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Does texting interrupt imitation learning in 19-month-old infants?

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ABSTRACT

Observed disruptions to parent-child interactions during parental media use, such as texting, have been termed technoference. For example, when a language learning interaction was disrupted by a phone call, toddlers were less likely to acquire the word. Other studies demonstrated that parents often exhibit a still face while silently reading information on their cell phones. In the present study, the effect of a text interruption on infant imitation learning was examined. Parents demonstrated three target actions to their infants and then infants were given the opportunity to repeat those interactions. The actions were demonstrated four times. Text interruptions occurred before or between demonstrations. Performance of these groups was compared to a baseline control group where the infant did not see a demonstration of the target actions and a no-interruption group where the parents demonstrated the target actions four times without interruption. Parents were randomly assigned to three conditions, interruption-first condition, one-interruption condition, or three-interruptions condition. Infant behavior was measured during the interruptions. Across text interruption groups parents exhibited high levels of still face during the interruptions (77 %). However, infants in all 3 interruption groups performed significantly above the baseline control indicating learning despite the interruptions. Higher reported maternal reliance on the smartphone was related to poorer imitation performance overall. In contrast, when parents reported that they found it easier to multi-task infant imitation rates were higher. These findings indicate that infants can learn under conditions of brief technoference and that individual differences in family media ecology are associated with learning.

1. Introduction

The introduction of the iPhone in 2007 and the iPad in 2010 heralded a rapid shift in the availability of mobile technology in the homes of infants. Nearly all U.S. homes with young children (95 %) have a smartphone, and three quarters have a tablet (Rideout, 2017) and in Germany the availability of smartphones is also very high (65 %, Medienpädagogischer Forschungsverbund Südwest (Hrsg.), 2015). During toddlerhood, however, use of smartphones by toddlers themselves is relatively low. Parents report that time spent using tablets or smartphones during early childhood does not typically exceed 30 min per day (e.g., Lauricella, Wartella, & Rideout, 2015). In a survey of parents with children aged 5–40 months in France, 75 % of families used touchscreen technology such as tablets to view videos or photos, and 50 % reported using tablet applications marketed as appropriate for babies (Cristia & Seidl, 2015).

Mobile device use occurs in brief, intermittent bursts (Radesky et al., 2020), and therefore is difficult for parents to self-report

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(Goedhart, Kromhout, Wiart, & Vermeulen, 2015). Recently, researchers have been able to track mobile device use via passive sensing on mobile devices. When measured using passive sensing technology, daily usage by parents can be relatively high with estimates around 2 h per day by parents of young children (Radesky et al., 2020). Parent's media usage on all devices (television, computers, smartphones and tablets) is strongly associated with children's screen usage from infancy to 8 years of age (Anderson & Hanson, 2017; Connell, Lauricella, & Wartella, 2015; Lauricella et al., 2015; Nikken & Schols, 2015).

Parental mobile phone usage can be problematic. Parents may not realize that they are disconnecting from the child multiple times at unpredictable intervals during the day. "Technoference" is defined as everyday interruptions to interpersonal interactions or time spent together that occur due to digital media (McDaniel & Radesky, 2018). The introduction of technology may disrupt the infant's ability to regulate attention during typical routines and play and reduce their ability to learn. Early childhood may be a particularly vulnerable time for technoference because media usage is entirely governed by family household media patterns. Infants choose neither the amount nor the content of exposure.

Parents are unlikely to be aware of how their own mobile media usage is affecting parent-infant interactions. When checking mobile phones, parents' faces typically have no expression, which may be perceived by young children as a "still face," to which children respond aversively (Adamson & Frick, 2003). Goldstein, Schwade, and Bornstein (2009) found that when 5-month-olds were exposed to a still face by an unfamiliar adult in a face-to-face interaction, infants initially attempted to re-engage the adult but then gave up. In a modified version of the still face procedure, Myruski et al. (2018) asked mothers of 50 7- to 23-month-olds to participate in a mobile device version of the still face. In an initial free play session, mothers were instructed to play freely with their infants for five minutes. Then in the still face phase, they were asked to view their mobile phone for two minutes. Finally, there was a one-minute second free play phase, called the reunion phase. Infants explored the room more during the first free play session than they did during the still face or reunion phases. When parents viewed their mobile device during the still face phase, infants exhibited the typical protest and distress response exhibited in other versions of the still face paradigm (Myruski et al., 2018). More frequent self-reported maternal mobile device use was correlated with less engagement with the mother during reunion. However, there were a number of limitations to the study. The study sample included a wide age-range of children between 7 and 23 months involving different developmental stages with varying levels of mobility, language ability, and emotion regulation ability. Pre-locomotive infants have less ways to interact with toys or distract themselves during the still face period and coded infant behaviors might have a different quality at an age as young as 7 months compared to 23 months. Furthermore, young infants were less exposed to smartphones in their lives than older infants. Unlike typical still face paradigms, children were allowed to run around the room freely meaning that they might not have noticed the disruption caused by the still phase. Finally, parents did not receive an actual text. Instead, parents were instructed to look at the phone as if receiving a text. From this study, it is not clear whether parents exhibit a still face when reading an actual text or whether children register a disruption.

Mobile phone calls do appear to interrupt children's learning. Reed, Hirsh-Pasek., and Golinkoff (2017) asked mothers to teach their 24-month-olds two novel words, one at a time for 60-sec each. Mothers received a 30-sec call that interrupted them after 30-sec while teaching one of the words, but not while teaching the other word. Children were significantly more likely to learn the word in the non-interrupted teaching phase than the word in the interrupted teaching phase. The result remained despite the child hearing the novel word the same number of times in both conditions. Maternal mobile phone use was assessed via self-reported number of daily calls and texts. Mothers' mobile phone use was not correlated with learning of the interrupted and uninterrupted word. Furthermore, providing an explanation to their child that they had to take a phone call did not affect if the child learned the interrupted word.

In summary, mobile phone use during interactions results in repeated disconnections between social partners and less engagement after a disruption. Twenty-four-month-olds were less likely to learn a novel word if learning was interrupted by a phone call. However, a phone call does not have to involve a parental still face to the child. During a call, the parent maintains eye contact, smiles and gestures to the child, which the parent is less able to do when reading and responding to a text. Therefore, looking at the smartphone while texting might thus be more disruptive for both parent-child interactions, as well as, for infant learning. Furthermore, the interruption may be perceived as a 'still face'. In the present study, we explored whether imitation learning was affected when the teaching phase was interrupted by texting. We tested whether a period of still face engendered during a text message (Myruski et al., 2018) may be more disruptive to learning than a phone call (Reed et al., 2017).

Previous empirical studies have examined whether infants imitate their parents under semi-naturalistic conditions (Seehagen & Herbert, 2010). For example, these researchers compared imitation learning of a 3-step rattle task comparing rates of learning from a prerecorded maternal demonstration versus a prerecorded experimenter demonstration. Imitation performance did not differ between the maternal and experimenter demonstrations. There were differences in the descriptors that mothers used, which were used to prepare a "motherstyle" narrative script. When experimenters used this "motherstyle," 18-month-olds imitated the target actions from television performing significantly above both the baseline group and the experimental group who viewed the experimenter perform the target actions accompanied by an empty narrative. An empty narrative does not contain any information about the stimuli or the target actions. The fact that the imitation rates were equal between parents and experimenters but that maternal style was beneficial led to our choice of mothers as demonstrators in the present study. Mothers were instructed to teach their children as they typically would with the exception that they could not label the target actions. They were also instructed that would be asked to complete brief questionnaires during the session and the experimenter would text the questions.

During early childhood, imitation is a highly efficient learning mechanism that is supported by social contingency and joint attention. Infants are born into an environment in which human interactions are predicated on social contingency, or the appropriate and timely back-and-forth manner of response (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008). Infants are sensitive to fluctuations in the timing (Henning & Striano, 2011) and frequency of contingent responses by caregivers (Goldstein et al., 2009). Infants are similarly sensitive to the contingency between their own behavior and that of their caregivers (Murray & Travarthen, 1985). In addition to social contingency, when learning about new objects, joint visual attention (JVA), or “following the direction of attention of another person to the object of their attention” (Butterworth, 2004, p. 213) is also required. A recent neuroimaging study of 14-month-infants indicated that the structures identified as part of the adult social network, that includes the superior temporal sulcus-temporoparietal junction (STS-TPJ) region, were most activated during joint attention tasks relative to face-to-face interactions and a no-social interaction control (Hakuno, Pirazzoli, Blasi, Johnson, & Lloyd-Fox, 2018). This finding indicates that infants were neurally detecting changes in communication signals from adults. A disruption due to texting during a social interaction may both violate infants’ expectations of social contingency and compromise JVA, such that infants and toddlers may learn less during a disrupted social interaction.

Given that prior studies involved interruptions of 30 s and 2 min. (Myruski et al., 2018; Reed et al., 2017, respectively) and were presented in the middle of the interaction, we wanted to manipulate both the timing and the frequency of the technoference. Parents were asked to teach their 18- to 20-months-old children three novel actions and were either interrupted before, once during, or multiple times during the teaching phase via text that they had been instructed to respond to. We selected a small age range of children since imitation learning changes as a function of age (e.g., Barr, Dowden, & Hayne, 1996). Restricting the age range restricted the range of linguistic, motor and emotion-regulation that was problematic in the Myruski and colleagues study. Furthermore, we were interested to see if technoference might disrupt learning in infants who only had a limited exposure to smartphones due to their young age. We manipulated timing of the text (beginning vs. middle of learning phase), as well frequency (single vs repeated) which resulted in 3 technoference conditions (interruption-first condition, one-interruption condition, three-interruptions condition). The interruption-first manipulation was aimed at inducing negative affect before learning, the one-interruption group was interrupted halfway through the demonstrations to induce negative affect during learning and the three-interruption condition to induce negative affect at multiple intervals. Infants were randomly assigned to 5 groups, 3 interruption conditions (interruption-first condition, one-interruption condition, three-interruptions condition) and two control conditions (baseline and no-interruption condition).

In the present study, we explored the following questions (1) would parents who used a smartphone for texting in front of their child display a still face even though not instructed to do so? (2) would infants react with negative affect during the texting period? (3) would imitation learning in infants be affected when the teaching phase was interrupted by texting? and (4) would parental report about their own smartphone use be associated with infant learning? We hypothesized that infants assigned to the interruption conditions would exhibit typical protest behaviors, such as negative vocalizations and negative facial expressions (Myruski et al., 2018) when their mothers responded to the text due to the appearance of a maternal “still face”. We also hypothesized the interruption groups would imitate significantly fewer target actions than the no-interruption group, but that they would perform above the baseline-control.

2. Method

2.1. Participants

The final sample consisted of $N = 90$ full-term, healthy 18−20-months-old infants ($M_{age} = 582$ days, $SD = 16$ days) and their parent (90 % mothers, 10 % fathers). Families were randomly assigned to one of three experimental conditions (interruption-first condition, one-interruption condition, three-interruptions condition) or a baseline-control condition (n = 18 per condition, 50 % female). An additional no-interruption condition with 18 infants (50 % female) was collected after the other conditions. Fifteen additional families participated, but had to be excluded from analysis due to (a) infants’ refusal to sit in the chair during test session ($n = 4$), (b) parent not demonstrating how to make the rattle correctly, or parental help during the test session ($n = 7$), (c) excessive infant crying ($n = 1$), (d) parent cancelling laboratory appointment ($n = 1$), and (e) experimenter error ($n = 2$). Data were collected between January 2018 and May 2019.

Families were recruited using birth registers from the city of Bochum, Germany. Families received a compensation of 5€, a small gift and a certificate for participation. The study was approved by the Ethics Committee of the Faculty of Psychology of Ruhr-University Bochum.

The participating parents had a mean age of 35 years ($SD = 4$ years) and were well-educated (12 % secondary school diploma, 27 % A-levels, 61 % university degree, 100 % families reporting). Almost all parents reported to have German nationality (94.4 %, $n = 84$ reporting) and being born in Germany (91.7 %, $n = 84$ reporting).

2.2. Design

There were three experimental conditions (interruption-first-condition, one-interruption-condition, three-interruptions) and two control conditions (no-interruption condition, baseline-control condition). During the demonstration phase, parents in the experimental conditions demonstrated the target actions to make the rattle (put the ball in the jar, put the lid on the jar, shake the stick) four times to their infants. As it is unclear, how much the interruption(s) disrupt learning in this task and we wanted to vary the time point of the interruption (middle vs. beginning, vs. three times), we decided to have four demonstrations. In the no-interruptions condition, they were not interrupted by the phone during the demonstration phase. In the interruption-first-condition, parents were interrupted for 30-sec *before* the four demonstrations. In the one-interruption-condition, parents were interrupted for 30-sec in the middle of the learning phase after two demonstrations. In the three-interruption-condition, parents were interrupted after each demonstration for 10-sec. Parents received a text and responded to questions on the phone during the interruption period. Furthermore, in order to have the same procedure for all infants, we chose to only interrupt after one full demonstration and not during an ongoing demonstration.

Otherwise, parents might be interrupted at different time points during the demonstrations and some might even finish one demonstration before attending to the smartphone.

Immediately after the demonstration, during the test phase, infants had 60-sec to reproduce any target actions. Infants in the baseline-control condition only participated in the test session to examine spontaneous production of any target actions.

2.3. Materials

2.3.1. CAFE media assessment questionnaire

Parents completed a 74-item Qualtrics survey covering 10 topics, including household composition and demographics, parental mediation of media use, parent attitudes toward media use, and access to and regularity of use of different devices frequently used in the modern household (Barr et al., 2020) (average time to complete in our sample ~35 min.).

Part II) Passive Sensing App: Although diaries have in the past been validated against direct observation with correlations ranging from .70 to .80 (Anderson, Field, Collins, Lorch, & Nathan, 1985), there are now many more household devices to track. Therefore, the CAFE tools use a converging methods approach and include passive sensing (Barr et al., 2020). Parents installed commercially available passive sensing apps (Quality time for Android and Moment for iPhone) for two to four days depending on the appointments of the home visit and lab session. Both apps track the duration of smartphone use and the frequency with which the smartphone is unlocked. The duration of use was averaged for the number of days the passive sensing was active.

2.3.2. Rattle stimulus

The stimuli for the green rattle consisted of a green stick (12 cm long) attached to a green circular disk (9.5 cm in diameter) with Velcro attached to the underside of the disk, a green wooden ball flattened on the bottom so it would not roll around (3 cm in diameter), and a clear plastic square cup with Velcro around the top (5.5 cm in diameter x 9 cm in height) (Fig. 1; Bauer & Dow, 1994; Herbert & Hayne, 2000). The opening of the plastic cup (3.5 cm in diameter) was covered with a 1 mm black rubber diaphragm, with 16 cuts radiating from the center.

2.3.3. Smartphone

A Samsung Galaxy J5 DUOS® connected to the internet was used by parents to answer the questions during interruption periods. We only put the SMS-icon on the front page so that operation was as easy as possible. The tone for incoming messages was set to a ping tone.

2.4. Procedure

Families in the interruption-first, one-interruption, and three-interruption conditions were visited at home two to four days before the lab session. Families in the baseline-control condition and the no-interruption condition only participated in the lab session.

2.4.1. Home visit

The purpose of this visit was to explain to the parents how to install an app to track the daily duration of smartphone use on the parents' phone. Parents were instructed to write down the minutes and number of phone pick-ups per day (number of times phone unlocked) displayed in the app on a sheet for each day. The experimenter told the parents that they would show their child how to make a rattle and showed them an image of the rattle. Infants also received an actiwatch from the experimenter to record sleep/wake patterns that they wore until the lab session, but these data are not reported here.

2.4.2. Lab session

The study was carried out in a laboratory that consisted of a test and a control room at Ruhr-University Bochum. After a short warm-

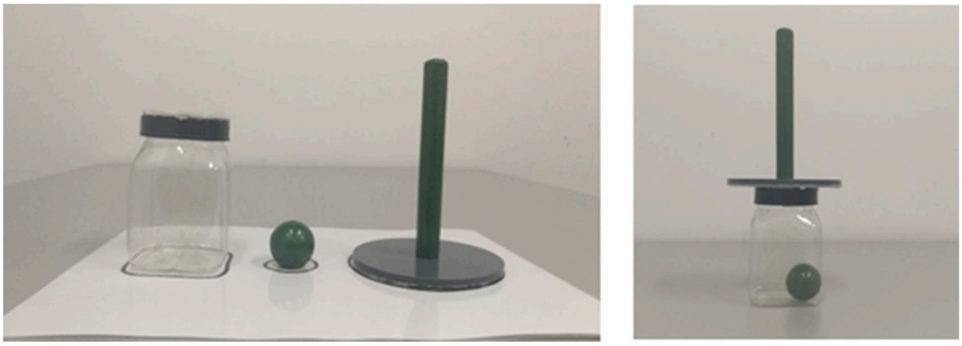

Fig. 1. Rattle stimulus used in this study. All three pieces (plastic cup, ball, handle) are depicted on the left side and the assembled rattle on the right side.

up phase with the experimenter, the experimenter explained the purpose of the study to the parent and informed consent was obtained. In order to provide a realistic context for the smartphone interruptions, the experimenter provided a cover story. Parents were told that we were interested in examining how infants learn from their parents and how parents feel while they teach something new to their infant. Parents were told that they would demonstrate how to make the rattle 4x to their infants. Parents in all conditions watched a video of how to build the rattle on a tablet. To ensure it was out of the infant's sight, parents stood up while watching the video. Additionally, we explained in the interruption conditions: *"Since we do not want to disturb the interaction between you and your child, we will be in the room next door and ask questions about how you feel via a smartphone at the beginning/in the middle/after each demonstration."* Then, the use of the smartphone was explained to the parent (how to open the text message and what the questionnaire would look like).

Afterwards as a warm-up, all infant-parent dyads played for 5 min on the play mat as they would usually at home with a set of toys without the experimenter. The parent, infant and experimenter then went behind the dividing wall to the test area and the infant was strapped into a chair opposite their parent (See Fig. 2 for the set-up of the lab). The table was 80 × 80 cm to ensure that the infant could not reach the rattle pieces or the smartphone. There was a sheet on the table marking where each part of the rattle belonged and the three parts of the rattle were placed on top of the sheet. The smartphone was placed on the right side of the sheet. There was one camera filming the infant, one filming the parent, and one filming the whole interaction. Parents were instructed not to explain what they were doing or to label the rattle or the pieces of the rattle. Parents in the interruption conditions were instructed to respond to a text from the researchers but received no instructions regarding how to interact with their infant while they answered the text.

2.4.2.1. Demonstration phase. After the experimenter left the room, the experiment started. The parents demonstrated how to build the rattle four times. After each time, the parent reset the rattle under the table and put the pieces back on the sheet on the table. The experimenter observed the parent from the control room and sent a text to the phone either before, in the middle or after each demonstration depending on the interruption condition. When the parent heard the smartphone text notification, the parent picked up the phone and opened the message. He or she was then redirected to a Qualtrics Survey asking them how they felt at the moment with a list of 6 different adjectives on a 5-point likert scale ranging from "not at all" to "very" ("At the moment, I feel calm"). We chose 6 adjectives since previous testing revealed that it takes approximately 30 s to complete the survey and is thus comparable to the interruption period used in Reed et al. (2017). For the three-interruption condition, we sent links with two adjectives at a time to receive three 10 s interruptions. The survey ended with a short instruction for the parent, depending on the condition (i.e., *"Thank you. You can now demonstrate how to build the rattle one more time and then give the pieces to your infant"*).

2.4.2.2. Test phase. Immediately after the demonstrations, the parents slid the three rattle pieces (without the sheet) across the table within reach of the infant. The child interacted with the stimuli for 60 s from the time the child first touched one piece of the stimuli. Parents were instructed not to help or prompt their infant. Infants in the baseline control condition did not see any demonstrations and only participated in the test phase (Herbert & Hayne, 2000). After the test phase, the experimenter entered the room and debriefed the parents explaining the rationale for sending the text messages during the study. None of the parents indicated that they were aware of the purpose of the texts.

2.5. Video coding

2.5.1. Demonstration phase

The duration of the interruption(s) was defined as time from the reception of the SMS on the smartphone (ping tone) until the parents finished using the smartphone. Infant and parental behavior during the demonstration phase was coded offline using INTERACT (Mangold International GmbH, Arnsdorf, Germany). The duration of infant negative affect during the demonstrations and interruption(s) was coded (see Table 1 for the coding scheme). 30 % of the videos were coded by a second independent observer. Interrater reliability was ICC = .97. In the interruption conditions, parental behavior during the interruption phase was coded. It was coded for how long they displayed a still face during the interruption phase. For the still face, 19 % of the videos were coded by a

Fig. 2. Set-up of the laboratory. On the left side is the warm-up play room and behind the dividing wall is the test area (right photo).

Table 1
Coding scheme for the demonstration and the test phase.

Demonstration phase			Examples
Negative affect	Child displays negative affect or shows protest or withdrawal.Child has to show negative facial expression and/or negative vocalization.		Child protests and tries to get out of the seatChild displays sad face; criesChild displays anger and reaches towards the rattle pieces
Parent still face	Parent displays no emotional reactions.		Parent stares on the smartphone without any emotions on her/his face.
Parent Interaction behavior during interruption	Parent explains what she is doing during the interruption or explains what will happen next after the interruption		Parent explains that they are just checking the phoneParent explains that she will play again soon
Test phase			
Target action	Push ball through diaphragm into jar.	Put stick on jar.	Shake stick to make rattle.
Coding instructions	Score when ball hits bottom of container.	Score when Velcro holds them together..	Must shake using the stick/handle. Shaking stick counts regardless of whether or not attached to jar. A shake is counted if handle goes back through own arc (side to side or top to bottom).
	If block not pushed through diaphragm, do not score.	Do not score putting the stick in upside down.	

second independent observer. Interrater reliability was ICC = .94. Furthermore, interaction behavior with their child during the interruption was coded (see Table 1 for the coding scheme). 19 % of the videos were coded by a second independent observer. Interrater reliability was ICC = .92.

2.5.2. Test phase

Each video-taped test phase was scored by two independent observers for the presence or absence of each target action during the 60-s test phase. The three target actions were: 1) push the ball into the jar, 2) put the stick on the jar, and 3) shake the stick. Additionally, the order of the target actions was scored. An infant received an order point if the infant 1) put the ball into the jar, *then* attached the stick to the jar, or 2) attached the stick to the jar, *then* shook the handle. See Table 1 for the coding scheme of the rattle task. An imitation score was calculated for each infant by summing the number of target actions (range = 0–3) and by summing up the points for the correct order (range = 0–2). Eighty out of ninety videos were coded by a second independent observer. Interrater reliability for the target actions was ICC = .99 and for the order ICC = .98.

2.6. Data analyses

The duration of the interruption differed between interruption conditions, $F(2, 51) = 14.60$, $p < .001$, $\eta^2 = 0.36$. Pairwise comparisons with Bonferroni corrections indicate that total interruption time was significantly longer in the three-interruption condition ($M = 76$ *s*, $SD = 25$ *s*) than in the interruption-first-condition ($M = 48$ *s*, $SD = 13$ *s*) and the one-interruption-condition ($M = 45$ *s*, $SD = 15$ *s*) ($ps < .001$). Therefore, all variables were calculated as percentages of the time of the interruption phase and the demonstration phase.

3. Results

All but two families filled out the CAFE Media questionnaire. 91 % of the parents reported that a smartphone is present in the household; 83 % had a computer in their household and 62 % had a tablet. Around 30 % of the parents reported to have apps for their children on their smartphone. 48 % let their child use videochat on their smartphone.

In the demonstration conditions ($N = 72$), 2.8 % of parents reported that they did not use their smartphone the previous day, 37.5 %

Table 2
Frequencies of parental reports in the demonstration conditions ($N = 72$) of how much parents relied on their smartphones for different functions.

	Need to stay in touch with work to be successful	Prefer exchange via SMS, Email or social media than directly	Multitask between children and smart phone	Over whelmed by how much I need to get done on my phone	Feel addicted to smart phone	Use phone to "escape" when with children
Strongly disagree	58.3 %	36.1 %	15.3 %	37.5 %	51.4 %	56.9 %
Somewhat disagree	19.4 %	30.6 %	44.4 %	13.9 %	19.4 %	22.2 %
Neither agree nor disagree	9.7 %	19.4 %	12.5 %	23.6 %	11.1 %	2.8 %
Somewhat agree	12.5 %	9.7 %	22.2 %	18.1 %	16.7 %	15.3 %
Strongly agree	0%	4.2 %	5.6 %	6.9 %	1.4 %	2.8 %

used it less than 30 min, 44.4 % used it 30−60 min, 11.2 % used it 1−2 hours, and 4.2 % used it 2−5 hours. 11.1 % of parents reported that they checked their smartphone less than 10 times per day, 19.4 % 10–20 times, 18.1 % 20–40 times, 22.2 % 40–60 times, 12.5 % 60–100 times, 11.1 % 100–150 times, 4.2 % more than 150 times, and 1.4 % reported that they did not to check it at all. 6.9 % of parents indicated that they never use the smartphone during play with the child, 47.2 % indicated that it is not very likely, 30.6 % indicated neutral, 13.9 % indicated that it is likely, and 1.4 % indicated that it is very likely. Furthermore, Table 2 displays frequencies of parental reports in the demonstration conditions ($N = 72$) of how much parents relied on their smartphones for different functions.

Only 48 % ($N = 26$) of the parents who received a home visit (i.e., the interruption conditions) and were shown the passive sensing apps were willing to use passive sensing. Parents also completed a time use diary and noted when their child used the smartphone throughout the day and what the child did on the phone. Two parents out of 25 reported the child using the smartphone (one child watched videos for 10 min and the other one looked at photos for 15 min but with the mother). One did not fill out the diary. Therefore, for this sample, we argue that the smartphone minutes estimated by the passive sensing app are a good estimate of maternal cell phone daily usage. Passive sensing indicated a mean of 211 min of smartphone use per day ($SD = 156$ min., range: 11–718 min., $N = 26$).

3.1. Still face during texting

Parents in the interruption conditions displayed a still face for about 77 % ($SD = 23$ %) of the time while using the smartphone in front of their child. There was no significant difference in the amount of still face during smartphone use between interruption conditions, $F(2, 51) = 0.90, p = .41, \eta^2 = .03$. Only 43 % of the parents explained or communicated the interruption to their child. The frequency with which parents explained the situation ranged from 0 to 6 times with a mean frequency of .85 ($SD = 1.3$).

3.2. Negative affect during the texting

Infants displayed negative affect both during the demonstration and the interruption phase(s) (see Fig. 3). However, infants displayed about double the percentage of negative affect during the interruption phase compared to the demonstration phase (see Fig. 3). The percentage of negative affect during the interruption was significantly greater than during the demonstration phase, $F(1, 51) = 14.96$, $p < .001$, $\eta^2 = .23$. There was no significant difference in the percentage of negative affect during interruption between interruption conditions, $F(2, 51) = 2.88, p = .066, \eta^2 = .10$, and no interaction effect, $F(2, 51) = 1.67, p = .20, \eta^2 = .06$. There was no significant association between the percentage of negative affect during interruption and parental still face, $r = .14, p = .30$. However, total duration in sec of negative affect during interruption was associated with duration of parental still face, $r = .57, p < .001$, likely due to the difference in length of interruptions across sessions. Frequency of parents explaining the interruption was not associated with the amount or duration of negative affect during the interruption ($ps > .05$). There was no significant difference in the percentage of negative affect during demonstrations between demonstration conditions, $F(3, 68) = 2.72$, $p = .051$, $\eta^2 = .11$.

3.3. Was imitation learning affected by texting?

Imitation scores are displayed in Fig. 4 as a function of condition. Learning in a standard imitation paradigm is defined as a performance above a baseline control condition to control for spontaneous production of any target action (Barr & Hayne, 2000). There was a significant effect of experimental condition on imitation score, $F(4, 85) = 32.13, p < .001, \eta^2 = .60$. Infants in the conditions that received demonstrations, performed significantly more target actions than infants in the baseline control condition as indicated by pairwise comparisons with Bonferroni correction (all $ps < .001$). This indicates that infants from all conditions learned the

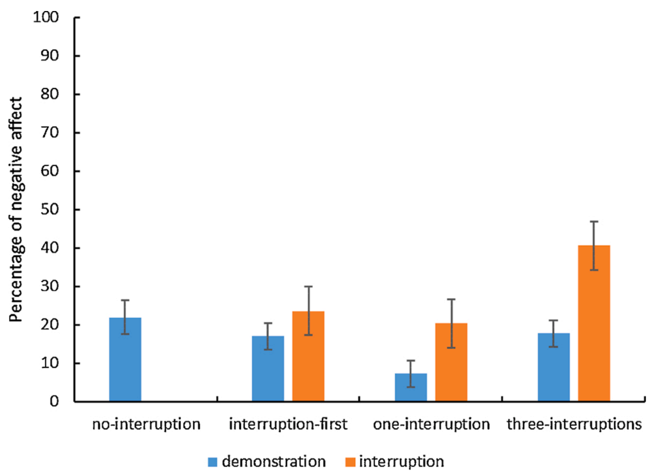

Fig. 3. Percentage of negative affect infants displayed during the demonstration and interruption phase as a function of condition. Error bars are SE of M.

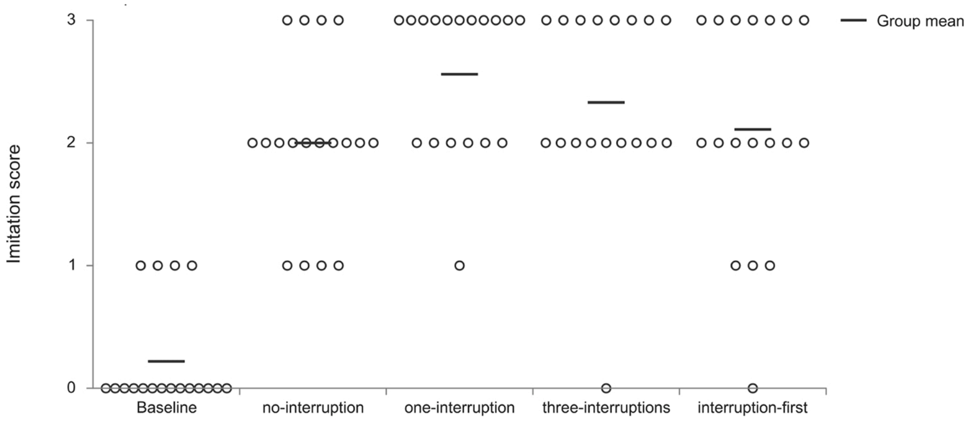

Fig. 4. Imitation scores as a function of condition with individual data points indicated with circles and group means displayed as a line. (Figure was generated using the program by Weissgerber et al., 2017).

target actions. However, contrary to our expectations, there was no significant difference between infants from the no-interruption condition and interruption conditions (all *ps* $> .05$). Furthermore, there was no difference in imitation scores between interruption conditions (all *ps* $> .05$). Thus, there was no immediate effect of texting during a learning episode on imitation learning. Order score was also examined. Mean order score in the baseline control condition was 0 ($SD = 0$), 0.89 ($SD = 0.76$) in the no-interruption condition, 1.17 ($SD = 0.79$) in the interruption-first condition, 1.5 ($SD = 0.62$) in the one-interruption condition, and 1.33 ($SD = 0.69$) in the three-interruptions condition. A one-way ANOVA indicated that there was a significant difference between the interruption conditions on order, $F(4, 85) = 15.38$, $p < .001$, $\eta^2 = .42$. Follow-up Bonferroni post-hoc tests ($p < .05$) indicated that all experimental conditions performed significantly better than the baseline control conditions.

There were no significant correlations between the amount of parental still face, negative affect, parental interaction behavior and imitation behavior (*ps* $> .05$).

3.4. Parental report on smartphone use and infant learning

Parental report on smartphone use was correlated with infant learning excluding the baseline control condition (see Table 3). Rating of minutes of parental smartphone use in front of the child per day was not associated with learning. Furthermore, for those parents who used passive sensing to track smartphone use, we correlated minutes of smartphone use and times of checking the smartphone with learning. In those parents, the measures were not associated with learning (Table 3). However, there were weak correlations between how much parents relied on their smartphones for different functions and infant learning. For example, the more parents indicated they were able to multitask between their child and using a smartphone, the higher the imitation and order score. The more parents feel obliged to always stay in touch with work, the more they feel addicted to their smartphone, or used their smartphone to escape during childcare, the lower the imitation and order score.

4. Discussion

The present study sought to investigate the impact of texting during a teaching phase on infant behavior and subsequent infant learning. The paper contributes to a small but growing body of literature that examines how the pervasive presence of mobile devices may be associated with learning during everyday activities. To our knowledge, however, this is the first study to investigate a parent's natural reaction during texting in front of their child. We predicted that technoference caused by an invitation to text and an increase in still face either before or during a learning task would induce negative affect and reduce imitative learning. Although parents were not instructed to display a still face, the vast majority fell silent and concentrated on texting without explaining what they were doing to their child. Infants protested the interruption with negative affect, but we did not see a decrease in immediate imitative learning. We interpret the finding that negative affect increased in response to the still face and then reduced during the demonstrations of the target actions indicated that infants reengaged during the demonstration as opposed to experiencing increasing frustration due to lack of access to the rattle components. For the infants in the no interruption condition negative affect increased across the course of the four demonstrations, likely due to not being able to touch the toys. That is, technoference may not always interfere with learning but rather infants may tolerate brief intermittent interruptions to parental attention in the context of an otherwise contingent and engaging interaction.

A robust body of literature using the still face paradigm has demonstrated that parental still face produces a behavioral change indexed by infant protest as well as changes in glucocorticoid release (for review see, Adamson & Frick, 2003). Glucocorticoids (GCs) released in response to a stressor have been shown to modulate memory. GC-modulated memories appear to provide an important mechanism for selecting and discarding information (Lupien, Maheu, Tu, Fiocco, & Schramek, 2007; McGaugh, 2000). It may be hard for infants to discern the relevance of stimuli from one context to the next. Findings regarding the role of GC's in modulating learning

Table 3
Correlations between smartphone use and learning in the demonstration conditions.

	Smartphone/ tablet use per day (min)	Times checking smart phone per day	Passive sensing: smart phone use per day (min)	Likelihood of smart phone use during play with child	Need to stay in touch with work to be successful	Prefer exchange via SMS, Email or social media than directly	Multitask between children and smart phone	Over whelmed by how much I need to get done on my phone	Feel addicted to smart phone	Use phone to “escape” when with children
Imitation score	−.085	−.098	−.082	.127	**−.392****	−.173	**.294***	−.161	**−.238***	**−.233***
Order score	−.116	−.143	−.084	.112	**−.309***	**−.241***	**.242***	−.227	**−.233***	−.215
N	72	72	26	72	72	72	72	72	72	72

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

during infancy have been mixed. Some prior studies have suggested that protest and negative affect during still face is associated with better memory consolidation. One study examined the associations between natural variation in circulating levels of GCs during learning in 3-month-old infants and found that elevated GCs on day 1 in response to learning challenge had a positive effect on memory consolidation on day 2 (Haley, Weinberg, & Grunau, 2006). A second study in 3-month-old infants found that GCs during retrieval disrupt memory (Thompson & Trevathan, 2008), and a third showed that this was also true in young non-human primates (Dettmer, Novak, Novak, Meyer, & Suomi, 2009). Thus, initial reports suggest that the actions of GC on memory consolidation are positive and memory retrieval are negative. It is therefore possible that our findings that texting and still face were not associated with disruptions to immediate imitation learning may be consistent with an initial boost or reengagement to the task once parents stopped the still face but the longer term retention may be disrupted. We are currently testing this possibility.

Contrary to the study by Reed et al. (2017) and to our expectation, smartphone use did not disrupt learning of the target actions. This could be due to several reasons. First, teaching itself was not interrupted - the interruption occurred after one or several full presentations of the target actions. It could be that smartphone use is only disruptive when the teaching itself is interrupted and the parent cannot finish demonstrating all the target actions. Furthermore, it is possible that a disruptive effect is only visible after a delay and not in immediate learning. The task might be too easy. However, it is also possible that infants react to the interruption but that there is no effect on imitation learning. Third, this was a non-verbal task and there was no verbal interaction during the texting. In the Reed and colleagues study, they examined a verbal learning task that was interrupted by conversation during the call with the experimenter. Thus, future studies could consider how technoference influences different forms of learning.

Subjective and objective smartphone use was not associated with learning or the amount of negative affect infants displayed. In contrast to the studies by Myruski et al. (2018) and Reed et al. (2017), the amount of time that mothers reported that they used their cell phones was not related to imitation performance. However, individual differences in parental reports of how much parents relied on their smartphones for different functions were associated with imitation performance. Specifically, imitation performance was lower if parents reported that they had to remain connected for work, that they felt more secure if their smartphone was nearby, or that they sometimes used their phone to escape when with their children. That is, higher reported maternal reliance on the smartphone was related to poorer imitation performance overall. In contrast, when parents reported that they found it easier to multi-task, infant imitation rates were higher. Additional research is required to examine patterns of smartphone use during parent-child interactions. Passive sensing technology in combination with time use sampling is likely to be an effective means to collect this data (Barr et al., 2020; Radesky et al., 2020). It is important to note however that in the present study, maternal attitudes towards their smartphones and the role that these devices play may be a useful proxy to examine technoference patterns.

There are a number of limitations to the current study. As is the case with a number of deferred imitation tasks (e.g. Barr et al., 2016) the range of performance on the rattle task is limited and under conditions of immediate recall performance is generally high (e.g. Barr & Hayne, 1999). We chose the task because researchers had already demonstrated that parents were reliable demonstrators and infants are generally highly interested in the task and perform well on this task (Seehagen & Herbert, 2010). It is possible that 18-month-olds learned the target actions after only a few demonstration and that the interruption did not have an effect with four demonstrations (Barr & Hayne, 1999). That is, although we observed a null effect here, this may have been due to a ceiling effect on a simple learning task. However, introduction of novel information can result in retroactive interference as early as 3 months of age (Rossi-George & Rovee-Collier, 1999), leading to the hypothesis that even if learning occurred after fewer demonstrations that it could also be susceptible to retroactive interference. Although the current study demonstrates that not all instances of technoference may interfere with ongoing learning, the generalizability of this finding needs to be tested in future studies. It is possible that under more complex learning conditions, such as increased number of items-to-be-remembered or a delay between demonstration and test, technoference will disrupt learning.

Future studies, increasing the memory load under conditions of interference, increasing the retrieval demands by introducing a delay between demonstration and test are warranted. In addition, it will be necessary to examine whether some forms of learning are more affected by different forms of technoference than others. For example, silent texting accompanied by still face might result in changes to immediate attention and later memory retrieval, whereas phone calls might disrupt ongoing language learning tasks but not forms of non-verbal learning. We intentionally tested 18- to 20-month-olds to examine how technoference might relate to imitation learning but it is also likely that there are age-related changes in patterns of technoference. Future studies could examine whether technoference differentially influences imitation learning across a wider age range. Finally, a closer examination of family media ecology is necessary to examine whether infants habituate to the effects of technoference or whether parental response to technoference affects infant learning. Future research should examine how parents respond to technoference when with their child from the extreme of parental absorption in the mobile device to discussion and explanations to the child regarding the disruption. An investigation of individual differences in family media ecology that might contribute to individual learning patterns as a function of the frequency with which infants typically encounter such technoference is underway. These remain open empirical questions during a time that is more and more dominated by mobile technology. The present study provides a good experimental protocol to build a series of studies to examine the effects on learning as a function of complexity, content type and delay and individual differences in family context.

CRediT authorship contribution statement

Carolin Konrad: Conceptualization, Methodology, Supervision, Formal analysis, Writing - original draft. **Melanie Berger-Hanke:** Investigation, Data curation. **Gina Hassel:** Investigation, Data curation. **Rachel Barr:** Conceptualization, Methodology, Writing - original draft.

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References

Adamson, L., & Frick, J. (2003). The still face: A history of a shared experimental paradigm. *Infancy, 4*, 451–473. https://doi.org/10.1207/S15327078IN0404_01.
Anderson, D. R., & Hanson, K. G. (2017). Screen media and parent–child interactions. In Media exposure during infancy and early childhood. In R. Barr, & D. N. Linebarger (Eds.), *Media Exposure During Infancy and Early Childhood: The Effect of Content and Context on Learning and Development* (pp. 173–194). New York, NY: Springer.
Anderson, D. R., Field, D. E., Collins, P. A., Lorch, E. P., & Nathan, J. G. (1985). Estimates of young children's time with television: A methodological comparison of parent reports with time-lapse video home observation. *Child Development*, 1345–1357.
Barr, R., & Hayne, H. (1999). Developmental changes in imitation from television during infancy. *Child Development, 70*, 1067–1081.
Barr, R., & Hayne, H. (2000). Age-related changes in imitation: Implications for memory development. In C. Rovee-Collier, L. P. Lipsitt, & H. Hayne (Eds.), *Progress in infancy research, 1* pp. 21–67). Mahwah, NJ: Erlbaum.
Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior & Development, 19*, 159–171. https://doi.org/10.1016/S0163-6383(96)90015-6.
Barr, R., Kirkorian, H., Radesky, J., Coyne, S., Nichols, D., Blanchfield, O., … Epstein, M. (2020). Beyond screen time: A synergistic approach to a more comprehensive assessment of family media exposure during early childhood. *Frontiers in Psychology, 11*.
Barr, R., Moser, A., Rusnak, S., Zimmermann, L., Dickerson, K., Lee, H., … Gerhardstein, P. (2016). The impact of memory load and perceptual cues on puzzle learning by 2-year-olds. *Developmental Psychobiology, 58*, 817–828. https://doi.org/10.1002/dev.21450.
Bauer, P. J., & Dow, G. A. (1994). Episodic memory in 16-and 20-month-old children: Specifics are generalized but not forgotten. *Developmental Psychology, 30*(3), 403.
Bornstein, M. H., Tamis-LeMonda, C. S., Hahn, C. S., & Haynes, O. M. (2008). Maternal responsiveness to young children at three ages: Longitudinal analysis of a multidimensional, modular, and specific parenting construct. *Developmental Psychology, 44*(3), 867.
Butterworth, G. (2004). Joint visual attention in infancy. In G. Bremner, & A. Fogel (Eds.), *Blackwell handbook of infant development*. https://doi.org/10.1002/9780470996348.ch8.
Connell, S. L., Lauricella, A. R., & Wartella, E. (2015). Parental co-use of media technology with their young children in the USA. *Journal of Children and Media, 9*(1), 5–21.
Cristia, A., & Seidl, A. (2015). Parental reports on touch screen use in early childhood. *PloS One, 10*(6), Article e0128338.
Dettmer, A. M., Novak, M. F. S. X., Novak, M. A., Meyer, J. S., & Suomi, S. J. (2009). Hair cortisol predicts object permanence performance in infant rhesus macaques (macaca mulatta). *Developmental Psychobiology, 51*, 706–713.
Goedhart, G., Kromhout, H., Wiart, J., & Vermeulen, R. (2015). Validating self-reported mobile phone use in adults using a newly developed smartphone application. *Occupational and Environmental Medicine, 72*(11), 812–818.
Goldstein, M. H., Schwade, J. A., & Bornstein, M. H. (2009). The value of vocalizing: Five-month-old infants associate their own noncry vocalizations with responses from adults. *Child Development, 80*, 636–644.
Hakuno, Y., Pirazzoli, L., Blasi, A., Johnson, M. H., & Lloyd-Fox, S. (2018). Optical imaging during toddlerhood: Brain responses during naturalistic social interactions. *Neurophotonics, 5*(1), Article 011020.
Haley, D. W., Weinberg, J., & Grunau, R. E. (2006). Cortisol, contingency learning, and memory in preterm and full-term infants. *Psychoneuroendocrionology, 31*, 108–117.
Henning, A., & Striano, T. (2011). Infant and maternal sensitivity to interpersonal timing. *Child Development, 82*(3), 916–931.
Herbert, J., & Hayne, H. (2000). Memory retrieval by 18-30-month-olds: Age-related changes in representational flexibility. *Developmental Psychology, 36*, 473–484. https://doi.org/10.1037//0012-1649.36.4.473.
Lauricella, A. R., Wartella, E., & Rideout, V. J. (2015). Young children's screen time: The complex role of parent and child factors. *Journal of Applied Developmental Psychology, 36*, 11–17.
Lupien, S. J., Maheu, F., Tu, M., Fiocco, A., & Schramek, T. E. (2007). The effects of stress and stress hormones on human cognition: Implications for the field of brain and cognition. *Brain and Cognition, 65*, 209–237.
McDaniel, B. T., & Radesky, J. S. (2018). Technoference: Parent distraction with technology and associations with child behavior problems. *Child Development, 89*, 100–109. https://doi.org/10.1111/cdev.12822.
McGaugh, J. L. (2000). Neuroscience – Memory – A century of consolidation. *Science, 287*, 248–251.
Medienpädagogischer Forschungsverbund Südwest (Hrsg.). (2015). *miniKIM 2014. Kleinkinder und Medien. Basisuntersuchung zum Medienumgang 2- bis 5-Jähriger in Deutschland*. Stuttgart: Medienpädagogischer Forschungsverbund Südwest.
Murray, L., & Travarthen, C. (1985). Emotional regulations of interactions between two-month-olds and their mothers. In T. M. Field, & N. A. Fox (Eds.), *Social perception in infants* (pp. 177–197). Norwood, NJ: Ablex Publishers.
Myruski, S., Gulyayeva, O., Birk, S., Pérez-Edgar, K., Buss, K. A., & Dennis-Tiwary, T. A. (2018). Digital disruption? Maternal mobile device use is related to infant social-emotional functioning. *Developmental Science, 21*(4), Article e12610.
Nikken, P., & Schols, M. (2015). How and why parents guide the media use of young children. *Journal of Child and Family Studies, 24*(11), 3423–3435.
Radesky, J., Weeks, H., Ball, R., Schaller, A., Yeo, S., Durnez, J., … Barr, R. (2020). Mobile device sampling: An unobtrusive, objective measure of child smartphone and tablet use. *Pediatrics, 146*(1).
Reed, J., Hirsh-Pasek, K., & Golinkoff, R. (2017). Learning on hold: Cell phones sidetrack parent-child interactions. *Developmental Psychology, 53*, 1428–1436. https://doi.org/10.1037/dev0000292.
Rideout, V. (2017). *The Common Sense census: Media use by kids age zero to eight* (pp. 263–283). San Francisco, CA: Common Sense Media.
Rossi-George, A., & Rovee-Collier, C. (1999). Retroactive interference in 3-month-old infants. *Developmental Psychobiology, 35*, 167–177. https://doi.org/10.1002/(SICI)1098-2302(199911)35:3<167::AID-DEV1>3.0.CO;2-V.
Seehagen, S., & Herbert, J. S. (2010). The role of demonstrator familiarity and language cues on infant imitation from television. *Infant Behavior and Development, 33*(2), 168–175.
Thompson, L. A., & Trevathan, W. R. (2008). Cortisol reactivity, maternal sensitivity, and learning in 3-month old infants. *Infant Behavior and Development, 31*, 92–106.
Weissgerber, T. L., Savic, M., Winham, S. J., Stanisavljevic, D., Garovic, V. D., & Milic, N. M. (2017). Data visualization, bar naked: A free tool for creating interactive graphics. *Journal of Biological Chemistry, 292*, 20592–20598.