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Infant behavioural effects of smartphone interrupted parent-infant interaction

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Abstract

Infants are vulnerable to changes in the dyadic synchrony with their caregivers, as demonstrated in numerous experiments employing the still-face paradigm. The sudden lack of attunement causes infant stress reactions and the still-face literature have suggested potential long-term costs of this in terms of development of social, emotional and cognitive skills. Acknowledging the rapid technological development accompanied by altered practices in the parent-infant interaction, the current study investigates infant behavioural reactions in a similar experimental paradigm, manipulating parental responsiveness and sensitivity in a slightly different manner. In the current study, the parent interrupts the ongoing interaction, simulating occupation with a smartphone, rather than making a 'still-face'. In a cross-sectional design, infants of six, nine and twelve months display increased levels of protest behaviour in response to the interrupted interaction with their parent, together with lowered levels of positive engagement and social monitoring, suggesting similar behavioural responses as the still-face effect. Implications for infant social and emotional development, as well as for mindful tech habits are discussed.

KEYWORDS

infant development, parent-infant interaction, smartphone paradigm, social cognition

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BACKGROUND

One of the major advances during the technological revolution is the ubiquitous, fast-growing communication technology allowing real-time interaction without geographical boundaries. Among several things, this provokes adaptation in the realms of societal rules, educational systems, families' integrity, how children play, learn, and how we understand the developmental trajectories of the human infant. The term 'technoference' captures the way in which digital technology competes with our children and family for our attention (McDaniel & Coyne, 2016), and the implications of this observed trend are at interest. Still, the fast development of this technology makes empirical studies of these phenomena at the danger of being inherently passé, and may leave the scientific community reluctant in terms of suggesting potential adverse outcomes caused by the rapidity and direction of this development. While the American Academy of Paediatrics have provided recommendations as to how much time preschool children should spend in front of a screen because of the potential risks (AAP, 2016), fewer recommendations have been given regarding parental occupation with their own technological devices in front of an infant. Nevertheless, several studies point to a relatively high prevalence of parental occupation with their tech devices while interacting with their children for example at the playground (Mangan et al., 2018), or during meals at restaurants (Radesky et al., 2014).

Compared to direct screen use, parental interruption of an interaction, as with smartphones, might affect infant development in different ways. Reduced modelling of infants' behaviour, failing to notice the infant's initiatives to interact, and under-stimulated interaction are some potential risks that could hinder an optimal development of early social, emotional and cognitive skills (Davis et al., 2017; Leclère et al., 2014).

In this study, we explore infants' sensitivity to interruptions in the caregiver-infant interaction, an increasingly relevant topic considering recent technological advances. Firstly, we discuss infant development to capture the important factors of what constitutes the alliance between an infant and the caregiver facilitating learning and development.

The parent-infant interaction

An important building block of infants' socio-emotional developmental path is the parent-infant dyad. Parental sensitivity (i.e., the contingent and attuned responsiveness to infant cues) is the strongest predictor of the parent-child relationship, secure attachment, and the associated long-term social, psychological and health outcomes (Fearon et al., 2010). The finely tuned interaction between a caregiver and an infant can decompose into mutual gaze, turn-taking, sensitivity and reciprocity in terms of facial expressions and vocalizations that generates a 'joint attention alliance' between the caregiver and the infant. The reciprocity between the two is dynamic, achieved through mutual engagement, and forms the starting point for the development of important social cognitive skills (Harrist & Waugh, 2002; Legerstee et al., 2007).

A wealth of research employing the still-face paradigm (Tronick et al., 1978) has demonstrated a strong and consistent protest reaction in infants when exposed to a partner posing a 'still-face' for one minute during everyday interaction (Mesman et al., 2009). The still-face effect has proven to be a robust infant reaction to the sudden lack of parental sensitivity in which the infants typically display decreased positive affect, along with increased negative affect and protest behaviour (Mesman et al., 2009). The effect is stronger with the mother compared to a stranger, and after its peak in negativity at 4 months of age it decreases to 6 and further to 8 months of age (Melinder et al., 2010). The parental unresponsiveness breaks the dyadic state of consciousness necessary for the synchrony in the ongoing regulation process, and leads to immediate stress and discomfort in the infant as demonstrated in the many studies employing the still-face (Melinder et al., 2010; Mesman et al., 2009; Tronick, 2005; Tronick et al., 1978). The proposed reason for the still-face effect has been the contradictive information signalled to the infant by keeping eye contact, albeit non modulated and unresponsive. Indeed, a

Statement of Contribution

What is already known on this subject?

- Infant vulnerability to loss of parental sensitivity and attunement.
- The still-face effect.

What the present study adds?

- Modern-day purpose of still-face paradigm.
- Infant reactions to parental occupation with smartphones.

longitudinal study employing the still-face paradigm demonstrated that infant responsiveness during the first three months were dependent on maternal responsiveness. Further, individual differences in maternal responsiveness in terms of vocalization and smiling predicted infant responsiveness during the still-face task, but also over time. Maternal responsiveness thereby facilitated infants' positive social engagement (Bigelow & Power, 2014). Infant sensitivity to maternal responsiveness during interaction is also demonstrated within the temporal dimension, in which a 3-second delay in maternal vocal and facial expressions negatively affected infant smiling, and the infants' perception of maternal responsiveness when interacting via videoconference (Henning & Striano, 2011).

Modern-day parenting challenges

The question of whether, or how parental occupation with technological devices affect their children has received increasing attention during the past few years, and different infant and child outcomes have been investigated. One study found greater externalizing behaviour in children under the age of five years to be predicted by parents' self-reported technofence in the parent–child relationship (McDaniel & Radesky, 2018). Further, studies of underprivileged families have found a positive association between parental technology use and children's psychosocial difficulties (Wong et al., 2020), and maternal perception of the child as difficult (Radesky et al., 2018). The effect of technofence on parental responsivity and sensitivity has also been investigated by means of various designs over the recent years. Less frequent parent–child interaction (Radesky et al., 2015), a decrease in response and response quality towards their children (Vanden Abeele et al., 2020), and lowered sensitivity to infant cues (Golen & Ventura, 2015) have all been positively associated with parental distraction and mobile device use. Interestingly, passive and fully absorbed phone use seems to have a greater impact on parental responsivity than occasional use, suggesting that level of absorption is an important factor when considering interference of technological devices on parenting quality (Vanden Abeele et al., 2020). Nuancing this picture, Wolfers and colleagues found in their naturalistic observational study of mothers and their children between the ages of 7 and 36 months, that mothers who reported using their mobile phone for a longer time period were rated less sensitive by trained observers. The same association was not found with regards to frequency of use, and the authors suggest a complexity of the matter, concerning duration, frequency, and possibly also the purpose of their mobile phone use (Wolfers et al., 2020). In their modification of the still-face paradigm, Myruski and colleagues tested mothers' interactions with their infants between the ages of 7 and 24 months (Myruski et al., 2018). The duration of the experimental phases was altered, and the infants could move around freely in the room with access to toys, also during the 'still-face'-episode in which the mothers were instructed to use a mobile device. The pattern of infant responses was similar to those consistently reported in the still-face literature. Also, higher levels of self-reported mobile device use by the mothers revealed fewer signs of successful

mother-infant repair during the reunion phase of the procedure (Myruski et al., 2018). Potential positive outcomes of the issue at hand are also suggested in that for parents of younger children, the smart phone might function as a way to seek relief from the child rearing task, although contextual factors needs to be considered both when evaluating effects, and when offering guidelines to the society (Knitter & Zemp, 2020).

Responsive and predictable interactions are not only central for infant wellbeing and comfort in general, but may also serve an important function later during development. For instance, in a recent experimental study, 2-year-olds only learned novel words when the teaching session by the mother was *not* interrupted by a phone call, as compared to the condition with the phone-call interruption (Reed et al., 2017). Further, toddlers are also shown to depend on socially contingent interactions when learning novel words through screen media. Live video chats as well as traditional face-to-face interaction facilitated word learning, whereas a condition with non-contingent video training did not (Roseberry et al., 2014). Thus, the learning facilitated by the contingent responsiveness in a dyad seems sensitive to unpredictable interruptions.

The caregiver-infant interaction is instrumental for infants to attribute intentions, emotions, and beliefs to predict overt and expected behaviour and to guide further learning (Gredebäck & Melinder, 2010, 2011). Emotion understanding is thus acquired through interactions with caregivers and starts already in infancy (for a review see Widen & Russell, 2008). Although an obviously complex developmental process with prominent individual variations (Grazzani et al., 2018), a continuous and predictable interactional partner seems highly relevant. Indeed, adult interactions are also shown to suffer in terms of the social and communicative outcomes from inattentive conversational partners preoccupied with their smartphone (Lopez-Rosenfeld et al., 2015).

The present study

In a day and age where our attention is challenged frequently by push notifications from numerous electronic devices, the caregiver-infant interaction is also likely to change or at the very least be put to the test. We have developed an experimental procedure similar to the still-face procedure by Tronick et al. (1978), only changing the second phase of the procedure to create a situation of interrupted interaction, resembling a parent consumed with her smartphone. We thereby investigate the nature of infants' sensitivity to a shift in the attention of the interaction partner to broaden the still-face effect's relevance to apply to other caregiver-infant settings. We label this the 'Smartphone Procedure' (SPP). The SPP enables us to test if the infant distress increases when the reciprocity of the interaction is interrupted and the eye contact removed (i.e., no contradictory information as with the original still-face paradigm), as often can be the case with parental technofeference. We investigate whether a simulated smartphone-like interruption during an interaction between caregiver and infant, affects infant behaviour according to well-known principles of infant behavioural expressions. In assessing the behavioural reactions of infants in three different age groups, we employ the Infant and Caregiver Engagement Phases (IECP), developed on the basis on Tronick's Monadic Phases Scoring System, Tronick and Weinberg's Infant and Maternal Regulatory Scoring Systems, and Weinberg and Tronick's affective configurations (Tronick et al., 2005; Weinberg & Tronick, 1994).

The present study composes of a cross-sectional experimental design with infants of 6, 9 and 12 months of age participating, in order to investigate any developmental change in behavioural response to our experimental procedure. Additionally, parents completed a questionnaire regarding their smartphone habits. We examined what behavioural expressions the infants would display during the SPP, and hypothesized based on the still-face literature, an increased demonstration of infant negative protest behaviour and less object and social engagement during the interruption-phase across all ages. Also in line the still-face literature, we hypothesized a lessening of protest behaviour in response to the interrupted interaction with age, as a reflection of further developed infant emotion regulation skills.

TABLE 1 Synopsis of the experimental procedure

Set-up	The infant is placed in car seat on a chair, securely fastened, facing his/her parent who sits in a chair directly opposite, 50 cm. Apart		
Recording	A camera with a microphone is placed obliquely behind the dyad, capturing the interaction		
Duration (s)	Phase 1 (baseline)	Phase 2 (interrupted interaction)	Phase 3 (reunion)
Interaction	120	60	120
SIGNAL START	Typical interaction between infant and parent, in which the parent initiates eye contact, and displays friendly facial expressions, vocalizations, and touch	The parent stops the ongoing interaction by leaning forward in the chair, and shifting the attention towards his/her hand that is now stretched out on the side of the infant. The parent fixates with a neutral facial expression at their hand, and does not respond to any effort made by the infant. Neither with vocalizations, touch, nor any other bodily gesture	The parent reinstates the typical interaction described for Phase 1
SIGNAL NEXT PHASE	SIGNAL NEXT PHASE	SIGNAL NEXT PHASE	SIGNAL END

METHOD

The overall project (Development of Infants' Social Cognitive Skills) was approved by the Regional Ethics Committee (ref. 2013/793), and conducted at the Department of Psychology, University of Oslo in accordance with the 1964 Declaration of Helsinki and APA ethical standards.

Participants

Invitation letters to families with infants in the Oslo area were sent by mail. The addresses were collected with granted access to the Norwegian National Population Register. The families wanting to participate made contact, and after agreement met for participation at the lab. All infants were born within two weeks of their due date, with no known disease, as reported by their parents upon scheduling of participation. Out of the 54 infants who met for participation, three were excluded (drowsiness, and too high levels of frustration early on in the procedure). Of the remaining 51 participants, five infants had the procedure aborted during Phase 3 due to a high level of frustration, corresponding to 1.8% of the total data. An additional 1.4% of the data were unscorable due to the parent blocking the camera. This total of 3.2% missing data was replaced by the age specific mean of each code for the relevant experimental phase. The final data set consisted of 51 infants divided into three age groups of 6 months ($n = 21$, $M = 6.31$ months, $SD = 0.36$, 9 girls), 9 months ($n = 17$, $M = 9.18$ months, $SD = 0.45$, 7 girls) and 12 months ($n = 13$, $M = 12.42$, $SD = 0.41$, 6 girls). The gender distribution of parents bringing their infants to participate was skewed and consisted of 44 mothers and 7 fathers.

Laboratory setting and procedure

The families met at the laboratory and were introduced to the study and the SPP, all by the same experimenter. After explaining the procedure in detail, including the information that they could abort the procedure if they were to become uncomfortable with the level of frustration of their infant, the parent gave their informed consent to participate. The lab was equipped with a chair for the parent, and opposite it, a chair with an infant car seat for the baby. A video camera with a microphone recording the procedure was directed towards the dyad, outside of the infants' view. Outside of the infants' view was also a window for the experimenter to monitor the procedure from outside the room.

The Smartphone Procedure (SPP) was inspired by the still-face paradigm and consisted of three phases as the original still-face procedure (Tronick et al., 1978). The first two minutes, Phase 1, compose a baseline with typical parent-infant interaction. Phase 2, lasting 1 min, is characterized by an unresponsive parent, before Phase 3 follows as the reunion phase for 2 min in which the parent-infant interaction is re-established. See [Table 1](#) for further description of the procedure.

After completing the SPP, the experimenter brought the parent and infant back into the welcoming area of the lab for a debriefing session and completion of a questionnaire. In addition to background questions related to gender, birth date, due date and known health issues of the infant, the background questionnaire also consisted of forced choice questions regarding marital status, education and income to inform about socio economic status. To map the parents' smart phone habits, 14 questions on this matter were added as for instance: 'Do you interrupt an activity when you hear a notification from your smartphone?', or 'Does your smartphone get in the way of direct communication with others?', in which the parents were asked to indicate their habits by choosing 'yes', 'no' or 'sometimes'. Composite scores based on participants' responses to these questionnaires were calculated both for socioeconomic status (SES), and for smartphone habits. For SES, the score range went from 1 (low) to 6 (high), based on both parents' education level and income, equally weighted. For smartphone habits, the scale range

went from 1 to 13, in which the higher score indicated more frequent use, as well as more perceived distraction from the smartphone in the daily life. See Table 2 for an overview of participant descriptive information.

Coding of data

We employed the coding procedure developed by Tronick and colleagues (Tronick et al., 2005; Weinberg & Tronick, 1994) in which six mutually exclusive behavioural codes are used to categorize the infants' behaviour during the whole procedure. The codes negative engagement, protest, object/environment engagement, social monitoring, and social positive engagement were scored on the basis of the infant's facial expressions, direction of gaze, body posture, gestures and vocalizations. Further, coders were instructed to categorize the infant behaviour as protest or withdrawal, and avoid the undifferentiated behavioural code, negative engagement, as long as the observed infant behaviour met the criteria specified in Table 3. These behavioural codes are quantified by registering the duration (in seconds) of each code in each of the three phases. Two different coders were qualified by going through test video recordings and agreeing on the complete set of properties for each code together. Further, reliability between coders was established by both coding 21.6% ($n = 11$) of randomly selected recordings, obtaining reliability on the duration of each code per participant within each experimental phase. The intra-class correlation coefficients (ICC) are listed in Table 4. As the codes for negative engagement and withdrawal were never used, these were not included in reliability analyses, nor for any statistical comparisons of our data.

Statistical analyses

The dependent measures were the proportions of time during each phase of the procedure infants' behaviour was consistent with the behavioural codes of protest, object/environment engagement, social monitoring, and positive social engagement. Neither parental SES nor smart phone habits were included in the statistical analyses due to a lack of variability in these scores in our data set. In order to investigate infants' reaction to our experimental manipulations, and identify whether these were susceptible to change with age, we conducted mixed design ANOVA's. We employed the proportional duration of each of the four behavioural codes (i.e., protest, object/environment engagement, social monitoring and social positive engagement) separated by experimental phase 1, 2 and 3 as within group variables, and age group as between group variable. Post hoc tests (Bonferroni-corrected) were used to investigate the nature of change between experimental phases within the behavioural codes. We employed two-tailed probabilities, and an alpha value of .05 to test significance. Effect sizes are presented as partial eta squared (η^2). These are interpreted according to Cohen's (1988) criteria in which values less than .06 are considered small, over .06 are considered moderate and those over .14 are considered large effect sizes (Cohen, 1988). Descriptive statistics of infant behaviour reactions are presented in Table 5.

TABLE 2 Summarizing table for parent gender, and scores on smartphone habits and SES

Infant age group	Parent gender		Smartphone habits	SES
	Female	Male	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
6	21	0	5.7 (2.1)	5.6 (0.6)
9	15	2	5.7 (1.6)	5.5 (0.7)
12	8	5	5.0 (1.3)	5.3 (1.1)

TABLE 3 Description of infant behavioural codes

Code	Description
Negative engagement	An undifferentiated category in which the infant displays negative facial expressions, which could be accompanied by vocalizations signalling discomfort
Protest	Specified negative engagement in which the infant displays protest through externalizing behaviours either with facial expressions, vocalization or gestures signalling protest
Withdrawal	Specified negative engagement in which the infant is minimally engaged and withdrawn, with a clear disengagement with regards to posture, gaze and facial expressions
Object/environment engagement	Infant engagement with proximal or distal object in an interested or neutral manner
Social monitoring	Infant attention to the parent in a neutral or interested manner
Social positive engagement	Infant attention to the parent in a positive manner, as displayed by happy facial expressions, and this could also be accompanied by positive vocalizations

TABLE 4 Intra-class correlation coefficients for inter-rater agreement per infant behaviour code per experimental phase ($n = 11$)

Infant behaviour code	Phase 1	Phase 2	Phase 3
Protest	0.98	0.93	0.99
Object Engagement	0.98	0.92	0.93
Social Monitoring	0.77	0.99	0.82
Social Positive Engagement	0.97	^a	0.96

^aThe code for Social Positive Engagement was not used during Phase 2 by either of the two raters.

RESULTS

After the replacement of missing data, a manual inspection of all recordings proved all phases to be of equal duration between all participants. One-way between-groups analyses of variance revealed no significant differences on any of the behavioural codes within all three phases of the experimental procedure in terms of infants' gender (p -values $> .05$). However, in inspecting differences due to the parents' gender the ANOVA's revealed that there was significantly more display of social monitoring during Phase 1 with fathers ($M = 0.27$, $SD = 0.29$) than with mothers, $M = 0.14$, $SD = 0.12$; $F(1, 49) = 4.42$, $p = .04$, $\eta^2 = .09$ (moderate effect). Because this phase is less central to the aims of this paper, and no other behavioural measure proved significant when tested, we did not include parental gender as a covariate in our further analyses.

For protest behaviour, there was a significant main effect for experimental phase with a large effect size, $F(2, 46) = 43.65$, $p < .05$, $\eta^2 = .66$. There were no significant effects between the three age groups, $F(2, 47) = 0.85$, $p = .43$, $\eta^2 = .04$, nor interaction between the experimental phases and age groups, $F(4, 92) = 0.60$, $p = .66$, $\eta^2 = .03$. Post hoc tests adjusting for multiple comparisons (Bonferroni) showed that there is a significant increase in protest behaviour from baseline ($M = 0.17$, $SE = .03$) to Phase 2 ($M = 0.59$, $SE = .05$), $p < .05$, and a significant decrease from Phase 2 to Phase 3 ($M = 0.35$, $SE = .05$), $p < .05$. The level of protest at baseline was not resumed, and the increase between baseline and Phase 3 was also significant ($p < .05$).

For object/environment engagement there was also a significant main effect for experimental phase, $F(1.57, 75.33) = 7.26$, $p < .05$, $\eta^2 = .13$. There were no differences between the age groups, $F(2, 48) = 0.34$, $p = .72$, $\eta^2 = .01$, nor interaction between the three phases on this code and age group, $F(3.14,$

TABLE 5 Descriptive statistics for Infants' behaviour during the experimental procedure ($n = 21$ (6 months), $n = 17$ (9 months) and $n = 13$ (12 months))

Infant behaviour code	Age group	Phase 1, M (SD)	Phase 2, M (SD)	Phase 3, M (SD)
Protest	6	0.21 (0.30)	0.67 (0.38)	0.39 (0.33)
	9	0.12 (0.17)	0.57 (0.37)	0.26 (0.32)
	12	0.17 (0.20)	0.53 (0.32)	0.40 (0.32)
Object Engagement	6	0.46 (0.31)	0.29 (0.35)	0.29 (0.28)
	9	0.44 (0.23)	0.40 (0.33)	0.37 (0.26)
	12	0.43 (0.25)	0.43 (0.28)	0.20 (0.17)
Social Monitoring	6	0.13 (0.12)	0.03 (0.05)	0.11 (0.10)
	9	0.14 (0.12)	0.03 (0.06)	0.14 (0.15)
	12	0.23 (0.22)	0.04 (0.06)	0.18 (0.19)
Social Positive Engagement	6	0.22 (0.25)	0.00 (0.00)	0.23 (0.27)
	9	0.30 (0.29)	0.00 (0.01)	0.23 (0.26)
	12	0.17 (0.14)	0.00 (0.00)	0.23 (0.23)

75.33) = 1.99, $p = .12$, $\eta^2 = .08$. As Mauchley's test of sphericity was violated, the Greenhouse–Geisser correction was used. The Bonferroni-corrected post hoc tests revealed a significant decrease in object engagement behaviour between baseline ($M = 0.44$, $SE = .04$) and Phase 3 ($M = 0.29$, $SE = .04$), $p < .05$, but not with any other comparisons.

For social monitoring behaviour we found a significant main effect for experimental phase and a large effect size, $F(2, 46) = 18.49$, $p < .05$, $\eta^2 = .45$. There were no differences in terms of age, $F(2, 47) = 1.79$, $p = .18$, $\eta^2 = .07$, nor any interaction effect between experimental phase and age group, $F(4, 92) = 0.83$, $p = .51$, $\eta^2 = .04$. Bonferroni-corrected post hoc tests revealed a significant decrease in social monitoring behaviour from baseline ($M = 0.17$, $SE = 0.02$) to Phase 2 ($M = 0.03$, $SE = 0.01$), $p < .05$. Similarly, there was a significant increase from Phase 2 to Phase 3 ($M = 0.14$, $SE = 0.02$), $p < .05$, in which baseline level was resumed.

Our corresponding calculations with social positive engagement demonstrated a significant main effect for experimental phase and large effect size, $F(2, 46) = 24.88$, $p < .05$, $\eta^2 = .52$. We found no differences between the age groups, $F(2, 47) = 0.34$, $p = .71$, $\eta^2 = .01$, nor did we find any interaction effect between experimental phase and age group, $F(4, 92) = 0.94$, $p = .45$, $\eta^2 = .04$. Post hoc tests with Bonferroni-corrections revealed a significant decrease of social positive engagement from baseline ($M = 0.23$, $SE = .03$) to Phase 2 ($M = 0.00$, $SE = .00$), $p < .05$, and an increase between Phase 2 and Phase 3 ($M = 0.23$, $SE = .04$), $p < .05$, resuming baseline level. See Figure 1 for a visualization of the results across the three experimental phases.

DISCUSSION

In this study we investigated the question many ask these days, namely how interruptions in ongoing parent–infant interactions, as with the use of smartphones, may affect their infants' sense of comfort and behaviour. While former studies have found solid evidence for increased negative protest behaviour and less positive expressions during the introduction of a still-face, we employed a novel stressful procedure, the Smartphone Procedure (SPP), to examine infants' behavioural expressions when interrupted during an interaction with their caregiver. Few studies have investigated developmental changes in infants' stress during parental disregard or inattentiveness in this way. To investigate the possible effect of infants' age during this procedure, three different age groups were included.

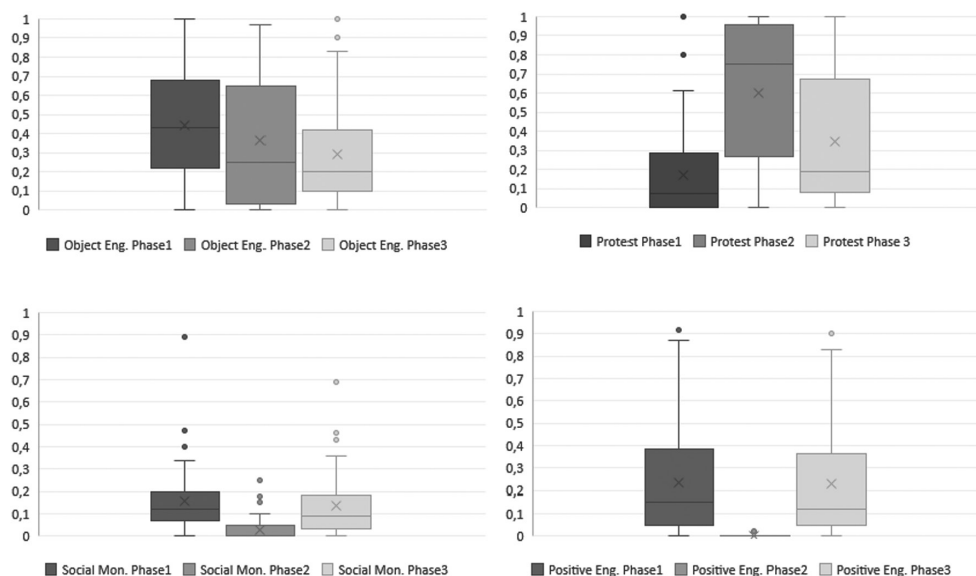


FIGURE 1 Box plot with error bars illustrating the change in observed infant behaviour for the four codes across the three experimental phases

Behavioural effects of interrupted parent-infant interactions

For all of the four behavioural outcomes, we observed an effect of the experimental manipulation. For protest behaviour, social monitoring behaviour, and positive engagement, the effects were especially prominent during the second phase in which the interaction was interrupted. Thus, infants showed more protest behaviour and less positive object and social engagement during the second phase, and only resumed their initial baseline level in Phase 3 (i.e., reunion) for social monitoring and positive engagement behaviour. Object engagement behaviour decreased between baseline and Phase 3, and finally protest behaviour remained elevated until closure of the procedure, meaning that infants never resumed their baseline behaviour in either subsequent phase of the experiment, as visualized in Figure 1. We regard these reactions as typical responses to discontinued interaction, as with an unpredictable interlocutor (Melinder et al., 2010; Mesman et al., 2009; Myruski et al., 2018). As scholars have shown before, such volatile sensitivity might compromise the infant's healthy development in the longer run (Davis et al., 2017; Tronick, 2005).

Conventional parent-infant interaction involves looking at the infant's face and responding to the facial expressions and vocalizations of the infant (i.e., mirroring the infant's expressions), accompanied by monitoring how new responses are evoked. When this finely tuned interaction is interrupted the infant reacts with discomfort and stress. Such regular interruptions are likely to jeopardize the frequency of empathic communication between infant and caregiver and reduce the opportunities for learning and reinforcement of appropriate social behaviour.

Time spent in front of a screen is time *lost* for social interactions (Skalická et al., 2019). Based on our present data, we are inclined to state the same about parental smartphone use while interacting with the infant. At certain ages this might be more critical. For instance, when the infant is about to extend his context to a third object, an ability gradually developing from the first half year of life, the direction of parental gaze and contingent interaction is at stake (Mundy & Gomes, 1998). Interestingly, infants' age was not associated with any effects of the manipulations that we could detect during the experiment. Six months old, as well as 9 and 12 month's old infants in our study all responded similarly to the interruption and loss of synchrony. Previously, infants' protest behaviour in response to the still-face has been shown to decline with age during infancy (Melinder et al., 2010). Yet, in a recent study employing an

altered still-face paradigm with mobile phone interruption, the infants' age did not significantly affect the pattern of results despite the lower intensity of protest behaviour (Myruski et al., 2018). With the traditional still-face paradigm, a reduction in negative affect can be explained by the infants' gradually improving emotion regulation skills. With the current experimental manipulation, we argue that the behavioural reactions are caused by the unpleasantness of the interrupted interaction, rather than the ambiguous change in responsiveness or sensitivity.

Children imitate and modulate their parents' behaviour and routines, and families' habits are generally transferred to the next generation by such transactions, including parental technological habits (Wong et al., 2020). A very limited number of studies have focused on the effects of smartphone use in infants and children. Still, recent research suggest that children's own screen activities pose emotional, neurocognitive and neurobiological risks (Horowitz-Kraus & Hutton, 2018; Hutton et al., 2019; Skalická et al., 2019; Zivan et al., 2019). On the other hand, in a recent systematic review potential parental benefits of smartphone use have been suggested in relation to easily accessible parental support along with entertainment and the relief from the otherwise all-consuming task of parenting (Knitter & Zemp, 2020). These are, however, parental benefits, and the need for more knowledge on the infant cost is evident.

Strengths and limitations

There are both strengths and limitations in the present study that should be mentioned. The experimental context represents in itself a less secure environment to an infant and may as such have contributed to the observed effect of an increasingly negative infant behaviour and a parallel decrease of positive infant engagement during the procedure. While this might be a concern, we argue that the typical pattern seen in still-face paradigms were evident also in our experiment. In addition, the infant serves as his own control in this paradigm as Phase 1 constitutes a behavioural baseline, and thereby validating the paradigm. The still-face literature, along with the relatively young base of literature investigating the effects of technofence on infants and children largely relies on maternal behaviour. In this study, we have included both male and female parents for nuance. Although a skewed sample (relatively few male parents), our data do not indicate different patterns of infant reactions as a result of parental gender. Further, our cross-sectional design comparing infants of three age groups also allows for a discussion of developmental effects. Another limitation of our study is the small variability in the participants' SES (i.e., the majority reported a high SES) and in the parents' reported smartphone habits, which could be addressed in future studies including a more diverse sample. In particular, parental self-report is at danger of reflecting an underestimate of actual smartphone use, and studies have previously revealed a discrepancy in that direction between parents' self-reports and observational data (Knitter & Zemp, 2020). Although higher frequency of smartphone use was not associated with altered levels of positive nor negative affect in the modified still-face paradigm conducted by Myruski et al. (2018), we still encourage future studies employing this paradigm to consider other ways of measuring parental smartphone use as with observations of waiting room behaviour, also on lower SES samples. Another strength of our study is that the simplicity of the paradigm allows for adaptation and replication. However, the current study did not make use of an actual smartphone. As previous modifications of the still-face paradigm have demonstrated that the still-face effect is partly dependent on infants' interpretation of the context and possible explanations for their parent's unresponsiveness (Legerstee & Markova, 2007), an important notion for the current paradigm was to keep the parent's hand out the infant's sight, and as such controlling for the possible infant rationalization of the parental behaviour. To increase the ecological validity, future research should investigate differences in the observed still-face effect with *and* without actual smartphones visible to the infants, keeping in mind infant developmental trajectories within social and emotional capacities. We acknowledge that our results are not suitable for any predictions regarding long-term effects, and more longitudinal studies are needed to improve our

understanding. Rather, we have demonstrated infants' behavioural reactions to interrupted parent-infant interaction 'here-and-now' – a pattern of reactions consistent across the age groups included.

CONCLUSION

With the increasing use and availability of smartphones, parents' attention towards their infant is facing challenge and the imperative responsiveness in the interaction is at danger of being jeopardized. Leading authorities have recently released restrictive recommendations for younger children regarding their own use of such devices, but these risk factors are, however, less explored when it comes to parental use and infants experiencing interrupted interaction with a significant caregiver. We have found the interruption of everyday interaction between caregiver and infant to evoke similar reactions in the infant as with the traditional still-face, across age groups. Our data demonstrates a reduction in positive infant engagement (e.g., smiling, cooing, laughing, etc.), and an increase in protest behaviour (e.g., crying, trying to escape the chair, kicking etc.), and we uphold that these reactions can be attributed to the discomfort of loss of parental responsiveness and social contingency. Recent literature suggests paying attention to contextual factors as frequency of use, duration, reason for use, and timing when it comes to parents' smartphone use (Knitter & Zemp, 2020). Appreciating the transactional processes at work in the family environment, we do, however, advice authorities to guide parents and health personnel on these complex matters. We suggest promoting mindful practice of technology, keeping in mind the potential of misuse to become a new epidemic in the growing generation.

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CONFLICT OF INTEREST

We have no conflicts of interest to disclose.

AUTHOR CONTRIBUTIONS

Ida Tidemann: Investigation; methodology; validation; visualization. **Annika M. D. Melinder:** Conceptualization; methodology; supervision; validation.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request, pending specific consent to share from the participants.

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