t***	***p***
Maternal age	0.053	0.061	0.043	0.871	0.386	0.055	0.060	0.044	0.907	0.368
Infant age	−0.177	0.192	−0.039	−0.924	0.356	−0.088	0.183	−0.019	−0.480	0.631
Infant sex	0.368	0.634	0.024	0.581	0.561	0.365	0.600	0.024	0.608	0.543
Premature birth	−1.408	0.999	−0.058	−1.409	0.159	−0.1.026	0.948	−0.042	−1.082	0.279
Maternal education	−0.057	0.372	−0.006	−0.153	0.879	−0.236	0.357	−0.027	−0.661	0.509
Parity	0.899	0.482	0.078	1.865	0.062	1.091	0.465	0.094	2.343	0.019*
ASQ:SE-2	−0.192	0.020	−0.413	−9.444	< 0.001**	−0.166	0.020	−0.356	−8.313	< 0.001**
DASS-21 (D)	−0.413	0.164	−0.174	−2.519	0.012*	−0.276	0.157	−0.117	−1.759	0.079
DASS-21 (A)	−0.053	0.167	−0.019	−0.314	0.753	−0.002	0.160	−0.009	−0.015	0.988
DASS-21 (S)	0.173	0.150	0.081	1.154	0.249	0.148	0.142	0.068	1.039	0.299
WHO-5	−0.012	0.099	−0.007	−0.121	0.904	0.106	0.096	0.061	1.104	0.270
ISEL-12 (A)	0.450	0.177	0.162	2.542	0.011*	0.382	0.169	0.137	2.256	0.024*
ISEL-12 (B)	0.151	0.165	0.057	0.913	0.362	0.164	0.155	0.062	1.054	0.293
ISEL-12 (T)	−0.002	0.177	−0.001	−0.013	0.990	−0.219	0.174	−0.074	−1.261	0.208
TIPS (active)						0.066	0.200	0.017	0.329	0.724
TIPS (passive)						−0.689	0.117	−0.316	−5.879	< 0.001**
TIPS (sleep)						0.084	0.120	0.031	0.703	0.483
Adjusted R^2			0.310					0.385		
F change			14.00**					17.33**		

Abbreviations: ASQ-SE:2, ages and stages questionnaire; DASS-21 (A), depression, anxiety and stress scale anxiety subscale; DASS-21 (D), depression, anxiety and stress scale depression subscale; DASS-21 (S), depression, anxiety and stress scale stress subscale; ISEL (T), interpersonal support evaluation list tangible subscale; ISEL-12 (A), interpersonal support evaluation list appraisal subscale; ISEL-12 (B), interpersonal support evaluation list belonging subscale; TIPS, technology interference with parenting scale; WHO-5, WHO (five) well-being index.
*$p < 0.05$, **$p < 0.001$.

The correlational analysis of this survey identified a significant negative association between infant social-emotional development and mother-infant responsiveness, as well as maternal mental health outcomes (depressive, anxiety, and stress symptoms) and the outcome variable. Higher levels of maternal wellbeing and social support were positively associated with mother-infant responsiveness. Additionally, a significant negative association was found between maternal smartphone use, behavior patterns and mother-infant responsiveness. Using a factor analysis, three patterns of smartphone use were identified, namely (i) when the infant could be considered to be an active partner in the dyad, (ii) when the infant could be considered to be a passive partner in the dyad, and (iii) when the infant was asleep. Further, even though this association is seen across all three domains, a stronger association between likelihood of maternal smartphone use and lower mother-infant responsiveness was found when smartphones are used during parenting domains when the infant may be perceived as a passive partner in the dyad, for example, when getting ready for the day or during hygiene practices. These results support existing literature suggesting that perceived infant social-emotional issues (Mäntymaa et al. 2009), maternal mental health (Lotzin et al. 2016; Moore et al. 2016), and habitual parental smartphone use (McDaniel 2020; Braune-Krickau et al. 2021) are all potential risk factors for the development of sensitive interactions between mother and child.

The linear regression analysis, with an outcome variable of mother-infant responsiveness, explained 38.5% of the variance within the final model and identified a number of factors associated with the outcome variable of mother-infant responsiveness. While a number of the predictor variables were non-significant in the model there were, nonetheless, four significant predictors for mother-infant responsiveness; infant social emotional development, birth parity, perceived social support in the form of appraisal, and the likelihood of maternal smartphone use when the infant may be perceived as a passive partner. When adding maternal smartphone use to the model, the results suggest that maternal smartphone use, and particularly when the infant may be perceived as a passive partner in the dyad, uniquely and significantly predicted poorer mother-infant responsiveness within the dyad.

In addition to the statistical analysis, it is important to note that self-reported smartphone use within the sample was consistent with findings on associations between reported smartphone use and mother-child interactions in dyads with both older infants and children (McDaniel and Radesky 2018a; Sundqvist et al. 2021). For example, across certain parenting domains (e.g., getting ready for the day or diaper changing), approximately 80%–95% of mothers reported that they were not likely to use their smartphone in the presence of their infant, however a small percentage of mothers still reported a potential likelihood of use during these caregiving activities. In other parenting domains, maternal reported likelihood of using the device was much higher. For example, during naptime, 75.8% of mothers reported that they were likely to use their device at least some of the time. These results may suggest that maternal smartphone use habits are founded when the infant is as young as 3 months old and appear to stay relatively consistent throughout the child's first years of life (for a full list of measured parenting domains and reported likelihood of smartphone use see Table S1).

When considering the addition of maternal smartphone use as a risk factor to the dyad, due to the cross-sectional nature of the results, we cannot assume directionality in the associations between mother-infant responsiveness and the likelihood of maternal smartphone use in the presence of the infant. Existing research suggests that maternal smartphone use affects maternal sensitivity and responsivity to the infant's interactional cues (Ventura, Levy, and Sheeper 2019). However, an alternative explanation for such findings as in this regression may be that mothers who perceive their child to be less responsive may turn to their smartphone in an attempt to withdraw from a relationship that may at times feel frustrating or isolating (Radesky et al. 2016). There is also scope to suggest that both of these positions can be true at the same time and that there is a potential risk of a bidirectional association between higher likelihood of maternal smartphone use and lower mother-infant responsiveness (Radesky et al. 2018).

Within this survey, mothers were asked about the likelihood of smartphone use, and as such were not necessarily asked to report actual smartphone usage levels. Therefore, it could be suggested that the likelihood of smartphone use across caregiving domains is actually symptomatic of other problems within the mother-infant relationship (Knitter and Zemp 2020). For example, if the mother is experiencing negative affect, or perceives the infant to be experiencing social emotional difficulties, then she may turn to her smartphone as a means of emotion regulation, or to access information or support to improve her self-efficacy within the situation. Additionally, the likelihood of smartphone usage may be a consequence of the mother's unresponsiveness that encourages her to engage more with her smartphone during parenting domains (Abels et al. 2018). Regulatory and interactive issues within the dyad may result in an increase in the likelihood of mothers using their phones at times when it may seem inappropriate to others. Therefore, it may be the case that the mother feeling comfortable to use her phone during these activities is what creates a risk factor for the dyad, rather than the actual smartphone use per se.

Alternatively, asking mothers to report the likelihood of their smartphone use across different parenting domains may capture a reasonable estimate of their actual phone use within these domains (Andrews et al. 2015). It would therefore be important to consider how mothers use their phones throughout the day, as smartphone use may look different within different parenting domains. While many mothers reported that they are likely to use their phones during playtime with their infant, the modality with which they use the phone may have implications for the disruptions which it poses. For example, many mothers use their device to take photographs of their infant during play, and while it may inhibit mother-infant interactions to do so, in this situation the mother is still inherently focused on their infant while using the smartphone (Inoue, Hashimoto, and Ohira 2021). However, during parenting domains such as getting the child ready for the day, or during hygiene practices, mothers may use the smartphone for alternative purposes, such as logging daily routines or accessing information (Virani, Duffett-Leger, and Letourneau 2021). As the main purpose for smartphone use during different caregiving activities was not asked of the mothers within this survey, we are not able to provide definitive suggestions regarding this, however it seems

reasonable to suggest that different modalities of phone use may present unique opportunities for either engagement or disruption to mother-infant interactions throughout the day.

Importantly, as many mothers are aware that smartphone use in the presence of their child may be detrimental to their relationship (Radesky et al. 2016), they may perceive that there are optimal times to use their phone, e.g. once their child is asleep, or, crucially, when they think their child is not really actively engaged as part of the dyad. However, the findings of this survey suggest that smartphone use particularly within these domains may be associated with suboptimal dyadic responsiveness.

The linear regression model accounted for 38.5% of the variance for mother-infant responsiveness, suggesting other risk factors are also likely to impact this relationship. It is possible that likelihood of using a smartphone in the presence of the infant is indicative of other so far unmeasured risk characteristics that may impact the mother-infant dyad, such as coping strategies (e.g., Uzundağ et al. 2022), or emotion regulation difficulties (e.g., G. Feldman et al. 2011). Notably, a number of previously identified risk factors for poor mother-infant synchrony (i.e. maternal depressive, anxiety and stress symptoms, as well as premature birth, and maternal age and level of education) showed no significant associations with mother-infant responsiveness within this sample. However, this may be attributable to the fact that this sample comprises a large community sample with low-risk profiles. This is in contradiction to studies which have focused on "high-risk" dyads such as mothers with high levels of depressive or anxiety symptoms (e.g. Coburn, Crnic, and Ross 2015; Moore et al. 2016).

4.1 | Limitations

Study recruitment was undertaken during the COVID-19 pandemic. Consequently, social distancing measures meant that smartphone use in general was likely increased in an attempt to seek external support and maintain social connection (David and Roberts 2021). It may therefore be useful to re-examine whether these results are replicable now that the social distancing measures are no longer in place in the UK. Research undertaken since the pandemic also suggests that parental mental wellbeing was negatively impacted, and that parents of infants aged 0–23 months showed a decrease in mental wellbeing at this time (Tisborn et al. 2022), which may have had an effect on the results captured herein. As just over half of the study participants (51.3%) reported that a frontline worker was present in their household, and just under half of participants (41.1%) reported contracting COVID while parenting their infant, such factors may indicate that heightened stress due to the pandemic was experienced, and this should be considered when interpreting the results of the study. As discussed, smartphone use habits are likely to have changed throughout the pandemic, however in some populations, there is evidence that these changes may have become habitual and are still observed in post-pandemic society (Massar et al. 2022).

Additionally, due to COVID-19 all data collection was undertaken online, mostly through social media platforms such as Facebook. Many of the support groups that were open to the recruitment call being posted on their page were run by white, well-educated women and this was reflected in the women who were members of the groups. Efforts were made to recruit other ethnic groups, single mothers, mothers whose infants were preterm, and teenage mothers with varying levels of success, but lack of diversity remains a limitation of the study. This means that it is unknown whether the results of this study can be generalized to samples that are more racially and ethnically diverse. Additionally, the majority of participants (95.1%) were living in a 2-person parental household, with 69% of the sample working full-time or were self-employed. Further, 88% of the sample were currently on maternity leave. This also means that the sample was limited in its diversity, and it is therefore important to consider whether different forms of household composition or employment status may also make a difference to the results. Further, while we can report that 95.1% of participants had a partner, we did not ask whether these partnerships were heterosexual or same sex relationships, or correspondingly whether the mother was a birthing or non-birthing partner of their infant. In considering participants' perceptions of their relationship with their infants, we note that scores on the MIRI were quite high, with an overall mean of 98 and a range of 72–110. This suggests that even participants who were classified as having lower responsiveness were likely well within the average range of a community sample.

Methodologically, as no hypothesis about specific risk factors was established a priori, the variables to be entered into the regression models were instead explored through correlation analysis. Additionally, as the survey was cross-sectional, it is difficult to ascertain the direction of causality of the results, as we only see a snapshot of behavior.

Finally, while the self-report scales used in the study are well validated, they are not always able to capture objective behavior. Particularly when we consider smartphone use, it has been suggested that most individuals will underestimate both the duration of use and the number of uses per day (Andrews et al. 2015), therefore self-report measures of smartphone use should still be interpreted with caution. Additionally, a small number of the scales within the survey reported Cronbach's alphas of between 0.6 and 0.7. While these scores are deemed acceptable within exploratory work, it is still important to consider what may cause lower internal consistency. In relation to smartphone use (TIPS), one reason may be again due to underestimations of phone use during different parenting domains. It may be that some participants are unwilling to reveal how often they use their smartphones in the presence of their child due to social desirability effects. Additionally, some ambiguity may be found within the scale itself, for example when thinking about phone use during "naptime", some participants may consider this as when the infant is in bed and asleep, while for others, they may understand this to mean as they are readying the infant for a nap. In relation to infant social emotional development (ASQ:SE-2), low internal consistency may be reported due to the age of the infant. For example, there is a large developmental leap between 3 and 9 months of age, and so this may affect the way in which parents infer the meaning of these questions, as has been indicated in various other scales measuring infant development (Giesbrecht and Dewey 2014).

4.2 | Future Directions for Research

To further enhance this research, there is scope to explore more diverse populations. For instance, mothers are not the only individuals who have a developing relationship with the infant, and as such future research should explore the relationships between non-birthing partners' smartphone use, and caregiver-infant interactions. Currently there is very little known about paternal smartphone use and its impact on the father-infant relationship (Braune-Krickau et al. 2021) as well as what differences may lie between maternal and paternal smartphone use in the presence of their child. As we learn more about the effects of paternal depression on the child's development (Sweeney and MacBeth 2016), further research needs to explore the associations between paternal mental health, infant development and smartphone use impacting the father-infant relationship.

Additionally, the underlying motivation for smartphone use may differ between individuals. For instance, extant literature indicates that mothers are, at least some of the time, using smartphones as a form of emotional escape and regulation by taking small breaks from their immediate environment (Rieger, Hefner, and Vorderer 2017; Wolfers et al. 2020), as well as a tool to obtain social and emotional support online (Archer and Kao 2018; Baker and Yang 2018). While both of these functions are valid uses of a smartphone, recent findings suggest that there are significant differences in how communicative versus passive consumption affect us, with many people reporting higher levels of passive consumption (i.e., escape seeking behaviors), further leading to decreased mental wellbeing outcomes (Stevic et al. 2021). It has also been suggested that passive consumption is more likely to lead to smartphone addiction and further problematic use (Elhai et al. 2017). For these reasons, understanding mothers' motivations for smartphone use is increasingly important.

Further, the sample within this study shows low clinical symptomatology and relatively high wellbeing, as indicated by scores on the DASS-21 and WHO-5. Further investigation into mothers with high, or even clinical, levels of mental ill health symptomology is necessary to understand how smartphone use may impact on relationships. Indeed, mothers with mental health issues such as bipolar disorder, postnatal depression, clinical depression, and schizophrenia, may be at higher risk for unattuned interactions and insecure attachments with their infant (Davidsen et al. 2015; Bernard et al. 2018), and the use of a smartphone is an unknown variable in this relationship.

5 | Conclusion

This study has highlighted that a number of risk factors may be associated with reduced mother-infant responsiveness in infants aged between 3 and 9 months old. This study supports previous literature in suggesting that (i) perceived infant social-emotional development issues may pose a risk to the dyad, that (ii) maternal wellbeing outcomes, particularly in the form of mothers feeling that they have someone to talk to about their problems may pose a risk to the dyad, and that (iii) maternal smartphone use while parenting, and specifically when mothers may feel that their infant is a passive participant within such parenting domains may pose a risk to the dyad. As little research to date has been carried out looking particularly at maternal smartphone use and its impacts on mother-infant relationships, the results of this study are useful in identifying that alongside a number of well documented risks, such as infant social emotional development issues and lack of maternal social support, maternal smartphone use may also be a risk factor to the mother-infant dyad from an early age, specifically during the development of relational processes such as dyadic synchrony between 3 and 9 months of age (Beebe et al. 2016; R. Feldman 2007).

Our findings are not intended to blame mothers who are often using their smartphones with good intentions. Indeed, smartphone apps can be used to inform good parenting practices, educate parents on milestones, or help log daily care-taking routines (Frizzo-Barker and Chow-White 2012; Virani, Duffett-Leger, and Letourneau 2021). Despite this, the ways in which the technology is used may be impactful, both for the mother and for the development of the dyad (McDaniel 2019). What these results do suggest is that identifying risk factors such as how and when mothers are using their smartphones, factors surrounding social isolation in the perinatal period, and infant development issues early, and providing relevant support, is crucial for both the mother and the infant.

Author Contributions

Lisa Golds: conceptualization, data curation, formal analysis, investigation, methodology, visualization, writing–original draft, writing–review & editing. **Karri Gillespie-Smith:** conceptualization, supervision, visualization, writing–original draft, writing–review & editing. **Angus MacBeth:** conceptualization, supervision, visualization, writing–original draft, writing–review & editing.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.