Interrupted Interactions: Parental Smartphone Technoference and Language Development in Early Childhood

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Beginning a PhD as a mature student with an established teaching career led to many people asking ‘why’ I would want to undertake such a challenge at this stage in my life and how would this benefit my career. However, shaping my career was not the driver for this journey; simply, I enjoy learning. It is this desire to learn that enabled me to work both a full-time and part-time job, whilst completing this thesis.

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Author Declaration

I confirm that the work submitted for this thesis is my own original work, that has been shaped by discussions with Dr Silvia Rigato and Dr Maria Laura Filippetti. An adapted version of Chapter 1 has been published. One paper has been submitted based on Chapter 4 (Study 2b), Chapter 5 (Study 3), and another (based on Chapter 6, Study 4) is in preparation. These three papers are co-authored with Dr Silvia Rigato and Dr Maria Laura Filippetti.

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The work presented in this thesis has not previously been submitted for any degree or other qualification either at the University of Essex or elsewhere.

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Summary of Work

Children are born into a world where digital technology is intwined into our daily lives. The growing reliance on digital technology has the potential to interrupt social interactions, i.e. technoference, including parent-child interactions, which are important in shaping child development. Feasibly, repeated technoference from smartphones during parenting could affect developmental outcomes, including language development. Whilst studies testing the impact of technoference during parenting are emerging, there are a limited number of studies which have focused specifically on smartphones and child language development. This thesis therefore explores the impact of parent smartphone technoference on the mechanisms which shape language development, and child language outcomes, drawing on findings from four studies. . Study 1 gathered survey data from parents of children under 2 years (N=68), recruited via a university database, on how parents use their smartphones. In an experimental study conducted online, Study 2a observed parents and their 9-11-month-olds (N=59), recruited via a university database and an external database, across four different play conditions. In Study 2b, parents of 12-18-month-olds (N=134), recruited via a university database, responded to a survey measuring technoference, responsiveness, and child language outcomes. Using an experimental design, Study 3 tested whether how a caregiver uses their phone can influence word learning in 24-36-month-olds (N=69), recruited via a university database. Finally, Study 4 used neuroimaging to measure neural activity in 6.5-7.5-month-olds (N=48), recruited via a university database, implementing an experimental design where infants viewed an adult model either avert their gaze to a smartphone or book. Across all studies, samples were predominantly White and of medium socioeconomic status. I found that parents reduce their phone use when

engaged versus not engaged with their infant and that the most responsive parents put their phones away most frequently. In addition, parent smartphone technoference was shown to disrupt social gaze, infant positive spontaneous expression, parent talk to their infant, and parent responsiveness during parent-child interactions. Technoference was negatively associated with child language, specifically use of gestures. Type of phone use mattered, using the phone to make a call was found to be more disruptive than using the phone to take photos. However, type of phone use did not affect children's novel word learning – but word learning was less affected when phone use created a shared interaction between the parent and child. Finally, no difference was found in neural activity regardless of whether the source of the interruption was digital or not. Together these findings provide evidence that technoference is one form of interruption, but it may not be unique in its ability to disrupt social interactions. Furthermore, technoference is nuanced and how the phone is used may moderate its effect on child language outcomes. This suggests that intervention and guidance for parents should focus less on phone use per se, and more on the nature and context of that use.

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List of Abbreviations

ANOVA	Analysis of Variance
ASD	Autism Spectrum Disorder
CBF	Cerebral Blood Flow
CI	Confidence Interval
CW	Continuous Wave
DISRUPT	Distraction In Social Relations and Use of Parent Technology
EDD	Eye Direction Detector
EEG	Electroencephalogram
ERP	Event Related Potential
fMRI	Functional Magnetic Resonance Imaging
fNIRS	Functional Near-Infrared Spectroscopy
HbO	Oxyhemoglobin
HHb	Deoxyhemoglobin
HRF	Haemodynamic Response Function
ICC	Intraclass Correlation Coefficient
IDS	Infant Directed Speech
IJA	Initiated Joint Attention
JME	Joint Media Engagement
PRS	Parent Responsiveness Scale
RJA	Responsive Joint Attention
SES	Socioeconomic Status
SFP	Still Face Paradigm
TD	Typically Developing

UK-CDI	UK Communicative Development Inventory

Chapter 1 Introduction

1.1 Introduction

Smartphones are ubiquitous in our lives. In the UK, smartphone ownership for adults has increased from 39% in 2012 to 95% in 2025 (Barber, 2025; Ofcom, 2018). As most adults now own a smartphone, it is possible that they are present during parent-child interactions. A child spends a considerable amount of their first few years of life with their parents, and the interaction between the child and their parents[1] shapes much of the child's early development (Bordeleau, Bernier, & Carrier, 2012; Shaw, Owens, Giovannelli, & Winslow, 2001; Youngblade & Belsky, 1992). The potential effects on child development of parent smartphone use during dyadic interactions with their child, therefore needs to be explored.

The presence of technology in the home is not new; however, smartphones have greater potential to affect parent-child interactions in comparison to other devices. Firstly, the portable nature of smartphones means that a parent can always have it with them, including when interacting with their children. Whilst other devices, such as tablets and laptops are portable, they are bigger and cannot fit so easily into a pocket. Consequently, these devices are less likely to be present during parent-child interactions than a phone, reducing the likelihood of spontaneous use during play, or distraction via notifications. Secondly, a smartphone has the functions of many other devices combined. Functionality includes the facility to talk to others, play games, manage finances, watch television, and track our health; with new features continually being developed. This can create a dependency on the

[1] In this thesis the term 'parent' is used as synonymous for any primary caregiver. The term 'caregiver' and 'mother' is used in relation to research which specifies this sample.

smartphone, which in some cases can lead to ‘nomophobia’; the fear of being without a smartphone, creating anxiety around being unable to communicate through a smartphone and losing connectedness (King et al., 2014; Yildirim & Correia, 2015). Due to its portability, flexibility and personalisation, nomophobia is specific to mobile phones (King et al., 2014). Thirdly, the smartphone is designed for one user, meaning that only the user can really see the screen, unlike watching television which the whole household can do together (Raudaskoski et al., 2017). This creates privacy around the smartphone (Aagaard, 2016), with social norms in the UK being that you do not lean over and look at what someone is doing on their phone. For these reasons, the focus of this thesis will be specifically on smartphones.

In this chapter, I will introduce the key concepts that are integral to this thesis. In Section 1.2, I begin by reviewing explanations for how parent smartphone use may be disruptive to the parent-child interaction. This is followed in Section 1.3 by an overview of the literature that has tested the effects of parent smartphone use on child developmental outcomes. I then move onto three precursors to language development that I argue are disrupted by parent smartphone use: eye gaze (Section 1.4), joint attention (Section 1.5), and parent responsiveness (Section 1.6). In each of these sections I review the concept in relation to child development before focusing on evidence exploring how each might be disrupted by parent smartphone use. Section 1.7 reviews literature that has tested the relationship between parent smartphone use and child language outcomes. Finally, in Section 1.8 I identify the key research questions addressed in this thesis.

1.2 Disruption to Social Interactions

The act of ignoring a social partner to interact with a smartphone has become normative in everyday adult communication (Chotpitayasunondh & Douglas, 2016).

This behaviour interferes with social interactions, suggesting the individual using the phone has no interest in the interaction, negatively affecting perceived communication quality, and relationship satisfaction (Chotpitayasunondh & Douglas, 2018a; Nakamura, 2015). This disruption extends beyond adult social interactions and has been recently reported during parent-child interactions (McDaniel, 2020). Next, I cover three explanations on the potential effects that parent smartphone use may have on parent-child interactions.

1.2.1 Technoference

One way that parent smartphone use can affect the parent-child interaction is through technoference, which is the interruption to social interactions due to technology (McDaniel & Coyne, 2016). Smartphones are one source of technology which can cause technoference during an interaction between a parent and their child. This disruption can also occur without physically using the phone if a parent is cognitively distracted by their phone. This may include hearing a notification and thinking about the potential content of the notification; in this example the parent is still physically present during the interaction, but they are ‘absent present’ (Gergen, 2002).

Technoference can affect the parent-child interaction as it disrupts its natural flow. Babies quickly learn communicative norms when engaged in face-to-face interactions with a parent, preferring to look at faces with direct rather than averted gaze (Farroni et al., 2002) and expecting to see something of interest when following the gaze of an adult (Csibra & Volein, 2008). Through interactions in communicative exchanges with their parent, both infant and parent become attuned and mutually regulate each other (Tronick, 2017). Disruptions to these interactions, as seen in the Still Face Paradigm (SFP) (Tronick et al., 1978), result in the infant trying to repair

the interaction and, when this is unsuccessful, in infants expressing negative emotions (Tronick, 2017). Technoference has been found to create the same responses in infants as the traditional SFP (Myruski et al., 2017; Stockdale et al., 2020) and to disrupt the parent's gaze direction to their infant (Elias et al., 2020).

1.2.2 Disrupted Attention

Smartphones may disrupt the amount of attention a parent has available for their child through receiving incoming notifications when the phone is within the user's sight (Kushlev et al., 2016). In fact, the phone does not even have to be used to reduce attention: an unchecked notification still reduces attention (Stothart et al., 2015) as does the mere presence of a smartphone (Ward et al., 2017).

When using a smartphone, a parent may simultaneously continue interacting with their child and multitask, dividing their attention. However, this is unlikely to be genuine multitasking and instead involves task switching whereby the user switches their attention between the two tasks (Amichai-Hamburger & Etgar, 2016). Several studies have found links between smartphone use and reduced performance in tasks requiring attention, including difficulties in attentional shifting (Sansevere & Ward, 2021), impaired driving performance (Ortiz et al., 2018), and impaired learning (Mendoza et al., 2018). During parenting, task switching between the phone and child may result in parents missing bids for attention or responding non-contingently to the child, leading to lower levels of responsiveness (see Braune-Krichau et al. 2021 for a review). Lemish et al. (2020) found that parents who were distracted from their child in the park redirected their attention to their child more quickly when the distraction was not by a mobile phone, e.g. talking to a friend, than when they were distracted by their phone, suggesting the smartphone may be more absorbing than other distractions. Indeed, Vanden Abeele et al. (2020) found that parents were less

responsive when absorbed in phone use compared to non-phone use, and that occasionally glancing towards a phone did not have the same effect on responsiveness. A phone therefore may be more disruptive to attention if the user becomes absorbed in it.

1.2.3 Displacement Hypothesis

Displacement involves substituting one activity for another. In the context of phone use, the displacement hypothesis states that using a phone reduces the amount of time available for other activities, such as social interactions (Neuman, 1988). Thus, the more a parent uses their smartphone, the less time and attention available to interact with their child (Coyne et al., 2014). However, recent findings suggest that it is a little more nuanced than this. Tracking daily smartphone use and face to face communication over fifteen days, Verduyn et al. (2021) found no difference in time spent in face-to-face communication between those who spent a lot of time communicating on their smartphone, and those who rarely communicated on their smartphone. Yet, at the individual level, days with more-than-usual smartphone communication were also associated with less face-to-face interactions. Similarly, Denecker et al. (2023) found that parents of 4-10-year-olds reported increased time displacement (i.e., not interacting with their child because they were using their smartphone) on days where they used their smartphone more than usual. Interestingly, time displacement was negatively associated with reduced child restlessness. This may suggest that parents are more likely to use their smartphone when their child is calm, rather than when the child is restless and requires parental interaction (Denecker et al., 2023). Therefore, smartphone use may not necessarily displace time parents would otherwise spend engaging with their child; instead,

parents may use their phone more when they perceive that their child does not require their attention.

Of these three accounts, this thesis focuses on technoference as an explanation for how parent smartphone use may affect developmental outcomes. Whilst each has merit, technoference is distinct in centring the impact of parent smartphone use on the parent-child interaction itself. Given the importance of dyadic interactions for child development, this thesis explores whether parent smartphone use is disruptive to these interactions, specifically through its effects on social eye gaze, joint attention, parent responsiveness, and how this disruption relates to subsequent language development.

1.2.4 Other Parental Distractions

Smartphone use is not unique as a potential distractor or an interruption to parent-child interactions, and of course it is not expected that parents are in constant engagement with their child. Throughout the day, parents complete several other tasks that require directing their attention away from their child. Reading, housework, and cooking for example, all lead parents to direct attention away from their child and can interrupt the interaction between the dyad. However, there is little, if any, concern about the impact of completing chores on child development. Therefore, it needs to be considered what differs when parents use smartphones compared to when parents are engaged in other tasks. Raudaskoski et al. (2017) coined the term ‘bystander ignorance’ to highlight this important difference. Bystander ignorance refers to the unawareness of the bystander (in this case the child who wants to engage in face-to-face interaction) of the current activity the smartphone user is engaged in. With other solitary tasks, such as cooking, the child is able to infer the goal of the actions, as the parent will provide several cues from the direction of their

gaze as to where their focus is (Raudaskoski et al., 2017). However, when using a smartphone, it may be more difficult for the child to infer the goal of the activity, as smartphone use requires near-constant visual attention. Additionally, and as mentioned earlier, smartphone use is generally a private activity. Therefore, the child is usually unable to see what the parent is doing on their phone, and the parent is unlikely to provide cues indicating the purpose of the activity (Raudaskoski et al., 2017). The lack of behavioural cues during smartphone use means the child is unlikely to infer what the smartphone is being used for. From the child's perspective, this unawareness of the nature of the activity may make smartphone-related interruptions unique, and they may affect children in ways that other tasks do not. However, parents can signal to the child how they are using their phone by involving the child in the phone use, for example, putting a call on loudspeaker, or commenting aloud on what they are reading/viewing (Amery, Danby and Brereton, 2026).

A further consideration is that smartphones may not be a unique form of distraction when compared to tasks which similarly make demands on the user's visual attention. Konrad, Hillmann, et al. (2021) found that when a parent-child interaction was interrupted by parents completing a survey, either via a smartphone or on pen and paper, parents were less responsive and children increased their bids for attention regardless of the medium.

Taken together, these findings suggest that the disruptive effect of technoference may not be attributable to the device use per se, but rather the visual and attentional demands of the task and whether the task is made transparent to the child.

1.3 Effects of Technoference on Child Development

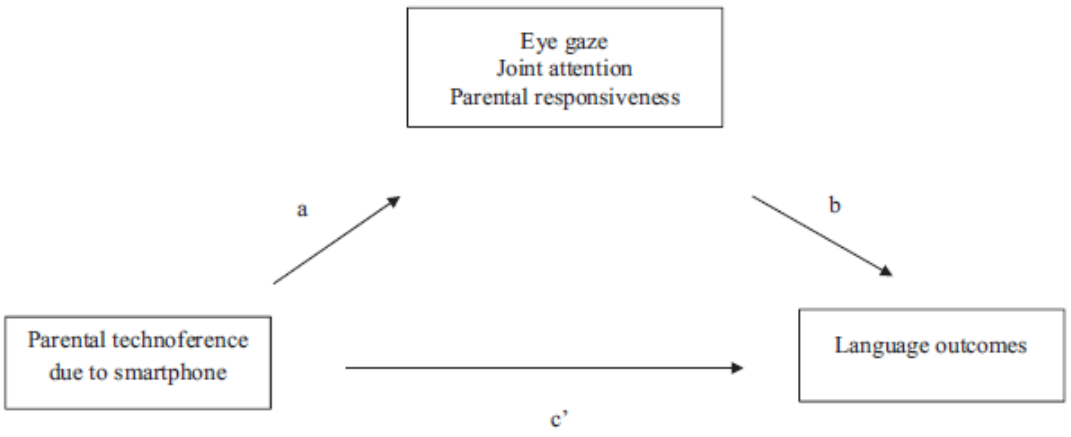
The frequency of parent phone use has been explored in numerous studies (Elias et al., 2020; Mangan et al., 2018; Radesky et al., 2014). Despite phone use being a regular daily activity, Hiniker et al. (2015) observed that caregivers used their phone for less than 5% of the time when at the park with their child. In fact, 41% of caregivers did not use their phone at all and if they did use their phone, just under 30% of these instances were less than 10 seconds long, suggesting that when engaged in hands-on activities with their child, parent phone use is relatively low. This is supported by Abels et al. (2018) who observed caregivers in playgrounds and health centres and found that caregivers spent less time on the phone than other activities such as talking or attending to another child. Importantly however, Abels et al. (2018) found that when the phone is used, it tends to be used exclusively and not alongside other activities, and it encompasses a higher level of exclusive engagement than activities such as reading and looking around. This suggests that whilst not all parents use their phones when interacting with their children, when they do it becomes all absorbing.

Recent evidence shows that technoference has the potential to influence numerous developmental outcomes including parenting style (Ante-Contreras, 2016), the child's externalising behaviour (McDaniel & Radesky, 2018a, 2018b; Sundqvist et al., 2020), eating behaviour (Gramm et al., 2020), negative affect (Kildare, 2017; Stockdale et al., 2020), imitative behaviour (Flatebø et al., 2024), and attachment (Koulomzin et al., 2002; Linder et al., 2021). Importantly, as parents have been found to use mobile devices in early activities such as during bottle feeding their babies (Golen & Ventura, 2015), phone use during parent-child interactions may have an impact from the very first stages of a child's life.

Whilst it is possible that parent smartphone use can affect the child on numerous outcomes, this thesis focuses on the effect on language development. In Morris et al. (2022), we proposed that technoference may influence language outcomes indirectly through its disruption of eye gaze, joint attention, and parent responsiveness, and via a direct pathway (see Figure 1.1). The direct pathway was included in the original model to account for the effects on language outcomes not captured by the three specified mediators e.g., variation in the parent's quality and quantity of linguistic input during technoference episodes, but it is not the focus of investigation in this thesis. The thesis primarily focuses on the indirect pathway and therefore this chapter reviews research exploring the association between technoference and each proposed mediator, and between each mediator and child language outcomes. Overall, the majority of the research to date in children under the age of 5 suggests that smartphone technoference can disrupt eye gaze, joint attention, parent responsiveness, and subsequently language development (see Table 1.1).

Figure 1.1

The Mediation Model Proposed in Morris et al. (2022)



Note. Reproduced from Morris et al. (2022). This model suggests that parent smartphone use can affect children's language development both directly, and indirectly, by disrupting social gaze, joint attention, and parental responsiveness.

Table 1.1

Evidence Supporting the Impact of Parent Smartphone Technoference on Eye Gaze, Joint Attention, Parent Responsiveness, and Language Outcomes

Author/s	Sample (children and 'adult')	Concept/s studied	Operationalisation of phone use	Methodology	Outcomes measured	Key findings
Abels et al. (2018)	25 children aged 0-5 years and a primary caregiver.	Parent responsiveness	Passive e.g. holding but not using the phone. Occasional e.g. glancing at the phone occasionally. Exclusive e.g. fully focused on the phone.	Natural observation (time sampled) of caregivers' behaviour and caregivers' responses to the child's bids for attention.	Caregiver's behaviour, whether child directed or not. Non-child related activities were measured for levels of absorption. Child's bids for attention and types of bids made. Caregiver's responsiveness.	Caregivers' responses to their child's bids for attention were associated with phone use. Responses were less frequent, weaker and took longer when exclusively engaged with a phone.
Bury et al. (2020)	85 children aged 0-5 years (estimated) and their parent/ caregiver.	Parent responsiveness	The dominant mode of mobile use – classified as either telephone call, scrolling/typing or camera, and the duration of use.	Mixed methods. Natural observation in playgrounds and a follow up interview with 20 parents/caregivers.	Type of smartphone use. Caregiver supervision. Caregiver-child interaction. Potential for child injury.	The more a mobile device was used, the less supervision and less parent-child play there was. There was also an increased potential for children to be injured during parent phone use.
Corkin et al. (2021)	43 children aged approximately 20 months and their parents.	Language	Amount of time spent on the phone per hour when with their infant. Average number of audible notifications per hour, number of times device is checked per hour, average screen time when with their	Mixed methods. Controlled observation of a 3-minute play interaction. Questionnaire to measure technoference.	Parent and child screen use. Problematic use of mobile technology. Language development. Parent responsiveness. Scaffolding. Joint attention. Directiveness.	Increased audible notifications were associated with lower infant vocabulary scores, but this was mediated by parent directiveness. Association between infant vocabulary size and parents who make a conscious effort to put their phones away.

			infant and score on the DISRUPT (McDaniel, 2021).			Negative association between parents who co-use screens with infants and infant vocabulary.
Dinzinger et al. (2025)	65 infants aged 3-10 months and their mother.	Eye gaze	Completing a crossword puzzle on the phone.	Experiment – within participants. Mother engaged in free play, followed by an interruption of phone use or a still face (order counterbalanced). A reunion phase followed each interruption.	Cardiac activity in both infant and mother. Infant behaviour – protest and self-soothing. Maternal behaviour – soothing touch, gaze, and vocalisations	During technoference infants had increased heart rate and protest behaviours but reduced self-regulatory behaviours. Mothers reduced social gaze, touch, vocalisations, and heart rate during both interruptions. Respiratory sinus arrhythmia decreased during both interruptions.
Elias et al. (2020)	153 children aged 2-6 years (estimated) and their parents.	Parent responsiveness	Any phone use including typing, scrolling, taking photos, watching, reading, and talking.	Naturalistic observation in playgrounds and eateries.	Duration of phone use. Type of smartphone use. When the phone is used. Parent and child's body language and facial expressions. Quality of parent-child interaction. Parent sensitivity and responsiveness. Parent and child engagement in non-smartphone activities.	When engaged in phone use, parents often failed to notice when their child's safety may be compromised and when their child required emotional support.
Ewin, Reupert, McLean, et al. (2021)	24 children aged 2-3 years and a parent.	Language	Use of apps on the parent's smartphone.	Experiment – within participants. Parents interacted with their child across four conditions,	Number of utterances and number of words spoken per minute.	Parents spoke more during the shared non-digital play. Parents used more language during shared phone use than independent phone or magazine use.

				1) Independent parent device use 2) Independent parent magazine use 3) Parent and child joint interaction on the parent's phone 4) Parent and child joint interaction with a non-digital toy.		
Gaudreau et al. (2021)	57 children aged 3-5 years and a parent.	Language	Completion of a survey on the phone.	Experiment – between participants. Children were able to play with a novel toy whilst the parent completed a survey either, 1) Using a smartphone 2) On paper 3) No survey (control)	Language skills. Parent and child's questions and responses to questions. Number of hidden functions found on the novel toy.	More information seeking questions were asked in the control group, followed by the paper survey. No difference in children's questions or parent and child responsiveness when the survey was completed by phone or on paper.
Golds et al. (2025)	450 mothers of infants aged 3-9-months.	Parent responsiveness	The Technology Interference with Parenting Scale.	Survey	COVID-19. Infant social and emotional development. Maternal mental health. Social support. Maternal smartphone use in the presence of the infant. Mother-infant responsiveness.	Higher levels of wellbeing and social support were positively associated with mother-infant responsiveness. Mother smartphone use was a predictor of mother-infant responsiveness when the infant was perceived as not actively engaging with the mother.

Hiniker et al. (2015)	466 adults who have children under the age of 10 years and any caregiver – parent, grandparent, nanny.	Parent responsiveness	Time spent using the phone.	Mixed methods. Naturalistic observations in playgrounds. A separate sample completed surveys, and an additional sample participated in an interview.	Time spent on phone. Type of smartphone use and why. Caregiver responsiveness. Experiences of absorption.	Parents were more likely to respond to bids for attention when not using a phone, most of the playground time was spent with children playing independently.
Inoue et al. (2021)	13 children aged 2-6 months and their mother.	Eye gaze and parent responsiveness	Using the smartphone how they usually would at home.	Experiment – within participants. Mother breastfed without phone use and again whilst using their own smartphone.	Maternal gaze to infant and to the phone. Mothers' behaviours towards the child. Infant's actions. Quality of mother-infant interactions. Maternal sensitivity. Mothers' feelings towards the child.	No association between smartphone use and quality mother-child interactions. Mothers directed less visual attention to their infant when using their smartphone.
Kelly and Ocular (2021)	77 families. 1 child per family aged 3-8 years and a parent (56% mothers).	Language	Taking a photo, looking at the phone alone, looking at the phone with the child.	Mixed methods involving parents visiting an aquarium. All participants completed a survey about their phone use and discussions with their child during their visit. A subset were audio recorded during their visit and some of these families were observed throughout.	Observation of frequency of smartphone use and accessibility of the phone. Audio recorded parent and child utterances. Self-reported frequency and type of smartphone use in the exhibit. Self-reported type of talk with child during the exhibit.	More off topic talk was reported by parents who used their smartphone. The more the parents used the smartphone, the less contingent the conversation with the child.
Konrad, Hillmann,	54 children aged 20-22	Parent responsiveness	Answer a questionnaire on the	Experiment – between participants.	Maternal behaviour – 16 behaviours measured	Mothers more responsive when there was no

et al. (2021)	months and their mother.		phone.	Free play session followed by random allocation to one of three conditions: 1) Smartphone interruption 2) Paper and pencil interruption 3) No interruption Followed by a further free play session. Survey to measure media use and attitudes towards media use.	including responsiveness, reciprocity, directing attention, and initiating an interaction. Child behaviour – bids for attention (positive and negative), prohibited behaviour, negative affect, and toy engagement.	interruption to play. No difference in responsiveness between two interruption conditions. Children made more positive bids for attention during both interruptions in comparison to the free play sessions.
Krapf-Bar et al. (2022)	114 children with a mean age of 11 months and their mother.	Joint attention	Text messages sent by experimenter that the mother had to reply to.	Experiment – between participants. Participants completed a modified still face, and during the 'still face' phase were disrupted by one of three conditions: 1) Mobile phone 2) In person by the experimenter 3) No interruption	Initiating and responding to joint attention in both mothers and children. Success rate of joint attention. Length of joint attention episodes.	Higher infant initiation of joint attention in the phone and social disruption conditions (no difference between the two) than no disruption. Mothers initiated joint attention more when using the phone. Mothers less likely to respond contingently when using the mobile phone, but no difference between infants across conditions. Joint attention was less likely to occur, and episodes were shorter when the phone was used.
Lederer et al. (2022)	33 children aged 24-36 months and their mother.	Language	Mothers asked to go onto a Facebook page (designed for the experiment) and to 'like' any posts	Experiment – within participants. Mothers played with their infants whilst also,	Mother's media use. Child's language development. Number of maternal utterances.	Mothers produced fewer utterances and were less verbally responsive when there was a disruption (no difference between the two

			they found interesting.	1) Using their smartphone 2) Reading a magazine 3) Uninterrupted free play Order pseudo-random.	Mother's verbal responsiveness. Maternal non responsiveness. Conversational turns between mother and child.	types). Mothers were more likely to miss bids for attention when using the smartphone. Fewer conversational turns occurred when there was a disruption (no difference between the two types).
Mangan et al. (2018)	50 children under the age of 5 years and their parents/carers.	Parent responsiveness	Time spent using phone, type of use.	Mixed methods. Natural observation in playgrounds and follow up interview (n=25).	Time spent on mobile device. Interaction between the dyad. Caregiver perceptions and attitudes of mobile device use.	76% of parents used their phone. Most parents spent less than 5 (out of 20) minutes on the phone. Children spent most of their time in independent play. Parents ignored a child's bid for attention or left an interaction when using the phone in around 4% of the total observation time.
Mikhelson et al. (2024)	16 children aged 4 months and their mothers.	Language	Time spent on the phone via a passive sensing app.	Correlation. Phone use was recorded over a one-week period. Mothers use of language when with their infant measured via Language Environment Analysis during the week. Ecological momentary assessment surveys sent throughout the week.	Maternal phone use. Maternal and infant language. Infant sleep.	Maternal speech and word count decreased during phone use. Short phone use (1-2 minutes) had the strongest association with speech.
Mikić et al. (2025)	52 children aged 5-6	Parent responsiveness	Responding to four text messages as	Experiment – within participants. Mother	Infant affect. Emotional availability of the dyad.	Infants showed less positive affect during the interruption

	months and 15 days and their mother.		quickly as possible via WhatsApp.	engaged in: 1) An infant free play session 2) A smartphone interruption session Order counterbalanced.	Maternal responsiveness. Behaviours which aimed to maintain contact with the infant.	phase when the free play phase was first. Mothers were less sensitive and responded more slowly during the interruption phase.
Nakagawa et al. (2019)	7 children aged 3-6 months and their mother.	Parent responsiveness	Reading the news on the phone or typing characters on the phone.	Experiment – within participants. Mothers: 1) Read the news on their phone whilst breastfeeding 2) Breast fed whilst typing characters on their phone 3) Breastfed without using a phone Questionnaire on phone use during breastfeeding.	Changes in mother's posture. Frequency and time of smartphone use. Baby's usual reaction. How the smartphone is usually used. Feelings of guilt around using smartphone.	When using the smartphone, mothers posture changed, and they looked less at their baby's face. Response time to notice the infant had finished feeding was also longer when the smartphone was being used.
Nguyen (2024)	42 children aged 17-19 months and a parent.	Language	Received a text message to notify parent to complete a questionnaire on the phone.	Experiment – mixed design. Within participants – parents taught their child two novel words across two conditions: 1) The teaching period was interrupted by the phone 2) No interruption to teaching Order counterbalanced.	Child language. Novel word learning. Average parent screen time.	No difference in children's word learning when teaching was interrupted compared to no interruption. Children learnt the words better when parents were told the true purpose of the study.

				Between participants – parents either told: 1) True purpose of study 2) A cover story Parents completed a questionnaire to measure screen time and child language.		
Nomkin and Gordon (2021)	20 children aged 3-6 months and their mother.	Eye gaze	Five WhatsApp messages sent by the experimenter.	Experiment – within participants. Mothers breastfed and had a face-to-face interaction with their infant in the following conditions, 1) Whilst using their phone 2) Smartphone away but volume on 3) Smartphone away and on mute Each breastfeeding period was followed by a face-to-face interaction.	Physiological response of autonomic nervous system. Gaze direction. Smartphone addiction. Infant behaviour.	Mothers looked longer at the smartphone than the infant when breastfeeding and looked longer at the infant than the smartphone in the face-to-face interaction. When breastfeeding tonic skin conductance level was higher in the smartphone mute condition than when using the smartphone.
Ochoa et al. (2021)	98 children under the age of 4 years and their caregiver.	Joint attention and language	If the phone was used, type of use.	Natural observation across three settings, 1) Parks and playgrounds 2) Food courts 3) Courtyards or lounging areas in shopping centres.	Device use and type of smartphone use. Caregiver emotional input. Caregiver talk. Caregiver initiation of interaction. Caregiver responsiveness. Child emotional input.	Joint attention was less likely to occur and caregivers were less likely to initiate an interaction when the phone was used. Less caregiver talk was present when a mobile was being used. Caregivers showed fewer positive emotions when

					Child talk. Child initiation of interaction. Child responsiveness. Proximity of the dyad. Joint attention.	using the phone. Caregiver device use was not related to caregiver responsiveness, child talk or child's positive emotions. Type of phone use had an effect, looking at a screen was less problematic for engaging in joint attention and caregiver talk than texting or swiping.
Reed et al. (2017)	44 children aged 2-years old and their mother.	Language	30 second phone call.	Experiment – within participants. Task of teaching a novel word was tested when: 1) Teaching was interrupted by a phone call 2) No interruption to teaching Order counterbalanced.	Comprehension of novel words. Self-reported phone use.	Children were more likely to learn the word when the parent was not interrupted with a phone call. The amount of time the word was said by the mother did not differ across conditions.
Rothstein (2018)	39 children aged between 13-51 months and parents.	Parent responsiveness	Phoned turned on.	Experiment -within participants. Parents waiting to participate in a study on reading were told they could: 1) Keep their phone on 2) Turn their phone off Order counterbalanced.	Quality of the parent-child interaction including affection, responsiveness, encouragement, and teaching.	When the phone was turned on, there was a significant decrease in affection, parent responsiveness, and encouragement in comparison to when the phone was turned off. There was no difference in teaching when the phone was on or off.
Wolfers et al. (2020)	89 infants aged 7-36 months and their mother.	Parent responsiveness	Frequency of use, duration of use.	Natural observation in playgrounds with a follow up interview. Survey on	Frequency and duration of phone use. Maternal sensitivity. Smartphone use habits.	Duration of smartphone use was related to mothers' sensitivity, but frequency of use was not. Mothers who

demographics and type of smartphone use in last 15 minutes.	Type of smartphone use.	used their phones to connect with family were more sensitive to their children.

1.4 Eye Gaze

Natural pedagogy theory proposes that infants are innately programmed to be receptive to ostensive signals (Csibra & Gergely, 2009). An ostensive signal is a cue which indicates that the recipient is being addressed and often precedes or accompanies communication (Csibra & Gergely, 2009). Direct eye gaze is an ostensive signal which is key to the development of social understanding in infants (Itier & Batty, 2009). It facilitates joint visual attention (Moore & Corkum, 1998) and creates the opportunity for communication between an infant and others (Csibra, 2010; Dimitrova, 2020), following a pattern that is identical to that of adult verbal conversations (Jaffe et al., 1973). Stephenson et al. (2021) proposed the shared-attention system (SAS) which highlights the importance of eye gaze in obtaining meaning from, and to respond to, social interactions e.g., through gaze following. These processes allow for joint attention to occur, which is a precursor to language development (Markus et al., 2000; Tomasello & Farrar, 1986). Thus, eye gaze plays a key role in infant's language development.

Although an infant is born with no experience of social interactions (though see Castiello et al. (2010) for evidence in utero), extant research has found that neonates prefer looking at another person's eyes from as early as the days following birth (Batki et al., 2000; Farroni, Massaccesi, et al., 2004; Farroni et al., 2006). Eye preference may be innate or may develop from a general face preference. Baron-Cohen (1995) suggest that infants are innately equipped with an eye direction detector (EDD) which is activated in response to stimuli that represent an eye. Being sensitive to gaze directed toward oneself would enable humans to rapidly detect whether another species is observing them as potential prey. Whilst this initial detection is innate, Baron-Cohen (1995) proposes that through experience infants

gradually develop an understanding of social eye behaviour. This sensitivity to the eyes is demonstrated in neonates less than 2 days old, who prefer to look at a face with the eyes open, compared to the same face with the eyes closed (Batki et al., 2000). Evidence for the eyes, as opposed to the face, as drawing attention can be seen in studies which find that direct gaze (compared to averted gaze) aids with remembering faces in 4-month-olds, children aged 6-7 years, and adults (Farroni, Massaccesi, et al., 2007; Hood et al., 2003). However, Johnson et al. (2015) present an alternative line of argument which identifies the face, rather than the eyes, as the most relevant stimulus in the environment. Johnson et al. (2015) propose two systems, namely the CONSPEC, i.e. the inbuilt mechanism whereby infants attend to faces, and the CONLERN, i.e. the development of neural circuits which facilitate the ability to process faces (for a review of the development of the social brain, see Grossmann et al. (2013)). Whilst both explanations concur that infants are born with a preference for the face region, they differ as to whether that preference is for the eyes (EDD) or the face (CONSPEC). Findings that one- to five-day-old infants look longer at a face with direct gaze than a face with averted gaze (Farroni, Massaccesi, et al., 2004; Farroni et al., 2006), only when presented in its typical upright configuration (not when inverted or turned to the side) (Farroni et al., 2006), support that infant sensitivity to gaze direction may be part of a general mechanism for face detection as opposed to a specific mechanism for detecting eye direction (Farroni et al., 2006). This suggestion might seem conflicting with a study that found that 1-3-day-old infants looked longer at a familiar face with direct rather than upwards averted gaze (Guellaï et al., 2020). However, this latest study employed a dynamic face stimulus, which might be more ecologically valid than the face stimuli employed in Farroni's studies. Therefore, in a more naturalistic social situation, the eyes may

be uniquely important as opposed to being processed via a general interest in the face when using still images. It is difficult to know whether studies which looked at visual preference in neonates measured looking behaviour towards the eye area specifically, or the face more generally. Despite the challenges associated to the use of eye tracking devices with newborn population, the implementation of this technique might help explain some of the conflicting findings.

Regardless of whether it is the eyes or the face which initially draws infant attention to human faces, when focused on a face, infants can process characteristics within faces such as emotional expressions and identity (Bushneil et al., 1989; Farroni, Menon, et al., 2007). Additionally, 3-to 6-month-olds smile less and their visual attention is reduced when adults look away, i.e. display an averted gaze (Hains & Muir, 1996), and by 5 months of age, infants smile less when adults avert the head and eyes, but not the head alone (Caron et al., 1997), showing an awareness of sensitivity to both the head and eyes. These findings are in line with the existence of the CONLERN (Johnson et al., 2015), a system that supports more complex facial processing mechanisms from 2 months onwards. However, another possibility is that infant's interest in faces is a by-product of interest in the eyes (Gliga & Csibra, 2007), which occurs due to the EDD (Baron-Cohen, 1995).

Eye gaze has also been studied from a neurodevelopmental perspective using event related potentials (ERPs). Studies using ERPs, have identified several components involved in processing faces during infancy (de Haan et al., 2003). The N170 is a negative component that occurs around 170ms in response to a face in the adult brain (Bentin et al., 1996) and around 290ms in the infant brain (see Meltzoff and Ryczek (2025) for a review). The 'infant N170' (or N290) is not only present in response to human faces (de Haan et al., 2002) but it is also modulated

by gaze direction, so that it has a larger amplitude in response to direct gaze compared to averted gaze in 4-month-olds (Farroni et al., 2002). Gaze direction has also been found to modulate other ERP components in young infants. For example, Rigato et al. (2010) found that in 4-month-olds, P1 (an occipital ERP component that peaks around 100ms (Itier & Taylor, 2004)), peaked earlier in response to averted than direct gaze in happy faces, but not in fearful faces. In another study with 4-month-olds, direct gaze in angry faces resulted in increased activity in a positive slow wave component in comparison to angry faces with averted gaze, but this difference was not found for neutral or happy faces (Striano, Kopp, et al., 2006). Research with 7-month-olds, using functional near-infrared spectroscopy (fNIRS), shows increased activity in the dorsomedial prefrontal cortex (mPFC), inferior frontal, anterior temporal, and temporo-parietal regions in response to direct versus averted gaze (Lloyd-Fox et al., 2015; Urakawa et al., 2015), To summarise, the neural evidence suggests that by the age of four months, infants can differentiate between direct and averted gaze, but the emotional expression of the face also influences the encoding process.

1.4.1 Gaze Following

The initial interest that infants have in the eyes is thought to aid the development of gaze following (Del Bianco et al., 2019). Gaze following occurs when an infant, who is initially focusing on an individual's eyes, follows the individual's shift in gaze towards an object, and also looks at the object (Del Bianco et al., 2019). Gaze following forms the basis of joint visual attention, whereby the infant looks where another individual is paying attention *because* the individual is paying attention to the object (Deák et al., 2000). In Section 1.5.1, I discuss the importance of joint attention for language development. As the interest in the eyes precedes

gaze following, which precedes joint attention, gaze following ability is addressed in Study 2a (Chapter 4). Here, I explain how gaze following aids infants' understanding of others, followed by a review of gaze following literature which identifies the eyes as central in this process. I then explore the influence of smartphone technoference on social gaze (Section 1.4.2).

This thesis applies a social cognitive framework to understand social eye gaze and gaze following. The social cognitive framework suggests that infants learn to follow other people's gaze as it aids their understanding of what others are thinking, as by following gaze, the infant's attention is directed to a location, object or event that holds important information within the context of the dyadic interaction (Meltzoff, 2013). Findings that 5-month-olds had increased activity in the left pre-frontal cortex when their social partner followed gaze to an object the infant had previously looked at, compared to looking at an object the infant had not previously looked at, suggests infants have some awareness of the adult's mental state (Grossmann et al., 2013). Some support for social cognitive framework comes from studying children with autism spectrum disorder (ASD) who have been found to not follow others' gaze at 18-months old, unlike typically developing (TD) children (Baron-Cohen et al., 1996). Children at risk of ASD who later developed socio-communication problems were also found to look less at the object of interest after gaze following (Bedford et al., 2012; Parsons et al., 2019), which may signal that children at risk of ASD do not follow gaze as a way to understand others' thinking. Indeed, Bedford et al. (2012) suggest that children with ASD may not understand the communicative element in eye gaze and are not following the gaze to attend to the object. Further support for gaze following being driven by social cognition comes from comparative research showing that while great apes rely on head direction, 12-

and 18-month-old infants rely more on the eyes to follow eye gaze (Tomasello, Hare, et al., 2007). Tomasello, Hare, et al. (2007) explain their findings in the context of the cooperative eye hypothesis, which suggests that humans have evolved to be able to initiate and maintain communicative interactions with other humans and that the eyes are key to this due to their distinctive black and white contrast. Although, evidence from non-Western cultures identifies that cues aside from eye gaze may be important to developing an understanding of others (Akhtar & Gernsbacher, 2008). For example, in cultures where infants are carried facing away from their parents, signals such as vocal cues (Fernald, 1993) and touch (Stack & Arnold, 1998) may be as important as mutual gaze. This suggests that whilst important, eye gaze is not the only factor which facilities social cognition.

Regardless of its underlying cause, research shows that gaze following is a robust phenomenon in infants, though findings are mixed on when it emerges. For example, Gredebäck et al. (2010) found that gaze following develops between 2-4 months and is established between 6-8 months. Butterworth and Jarrett (1991) however found that gaze following begins to develop slightly later, at 3-6 months, following a developmental trajectory. For example, 6-month-olds could follow the direction of the gaze correctly, but they were less accurate at identifying the location of the object of interest, whereas at 18 months, the infants could accurately follow the direction of gaze to the location of target (Butterworth & Jarrett, 1991). Key to the conclusions by Butterworth and Jarrett (1991) is that up until 12 months an infant can only follow gaze within their own visual space. To test whether infants can follow gaze beyond their line of sight, Moll and Tomasello (2004) blocked the infants' line of sight by a barrier and found that both 12- and 18-month-old infants followed the model's gaze behind the barrier by crawling or walking to see what the model was

looking at. Infants did not do this in the control conditions where no one was looking behind the barrier, adding support that by 12 months infants may follow eye gaze with an understanding of others' minds.

Whilst the research presented so far points towards the eyes being important for gaze following, outside of the laboratory, gaze following does not occur in isolation and an adult will use other secondary cues including head orientation, body posture, communicative gestures such as pointing (Corkum & Moore, 1998; Deák et al., 2000), and infant directed speech (IDS) (Senju & Csibra, 2008). The object of attention is also an important factor to consider as infants are more likely to follow gaze and use pointing when the target objects are distinctive from each other, i.e. varying colours (Deák et al., 2000). It is possible that these secondary cues are more effective than the eyes at aiding an infant following an adult's direction of attention. For example, movement of the head is more distinctive than a change in gaze direction for 3-6-month-olds (D'Entremont et al., 1997), and if the pupils remain stationary but the face changes direction 4-5-month-olds follow the face movement rather than stay focused on the pupils (Farroni et al., 2000). This evidence suggests that it may be movement which is important in infants under 6-months-old, rather than the eyes. Indeed, it is not until around 18 months of age that infants can follow eye gaze without head movement accompanying it (Moore & Corkum, 1998). However, subsequent research with methodological modifications has found support for the role of the eyes as the key cue for initiating gaze following. Caron et al. (2002) measured gaze following in 12- and 14-month-olds across five different cues; head and eye turn, head and eye turn with a verbal cue, head and eye turn with additional scanning time of the target, head turn only (eyes stayed fixed on the infant) and head turn with closed eyes. Fourteen-month-olds followed gaze more frequently when

both the head and eyes moved together. As the head-only conditions did not yield more gaze following, it suggests that the eyes and head turning together are key for an infant to identify the adult as looking elsewhere. To further understand the importance of the eyes, Brooks and Meltzoff (2002) compared infants' gaze following to an adult that either had open or closed eyes. Head movement was kept the same across conditions. In a between participants experiment with 12-, 14-, and 18-month-olds, Brooks and Meltzoff (2002) found that infants across all three ages looked longer, and more often, at targets which had eyes open than with eyes closed. Infants also vocalised and pointed more frequently when the adult's eyes were open. In a second experiment, Brooks and Meltzoff (2002) found that across all three ages infants followed eye gaze more frequently when the adult wore a headband (not masking the eyes) than when they wore a blindfold (which did mask the eyes). As head movement was controlled across all conditions, these findings suggest that infants are sensitive to eyes and use an adult's eyes to attend to important information (Brooks & Meltzoff, 2002).

1.4.2 Technoference and Gaze

As smartphone use requires sustained eye gaze (Bury et al., 2020), a parent using their phone could reduce opportunities for direct and mutual gaze. Whilst some observational research has found that eye contact is maintained between a parent and child during phone calls, but not during swiping tasks (Radesky et al., 2014), other studies have found that parents turn their bodies away from their child during phone use, therefore eye contact is minimal to none (Elias et al., 2020). Possibly, the way in which the phone is being used is a moderator of the impact of technoference on gaze, as swiping tasks, which require looking at the smartphone, are more absorbing than calls (Radesky et al., 2014). The type of parent-child interaction may

also moderate the impact of smartphone use on maternal gaze. During breastfeeding, mothers look longer at their smartphones than at their infant (Inoue et al., 2021; Nomkin & Gordon, 2021), whereas during face-to-face interactions, mothers direct their gaze toward the infant for longer than toward the smartphone (Nomkin & Gordon, 2021). Nevertheless, smartphone use remains disruptive even in face-to-face contexts, reducing mothers' social gaze compared to uninterrupted interactions (Dinzinger et al., 2025). Increased visual attention to the phone during breastfeeding maybe due to the nature of the task. Nomkin and Gordon (2021) argue that mothers may be more susceptible to any distraction, not only smartphones, during breastfeeding, as the infant is feeding and not seeking a face-to-face interaction allowing the mother's attention to be directed elsewhere.

The eyes, therefore, are a crucial aspect of establishing early social communication between infants and their caregivers, facilitating the development of social cognition. A small number of studies tentatively show that parent smartphone use can disrupt parents' social gaze directed to their child, but it remains unclear whether the nature of the phone use, rather than the phone use per se, impacts this relationship. As a potential mediator in the relationship between parent smartphone use and child language outcomes (Figure 1.1), this thesis tests whether the way in which the phone is used differentially affects caregiver's visual attention and tests whether infants differentiate between gaze disruption caused by a smartphone in comparison to non-digital disruption.

1.5 Joint Attention

Eye gaze and gaze following are features of primary intersubjectivity, i.e. the early ability an infant has to engage in face-to-face interactions with other humans (Trevarthen, 1979). Around the age of 9-12 months, infants develop secondary

intersubjectivity which allows the child to engage in triadic interactions, facilitating joint attention. Joint attention involves the adult and child both focusing on the same object and crucially both being aware that the other is also focused on the object, as signalled by an overt behaviour such as shifting eye gaze between the object and the partner to signal shared interest, or through verbalisation that is directed towards the partner (Tomasello & Todd, 1983). Joint attention can occur either because the child responds to joint attention bids from others (responsive joint attention, RJA), or because the child initiates joint attention (initiated joint attention, IJA) (Mundy et al., 2007). If the child follows the parent's gaze to an object and the dyad has a period of joint attention with this object, the child has *responded* to the parent's initiation of looking. If the child points to an object and the parent responds by engaging with the object and child, the child has *initiated* joint attention. In TD children, engagement in joint attention increases with age between 6 and 18-months: IJA is present at 9-months but declines between 12-to-15-months before rapidly rebounding between 15 and 18-months, whilst RJA follows a linear trajectory (Bakeman & Adamson, 1984; Mundy et al., 2007). In this section, I first summarise the development of joint attention. Next, I review the literature on joint attention and language outcomes (Section 1.5.1), followed by the relationship between parent smartphone technoference and joint attention (Section 1.5.2).

The social cognitive framework discussed in Section 1.4.1, can also be applied to explain joint attention. A social cognitive perspective proposes that regardless of whether an infant is RJA or IJA, to do so requires an understanding that others have differing intentions to their own (Tomasello, 1995). Understanding of intentions begins to develop at 9 months of age, 10-month-olds recognise others as having goal directed behaviour, and at 14 months, infants have developed an

understanding of others as having intentions, allowing the infant to engage in coordinated shared activities and shared communication (Brandone & Wellman, 2009; Tomasello et al., 2005; Tomasello, Carpenter, et al., 2007). Whilst the social cognitive framework suggests that at 9 months infants begin to acquire crucial skills to understand others, neuroimaging studies suggest that infants might be sensitive to joint attention before that age. For example, Grossmann and Johnson (2010) found that infants as young as 5-months-old showed increased neural activity in the left dorsal prefrontal cortex during joint attention with an adult on screen, compared to the adult engaging in similar behaviours but without the features necessary for joint attention (i.e. looking towards an object, making eye contact). One study measured alpha event related desynchronisation (ERD) which is the attenuation in alpha frequency after the onset of a stimulus (Pfurtscheller, 1991). Alpha ERD was greater in both 6.5 and 9.5-month-olds who viewed an on-screen actor that followed the infant's gaze, compared to an actor who did not (Rayson et al., 2019). Other neuroimaging studies provide evidence that infants develop skills to support social cognition at 9-months-old. In live social interactions, Angelini et al. (2023) found alpha activity increased in the frontal brain areas when an adult's gaze direction was congruent with 9-month-olds compared to incongruent gaze. The differences in the direction of the change in alpha activity between Rayson et al. (2019) and Angelini et al. (2023) may be explained by the artificial versus live stimuli used in each study. Nevertheless, the difference in alpha activity between congruent and incongruent conditions in both studies, suggests that infants discriminate between the two interactions. Another study which utilised a live paradigm where an actor engaged in joint attention with a 9-month-old, found that the mid-latency negative component (Nc) of an ERP was larger than when the actor did not engage in joint attention

(Striano, Reid, et al., 2006). The Nc occurs approximately 300-700 milliseconds after stimulus onset (Striano, Reid, et al., 2006) and is believed to be involved in attentional processes (Richards, 2003). Striano, Reid, et al. (2006) interpret their findings as demonstrating that infants increase their attention to the more important aspects of a situation; in this case joint attention.

1.5.1 Joint Attention and Language

When engaged in joint attention, infants have an understanding that their social partner is like them but with differing perspectives that can be shared, followed or directed (Carpenter et al., 1998). This facilitates the development of social cognition including, imitative learning, communicative gestures, intentional communication, theory of mind, and, central to my thesis, language development (Adamson et al., 2019; Carpenter et al., 1998; Charman et al., 2000; Tomasello et al., 1993). Joint attention as a precursor to language development is well established in the literature (Markus et al., 2000; Tomasello & Farrar, 1986; Tomasello & Todd, 1983).

Joint attention may aid language development because when a child is engaged in joint attention, they are attentive to the interaction and are better placed to interpret the meaning of the parent's use of language (Tomasello & Farrar, 1986). This is particularly evident in routine social interactions, where predictability facilitates children's ability to associate an adult's language to their focus of attention (Bruner, 1983). One example is book reading, which follows a routine, facilitates joint attention, uses pointing gestures and verbal labelling to support word mapping, and influences expressive language (Farrant & Zubrick, 2012; Sato & Uchiyama, 2012; Snow & Goldfield, 1983). The role of joint attention in aiding word mapping is further reported in research with 18-20-month-olds (Baldwin et al., 1996). In this study,

infants mapped a novel word onto an object more often when labelling of an object occurred during joint attention, as opposed to labelling occurring without any social referencing from the adult. These findings suggest that by the age of 18-20 months infants are aware of where others are focusing their attention and understand the value of shared attentional focus during communication (Baldwin, 1995). Interestingly, language learning can occur observing others engaged in joint attention, without the infant being directly involved (Fitch, 2020). The importance of joint attention for language learning therefore extends beyond direct involvement in an episode of joint attention.

The effect of joint attention on language development has been found to differ depending on whether infants are IJA or RJA. Episodes of joint attention that are initiated by the infant are more effective for language development than when an infant is RJA (Akhtar et al., 1991; Colonnesi et al., 2010; Dunham et al., 1993; Tomasello & Farrar, 1986; Tomasello & Todd, 1983). For an infant to respond to a parent's attempts to direct attention to a shared focus, the infant must shift their attention and attempt to decipher accurately where their attention is being directed. The process of associating the word label with the relevant object or action in this way might be more complex than if the infant IJA, and their attention is therefore already focused on the object (Tomasello & Todd, 1983). Thus, it is not what the parent says that seems to be important for language development but *when* they say it. To facilitate word mapping, the child's attention should already be on the object at the time of the adult's speech. That said, RJA has been found to predict both receptive (Mundy & Gomes, 1998) and expressive language (Delgado et al., 2002), thus it is possible that IJA and RJA affect language development differently utilising

different abilities across developmental stages (Brooks & Meltzoff, 2008; Salo et al., 2019).

Cultural differences also offer an insight into the significance of joint attention in later language development. Differences in parent-infant interactions may mean that children in non-Western cultures experiences of joint attention differ to those of children in Western cultures. For example, Dutch caregivers use gestures alongside verbal utterances more than Mozambican caregivers (Vogt et al., 2020). Differences also occur within cultures, for example Mozambican infants living in rural communities spend less time in joint attention than Mozambican children in urban communities, likely due to their different lifestyles (Mastin & Vogt, 2016). Interestingly there was a positive correlation between joint attention and later language in the urban infants but a negative correlation in the rural infants. Mastin and Vogt (2016) suggest these differences may be due to different cultural practices, with joint attention in rural communities focused more on knowledge sharing as opposed to object naming. Further cultural differences are found in Nigerian Ngas speaking toddlers, as Childers et al. (2007) found that play without a shared object of attention and solo object play were a better predictor of both noun and verb comprehension, and production, than joint attention involving shared engagement with an object. The studies in this thesis all involve Western participants, and it is noted that findings will be culture specific.

Several methodological issues are present across studies exploring joint attention. First, the term is operationalised differently across studies. Many studies measure joint visual attention (e.g. Tomasello and Todd (1983)), which may overlook other sensory means of sustaining joint attention such as touch and vocal cues which can also guide infants with word mapping (Akhtar & Gernsbacher, 2007;

Akhtar & Gernsbacher, 2008; Botero, 2016; Suarez-Rivera et al., 2019). If joint attention can occur without visual cues, the full impact of joint attention on language may have been understated in research which has only focused on overt visual awareness of shared attention. Second, most studies which investigate joint attention and language do so in highly controlled settings designed to elicit the phenomenon. In the laboratory, the dyad is usually given toys to engage with, and the parent is kept near the infant. This setting is highly likely to result in the parent talking about the objects which are in close proximity to the dyad (Suarez-Rivera et al., 2022), and it is possible that the joint attention instances may differ from those that occur spontaneously at home. Despite there being minimal research outside of the laboratory, Schatz et al. (2022) found that in the home, joint attention is present, is multimodal, happens more often when the dyad are in close proximity, and occurs in bursts. Longer periods of joint attention occurred when mothers used touch or gesture during joint attention and applied object-related talk as opposed to unrelated talk or silence. A further issue with laboratory studies is that they tend to use mother-infant dyads when measuring joint attention. Outside of the laboratory, interactions are unlikely to always be dyadic and can involve additional social partners such as siblings or other adults (Akhtar & Gernsbacher, 2007), with triadic parent-infant—sibling interactions shown to last nearly three times longer than dyadic interactions (Barton & Tomasello, 1991). Therefore, in highly controlled settings, the complexities of joint attention are unlikely to have been adequately tested.

1.5.2 Technoference and Joint Attention

By interfering with IJA or RJA, parent smartphone technoference has the potential to affect joint attention. If a parent is using their phone and becomes absorbed in its use, they are less likely to initiate joint attention (Ochoa et al., 2021).

Similarly, parents may miss bids for attention from their infant when using their smartphone (Davidovitch et al., 2018), or have a delayed and/or non-contingent response. Several studies support this assumption. Ochoa et al. (2021) found joint attention was reduced when caregivers used a phone compared to not using a phone. Radesky et al. (2015) found that in a structured eating task, mothers initiated fewer verbal and nonverbal interactions when using their phone. This effect was most pronounced when the child was offered unfamiliar food, i.e. in unfamiliar tasks where parental support and role modelling is required. Another study found that mothers missed more bids for attention when using a smartphone than when reading a magazine or when there was no interruption (Lederer et al., 2022). However, Corkin et al. (2021) found no relationship between joint attention and technoference. In this study, a parent and child dyad were observed playing in the laboratory and smartphone technoference was measured separately via an online questionnaire, therefore not *during* the interaction. This difference in study design could explain the discrepancy in results, as parents self-reported technoference may be biased. Nevertheless, the approach taken by Corkin et al. (2021) might reveal the potential cumulative effects rather than the immediate effects of technoference.

To understand whether technoference is unique in its ability to disrupt joint attention, researchers have used a modified SFP (Tronick et al., 1978). The traditional SFP involves three phases: 1) the mother and child interact naturally, 2) the mother remains unresponsive and maintains a neutral expression, and 3) the reunion phase where the mother interacts as she usually would (Tronick et al., 1978). During phase 2 the interaction is disrupted, and it is not repaired by the child's usual attempts. This usually leads infants to express negative emotions and turn away from the mother; the still face effect (Tronick, 2017). Krapf-Bar et al. (2022)

replaced the ‘still face’ with either disruption via a mobile phone (texting), a social disruption (a face-to-face conversation with the experimenter), or no disruption and measured the effects on both the infants and mothers’ behaviours. While infants contingent RJA behaviours were not affected across the three conditions, infants IJA behaviours increased during both the phone and social disruption phases of the procedure, in comparison to the free play and reunion phases. This effect was not found when there was no disruption. These findings suggest that infants’ attempts to IJA are equally disrupted regardless of the medium of distraction. However, the pattern of results for mothers suggests the medium of disruption does impact mothers’ response to infants’ IJA. Mothers were least likely to respond contingently to these bids during mobile phone disruption compared to when the disruption involved a face-to-face conversation with the experimenter, or there was no disruption. When joint attention was established, the duration of joint attention episodes was also shorter when the disruption was from a mobile phone, than the face-to-face disruption. The face-to-face disruption was however related to shorter joint attention episodes than no disruption, suggesting that non-digital interruptions also disrupt joint attention. These findings provide support for mobile phones being a bigger disrupter to joint attention for mothers than a non-digital distraction.

While I have thus far focused on parent smartphone use disrupting joint attention, there is some evidence suggesting that smartphone technoference can aid the initiation of joint attention, depending on how the smartphone is used. Natural observations show that parent phone use can spontaneously lead to joint attention when the phone is used to take a picture, or to look at videos or photos (Ochoa et al., 2021; Radesky et al., 2014). In a case study in the home, Amery, Danby and Brereton (2026) found the mother was able to achieve mutual attention with her 3-

month-old if using the phone without needing to hold it, i.e. hands-free. Thus, tasks which do not involve constant interaction with the phone (such as typing) may aid joint attention.

A related concept, but specific for technology, is joint media engagement (JME), which involves individuals engaging in media experiences together (Takeuchi et al., 2011). As previously stated, the smartphone can become the object of attention during joint attention episodes (Ochoa et al., 2021; Radesky et al., 2014). Looking to research on JME may provide further insights on parent smartphone use and the potential for joint attention. Ewin, Reupert, McLean and Ewin's (2020) review found that mobile devices facilitate JME in a similar way as television does, creating a positive atmosphere. Furthermore, when comparing JME to non-digital shared activities (e.g., book reading, toy play), children tended to be more engaged in the activity during JME. However, findings are mixed with some research showing that parents observe their child whist using the device, sitting nearby and occasionally offering support, as opposed to sharing in the activity, leading to reduced interaction between parents and their children (Hiniker et al., 2018).

The relationship between joint attention and language development is therefore well established in the field, particularly when an adult follows the direction of the child's attention. Whether parent smartphone use is disruptive to joint attention is less clear, with emerging research reporting mixed findings overall. Converging evidence suggests that smartphone use has similar effects to non-digital disruptions on infants initiating joint attention (IJA) but is more disruptive than non-digital interruptions when considering parents' responses to their child's bids for attention (RJA). Smartphone use may, however, also have the potential to initiate joint attention via joint media engagement (JME). As a potential mediator in the

relationship between parent smartphone use and child language outcomes (Figure 1.1), this thesis tests whether smartphone use involving JME is less detrimental to child language than smartphone use which leads to technoference.

1.6 Parent Responsiveness

The previous section touched on parent responsiveness in considering infants IJA. If an infant IJA, e.g., by pointing, a joint attention episode can only occur if the adult *responds* to the bid for attention in a contingent way. If the infant points at an object to show interest and the parent responds but does so by trying to direct the infant's attention elsewhere, this is not contingent. However, if the infant points and the parent responds by looking at the object being pointed to, the parent has responded contingently and, with both members of the dyad now focused on the same object, joint attention may occur. Thus, whilst gaze following is a developmental precursor for the infant's ability to develop the skills necessary for joint attention, parent responsiveness helps by providing the conditions to allow for joint attention to occur once the infant is developmentally ready.

The concept of responsiveness derives from the initial conceptualisation of maternal sensitivity proposed by Ainsworth (1967). Ainsworth (1967) defined sensitive caregiving as correctly interpreting the infant's signals and responding promptly and appropriately to them. A sensitive parent is attuned to their infant's emotional state and responds to the infant, rather than to their own pace. A subset of general sensitivity, verbal responsiveness, refers to how a parent verbally responds to their infant's actions and vocalisations (Alvarenga et al., 2022). Verbal responsiveness involves three key features, that the response is prompt (occurring close to the infant's cue), contingent (dependent on the infant's action), and appropriate (fits with the infant's cue) (Bornstein et al., 2008; Tamis-LeMonda et al.,

2014). Responsiveness is multifaceted and parents may differ as to which cues they are more responsive to. For example, some may be responsive to their infant's vocalisations whereas others may be responsive to the infant's exploration (Bornstein et al., 2008).

1.6.1 Parent Responsiveness and Language

Parent responsiveness is integral to language development because language development cannot happen in isolation without input from, and interactions with, others. As already discussed, infants use cues to signal their interest such as gaze or pointing, and a parent responds to these signals with language and/or behavioural actions (Tamis-LeMonda et al., 2014). Tamis-LeMonda et al. (2014) identified three types of responsive behaviours that facilitate language development in infants: 1) contiguity and contingency, 2) didactics and embodiment, and 3) scaffolding. A description of each of these terms follows. Contiguous responses occur within a brief time frame after the initial cue from the infant and contingency refers to adults using words to label objects that an infant is attending to (Tamis-LeMonda et al., 2014). This fits with the research previously discussed on joint attention (Section 1.5.1) which has shown that language learning during episodes of joint attention is more successful when an adult responds to the infant's already focused attention than when directing attention (Dunham et al., 1993; Tomasello & Farrar, 1986; Tomasello & Todd, 1983). Didactic language is that which provides information, by labelling and describing, objects and events (Tamis-LeMonda et al., 2014). Research has found that mothers label objects that infants are attending to (West & Iverson, 2017), and that labelling which occurs in response to infant gestures (i.e. responsive labelling) predict infants' vocabularies (Olson et al., 2015). Embodiment occurs when parent's responses are multimodal and include

physical and verbal cues, which occurs in around 40% of parent responses (Tamis-LeMonda et al., 2014; van der Klis et al., 2023). Multimodal responses have been found to facilitate language development (Abu-Zhaya et al., 2017; Igualada et al., 2015), possibly due to 'motionese'[2] increasing infant attention (Koterba & Iverson, 2009). Increased attention allows the infant to map object labelling onto the correct object, enhancing language development (Masek et al., 2021). Scaffolding occurs when an expert (in this case parents) provides support to a novice learner (in this case children), adapting the support to the learner's performance (Wood et al., 1976). In the context of language development, this involves a parent adjusting their use of language to match their verbal input with the infant's current developmental level. For a 6-month-old who cannot yet speak, labelling objects with one word e.g., "Spoon" will be more beneficial than for an 18-month-old. Pitching the verbal input to the 18-month-olds development level may include extending the labelling e.g., "It is a pink spoon. We use the spoon to eat our cereal." Parents increase their expansions and questions as infants get older, suggesting they are adapting to the current language skills of the infant (Bornstein et al., 2008). Additionally, scaffolding has been found to facilitate language development through introducing new words, asking questions to extend vocabulary, increasing turn taking, and providing verbal feedback (Donnelly & Kidd, 2021; Wasik & Jacobi-Vessels, 2017). In sum, each of the key components of responsive behaviour, as identified by Tamis-LeMonda et al. (2014), influence language development.

Parent responsiveness as a predictor of language development is supported by a large body of evidence. For example, longitudinal research has shown that maternal sensitivity at 5 months uniquely predicts language outcomes in the child at

[2] Motionese refers to infant-directed actions that adults use when interacting with infants, including close proximity and simple movements which are repeated (Brand, et al., 2002).

4 years (Bornstein et al., 2020). Furthermore, Tamis-LeMonda et al. (2001) found that maternal responsiveness at both 9 months and 13 months predicted five key language milestones; first imitation of an adult word, first words, 50 words acquired, combining two or more words, and language used to talk about the past. Importantly, none of the infant's behaviours (such as vocalisations and looks towards the mother) predicted language outcomes above maternal responsiveness. Of note, *how* the mother responded also impacted language outcomes. At 9 months, mother's affirmations (e.g., "Good job") and descriptions of an object, event or activity were predictors of language outcomes, whereas at 13 months vocal imitations and expansions were important predictors. Thus, successful scaffolding is important for language development. Although, some features of parent scaffolding may be more important for language development than others, including verbal sensitivity, expansions on infant vocalisations, and verbal responses which are both semantically and temporally contingent (Baumwell et al., 1997; Levickis et al., 2014; McGillion et al., 2013).

Cultural differences must also be considered when seeking to understand the relationship between parent responsiveness and language development. The research discussed thus far has been conducted in Western populations and therefore the importance of parent responsiveness for child language may have been overstated. This can be seen in rural populations, including those which rely on farming, where there are fewer instances of infant directed vocalisations (Cristia, 2023). Which infant behaviours parents respond to and how also differ between cultures, American mothers' responses to their infant are more likely to include directing their infant's attention to environmental stimuli, whereas Japanese mothers were more likely to respond with affective responses (Bornstein et al., 1992). Despite

cultural variations in frequency of vocalisations and how parents respond to infant's vocalisations, there are some consistencies across cultures. For example, Bornstein et al. (1992) found across three cultures mothers responded to their infants most commonly with verbal exclamations, questions and non-imitative babbling. Furthermore, contingency to infant vocalisations is fairly consistent across a broad range of communities and by the time an infant is 5 months of age a turn taking pattern of vocal communication between parent and infant has developed (Bornstein et al., 2015). Together, these findings suggest that while the frequency and style of parent responsiveness vary across cultures, contingent responding to infant vocalisations and the subsequent development of vocal turn-taking maybe a more consistent feature of early dyadic interactions. Thus, contingency may be a more necessary feature of language development, whereas infant directed communication may enrich language development.

Parent-infant interactions are complex, as such characteristics of the infant and parent may moderate the relationship between parent responsiveness and language. Infant age is a potential moderator in this relationship. Paavola-Ruotsalainen et al. (2018) found that whilst responsive utterances and supportive behavioural directives at 10-months predicted language at 12 months, the same variables at 24 months did not predict language at 30 months. Similarly, Rantalainen et al. (2022) did not find a relationship between maternal verbal responsiveness at 24 months and infant expressive and receptive vocabulary at 24, 30, and 36 months. Child temperament may also influence the relationship between maternal responsiveness and language development. Nozadi et al. (2013) measured maternal sensitivity, toddler's expressive language, and child anger at 18- and 30-months-old. At 18-months maternal sensitivity and children's anger expressions positively

predicted expressive language. When the toddlers were 30 months old, expressive language was related to maternal sensitivity but for boys only, this relationship was mediated by the child's anger expressions. Maternal mental health can also impact the relationship between maternal responsiveness and language. Brookman et al. (2023) found infants' vocabulary at 18-months was related to maternal responsiveness at 9 and 12 months and maternal depression moderated this relationship. Maternal responsiveness from mothers who had mid-to-low depression scores, was positively related to infants' vocabulary scores. This relationship was not present in mothers who had high depression scores, regardless of their level of maternal responsiveness. This thesis does not include these potential moderators within the analysis, primarily due to seeking to first explore whether there is a relationship between technoference, parent responsiveness and language. However, when interpreting the findings in this thesis, it is important to keep these complexities in mind as tentative evidence suggests a relationship between maternal mental health and smartphone technoference (Golds et al., 2025). Crucially, as parent responsiveness does contribute to language development, any disruptions to the ability of the parent to respond promptly, contingently, and appropriately may have knock on effects on infants' language development (Bornstein et al., 2008).

1.6.2 Technoference and Parent Responsiveness

If parents are distracted by their mobile phones when caring for and interacting with their young children, this can affect levels of responsiveness and the sensitivity of the response (Mangan et al., 2018). Specifically, Mangan et al. (2018) found that when using a mobile phone, parents were more likely to ignore their child's bids for attention. This effect appears to begin early on in children's lives, with Nakagawa et al. (2019) finding that smartphone use reduced maternal

responsiveness to notice their baby had stopped feeding during breastfeeding in comparison to non-phone using mothers. However, the findings from Mangan et al. (2018) and Nakagawa et al. (2019) need to be treated with caution due to lack of robust statistical analysis. Neither study report on any statistical analysis other than descriptive statistics, making it difficult to draw firm conclusions. Indeed, research using more rigorous analysis found that mothers using a smartphone compared to no phone during breastfeeding, did not have a significant effect on the quality of mother-infant interactions (Inoue et al., 2021). Nevertheless, and in line with previous findings, the study did find that prolonged smartphone use during breastfeeding reduced mother's responsiveness to their infant's bids for attention. Reduced parent responsiveness when using a smartphone have been reported across contexts including playgrounds, eateries, health centres and the laboratory (Abels et al., 2018; Elias et al., 2020; Mikić et al., 2025; Rothstein, 2018). In natural settings, observations show that parents are less responsive to their child's emotional needs, less likely to respond to the child's bid for attention, less likely to respond quickly to the attention bid and less likely to respond by showing anything other than mere awareness compared to when not using their phone (Abels et al., 2018; Elias et al., 2020). However, observational studies do not allow us to make conclusions on whether parent smartphone technoference is having a causal effect on parent responsiveness. Research conducted in experimental settings is therefore necessary to disentangle this relationship. In one experimental setting Mikić et al. (2025) found mothers responded less frequently to their infants' signals and were slower to respond when interrupted by text messages on a smartphone in comparison to no interruption. An experiment from Rothstein (2018) found that when parents had their phones turned on, they were less affectionate (measured as warmth, physical

closeness, and positive expressions towards the child) than when the phone was turned off. This was also the case for responsiveness (measured as flexibility towards the child's activity, physical response, and attentiveness) and encouragement (measured as supporting exploration, self-help skills, inquisitiveness, creativity, and play), suggesting that having a phone turned on creates technoference. It is unclear from these findings whether when the phone was turned on, it was also in sight. It is possible that the mere visual presence of the phone might have driven the effect, especially if the turned off phones were out of visual awareness. This is an important consideration as Misra et al. (2016) found just having a mobile phone on the table, or holding it, but not using it, lead to lower quality adult conversations than when a phone was not present. Possibly, the mere visual presence of a phone can have a similar impact on parent-child interactions.

Knowing that parent phone use can disrupt the parent-child interaction only tells us what is happening; however, this doesn't inform us about the "why" or "how". To address these questions, Abels et al. (2018) identified some of the interacting variables in the parent-child relationship including the number and use of multiple interaction modalities (such as gaze, motor behaviour e.g. waving, auditory, touch or taking an object) used by the child to bid for attention. They found that using multiple modalities for attention bidding led to a stronger response from parents regardless of whether the parent was using a phone. However, the number of bids for attention made by a child interacted with phone use, i.e. the more bids made, led to a quicker response in phone users, but parents who did not use their phone responded promptly regardless of the number of bids made. The duration of time a parent spends on their phone, but not the frequency of phone use, has been found to be negatively associated with maternal responsiveness (Wolfers et al., 2020). This

naturalistic observation also found that mothers were less responsive regardless of how they used the phone, suggesting the act of looking at the phone as opposed to the demands of the task is what reduced responsiveness. This gives further detail on how parent phone use may impact the interaction, although as Wolfers et al. (2020) point out, it is possible that in this particular observation interruptions did not occur very often as children were occupied at the park. Taken together, the research suggests that how long, and through which modalities a child bids for attention affect how a parent responds to the child when on the phone. This gives further insight into "how" phone use may be disrupting the parent-child interaction, but "why" this is happening is still an area that requires exploration. Whilst findings from Garg (2021) identified that context, parents' beliefs around responsiveness, as well as their working practice and day care availability influenced decisions around phone use with a young child, this area needs further exploration. One study explored the reasons behind maternal media use (which primarily involved smartphone use) when feeding infants under the age of 12 months and found that the three most common reasons were to research information on their infant, to be more productive with their time, and to connect with other adults (Coyne et al., 2022). Conceivably, the rationale behind phone use could interact with the parent's ability to be responsive.

Parent responsiveness also extends to recognising when the child may be in a situation that puts their safety at risk (Elias et al., 2020). A few recent studies reported that parents using their phones when with their child in public places are less likely to notice safety risks to their child and more likely to have periods of no/inadequate supervision in parks (Bury et al., 2020; Elias et al., 2020), at swimming pools (Wickens et al., 2020), and at the beach (Moran, 2010). This research suggests that disruption to the parent-child interaction due to phone use

can have potentially serious consequences when in public places. However, little is known about whether that is the case in the home, where both the child and adult are likely to feel at ease. If parents use their phones in public places where there is the potential to put their child's safety at risk, it may be that in a more familiar environment phone use is even more common. There is a need to research parent phone use in the comfort of the home to explore whether phone use during parent-child interaction is common and whether sensitive parenting can take place simultaneously.

However, not all research supports that smartphone use negatively impacts parent responsiveness. In an ethnographic observation, Amery, Danby and Bereton (2026) found a mother was able to simultaneously use her smartphone whilst continuing to provide contingent and reciprocal responses to her child. Furthermore, parent smartphone use may have positive effects on the parent, such as providing social support or relieving stress (Wolfers, 2021), which in turn allows the parent to be more present in subsequent interactions, which can result in increased engagement (Linder et al., 2022). Relatedly, Fusha et al. (2025) found that higher levels of parental warmth were associated with increased phone checking and audible notifications. Together, these findings suggest that the relationship between parent smartphone use and responsiveness is not necessarily negative and may depend on how phone use serves the parent's needs.

This raises a further question as to whether the phone is unique in its ability to disrupt responsiveness, or whether other forms of distraction would produce similar effects. A small number of studies have begun to conduct experimental work that compares smartphone use to a non-digital distraction to see the effects on parent responsiveness. One study found no difference in maternal verbal responsiveness

when mothers used a smartphone during an interaction with their child compared to when they read magazines, and in both cases mothers were less responsive than when there was no interruption (Lederer et al., 2022). This effect was greater when the analysis was limited to only the time periods when the mother was using the smartphone/magazine for 3 seconds or more, and therefore more absorbed in the smartphone/magazine. Chamam et al. (2024) report similar findings, both smartphone technoference and a pen and paper task reduced parent responsiveness in comparison to no interruption. These findings suggest that a smartphone is not unique in its ability to disrupt a dyadic interaction, and a non-digital disruption can also affect parent responsiveness, especially if the parent becomes absorbed in the distraction.

To summarise, parent responsiveness is multimodal and supports language development via several mechanisms including scaffolding. However, the mechanisms involved in this relationship are complex and moderated by factors such as child gender, child age, and maternal mental health. Research to date largely supports that parent smartphone technoference negatively affects parent responsiveness, although the impact is similar to non-digital disruptions. However, less is known on whether the way in which a parent uses their phone effects this relationship. As a potential mediator in the relationship between parent smartphone use and child language outcomes (Figure 1.1), this thesis tests whether how the phone is used affects parent responsiveness and whether smartphone use which has the potential to reduce parent responsiveness (such as making a phone call) is disruptive to word learning.

1.7 Technoference and Language

As discussed in Sections 1.4, 1.5, and 1.6, features of parent-child interactions which aid language development (social gaze, joint attention, parent responsiveness) have the potential to be disrupted by parent smartphone technoference. This, in turn, could subsequently affect language development. Alternatively, as proposed in Figure 1.1, smartphone technoference could have a direct effect on language outcomes. In this section, I review the literature which has directly measured the relationship between parent smartphone technoference and language, focusing on communication within the interaction and children's ability to learn new words.

Parent smartphone technoference has the potential to negatively affect the quality of communication between the parent and child by disrupting the interaction. Longitudinal evidence of maternal media use (including smartphones) found mothers who used media the least created higher quality language environments with their child, than mothers who used media more frequently. This included using more words, and engaging in more conversational turns (Holmgren et al., 2025). Research focusing specifically on maternal smartphone use within the home, shows that maternal smartphone use is associated with a reduction in the number of words directed to the infant in comparison to non-phone use (Mikhelson et al., 2024). The content of language is also affected by parent smartphone use. Kelly and Ocular (2021) observed families with children between 3, and 8 years of age visiting an aquarium and reported more off topic conversation in those families where smartphones were used. In addition, where parents used a smartphone, contingency in conversation with their child was lower than families who were not using smartphones. Although, other studies have found no difference in conversational turn

taking or maternal utterances when mothers used a smartphone or a magazine during an interaction with their child (Ewin, Reupert, McLean, et al., 2021; Lederer et al., 2022) showing that smartphones may not be unique in disrupting quality of communication. Yet, there may be different effects depending on the type of non-digital distraction. For example, Gaudreau et al. (2021) found that parents asked fewer questions seeking information when completing a survey on their phone, than when completing a survey with pen and paper. Type of phone use is likely to be important when considering the impact of technoference on language, as Ochoa et al. (2021) found that children were less likely to talk when the caregiver was looking at the screen or making a phone call, compared to when they were texting or swiping. Caregivers, however, were more likely to talk when looking at screens than when texting or swiping, suggesting that how the phone is used affects the caregiver and child differently. In sum, technoference does affect communication within parent-child interactions, but this may depend on the how the phone is being used.

As well as disrupting the communicative exchanges in a dyadic interaction, experimental work has tested whether technoference can disrupt children's language development. Using parent self-report, Paoletti et al. (2025) found a negative association between frequency of maternal media use (smartphone or tablet) during routines (e.g., during meals) and their 8-month-olds language comprehension. Similarly, Sundqvist et al. (2021) found using digital media (including smartphones) during child routines with 2-year-olds was negatively associated with child language outcomes. As discussed in Section 1.5.1, the predictability of a routine facilitates children's ability to associate an adult's language to their focus of attention (Bruner, 1983), which can explain these findings. Focusing specifically on smartphone technoference, evidence suggests that technoference is associated with short-term,

but not longer-term language outcomes in children (Coyne et al., 2026). Consistent with this, Reed et al. (2017), found that 2-year-olds were more likely to learn a novel word following an uninterrupted teaching period than one interrupted by a phone call. However, these results need to be treated with caution. Firstly, parents had been specifically told to teach their child two distinct words. In everyday interactions language development is not so formalised and occurs in the home through play, maternal responsiveness, and involvement with the child (Elardo et al., 1977). It is possible that technoference interacts differently with language development in a more natural home environment. Secondly, the words being taught are novel and not ones that the parent would be using during the phone call. Whilst this allows for control, one caveat is that children can learn language through overhearing others' using language, without any direct instruction (Akhtar et al., 2001). Therefore, it's possible that if the parents in the research conducted by Reed et al. (2017) had used the novel word in their conversation, this may have led to better word learning. However, learning via overhearing may only occur if joint attention between the dyad in conversation is also present (Fitch, 2020), which is not possible when the second person in the conversation is not visible; as is the case during a phone call. Thirdly, Reed et al. (2017) manipulated technoference with a phone call, which may not truly represent the technoference from a phone in everyday life. In fact, observational studies show that parents use finger swiping and touch tasks more than phone calls (Bury et al., 2020; Mangan et al., 2018). These tasks are more likely to divert eye gaze away from the child. Therefore, it is possible that the impact on language development and learning words is more pronounced than Reed et al. (2017) found, as technoference which disrupts eye gaze, as opposed to phone calls, may have a different effect on learning words. Alternatively, as many of the other uses of mobile

phones do not interfere directly with verbal interaction, i.e. people can talk and swipe, it may be that other forms of technoference do not have such an impact on language development. This is supported by a partial replication of Reed et al. (2017) where the phone interruption was implemented via a text message (Nguyen, 2024). In this study, Nguyen (2024) found that 17-19-month-olds were able to learn novel words equally well when teaching was not interrupted vs. interruption to teaching from a text message. An interesting finding from Corkin et al. (2021) is that the effect of technoference on the development of infant vocabulary can occur without direct engagement with the smartphone. Increased audible notifications from the device were found to be associated with lower levels of infant vocabulary development in 20-month-olds, an effect that was mediated by parent directiveness during play. Increased audible notifications have been found to be related to increased inattention in comparison to when notifications were turned off (Kushlev et al., 2016). In the context of the findings from Corkin et al. (2021), possibly the audible notifications increased demands on parent's attention, leaving fewer attentional resources to allocate to their child, resulting in increased directiveness. In addition, an association was found between increased infant vocabulary and parents who made a conscious effort to put their phone away. Thus, technoference appears to be affecting language development via more complex means than overtly interfering with the parent-child interaction.

It should not be overlooked that it is possible that parent phone use could have positive effects on language development. Other screen interaction has been found to facilitate language, but only when parents were co-viewing with their children (Al-Harbi, 2015). Specifically, parent-child conversational turn taking and parents' use of mental state talk has been found to mediate the relationship between

the amount of video content a child watches and their language outcomes (Sundqvist et al., 2022). Applying these findings to mobile phone use, if a parent is engaging with their phone during a parent-child interaction, the effects may be dependent on the parents' talk and if the phone use is contingent to the situation. This is especially pertinent due to the previously mentioned findings that children are more engaged in interactions involving media (Ewin et al., 2020). The higher levels of engagement when technology is involved may explain why children have been found to be able to learn language from both video chats and live video interactions, if the interactions were socially contingent (Roseberry et al., 2014). Contingent conversations, as already mentioned, occur less when using smartphones (Kelly & Ocular, 2021) suggesting that parent responsiveness is important. If the parent is engaging with their phone and can give immediate and accurate responses to children's verbal bids, language may not be hindered. A recent case study in the home environment demonstrates that a mother was able to establish shared attention and be responsive during smartphone use (Amery, Danby, & Brereton, 2026). Further research in the home with larger samples is necessary to understand whether parents can maintain this contingency in familiar everyday interactions.

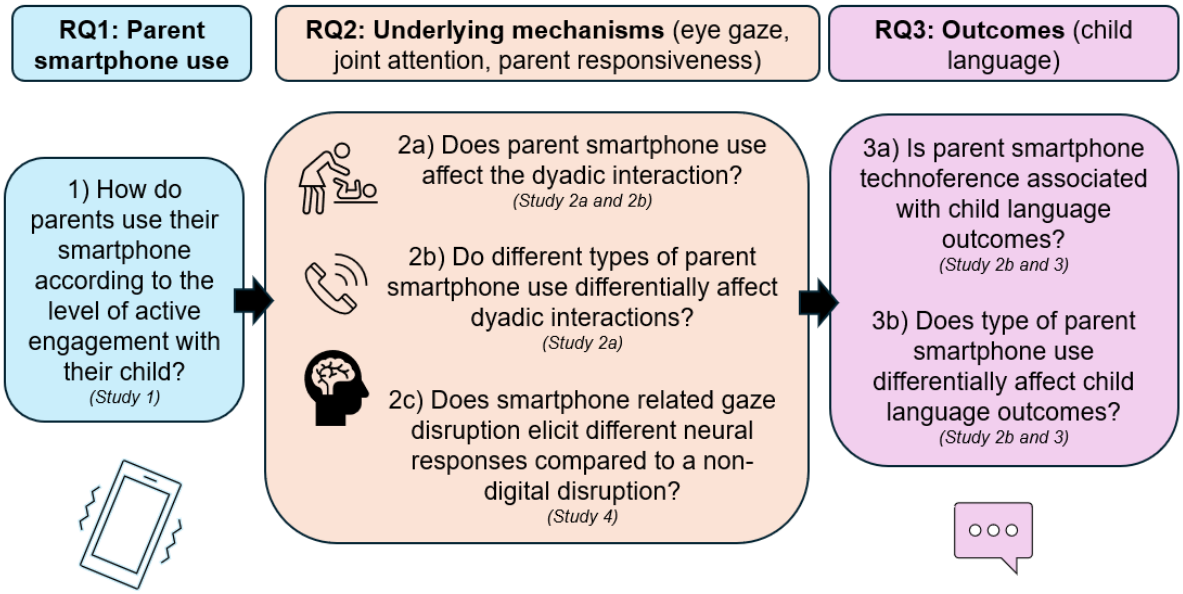
1.8 Summary and Research Questions

To conclude, this chapter has presented evidence that parent smartphone technoference can affect parent-child interactions, including disrupting social gaze and joint attention, and reducing parent responsiveness. As precursors to language development, this may explain the emerging research which has found parent smartphone technoference can affect child language development. Two key caveats were addressed in relation to my suggestion that the relationship between parent smartphone technoference and language outcomes may be mediated by social

gaze, joint attention, and parent responsiveness. 1) How the smartphone is used may have different effects on the interaction. 2) Smartphones may not be unique in their ability to disrupt parent-infant interactions, non-digital disruptions can be similarly disruptive. Based on this, in the thesis I seek to address the research questions outlined in Figure 1.2.

Figure 1.2

Research Questions Addressed in This Thesis



Next, in Chapter 2, I review the key methods that will be used in this thesis to address these research questions.

Chapter 2 Methods and measures

2.1 Introduction

This thesis is focused on the relationship between parent smartphone technoference and language outcomes in young children. At the beginning of this research project, in 2020, there was a limited amount of research exploring parent smartphone technoference and child language outcomes. Subsequently, several of the studies were exploratory and designed to help to shape the next steps in the research. The first study (Study 1) described in Chapter 3 of this thesis aimed to build a picture of parent smartphone technoference and as such, it employed a non-experimental approach, gathering data via parent self-report as opposed to directly studying young children. Study 2a (Chapter 4) was informed by the findings from Study 1 and implemented an experimental method, measuring parent-infant interaction via a natural observation. This allowed for testing for a causal relationship between the effect of parent smartphone technoference on features of the parent-infant interaction which support language development. Study 2b (Chapter 4) built on Study 2a by testing for a relationship between parent smartphone technoference, responsiveness, and joint media engagement (JME) as precursors to language development and child language outcomes. To compliment the experimental design used in Study 2a, Study 2b measured this relationship as self-reported by parents, using a non-experimental method. Study 3 (Chapter 5) further explored the findings from Study 2a, using an experiment to directly measure language outcomes in children using a looking paradigm. Finally, Study 4 also conducted an experiment to measure the effect of smartphone technoference on neural activation in adults and

infants. This range of measures was necessary to address the specific research question(s) in each chapter, and to match the developmental level of the children in the sample.

This chapter outlines each of the measures used within this thesis, describing their key features, the aspects of language development they measure, and the strengths and limitations associated with their use. Table 2.1 provides an overview of the measures used for each study within the thesis.

Table 2.1

Summary of Methods and Measures Used Within the Thesis

Study	**Method**	**Outcome/s and measures used**
1	Non-experimental	Parent smartphone technoference - **Self-report**: questionnaire, designed for this thesis
2a	Experimental	Parents' use of language - **Observation**: Coding based on Chang et al. (2016) Parent responsiveness - **Observation**: Coding based on Tamis-LeMonda et al. (2001) Infant vocalisations - **Observation**: Coding based on Chang et al. (2016) Gaze (infant and parent) - **Observation**: Coding developed for this thesis Infant spontaneous expression - **Observation**: Coding based on Nicely et al. (1999)
2b	Non-experimental	Parent smartphone technoference – **Self-report:** Distraction In Social Relations and Use of Parent Technology (DISRUPT)

		(McDaniel, 2021) Parent responsiveness - **Self-report:** Parent Responsiveness Scale (PRS) (Anikiej-Wiczenbach & Kaźmierczak, 2021) Child language outcomes - **Self-report:** UK Communicative Development Inventory (UK-CDI) (Alcock et al., 2020)
3	Experimental	Novel word learning – **Observation:** The intermodal preferential looking paradigm (IPLP)
4	Experimental	Brain activation – **Neuroimaging:** Functional near-infrared spectroscopy (fNIRS)

2.2 Experimental Methods

2.2.1 Rationale

The purpose of this thesis is to contribute to the literature on the relationship between parent smartphone technoference and language outcomes in young children. Crucial to this is testing which aspects of parent smartphone technoference may have a direct effect on language development, when other potentially important variables are controlled for. An experimental approach allows cause and effect to be established through the manipulation of key features of parent smartphone technoference, such as the way in which the phone is used. Importantly, an experiment allows for control over confounding variables, e.g., length of time on the phone, that may affect parent-infant interactions regardless of how the phone is used. By controlling many of these variables, it increases confidence in the conclusions drawn, as to whether parent smartphone technoference affects the

precursors to language development and language outcomes. In this thesis the experimental method was implemented to test whether type of parent smartphone use has different effects on precursors to language development within the parent-child interaction (Study 2a), whether type of parent smartphone technoference affects child's learning of new vocabulary (Study 3), and whether the type of object which disrupts adult direct gaze affects child's neural activation in the prefrontal cortex and across the temporal and parietal cortex (Study 4). To successfully test each of these outcomes, different measures were used across the three experimental studies. I describe each measure used in more detail below.

2.2.2 Measures: Observation

Studying young infants is challenging because you cannot ask infants to follow a set of instructions, due to limited receptive language. Observations are suitable as they can be implemented without needing to direct the infant. Instead, the researcher observes how the infant behaves or responds during the observation, providing objective data concerned with responses that are external and can be seen. When studying infants, observations typically involve observing an interaction between the parent and child, either in a natural or controlled environment. Naturalistic observations take place in environments that are familiar to the infant, i.e., the home, whereas controlled observations occur in an environment that is setup specifically for that study, i.e., in the laboratory. For young children, an observation in the home environment has the benefit of the child feeling comfortable and relaxed. Conducting an observation in an environment that is unfamiliar to the infant can be stressful and distracting, as the infant processes the new sensory information. This in turn can impact interaction with the parent, as the parent responds to their child's behaviour. However, the home environment does not have the technological setup

that a laboratory has, which can make it a challenge to present stimuli and to video record the observation from different angles. This is important when observing parent-infant interactions which can be fast paced and contain complex and nuanced interactions. Recording the observation allows for frame-by-frame analysis and for interrater reliability to be assessed. Observations can also be participant, whereby the researcher is involved in the observation, or non-participant, where the researcher observes from a distance. If seeking to gather data on the parent-infant interaction, as in this thesis, non-participant observation is more appropriate as it reduces the likelihood of the researcher's presence shaping the interaction. Although, if the infant is aware of the researcher's presence, as in an overt observation, this may affect how they behave. It is for that reason, that in this thesis the researcher is covert, and not visible to the infant during the observations. However, the parent is aware they are being observed which can affect their behaviour, for example leading them to be more conscious of how they interact and less natural in their interactions with their infant (Perez et al., 2018).

Study 2a used an observation to collect the data for the dependent variables within an experimental setup. As discussed in Chapter 1, technoference can disrupt the natural flow of a parent-infant interaction and potentially affect aspects of the interaction which facilitate language development (Morris et al., 2022). Study 2a tested whether parent smartphone technoference, and type of smartphone use, affected behaviour related to language acquisition during the interaction (Bornstein et al., 2020; Çetinçelik et al., 2021; Donnellan et al., 2020; Huttenlocher et al., 1991; Newman et al., 2016; Wu & Gros-Louis, 2017). Central to Study 2a was the observable behaviour exhibited by each of the dyad during the interaction, including gaze direction, infant vocalisations, parent use of language, and parent

responsiveness, which is why an observation was implemented to measure these outcomes.

Data collection for Study 2a began in 2020 and as such, the Covid-19 pandemic prevented in-person testing, either in the laboratory or the home environment. The experimental observation was therefore hosted on the Children Helping Science website (https://childrenhelpingscience.com/). Parents select a study to participate in via the website and position their webcam to enable the interaction with their child to be recorded. Approaching the observation in this way overcame some of the earlier issues discussed. Firstly, the researcher does not need to be present which means neither the infant nor parent are affected by the presence of a stranger. Secondly, the infant is in their own home, addressing the issue of infants being uncomfortable in a new environment. Third, the webcam means the video can be coded offline, allowing reliability of coding to be assessed. However, conducting the observation via the internet had several limitations. First, having only one camera angle is not optimum as the dyad can move out of the camera shot. Second, is the potential for distractions, e.g., siblings and other family members in the home environment. As these distractions are not consistent across the experimental manipulations, they add noise to the data. Third, without the presence of the researcher, parents cannot ask clarification questions and may not fully adhere to study instructions (Scott & Schulz, 2017).

To allow for statistical testing, a coding scheme is typically applied to the observations to obtain quantitative data. A coding scheme is a clear set of instructions that define which behaviours are to be recorded and the way they are recorded (Chorney et al., 2015). For example, in Chapter 4 (Study 2a) a coding scheme is applied to measure parent use of language and infant vocalisations. This

coding scheme was adapted from Chang et al. (2016) which provides clear guidance on what constitutes parent language use and should therefore be recorded. For instance, non-linguistic vocalisations such as gasps are excluded and a new utterance is recorded after more than 200ms of silence. A coding scheme also provides detail on how the behaviour can be quantified, this can include recording the length of time the behaviour occurred, the frequency of the behaviour (Baumwell et al., 1997), or rating the behaviour on a scale (Sylvestre et al., 2021). Once the behaviour has been recorded, it is necessary to assess interrater reliability to ensure that the coding criteria is applied objectively and consistently. This is important when conducting observations, as application of the coding scheme is susceptible to measurement error due to potential subjectivity in applying the codes. One way to assess interrater reliability is to use an intraclass correlation coefficient (ICC). As described by Koo and Li (2016) there are different models of ICC and different types of ICC. A one-way random-effects model is used when each participant is rated by a different set of observers, and these observers are selected randomly to assess interrater reliability. A two-way random-effects model should be applied when a set of observers are randomly selected, and each participant is measured by the same set of observers. This model allows reliability to be generalised to any rater possessing similar characteristics to the observers used in the analysis. The most appropriate model for the data collected in this thesis was a two-way mixed-effects model. In this model the observers are considered fixed, and the results only represent the reliability of the specific observers tested. Of consideration is whether the data being analysed is a single or average measurement. A single measurement applies when only one rater is of interest, whereas an average measurement estimates reliability of the mean of *k* raters and was therefore more appropriate in this thesis where

several observers coded the observational data. Finally, for a two-way model, the ICC can either assess absolute agreement, which assesses whether different observers assign the same score to each participant, or consistency, i.e. if the ratings are correlated. Absolute agreement was applied in this thesis as this is a more stringent measure of agreement.

2.2.3 Measures: Intermodal Preferential Looking Paradigm (IPLP)

Study 3 implemented the IPLP to measure whether 24-30-month-olds could learn novel verbs when teaching was interrupted by parent smartphone technoference. As Study 3 was a partial replication of Reed et al. (2017), the IPLP was used to stay true to the replication. The IPLP is a measure of language comprehension and is therefore suitable for young children who are still developing expressive language. As comprehension develops ahead of production (Goldin-Meadow et al., 1976), the IPLP allows researchers to study language acquisition which may be missed with other methods. The IPLP involves the child sitting on their parent's lap, in front of a split screen. Each side of the screen presents two video clips concurrently. Crucially, these two clips differ. The parent keeps their eyes closed, to not influence the process, and the child hears audio over a speaker asking them to look to a verb or noun that is depicted in one of the videos. Children are shown several trials and between each trial is an attention grabber. In the first use of the IPLP, Golinkoff et al. (1987) tested 16-month-olds understanding of common nouns e.g., cookie, shoe. This involved two images presented simultaneously, such as a sock and a cookie, with audio that asks "Where's the cookie? Find the cookie". A similar setup occurred for verbs, except that the stimuli was dynamic to illustrate the action e.g., drinking from a coffee cup.

If the child comprehends the word, they should quickly look to the correct scene if initially their gaze is directed to the incorrect scene. The child is also expected to spend a larger proportion of the trial looking to the matching scene compared to the non-matching scene. To measure whether children understand the word, a camera records where the child is looking throughout each trial. Coding is then completed offline to record looking behaviour. For example, Golinkoff et al. (1987) measured latency to look at the matching scene, e.g., to look to the cookie rather than the sock, and total fixation time on both images.

In addition to measuring language that a child already knows, the IPLP has also been applied to test children's novel word learning, as in the present thesis. In this context, children are taught a novel word and the IPLP is applied in the testing phase. This phase often also incorporates a trial which applies the concept of mutual exclusivity - mapping novel labels to novel objects/actions (Markman & Wachtel, 1988). If a child is presented with two objects, one of which is familiar and the other unfamiliar, alongside a novel label e.g. 'modi', the child will associate the novel label with the unfamiliar object. Within the IPLP, this involves presenting the newly learnt object/action alongside a novel object/action and a novel label. In this trial, the child should be quicker to look and look longer at the non-matching scene. Children as young as 16 months have been found to successfully use mutual exclusivity to map novel words to novel objects when presented alongside familiar objects (Mather & Plunkett, 2011). Older children, aged 24-30 months, can successfully use mutual exclusivity to identify novel verbs when presented alongside recently learnt verbs (Roseberry et al., 2014).

The IPLP has several benefits over other measures of language comprehension. Firstly, the child does not have to produce an overt behavioural

response such as pointing, rendering it suitable for use with younger children who may not have developed pointing, or may not gesture when asked, even if they do comprehend the language (Golinkoff et al., 1987). As Study 3 measured verb learning, the IPLP, with its dynamic videos, was more suitable than still images, which may not clearly depict an action (Golinkoff et al., 1987), to measure verb comprehension. Secondly, the IPLP has been validated alongside other measures of child language comprehension (Houston-Price et al., 2007). The IPLP has also been found to measure comprehension in children as young as 13 months, when other methods, such as the child reaching, did not (Gurteen et al., 2011) - suggesting this to be a suitable measure of language comprehension. However, there are several limitations with measuring language using the child's looking behaviour. Firstly, inferences are being made as to why the child is looking to a particular scene over another. Whilst one explanation may be that the label is being matched to the scene, this is an assumption and there may be other reasons for the looking behaviour. Secondly, to measure looking behaviour, the child needs to maintain attention on the stimuli presented. The attention span of young children is short, and they can lose interest in the stimuli. In this instance, a child may not look at, or look longer at, one scene over the other, but this is not to say that the child does not comprehend the word being assessed. Finally, the IPLP is usually applied directly after novel word learning and whilst children may show a preference for the matching scene to the novel word, this does not demonstrate true comprehension of the word but maybe instead the ability to remember the word-action/object mapping over a short period of time. The discussion section of Chapter 5 addresses further specific limitations in the context of Study 3.

2.2.4 Measures: fNIRS

Functional near-infrared spectroscopy (fNIRS) is a non-invasive brain imaging technique. This is a useful technique when studying infants, as the technique does not require an overt response from the participant e.g., looking, pointing, which as previously mentioned can be problematic for data collection. This was particularly pronounced in Study 4 as the age of the infants studied (6.5-7.5 months) rendered instruction-based measures unsuitable. fNIRS measures changes in blood oxygenation using NIR light which can pass through layers of skin and bone. Activated neurons generate increased cerebral blood flow (CBF) resulting in increased blood oxygenation in the brain where the neural activity is occurring (Buxton, 2010). This hemodynamic response leads to increased oxyhaemoglobin (HbO_2) and decreased deoxyhaemoglobin (HHb) (Dick et al., 2013); this response is the canonical haemodynamic response function (HRF) (Lloyd-Fox et al., 2010).

To measure HbO_2 and HHb, NIR light is transmitted via sources which are attached to a cap placed on the participant's head. Detectors are placed adjacent to the sources which pick up the amount of receiving transmitting light. Each source-detector pair is referred to as a channel. Multi-channel optical topography systems, which provide a two-dimensional measure from the surface of the cortex (Gervain et al., 2011), are commonly used with infants. The positioning of the sources and detectors is decided by the researcher, depending on which area/s of the brain have been identified in previous literature as being related to the behaviour/cognitive process of interest. The number of channels measured during a study is dependent on the area/s of interest and the fNIRS system that is used.

The distribution of the light through the channel is banana shaped, and longer than the distance between the source and detector (Quaresima & Ferrari, 2019). The

distance between the sources and detectors affects the depth that the NIR light can reach. Two-3cm source-detector distance is considered acceptable for infants who have thinner skin and CSF, and 4-5cm for adults (Quaresima & Ferrari, 2019).

The NIR light both scatters and is absorbed when travelling through biological tissue (skull and brain) which affects the amount of light detected (Quaresima & Ferrari, 2019). The absorption of NIR light allows for differentiation between HbO_2 and HHb, because each absorbs light differently (Pinti et al., 2020). Wavelengths above 900nm are absorbed by water (Quaresima & Ferrari, 2019) and below 650nm the wavelengths are unable to penetrate tissue as all of the light is absorbed (Barstow, 2019). Most fNIRS systems measure NIR wavelengths in the range of 685-850nm, allowing the NIR bandwidth to capitalise on the difference in absorption between HbO_2 and HHb (Quaresima & Ferrari, 2019). As scattering is deemed to be fairly constant, the changes in attenuation allow for a measure of change in HbO_2 and HHb (Lloyd-Fox et al., 2010). This provides a measure of total haemoglobin, HbO_2 plus HHb, in the tissue between the source and the detector. Most studies with infants use continuous wave (CW) systems which involves emitting light with a constant light intensity and measuring the diffusely reflected (i.e. receiving) light intensity without accounting for the scattering and absorption of the light (Scholkmann et al., 2014).

fNIRS studies tend to follow a block design or an event-related design. In a block design, the stimulus is presented for 3-30 seconds, followed by a baseline condition which is longer than the experimental condition. This is necessary to allow the haemodynamic response to return to a baseline level after exposure to the experimental stimulus. The baseline condition ideally includes minimal stimulation and should not include characteristics which may activate the same areas of the

brain as the experimental stimuli (Lloyd-Fox et al., 2010). For example, if the experimental stimuli are social stimuli, the baseline stimuli should not have any social elements to it such as facial features. A benefit of the block design is that it allows for the haemodynamic signal to return to baseline before the onset of the next stimulus (Schaeffer et al., 2014). To reduce the likelihood that participants will have an anticipatory response to the onset of stimulus due to fixed timings, Lloyd-Fox et al. (2010) advise varying the length of the baseline condition to reduce predictability. A block design also has a robust signal to noise ratio (Schaeffer et al., 2014) which is crucial when using fNIRS, as the recorded signal can be influenced by other physiological processes such as blood pressure and Mayer waves, resulting in false positives (Tachtsidis & Scholkmann, 2016). An event-related design allows for measuring neural activity in response to a specific stimulus, rather than a specific time point; as in a block design (Schaeffer et al., 2014). In an event-related design, the event of interest can be presented at any time, and the inter-stimuli interval can vary. Typically, in an event related design the stimulus is presented for a short period of time (as short as 3s) and presentation is random. Most infant studies implement a block design. One reason for this is that the haemodynamic response may be slower in infants (Arichi et al., 2012), rendering block designs with longer baselines more appropriate than faster paced event-related designs.

Data collected when using fNIRS is pre-processed prior to statistical analysis. This is important to account for motion artefacts and noise, which are common when using fNIRS with infants whose attention is short and who cannot follow instructions to remain still (Gemignani & Gervain, 2021). While preprocessing practices vary (see Gemignani and Gervain (2021) for a comparison of pipelines), typical steps first involve visual inspection of the raw intensity data to assess the quality of the signal.

This is followed by addressing noise in the data occurring from motion artifacts and physiological processes (Pinti et al., 2019). Motion artifacts can either be corrected for, or the trials contaminated by the artifacts can be removed (Di Lorenzo et al., 2019). Due to the difficulty in obtaining an adequate number of trials in infants, correction is preferred to removal (Di Lorenzo et al., 2019). Homer3 is a MATLAB toolbox which can be used to preprocess fNIRS data and has a range of motion correction methods. In infant data, combing motion correction techniques has been shown to be more effective than applying individual techniques (Di Lorenzo et al., 2019). To remove physiological noise, specific frequency bands are filtered which remove low and high frequency components, the exact frequency varies across studies but typically in infant studies a bandpass filter between 0.01Hz to 0.7Hz (Gemignani & Gervain, 2021) or 0.8Hz (Filippetti et al., 2023) is applied. Last, the raw data is converted into optical density data and then into concentration changes of HbO_2 and HHb by applying the modified Beer-Lambert Law (Delpy et al., 1988).

To prepare the data for statistical analysis, the pre-processed data must be processed. Commonly used approaches are block (or baseline-corrected) averaging and the General Linear Model (GLM) (Yücel et al., 2025). Block averaging involves identifying a baseline measure of neural activity, typically the period prior to stimulus onset and subtracting this from the neural activity during stimulus presentation. These values are then averaged across trials for channels and conditions. The GLM uses one or more regressors to predict an outcome, computing beta weights. The model includes the measured fNIRS signal, a model of how the signal should look, i.e. the expected HRF, the beta weights which show how strongly each component contributes and residuals which account for discrepancies between the model and the data (von Lühmann et al., 2020). The GLM is more powerful than baseline-

corrected averaging as it considers the entire time series and allows for the addition of covariates, such as physiological signals, into the model (Pinti et al., 2019; Tachtsidis & Scholkmann, 2016). However, the GLM is based on a specified HRF as shown in adults, and as the infant HRF is less well established this may result in poor model fit.

There are several benefits of using fNIRS in comparison to alternative brain imaging techniques with infants. Firstly, unlike adults, infants cannot follow instructions to remain still during neuroimaging, but NIRS is less sensitive to motion artefacts than other brain imaging techniques including electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). NIRS also has higher spatial resolution than EEG (Lloyd-Fox et al., 2010), higher temporal resolution than fMRI (Minagawa-Kawai et al., 2008), and has good test-retest reliability (Blasi et al., 2014). Unlike fMRI, NIRS is silent and does not use a magnetic field, making it safe and non-invasive (Issard & Gervain, 2018). In addition, NIRS is beneficial when studying infants, as they generally have less hair than adults allowing for better contact between the scalp and the optodes, which reduces the light scatter, providing a more direct measure of blood oxygenation (Gervain et al., 2011).

There are several limitations of using NIRS with infants. First, there is high data attrition (Lloyd-Fox et al., 2010; Noreika et al., 2020), but this is lower than EEG (Baek et al., 2023). Reasons for high attrition include poor fitting headgear, motion artefacts, and infant non-compliance, which is more likely to occur the more channels there are on the cap (Baek et al., 2023). Second, like EEG, NIRS only allows for measurement of the surface of the cortex and cannot access deeper brain structures unlike fMRI. Third, the spatial resolution of fNIRS is less precise than fMRI (Minagawa-Kawai et al., 2008), and the temporal resolution is inferior to EEG (Lloyd-

Fox et al., 2010). Fourth, there is variability in the haemodynamic response dependent on the infants age and region of the brain being measured. Moreover, the HbO_2 does not always show a canonical response in infants, sometimes showing an inverted response (Issard & Gervain, 2018), which can make interpreting the neural activity a challenge. Fifth, as a relatively new neuroimaging technique, there is variability in analysis pipelines which can produce differing results (Pfeifer et al., 2018; Pinti et al., 2019). Although, a recent study found that whilst different teams use different pipelines, results are consistent for group level analysis (Yücel et al., 2025). However, agreement for individual level analysis was lower than at the group level. Decisions on how to handle poor quality data and statistical analysis also influenced levels of agreement. Nevertheless, implementing fNIRS into this thesis allowed for a multimethod approach to understanding how infants respond to parent smartphone technoference.

2.3 Non-Experimental Methods

2.3.1 Rationale

As previously mentioned, studying infants presents a challenge due to infants being pre-verbal and having limited motor skills. Whilst experimental methods allow for data collection directly from infants via observing behaviour or measuring neural activity, collecting data in this way has several limitations. Firstly, measures in an experimental setting only inform us about the infant's response within an experimental paradigm at one time point and do not allow for capturing cumulative or general patterns of behaviour. Secondly, the quality of the data is dependent on the performance of the infant during the testing session. If the infant is tired or fussy, they may not engage with the task or stimulus fully, and the researcher may not gain any valuable data. Incorporating non-experimental methods was important to this

thesis, firstly because of the exploratory nature of the research questions around parent smartphone technoference. Without established paradigms to study the impact of parent smartphone technoference on language development, it was necessary to apply a range of methods to develop an understanding of potential relationships. Secondly, non-experimental methods allow for data collection which is not reliant on performance at one time point, reducing data attrition and allowing for a general measure of both technoference and child outcomes. Finally, non-experimental methods allow for data collection from parents of the infant via self-report, as opposed to directly measuring the infant, providing a broader overview of the behaviour of interest (albeit potentially biased, see 2.3.2). Study 1 and Study 2b both utilised a non-experimental method to explore parent smartphone technoference and its potential effects. Due to the age of the children of interest (2 years and below), parent self-report measures were used to allow for detail that could not be captured via the behavioural and neural measures previously described. Studies 2a, 3, and 4 also incorporated parent self-report data to enable the inclusion of potential covariates into the experimental data analysis.

2.3.2 Measures: Parent-Report Questionnaires

Parent self-report measures commonly involve the parent completing a questionnaire about how their child typically behaves, their own parenting, or more general questions about the home environment of the child. Gathering data in this way has several advantages. Self-report is a cost-effective and efficient way to collect data, particularly as parents can complete the questionnaire at home, online, with minimal inconvenience to their day. This contrasts with methods which require parents and their infant to come to the laboratory to participate in research. In addition, parents can report on their child's general behaviour considering various

contexts and not being reliant on a one-off example of that behaviour (Law & Roy, 2008). However, this requires that parents can accurately recall information across days, week, or even months, which can be a challenge (Yuan, 2019). Further, parents may be biased in reporting on their child's current level of development, and when reporting on their own parenting behaviour (Bornstein et al., 2015). Whilst some studies find agreement between parent self-report of their child and other measures such as observation (Bornstein & Haynes, 1998), the level of agreement across measures seems to be influenced by, the child's age, temperament, and whether their developmental abilities fall within the typical range (Bennetts et al., 2016). Similarly, whether parent reports of parenting behaviour coincide with observed parenting, depends on factors such as questionnaire length and the type of behaviour being studied (Hendriks et al., 2018). Therefore, self-report measures alone may not provide truly valid measures of child development and parenting behaviour.

Due to the exploratory nature of Study 1, the questionnaire used was designed specifically for this thesis and its creation is covered in detail in Chapter 3. Robust self-report questionnaires that have been previously validated, and reliability established, are available for well researched constructs. Study 2a used three such self-report measures the DISRUPT (McDaniel, 2021), PRS (Anikiej-Wiczenbach & Kaźmierczak, 2021) and UK-CDI (Alcock et al., 2020). Each of which I describe in more detail below.

2.3.3 Distraction In Social Relations and Use of Parent Technology (DISRUPT)

The DISRUPT, devised by McDaniel (2021), is a measure of parent distraction via technology during time spent with their child. The DISRUPT is not designed specifically for smartphones and incorporates distractions other than direct

technoference including cognitive distraction. This measure (see Appendix A) includes 4 items e.g., “During the time I spend with my child, I feel like I use my phone or other mobile device too much.” Parents respond to each item on a 6-point Likert scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). Scores across the four items are averaged to provide an overall score. The initial development of the DISRUPT demonstrated validity and reliability, with Cronbach’s alpha ranging from 0.83-0.91 (McDaniel, 2021). Beyond its development, the DISRUPT has been applied in research testing the relationship between technoference and outcomes including infants’ language development (Corkin et al., 2021), parental warmth (Fusha et al., 2025), parent engagement (Linder et al., 2022), and parents’ desire to change their phone use (McDaniel, Pater, et al., 2023). Good reliability is demonstrated across studies (Corkin et al., 2021; Fusha et al., 2025).

As a short measure of technoference, the DISRUPT was convenient to use in Studies 2b, 3 and 4, which each involved parents answering questions across several different measures. However, due to its brief nature key aspects of problematic device use, such as reasons for use, may not be captured (McDaniel, 2021). As a self-report measure, the DISRUPT does not measure actual technoference and is therefore susceptible to inaccuracies in parent recall and potential bias in perception of own phone use (Coyne et al., 2023; Jarrett et al., 2022; Vanden Abeele et al., 2013; Yuan, 2019). However, implementing the DISRUPT allows for a time and cost-effective means to gather data on parent technoference.

2.3.4 Parent Responsiveness Scale (PRS)

Parent responsiveness is affected by parent smartphone technoference (see Chapter 1). There are different ways to measure responsiveness, one of which is the

PRS (Anikiej-Wiczenbach & Kaźmierczak, 2021). The PRS defines parent responsiveness as behaviours which are adequate, prompt, and provided with warmth (Anikiej-Wiczenbach & Kaźmierczak, 2021). The PRS (see Appendix B) includes 13 items and parents respond to each item using a 7-point Likert scale from 1 (*completely disagree)* to 7 (*completely agree).* Parents are asked to read the statements and consider the extent to which each reflects their relationship with their child. For example, “I reciprocate my child’s smile.” The PRS is a valid and reliable (Cronbach alpha = 0.9) measure of parent responsiveness (Anikiej-Wiczenbach & Kaźmierczak, 2021), although it was developed with Polish parents and is yet to be validated with other samples. This is notable as Study 2b used a sample of UK parents and culture has been shown to influence parents’ beliefs around sensitive parenting (Mesman et al., 2016). Specifically for Polish parents, distanced parenting (low warmth, low monitoring of child) has been shown to be culturally accepted (Lubiewska et al., 2023). It is therefore possible that what is deemed as responsive parenting in Poland does not apply to UK norms of parenting.

The PRS has benefits over alternative measures of parent responsiveness, such as observations. In an observation, the extent to which a parent is responsive is dependent on the child’s behaviour and needs during the observation. Therefore, an observation may not adequately capture general parent responsiveness. In addition, during an observation the parent and child are free from other distractions, as observations usually take place in the laboratory. This may lead to the parent being able to be more responsive than they might be in natural settings where distractions are likely to be more frequent. There is also the possibility that a parent may want to display optimal parenting when being observed and subsequently demonstrate behaviour that is more responsive than it usually would be. The PRS overcomes

these issues as it allows for a general measure of responsiveness whereby the parent can consider various contexts in everyday life. Nonetheless, self-reported parent responsiveness may also be susceptible to social desirability where parents wish to present their parenting favourably. As Study 2a measured parent's contingent responses via an observation, implementing a survey in Study 2b allowed for a multi method approach to studying the relationship between parent smartphone technoference and responsiveness. This is important as Anikiej-Wiczenbach et al. (2024) found that responsiveness measured via the PRS and observations were incongruent with each other. Therefore, by using both measures, it allows for potentially capturing elements of responsiveness that may not be obtained with only one method.

2.3.5 UK Communicative Development Inventory (UK-CDI)

Communicative Development Inventories (CDI) are a form of parent self-report which require parents to report on what words their child can say and understand. The first CDI was the MacArthur-Bates Communicative Development Inventory (MB-CDI), which was developed in the United States (Fenson et al., 1994). Fenson et al. (1994) developed an infant version and a toddler version of the MB-CDI, both of which demonstrated reliability and validity. To account for the difference in UK and US English and cultural differences in infants' exposure to specific words and cultural differences in language development between the UK and US (Hamilton et al., 2000), Alcock et al. (2020) developed a UK-CDI. The UK-CDI was standardised in the UK and is designed to be used with children aged 8 months and 0 days to 18 months and 30 days, with or without language delays, who are learning English in the UK. The UK-CDI (see Appendix C) measures both words (produced and understood) and gestures. The full version includes 395 items for words and 63

items for gestures and the short form includes 91 items for words and 29 gestures. Parents are provided with a checklist of words e.g. cuddle, dirty, mine, and must indicate if their child understands the word, or understands and says the word. Similarly for gestures, parents are provided with a list of actions e.g. clapping hands, and gestures e.g. shaking the head for ‘no’, and indicate whether their child does this ‘often’, ‘sometimes’, or ‘not yet’. A score is calculated for comprehension, production, and for gestures. Study 2a included the UK-CDI as a measure of language development, within a larger survey exploring parent smartphone technoference, parent responsiveness, and child language outcomes. The UK-CDI was suitable to include as it has high reliability, with Cronbach’s alpha score for comprehension and production of words at .99, and gestures at .98 (Alcock et al., 2020). This measure also correlates with a laboratory measure of language development, the Preschool Language Scale – Fifth Edition (PLS-5) (Alcock et al., 2020), suggesting the UK-CDI is a valid measure of child language development.

There are many alternatives to measuring language acquisition that do not require parents to report on their child, including the IPLP already mentioned in this chapter. However, the UK-CDI has several benefits over measuring language acquisition within the laboratory. Firstly, the measurement does not depend on the child having to cooperate with a task and is therefore not affected by fatigue or social inhibition. Secondly, as the measure asks parents about their child’s general communication, language development is assessed across contexts, a level of depth that is difficult to capture in a one-off laboratory visit. At a practical level, the UK-CDI can be administered at a low cost, quickly, and without specialist training, unlike other measures of language such as the PLS-5. This was important for Study 2a as the survey was administered online, and use of the UK-CDI ensured a valid measure

of language development. Nevertheless, as a self-report measure, the UK-CDI is susceptible to bias in parents' recording of their child's language abilities. Additionally, in Study 2a, there is the possibility that ceiling effects may have occurred. The children in the sample were aged 12-18 months, 18-months being the upper age limit of the UK-CDI. Variability in children with advanced language could subsequently be missed. Finally, whilst the UK-CDI measures expressive and receptive language, some elements of language development are not measured such as syntax, which may mean the nuances in language development are not captured.

Chapter 3 Study 1 Technoference in the home: An exploratory survey of parent smartphone use during parent-child interactions

3.1 Introduction

As explained in Chapter 2 (Section 2.1), when I began to research into the topic of parent smartphone technoference there was limited work in the field, specifically there was less knowledge of *how* parents are using their phone when with their infant. It is conceivable that using a phone to manage parenting stress (Radesky et al., 2016) may place different attentional demands on the user than using the phone due to work obligations (Bury et al., 2020), for example. This first study, therefore, sought to address this to inform the development of subsequent studies in the thesis.

Natural observations give some indication as to how parents use their phone when out of the house, but findings are varied both across and within outdoor settings. During a visit to an aquarium, parents reported using their phones to primarily take photos and record videos (Kelly & Ocular, 2021), whereas in a park setting parents have been observed using their phone most often to make calls, text, scroll, and use the camera (Hiniker et al., 2015; Lemish et al., 2020; Mangan et al., 2018). The inconsistency in findings is likely partly related to the age of the child, the setting, and how the data was gathered. In some cases, the parent is asked how

they were using their smartphone during the observation period (e.g. Mangan et al., 2018), in others the observer tracks the usage during the observation (e.g. Lemish et al., 2020). In addition, observing from a distance allows for the possibility of misinterpreting how the parent is using their phone, particularly if using the touch screen. Gathering data via natural observations in public spaces does also not allow us to understand how parents use their smartphone in the home, but survey data can give some indication on this. A longitudinal survey of breastfeeding mothers found that the most common way to use the smartphone during breastfeeding was to look at the screen, e.g. to check the time or for notifications and for searching and browsing the web (Inoue et al., 2021). Other common self-reported smartphone use by parents includes using the camera function (Hiniker et al., 2015; Kelly & Ocular, 2021), and for entertainment (Garg, 2021). Of course, it is possible that the way in which the phone is used is not an important factor when assessing the potential effects of technoference. Wolfers et al. (2020) found that during a park visit, type of phone use did not mediate the effect that duration and frequency of phone use had on the parent-child interaction. However, Wolfers et al. (2020) asked parents to report on six different types of smartphone use in a short observation window in a playground, therefore this may not reflect the full range of smartphone use or smartphone use over prolonged periods in the home.

Given that parent-child interactions are integral to developmental outcomes (Gerhold et al., 2002; Poehlmann & Fiese, 2001; Saxon, 1997), it is critical to understand technoference in the home where the dyad spend most of their time. Mothers' own perception of technoference is that it occurs more frequently during play time and free time with the child, as opposed to structured activities such as mealtime or bedtime (McDaniel & Coyne, 2016). Free time could incorporate some

of the natural observations, such as those in a playground (Bury et al., 2020; Hiniker et al., 2015; Lemish et al., 2020; Mangan et al., 2018) but not those in restaurants (Elias et al., 2020; Radesky et al., 2014; Radesky et al., 2015), and child health centres (Abels et al., 2018). The home environment includes both free time and structured activities related to childcare, making it a complex environment to gather data on how parents use their smartphone. Additionally, Garg (2021) found parents' phone use at home is not only context dependent but is also influenced by parent beliefs on both parenting and the impact of device use. Some parents reported using their smartphone as a teaching opportunity or as a source of information to support childcare routines, such as finding nutritional information for food, whereas others reported making a conscious effort to put the phone in another room believing it to be too distracting. Notably, Garg (2021) points out that these factors can contradict each other, resulting in parents continually weighing up whether to use their smartphone or not. Thus, technoference in the home is intricate and at present there is a gap in our understanding of how and why parents are using their smartphones during parent-child interactions.

In Study 1 I conducted a survey to investigate parents' smartphone use during and outside of interactions with their child. Studies which had gathered data via self-report informed the current survey. Myruski et al. (2017) measured parent mobile device use by asking parents to report on the frequency of mobile device use per day in front of the family, in front of the infant, and how often they use the device for communicating. The authors found that mobile device use was less around infants than family members generally, however in their study a mobile device extended to tablets and laptops, which differ to smartphones due to their size, for example by making them less likely to be kept in a parent's pocket. Terminology is important, as

absorption during smartphone use has been found to predict lower attachment security in 11–26-month-olds, whereas general media use did not (Linder et al., 2021). The current study therefore focuses explicitly and solely on smartphone use. Inoue et al. (2021) also specified device use by measuring mothers' smartphone use whilst breastfeeding, asking mothers to respond to how often during breastfeeding they engaged with several different tasks on their smartphone. Smartphone uses were preselected to include activities that required different levels of attention and time, e.g. short time and little focus would include checking the screen, whereas watching a long video would require both more attention and time. Whilst devising questions in this manner does address smartphone use directly and the ways in which parents use their phone, the questions only covered three quite broad categories; 'looking at screen', 'search, browse, selection', and 'watching long videos'. Although watching long videos is a specific task, the other two categories encompass a range of phone uses which require different levels of engagement. For example, looking at the screen could be a simple task such as checking the time, or could also include a more involved task such as reading a work email. Arguably these two tasks would place different attentional demands on the parent. A different approach to measuring technoference was employed by Stockdale et al. (2020) who devised a survey to parents which addressed how they use their smartphone during five daily activities with their child; "During meals," "Getting your child ready for school," "During playtime," "During bedtime routine," and "While driving them to or from an activity". A second survey asked parents about their beliefs regarding acceptability of media use across five different activities; "When I take my child to the park," "When my child is playing with toys," "When feeding (breast or bottle feeding) my child," "When my child is watching television," and "When my child's attention is

occupied by something else." Responses on both surveys were on a five-point Likert scale and gave participants a technoference score and a score for beliefs regarding technoference. The design of this survey potentially reveals more about the context in which parents use their smartphone when with their child. However, analysis did not include a comparison of the different activities, resulting in a lack of information on which activities are associated with increased smartphone use by parents. The current study aims to overcome some of these issues by focusing solely on smartphones and by increasing the number of uses available for selection on the survey.

As addressed in Chapter 2, self-report measures of parent phone use rely on parents being able to accurately recall their phone use. To assess how accurate parents are at reporting their daily smartphone use, Yuan (2019) compared data gathered via a passive sensing[3] app to self-report data, finding few parents accurately self-reported their daily smartphone usage. One way to improve data accuracy is by asking parents to report on their smartphone use directly after they have used their phone, an approach taken by Wolfers et al. (2020). Although asking parents to recall their smartphone use directly after using their phone addresses the issues of recall in self-reported data, it is not so simple to do this in the home whereby the parent may not have recently used their smartphone before completing a survey.

Recent research has begun to develop robust measurements of parent phone use. Ventura et al. (2020) developed the Maternal Distraction Questionnaire (MDQ) which measures how often the mother engages in a range of digital and non-digital distracting activities. Two of these are phone-based and ask the mother about

[3] A passive sensing app installed on the user's phone can record how long the user spends on the screen and what apps are used. The exact measurements taken depend on the sensing app used.

‘talking on the phone’ and ‘texting or using apps on a mobile device or tablet’, when feeding their child and during non-feeding interactions. Mothers are also asked more generally how distracted they are during feeding and non-feeding activities and how much attention they give their child both during feeding and non-feeding activities. Whilst Ventura et al. (2020) found high construct and criterion validity for the MDQ, this measure considers technology more broadly rather than focusing on the smartphone specifically. Building on this, McDaniel (2021) has developed a measure, called DISRUPT (Distraction In Social Relations and Use of Parent Technology), which considers parents self-reported problematic smartphone use during time with their child (see Appendix A). McDaniel (2021) found the DISRUPT to have high validity and reliability and to be a predictor of parenting quality. However, due to its focus on cognitive and behavioural distractions of phone use, the DISRUPT does not ask directly about smartphone use when engaging with the child. The four items refer to ‘time spent with my child’, but this does not specify time spent engaging with the child which would give a more precise measure of technoference. This still leaves us lacking a measure which gives detail on whether parents are using their smartphone when at home *during* interactions with their child. The design of the survey in the current study mirrors the MDQ by comparing smartphone use when the parent is engaged with their child and when they are not engaged with their child. This also overcomes some of the issues with the DISRUPT by asking parents directly about their smartphone use when engaging with their child. In addition, the DISRUPT is designed to be applicable to children of all ages. Arguably, the effects of technoference may be moderated by the child’s developmental stage. The survey in Study 1 therefore focused on children under the age of two.

3.1.1 The Current Study

This chapter reports on an exploratory survey that was designed to gather information on how parents use their smartphones when engaging with their child and whether this differs to when they are not engaged with their child. The survey was aimed at parents with children under two years of age due to the importance of parent-child interaction in the early years for the child's development (Bordeleau et al., 2012; Shaw et al., 2001; Youngblade & Belsky, 1992), in particular for the development of joint attention (Suarez-Rivera et al., 2019) and language development (Topping et al., 2013).

An additional consideration in the current study was to explore whether the parent's smartphone is of interest to the child. Joint attention is a key feature of parent-child interactions in the early years, and as discussed in Section 1.5.2, parent smartphone technoference can disrupt joint attention (Krapf-Bar et al., 2022; Lederer et al., 2022; Ochoa et al., 2021; Radesky et al., 2015), but dependent on how the phone is used, parent smartphone use can also create periods of joint attention (Amery, Danby, & Brereton, 2026; Ochoa et al., 2021; Radesky et al., 2014). To understand this further, the survey addressed whether the child shows interest in the smartphone and whether the parent and child co-use the device (i.e. JME).

When designing the survey, to try and gather as accurate information as possible, parents were asked about how they used their phone in the previous 24 hours. This builds on Wolfers et al. (2020) approach by focusing on a specific, albeit longer, time frame. The variety of ways to use a smartphone has also been increased from the six, included by Wolfers et al. (2020), to twenty-five items.

Due to a lack of previous research focusing solely on parent smartphone use and because of the inconsistent findings in the self-reported findings to date, there are no hypothesised outcomes.

3.2 Method

3.2.1 Participants

Parents who had signed up to the University of Essex Babylab database to participate in research were invited to participate in the study. In addition, parents were recruited through sharing the survey URL on social media platforms. Participants were not remunerated for their participation. The only inclusion criteria were having a child under the age of two and owning a smartphone. Ethical approval was gained from the University of Essex Science and Health Ethics Sub-committee (ID: ETH2021-0352).

Sixty-eight parents with children under the age of two completed the survey. The decision to stop recruiting at this sample size was driven by two practical reasons. First, as this study was intended to inform the design and measures used within the main studies in this thesis, data collection was time limited to fit within the overall project timeline. Second, no funding was available to incentivise participation, which limited recruitment. Given the study's exploratory nature, the achieved sample was deemed sufficient to identify preliminary patterns in parent smartphone use, to inform later study design. The small sample size is recognised as a limitation and discussion further in Section 3.4.7. The characteristics of the sample are shown in Table 3.1. Most of the children's primary caregiver was the mother (87%), the sample was predominantly White (88%), and the most common form of employment was part-time (57%). Twenty-two percent of respondents indicated that they owned a smartwatch.

Table 3.1

Characteristics of the Sample

Primary caregiver	**N (percentage)**
Mother	59 (87)
Father	0 (0)
Mother and father	9 (13)
Ethnicity	**N (percentage)**
Asian	2 (3)
Black	2 (3)
Other	4 (6)
White	60 (88)
Employment	**N (percentage)**
Employed full time	12 (18)
Employed part time	39 (5)
Homemaker	7 (10)
Other	8 (12)
Student	2 (3)

3.2.2 Procedure

Parents were sent an online survey link or could access the link via the Essex Babylab Facebook and Instagram pages. The survey was compatible for use with mobile phones. Participants completed the survey online via Qualtrics, with no time limit to complete the survey. Parents were asked to answer the survey questions with their youngest child in mind.

3.2.3 Measures

The survey contained 16 questions regarding the parent's age, gender, and ethnicity. Demographic information gathered included family income, education level of the parent completing the survey, who the primary caregiver is, and employment status of the parent responding to the survey. Questions related to the child included birth date, gender, number, and age of siblings, and whether the child had any diagnosed disorder. Three items asked parents about their general smartphone habits, and two questions asked around specific phone use when the parent was and was not engaged with their child in the previous 24 hours. Three questions assessed the child's use of their parent's smartphone, and the final two questions asked about ownership of a smartwatch (see Appendix D).

3.2.3.1 Questions on General Smartphone Use

The item first asked, "In a regular day, how many times per hour do you usually check your smartphone?" This was measured by number of times per hour "0-2 times an hour," "3-6 times an hour," "7-9 times an hour," "10-12 times an hour," "13-15 times an hour," and "More than 15 times an hour". The second item asked, "In a regular day, how long do you generally use your smartphone for?" Participants responded with time estimates ,"Less than 60 minutes per day", "1-2 hours per day," "3-4 hours per day," "5-6 hours per day," "7-8 hours per day," and "over 9 hours per day".

Parents phone use when with their child was measured by asking participants how often they use their phone across three different scenarios, when their child is "Sleeping/napping," "Awake and you are not actively engaging with them," "Awake and you are actively engaging with them". Measurement was on a five-point Likert scale; "Always," "Most of the time," "About half the time," "Sometimes," and "Never".

3.2.3.2 Questions on Specific Use of the Phone when Engaged and Not Engaged With Their Child

How parents use their phone in each of these contexts was then explored by asking participants how they used their smartphone in the last 24 hours in two different contexts, “When your youngest child was asleep or they were awake but not actively engaging with you,” and “When your youngest child was awake and actively engaging with you”. Participants responded on the four-point Likert scale used by Wolfers et al. (2020), “Not at all,” “I did this for less than half of the time I spent on my phone,” “I did this for about half of the time I spent on my phone,” and “I did this almost the entire time I used my phone”. There were 25 different ways of using the phone listed, for example “to play games”, “to text friends and family members”. There was also an option for parents to specify any other phone use not already listed, allowing for 26 responses in total.

3.2.3.3 The Child’s Interest in Their Parent’s Smartphone

To assess the child’s interest in and use of the parent’s phone, three questions were asked. “Does your youngest child show an interest in and try to interact with the smartphone when you are using it?”, “Do you let your youngest child use your smartphone independently?”, “Do you sit with your youngest child and interact with the smartphone when they are using it?” Participants could respond with “Yes,” “No,” or “Sometimes”.

3.2.3.4 Smartwatch Ownership

A final question was included which asked about smartwatch ownership. With wearable technology ever expanding, it is pertinent to know how common smartphone ownership is amongst parents and whether it is an area worth exploring

in future research. Parents were asked, “Do you currently own a smartwatch?” and if they responded “Yes” they were asked to list the main ways they use the smartwatch.

3.3 Results

Parents self-reported phone use can be seen in Table 3.2. Most parents reported checking their smartphone between 3-5 times per hour (44%) and using their smartphone for 3-4 hours (44%) in the previous 24 hours.

Table 3.2

Percentages of Duration and Frequency of Smartphone Use

Frequency	**N (percentage)**
0-2 times an hour	14 (21)
3-5 times an hour	30 (44)
6-9 times an hour	16 (24)
10-12 times an hour	5 (7)
13-15 times an hour	3 (4)
More than 15 times an hour	0 (0)
Duration	**N (percentage)**
Less than 60 minutes per day	1 (< 1)
1-2 hours per day	24 (35)
3-4 hours per day	30 (44)
5-6 hours per day	12 (18)
7-8 hours per day	1 (< 1)
Over 9 hours per day	0 (0)

To explore whether demographic factors were related to parent smartphone use, the following demographics were added to three different multiple regression models; parent employment, family income, number of GCSEs gained by parent, number of A Levels gained by parent, gender of the child, and who the primary caregiver was. By selecting these variables, some data was lost due to incomplete fields e.g., leaving number of A Levels blank rather than responding with 0. This reduced the data set from 68 to 47 responses for this part of the analysis. For the non-numerical predictors dummy coding was used. Each regression model focused on a different aspect of smartphone use.

3.3.1 Demographics and Parent Smartphone Use When Engaged With Their Child

The first multiple linear regression examined whether parent smartphone use during engagement with their child was predicted by the demographics above. The model was not a significant predictor of parent smartphone use F (6, 37) = 0.46, p = .83, R^2 = -.08, suggesting that there is no relationship between these demographics and parent use of the smartphone when engaged with their child.

3.3.2 Demographics and Parent Smartphone Checks Per Hour

Demographics were further explored in the second regression model for number of checks per hour. Overall, this model accounted for 26% of the variance, suggesting a significant effect of demographics on frequency of smartphone use, F(6, 37) = 3.46, p = .008, R^2 = .26. Number of times parents check their phone per hour was positively associated with number of GCSEs gained by the parent (B = 0.25, SE = 0.09, p = .007), who the primary caregiver was (B = 0.77, SE = 0.34, p = .028), and negatively associated with number of A Levels gained by the parent (B = -

0.43, *SE* = 0.17, *p* = .015). This suggests an inverse relationship between education and frequency of smartphone use, with the phone being checked more frequently by parents with a higher amount GCSEs, but less frequently by parents with the higher amount of A Levels. This model also suggests that more checks per hour occur when both the mother and father share the primary care than when the mother is the primary caregiver.

3.3.3 Demographics and Frequency of Parent Smartphone Use

Frequency of phone use per day were examined in association with demographics. The model was not a significant predictor of how much a parent uses their phone per day, $F(6, 37) = 0.74$, $p = .62$, $R^2 = -.04$, suggesting that there is no relationship between these demographics and how much time a parent spends using their smartphone per day.

3.3.4 General Phone Use Across Different Levels of Engagement

For all further analysis, where the survey response was measured on a Likert scale, the data was treated as ordinal. This allowed the data to remain in its original form, which helps to avoid some of the issues with analysing ordinal data using metric analysis, such as Type I and Type II errors (Liddell & Kruschke, 2018). Ordinal analysis was conducted using Bayesian methods, which identify the most probable parameter estimates and define the range of values that are statistically credible (Kruschke & Liddell, 2018; Liddell & Kruschke, 2018). Therefore, *p* values are not necessary in Bayesian analysis (Kruschke & Liddell, 2018) and are not included in the current analysis.

All Bayesian models were conducted with the brms package (Bürkner, 2017) in R version 1.3.959. This package uses the Markov Monte Carlo (MCMC) chain

convergence for Bayesian analysis. All models were fitted with a cumulative link function. Due to the exploratory nature of this research and the limited amount of data into parent smartphone use, conservative priors set by R were used throughout the analysis (Kruschke & Liddell, 2018).

3.3.5 Smartphone Use and Level of Engagement With the Child

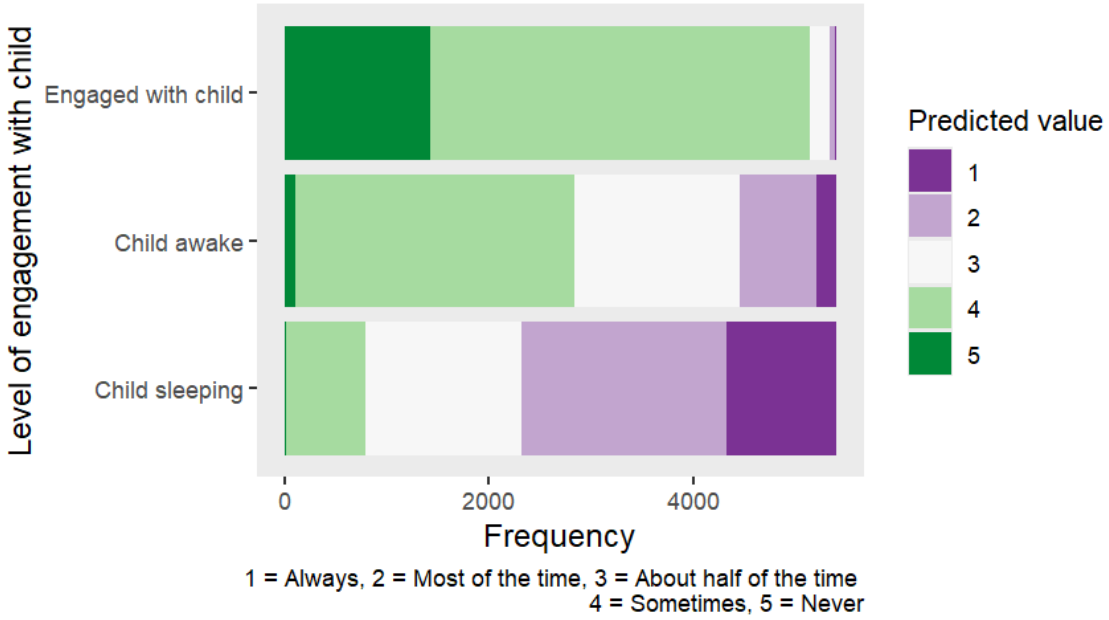
To explore the relationship between general smartphone use and the presence of the child, an ordinal regression was conducted. Frequency of smartphone use was measured as the outcome variable and the level of interaction with the child (child asleep, awake and not engaged, or awake and engaged) as the predictor. Frequency of smartphone use was measured on a five-point Likert scale, 1= “Always,” 2 = “Most of the time,” 3 = “About half the time,” 4 = “Sometimes,” and 5 = “Never”.

The prior set by R was flat for β, with μ as 0 and α as 2.5, for both the intercept and standard deviation. Trace plots indicated that the chains were well mixed, and the model had a Rhat of 1. The condition of the infant asleep was set as the intercept. An effect was found by condition, compared to when the infant was asleep, phone use was lower when the infant was awake and not engaged (β = 1.95, 95% CrI [1.28, 2.65]), and lower still when the infant was awake and engaging with the parent (β = 4.97, 95% CrI [3.92, 6.24]).

The plot predictions (see Figure 3.1) forecast that when engaged with their child a parent is more likely to respond that they use their smartphone ‘sometimes’ and very unlikely to respond that they use their smartphone ‘half of the time or more’. When the child is sleeping, parents are more likely to respond that they use their smartphone ‘always’ or ‘most of the time’.

Figure 3.1

Plot Predictions of the Probability That a Parent Will Use Their Phone Across Levels of Engagement (Engaged or Not Engaged)



3.3.6 Phone Use Across Engagement and Activities

Parents responded on a Likert scale where 1 = “Not at all”, 2 = “I did this for less than half of the time I was on my phone”, 3 = “I did this for about half of the time I spent on my phone,” and 4 = “I did this almost the entire time I was on my phone”. The mean of these responses to each activity, both when engaged with their child and when not engaged with their child, are represented in Figure 3.2. Figure 3.2 shows that parents use their smartphones more when they are not engaged with their child and a difference is particularly apparent for texting, social media, and organising daily life; with these activities being more common when not engaged with the child.

Figure 3.2

Comparison of How Parents' Use Their Smartphone When Engaged With Their Child in Comparison to Not Being Engaged With Their Child



Note. 1 = "Not at all," 2 = "I did this for less than half of the time I spent on my phone," 3 = "I did this for about half of the time I spent on my phone," and 4 = "I did this almost the entire time I used my phone".

To analyse if there was a meaningful effect of level of engagement and activity on the smartphone an ordinal multilevel regression was used to explore the fixed effects of condition (engaged, not engaged) and activity. Condition and activity were examined in association with smartphone use, and the interaction between them was also modelled. Participants were specified as random effects, modelling for random slopes and intercepts for participants across the activities the smartphone was used for. The model was coded in brms using the following syntax:

response~condition * activity + (activity|participant)

However, this model did not fit, and the chains would not run, meaning the model needed to be simplified. To keep participant as a random effect, the simplified model included an intercept for each participant, but not random slopes. The simplified model was coded in brms using the following syntax:

response~condition * activity + (1|participant)

In this model the condition (engaged, not engaged) and the activities were regressed onto smartphone use (scale = 1-4) as fixed effects, as well as modelling for an interaction between the two.

Due to reasons already noted, the priors set by R were used, which was flat for β, μ was set at 0 and α was 2.5, for both the intercept and standard deviation. Trace plots indicated that the chains were well mixed and the Rhat was 1 for all variables. Coefficients and credible intervals for each of the activities when not engaged with the child can be seen in Table 3.3.

On inspection of the data, some activities had a positive skew whereby most responses were rated as “not at all”. Where this occurred more than 85% in both conditions, the data was excluded. In these instances, parents rarely engaged with the activity regardless of whether they were interacting with their child or not, which does not provide sufficient variability to estimate reliable condition-specific effects. This resulted in 5 activities being excluded; controlling smart devices, exercise, playing games, accessing reward apps, and other.

Total condition effects for each phone use activity were calculated by summing the posterior draws for the main effect of level of engagement (engaged versus not engaged) and the corresponding interaction term. Point estimates and credible intervals where then calculated from the resulting posterior distribution. Table 3.3 shows the estimated condition effect (engaged versus not engaged) for each phone

use activity. Only using the phone for video calls was more common when parents are engaged with their child in comparison to when they are not engaged with their child (β = -0.84, 95& CrI [-1.57, =0.11]). Four activities showed no difference in frequency of use when parents are engaged with their child in comparison to when they are not engaged with their child, taking photos, making phone calls, monitoring children, and monitoring health. All other activities were more common when parents were not engaged with their child. After applying the Benjamini-Hochberg (BH) procedure to control for the false discovery rate, using the phone for studying/work did also not show a difference when engaged versus not engaged with the child.

Table 3.3

Estimated Effect of Phone Use Activities by Level of Engagement

Activity	β	Est. Error	95% CrI		Survived BH correction
			LL	UL	
Listen to music/podcasts/audio books	1.17	0.43	0.33	2.03	Yes
Research information on child development	1.91	0.42	1.12	2.74	Yes
Read current events	2.42	0.41	1.62	3.25	Yes

Read eBooks	2.29	0.87	0.79	4.13	Yes
Education/work	1,25	0.53	0.24	2.35	No
Access health apps	0.87	0.51	-0.10	1.94	No
Access maps	1.09	0.44	0.25	1.97	Yes
Monitor children	0.86	0.53	-0.15	1.92	No
Organise daily life	2.57	0.37	1.88	3.30	Yes
Access parent forums	1.21	0.49	0.27	2.17	Yes
Phone calls	0.38	0.39	-0.38	1.15	No
Take/view photos	0.16	0.33	-0.50	0.79	No
Read emails	1.94	0.39	1.18	2.73	Yes
Research child development	1.91	0.42	1.12	2.74	Yes
Shopping	2.55	0.42	1.75	3.40	Yes

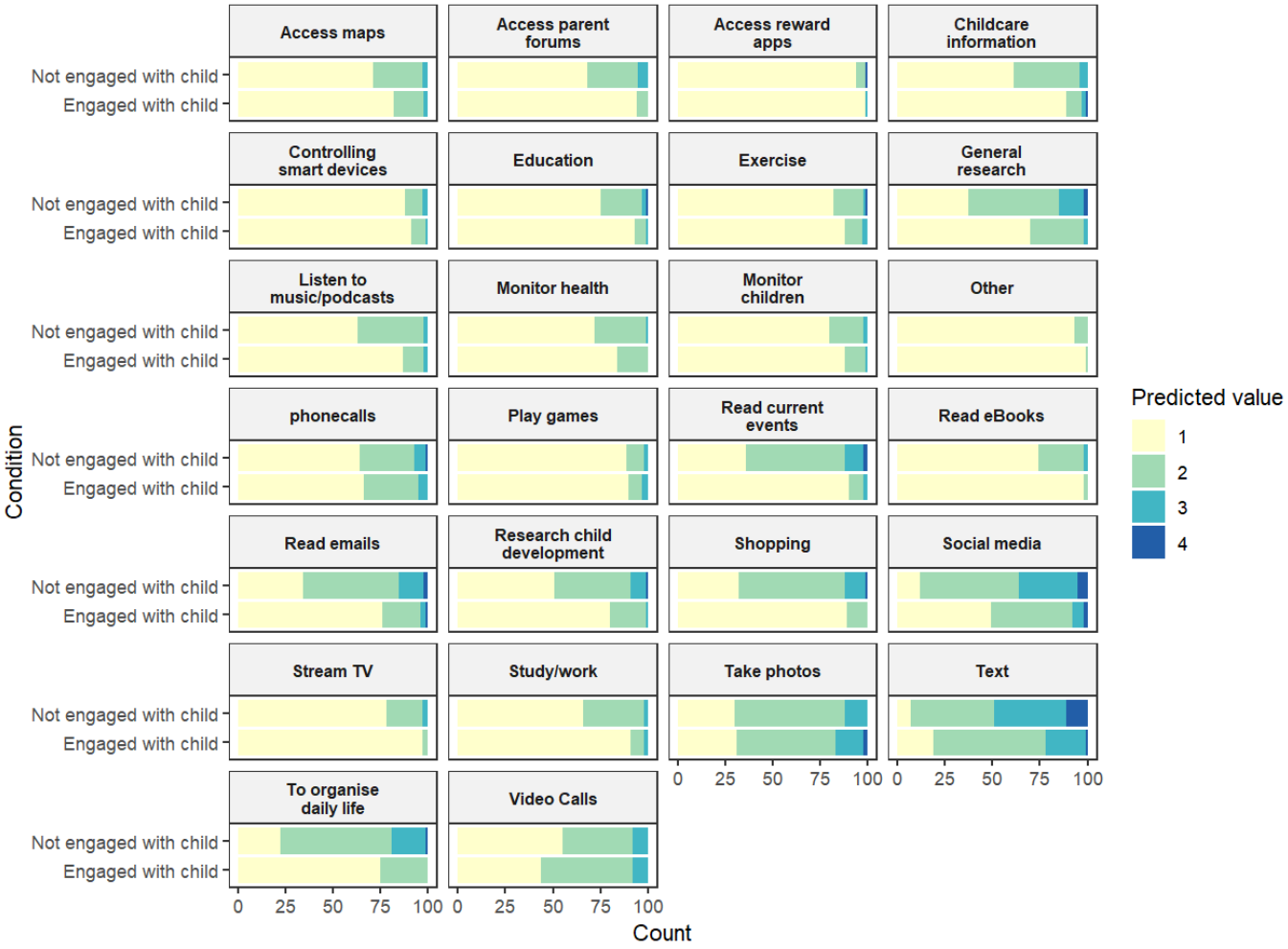
Social media	1.96	0.34	1.30	2.62	Yes
Stream films/TV series	1.71	0.57	0.65	2.89	Yes
Text	1.11	0.32	0.50	1.74	Yes
Video calls	-0.84	0.37	-1.57	-0.11	Yes

Note. CrI = credible interval, LL = lower limit, UL = upper limit.

Predictions of the model by activity and condition can be found in Figure 3.3. The predictions show that there are not many uses of the smartphone which are solely used either when the child is engaged or not engaged with the parent. For some activities there are clear differences between their use when not engaged with the child. For example, the model predicts parents are more likely to organise daily life, read about current events, access social media shop, and read emails when not engaged with the infant. The model predicts that video calls are the most frequent way in which the smartphone is used when a parent is with their child.

Figure 3.3

Model Predictions for Each Activity on the Phone



Note. 1 = “Not at all”, 2 = “I did this for less than half of the time I was on my phone”, 3 = “I did this for about half of the time I spent on my phone” and 4 = “I did this almost the entire time I was on my phone”.

3.3.7 Age as a Predictor

Age was analysed as a possible predictor for frequency of smartphone use and number of checks per hour using two ordinal regression models. For both, R set the priors as 0 for μ and 2.5 for α for both the intercept and standard deviation. Trace plots indicated that the chains were well mixed and the Rhat score was 1. Age did not predict number of smartphone checks per hour (β = -0.06, 95% CrI [-0.16, 0.04]), but was a predictor for frequency of smartphone use in the previous 24 hours (β = -

0.13, 95% CI [-0.24, -0.013). The relationship was negative, suggesting that as age increased, frequency of smartphone use decreased.

3.3.8 Child's Interest in Parent's Smartphone

Parents were asked, *'Does your youngest child show an interest in and try to interact with the smartphone when you are using it?'* and could respond with 'yes', 'no' or 'sometimes'. Given that the data included children under the age of two, this question was only analysed for children aged one and above (N=45) who are more likely to have the motor coordination to be able to interact with the phone.

As shown in Table 3.4, children do express an interest in their parent's smartphone when their parent is using it. Parents were also asked if they let their child use their smartphone independently, to which no one responded 'yes' to and 29% responded sometimes. Of those children who do use their parent's smartphone, 30% of parents responded that they sit and interact with their child when their child is using their smartphone, but 15% never sit and interact in shared smartphone use.

Table 3.4

Summary of the Child's Interest in and Use of Their Parents' Smartphone

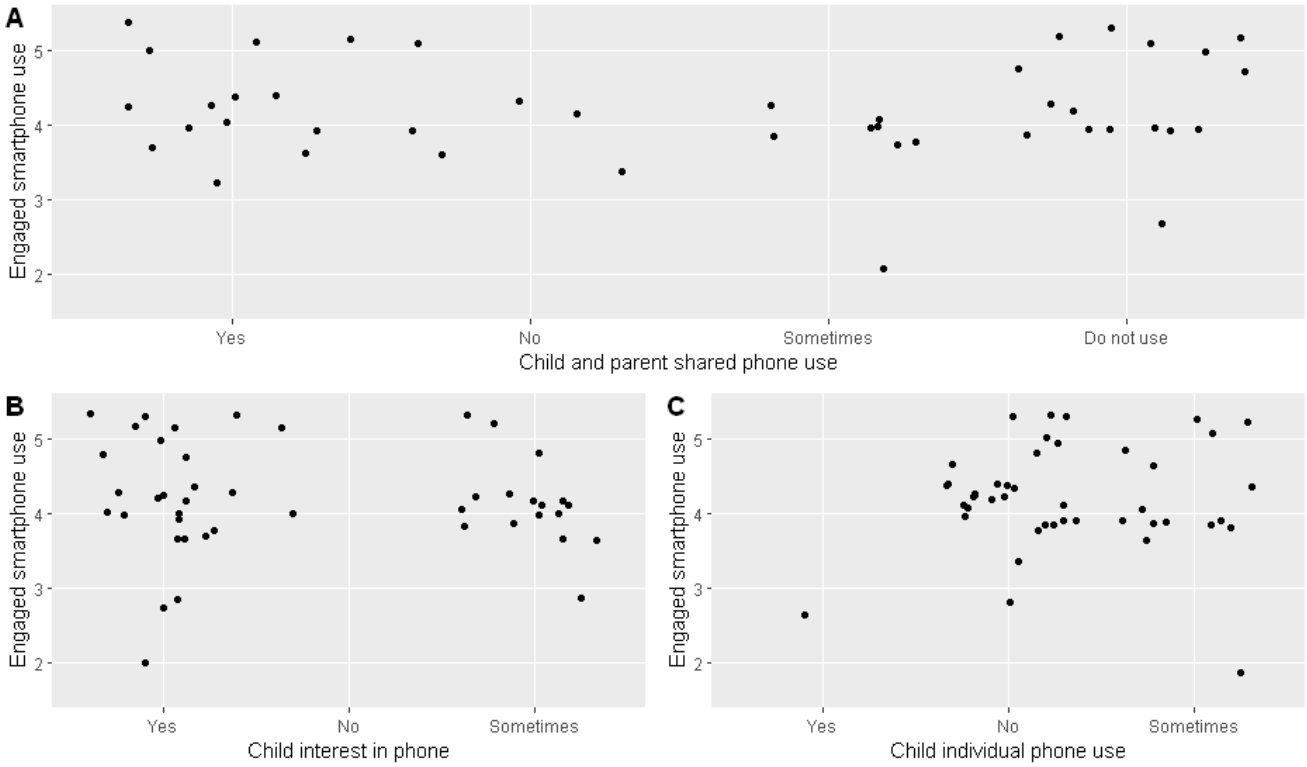
Does the child show interest in the smartphone when the parent is using it?	**N (percentage)**
No	2 (4)
Sometimes	17 (38)
Yes	26 (58)
Does the child use the smartphone independently?	**N (percentage)**

No	12 (71)
Sometimes	5 (29)
Yes	0 (0)
Does the parent co-use the smartphone with the child?	**N (percentage)**
Child does not use the smartphone	18 (38)
No	7 (15)
Sometimes	8 (17)
Yes	14 (30)

The data around the child's interest in and use of smartphones was explored in relation to the parent's use of their smartphone when engaged with their child i.e., does the child's level of interest play a role in whether parents use their smartphone when engaged with their child? However, the data for smartphone use when engaged with their child was clustered around the same response from most parents, which was that 65% of parents report 'sometimes' using their smartphone when engaged with their child and 29% reporting 'never' using their smartphone when engaged with their child. This skewness in the data, made it difficult to seek any meaningful patterns in relation to the child's interest and use of their parent's smartphone. Figure 3.4 illustrates the relationship between the child's interest in the smartphone (plot B), their individual use of their parent's smartphone (plot C), and shared use of the smartphone between parent and child (plot A). There appears to be no relationship between each of the three factors and whether the parent uses their smartphone when engaged with their child.

Figure 3.4

Relationship Between Children's Interest in and Use of Parent's Smartphone and Parent Smartphone Use When Engaged With Their Child



Note. Engaged smartphone use, 1 = Always, 2 = Most of the time, 3 = About half the time, 4 = Sometimes, 5 = Never.

3.4 Discussion

With smartphones having a stable presence in our daily lives, their potential to affect the parent-child interaction is one that needs exploring. The current survey sought to investigate whether parents use their smartphones when engaging with their child and how they use their smartphone during these interactions. The findings from this exploratory study are used to inform upcoming chapters, but I also hope they will be useful in designing future, experimental, and longitudinal research into smartphone technoference during parent-child interactions.

3.4.1 Demographics

Demographic factors did not predict the extent to which parents used their smartphone when engaged with their child or how much time they spent on their smartphone per day. There was some effect for how many times parents checked their smartphone per hour with parents who have a higher number of GCSEs associated with higher amounts of smartphone checking per hour. The inverse relationship was present for A Levels; parents were less likely to check their smartphone the higher number of A Levels they had. Higher education has previously been found to be related with increased smartphone use when driving, (Márquez et al., 2015), and during family mealtimes (Radesky et al., 2018). The findings are however mixed as other studies have found no relationship between education and problematic smartphone use (de-Sola et al., 2017) and some research has found that higher education is related to less frequent smartphone use (Demirbilek & Minaz, 2020). Differences in findings are likely to be related to the sample used and how smartphone use is measured.

There was also an effect of frequency of smartphone checking on the primary caregiver, with higher levels of phone checking occurring when both the mother and father are the joint primary caregiver, than when the mother is the sole primary caregiver. This finding needs to be treated with caution, as there were fewer parents who identified both parents as the primary caregiver, compared to the mother, creating some skewness in the data. Further exploration of the influence of the primary caregiver is warranted, however it is possible that when both parents are involved in the childcare there is more time to check one's smartphone as the childcare demands are shared.

3.4.2 Level of Engagement With the Child

The current study extends the literature on parent phone use in natural public settings, to consider parent smartphone use when engaged with their child in the home setting. Parents were more likely to use their smartphone when their infants were asleep and least likely to use their smartphone when they were engaging with their infant. This may be because parents are aware of the need to focus their attention on their child during parent-child interactions, or it may be that the demands of the interaction prevent the parent from using their smartphone. Research from Nomkin and Gordon (2021) appear to support this suggestion, finding that mothers fixated on their smartphone more when breastfeeding than they did when engaged in a face-to-face interaction with their child. The infant is less demanding for attention during breastfeeding compared to face-to-face interactions, which could explain the increased use of their smartphone. However, the findings from Radesky et al. (2016) that caregivers report internal tension over using their smartphone when with their child, suggests that it may not be the demands of the interaction preventing use of the smartphone but that parents are actively choosing not to use the phone. It is possible that although parents are not using their smartphone as much when engaged with their child, they are still distracted cognitively by thinking about their smartphone (McDaniel, 2021). This may particularly cause an issue for parents who have higher parenting stress, as suggested by Torres et al. (2021). In their study, the authors found that parents who used their smartphone as a virtual escape reported higher levels of parenting stress and guilt, compared to parents who did not use their smartphone as an escape. The reasons as to why parents use their smartphones less when engaged with their children under the age of two require further exploration, as it is possible the reasons for choosing to use the smartphone or not,

are mediated by other factors, such as child illness, being a lone parent, or whether the child attends day care (Garg, 2021).

3.4.3 How the Phone is Used

The analysis of the different ways that parents use their smartphones identified that when parents were engaged with their child, they were more likely to use their smartphone to make video calls. Although this was the only activity parents engaged with more frequently when engaged with their child, when engaged and not engaged with their child parents were equally as likely to use their phone to take photos, make phone calls, monitor children and health, and for studying/work. The absence of difference in frequency of use when engaged and when not engaged with the child for these activities partially aligns with findings from Garg (2021) that the most common ways parents use their phone when with their child includes phone calls, video calls, taking photos, and work-related activity. Using the smartphone to make phone calls (Mangan et al., 2018) and take photos (Wolfers et al., 2020) has been identified in previous research as common ways parents use their smartphones in settings away from the home when with their child. However, making video calls is not a use that has been previously identified as being of high usage by parents when considering technoference. Nevertheless, parents do report using video calls regularly with their children, with McClure et al. (2015) reporting that 84% of 6-16-month-olds and 88% of 17-24-month-olds use video calls with their parents, but notably only 39% of the time did the video call take place via a smartphone. It appears that video calls are a planned activity and may not be a form of technoference, which makes it a possibility that the effects of using a smartphone to make video calls may differ to phone calls, and photos, which are less likely to be planned shared activities between a parent and child. The reasons why parents use

the phone to monitor their own health, to monitor their child, and for studying/work similarly when engaged with their child or not is less clear. Possibly, monitoring apps may require brief engagement e.g. to update an infant's wake time from a nap, and therefore these shorter-term interruptions are deemed more acceptable by parents (Abels et al., 2024). Using the phone for work may occur similarly when engaged and not engaged with the child, as this type of phone use is reluctant (Garg, 2021).

Whilst the findings of the current study identify how parents use their smartphone when interacting with their child, this information does not add to our knowledge on *how* using a smartphone affects the interaction between a parent and child and whether any effects are dependent on how the phone is used. The effect of technoference may vary due to the specific smartphone use, for example the phone uses found to occur more often when engaged with a child, or similarly when engaged and not engaged with their child, all require different demands in terms of the user. Monitoring health, monitoring children, and using the phone for work/education are likely to involve the parent focused on the smartphone screen, with attention and eye gaze directed away from the child onto the smartphone. As discussed in Chapter 1 (Sections 1.4 and 1.5), shared eye gaze is important for the development of gaze following and later joint attention. It is possible that a parent using a smartphone in these ways could disrupt joint attention as the parent shifts their focus from the shared object to their smartphone. However, these processes may be less affected when a parent makes a phone call. During a phone call, a parent may still maintain eye gaze and use non-verbal gestures to signal joint attention such as shifting gaze between the child and shared object or pointing. It is less clear how a parent using their smartphone to take photos may affect the interaction between a parent and their child, but some research shows taking photos

can have positive effects on the parent-child interaction (Kelly et al., 2023; Ochoa et al., 2021). It is possible that parents can communicate with their child as they take photos, for example trying to make them smile, which may continue the interaction. However, if the smartphone is used to take photos without communication with the child, this may end an interaction with the child or prevent an interaction from being initiated. When parents use the smartphone to make video calls, this might enhance the parent child interaction by the phone becoming the shared object of attention. Alternatively, if the child is involved in the video call, they may engage in a social interaction involving joint visual attention via the phone (McClure et al., 2018). An additional factor to consider is prenatal maternal efficacy. For example, Coyne et al. (2020) found that mothers' who perceived themselves to be competent in caring for the infant had higher infant use of video chat around the age of 16 months. The extent to which an infant engages with a video call when a parent is using this smartphone function, may depend on prenatal maternal efficacy and how much experience the infant has had with video calls.

To build on the findings of the current study, parents need to be observed when interacting with the child in the home and using their smartphone to monitor health, monitor children, for work/education, to take photos and to make phone and video calls. Chapter 4 (Study 2a) addresses this by testing the effects of using the smartphone to take photos and to make calls on parent-child interactions in the home.

3.4.4 Age

Parent age has been found to be related to the quality of parenting, with older maternal age having an indirect effect on responsive parenting (Camberis et al., 2016). Previous research has found mixed results as to whether age is a factor

influencing technoference. Some research points to a relationship between maternal age and technoference, finding that the older the mother the less frequent technoference is (McDaniel & Coyne, 2016), and being a younger mother is associated with higher levels of technoference (McDaniel & Radesky, 2018a). Conversely, Linder et al. (2021) found no relationship between parent age and self-reported media absorption or media use, and Krogh et al. (2021) found that maternal age was not a significant predictor of technoference. However, all four studies exploring age and technoference measured device use more broadly, as opposed to smartphone use specifically, as in the current study. Here, I found that age predicted frequency of smartphone use but did not predict how regularly parents checked their smartphone. Age may therefore have an indirect effect on parent responsiveness via frequency of smartphone use, as Wolfers et al. (2020) found that how long the smartphone was used for, but not how regularly it was checked was related to maternal sensitivity; mothers who used their smartphones for longer were less sensitive to their child. It is possible that younger mothers who use their smartphones for longer periods of time are subsequently less sensitive. Alternatively, younger mothers may be less sensitive to their child's needs which results in longer use of their smartphone. This requires further exploration which is beyond the scope of this thesis.

3.4.5 Child's Interest in Parents' Smartphone

The data suggested that children are interested in their parent's smartphone when their parent is using it, but children are not regular users of their parent's smartphone. This may be due to the age of the children (under two) as infant screen time has been found to increase with age (Krogh et al., 2021). Alternatively, children may not use their parent's smartphone because the children have their own device

to use and the child engages in device use parallel to the parent (Domoff et al., 2019) and therefore does not need to use their parent's smartphone. If a child is interested in their parent's smartphone use but does not use their smartphone independently, perhaps the smartphone is not creating technoference and is instead acting as an object of shared attention. Whether parents co-use their smartphone with their child is explored in Chapter 4 (Study 2b).

3.4.6 Ownership of Smartwatch

The low levels of smartwatch ownership in the present sample suggest that at the time of data collection (2021) smartwatches were not as common as smartphones. As technology continues to develop, it is worth continuing to monitor levels of smartwatch ownership in parents to see if they can also create technoference in the parent-child interaction.

3.4.7 Limitations

The most obvious limitation to this study is that parents are self-reporting on their device use, which is liable to be prone to inaccuracies. The survey asked parents to reflect on their phone use in the past 24 hours, to try and reduce issues with accurately recalling smartphone use generally. However, as parents were not aware on the previous day that they were to complete the survey, it is still possible device use was misremembered due to not paying attention to every time they used their smartphone. An additional issue is social desirability; it is possible that parents reported using their smartphone less when engaged with their child not because they do so, but because that is the socially desirable response. These concerns are reinforced in a meta-analysis which found that self-reported device use rarely correlated with logged device use (Parry et al., 2021), a finding which is also found in

the parenting population (Yuan, 2019) as early as 6-8 weeks post-partum (McCaleb, 2020).

A second limitation centres around the sample size in this study. As noted in Section 3.2.1, the initial sample size was limited, both in size and heterogeneity, due to practical constraints and the exploratory nature of the study. Whilst statistical power is often not considered a primary concern in exploratory research, the sample still needs to be sufficient to yield informative results (Haile, 2023). The regression analysis exploring the relationship between demographics and parent smartphone use was particularly affected as participants with incomplete demographic data were excluded via listwise deletion, reducing the sample for this analysis from 68 to 47. This reduction is likely to have decreased statistical power for this analysis. Moreover, the reason for the missing data is unknown, i.e. whether the question was overlooked or consciously left unanswered, meaning it cannot be assumed that data were missing completely at random (Kang, 2013). Potentially, the missing data could be related to the demographic characteristics themselves, thus possibly rendering the remaining sample biased. Therefore, the findings reported in this chapter should be treated as tentative and hypothesis generating rather than as firm claims around parent smartphone use.

3.4.8 Conclusion

In this self-report measure of how parents use their smartphone when engaged with their child under the age of two, parents reported using their smartphone less when they are engaging with their child than when they are not engaging with their child. The most common way that parents use their smartphone when engaging with their child is to make video calls. Parents use the phone similarly when engaging with their child compared to not engaged with their child to

take photos, make phone calls, monitor health, monitor their child's health, and for education/work. Age was found to be a predictor of how long parents used their smartphone, but not how regularly they checked their smartphone. In Chapter 4, I move beyond exploring patterns in parent smartphone use and test whether parent smartphone technoference affects precursors to language development and language outcomes. Specifically, I use some of the key findings from Study 1 to inform the development of an experiment in the home environment.

Chapter 4 Study 2a and Study 2b Technoference in Early Parent–Child Interactions: Experimental and Survey Evidence on Language Precursors and Outcomes

4.1 Introduction

Findings from Chapter 3 indicate that parent smartphone use decreased when they actively engaged with their child; however, when parents did use their devices in this context, they were more likely to use their phone to make video calls than when not engaged with their child. Some uses of the phone were as likely to occur when engaged with the child in comparison to when not engaged with the child, these were taking photos, making phone calls, monitoring health, monitoring their child's health, and for education/work. The studies in this chapter build on these findings, and the line of argument presented in Chapter 1, by testing whether how the phone is used has different effects on features of the parent-child interaction which are believed to shape language development (Study 2a) and examines the relationship between parent smartphone technoference and child language outcomes (Study 2b).

As reviewed in detail in Chapter 1, parent smartphone technoference negatively affects parents' use of language during parent-child interactions (Gaudreau et al., 2021; Kelly & Ocular, 2021; Mikhelson et al., 2024) and language

outcomes in children (Corkin et al., 2021; Reed et al., 2017), although these findings are inconsistent (Nguyen, 2024). However, the underlying mechanisms as to how technoference may impact language is not yet known. I proposed that parent smartphone technoference may have an indirect effect on language by disrupting social eye gaze, parent responsiveness, and joint attention – each of which are precursors to language development (Morris et al., 2022). Indeed, parent smartphone use disrupts social gaze during parent-child interactions (Dinzinger et al., 2025; Elias et al., 2020; Inoue et al., 2021), but the task being completed on the phone impacts the extent to which gaze is disrupted, as does the context of the social interaction (Nomkin & Gordon, 2021; Radesky et al., 2014). In addition, smartphone technoference disrupts parent responsiveness both in natural observations and in experimental settings (Abels et al., 2018; Elias et al., 2020; Hiniker et al., 2018; Lederer et al., 2022; Mikić et al., 2025; Nakagawa et al., 2019; Ochoa et al., 2021; Vanden Abeele et al., 2020). Finally, parent smartphone use does not automatically create technoference, and a parenting breaking from the current dyadic interaction to use their smartphone could lead to joint media engagement (JME) (Takeuchi et al., 2011). JME has the potential to develop into joint attention, with the smartphone becoming the external object that a parent and child coordinate their attention to (Ochoa et al., 2021). Conceivably, smartphone technoference that subsequently leads to JME could have fewer negative effects on language development than technoference. Indeed, parent self-reports have found positive correlations between JME and language abilities in Argentinean 18-36-month-olds (Medawar et al., 2023). Furthermore, Corkin et al. (2021) found less frequent parent and infant co-use of screens was associated with lower infant vocabulary in 18-25-month-olds from New Zealand. Together these studies suggest

that JME may have some relationship with language development. However, it is also possible that parents who engage in more frequent JME also engage in more shared interactions generally. Without experimental work which manipulates JME, it is difficult to know whether a smartphone can increase shared interactions. This may explain why the same pattern of results is not reported in experimental research comparing shared non-digital play to shared digital play (i.e. JME) (Ewin, Reupert, McLean, et al., 2021). In this study, dyads spoke more new words per minute, and parents made more utterances to their 2-4-year-old when engaged in shared non-digital play compared to shared digital play. However, the shared digital play did result in more new words per minute and more utterances between the dyad than when the parent was independently using a device or magazine (Ewin, Reupert, McLean, et al., 2021). Whilst these findings suggest that shared device use has more positive effects on language than no interaction at all, it is important to note that the device used by parents for the shared interaction in this study was an iPad which had been preloaded with both educational and entertainment apps that were deemed high quality and suitable to the age of the children in the study. If JME were to occur with the parent's smartphone, findings may differ due to the smaller screen which could make it more difficult to jointly engage in the device. Secondly, due to the wide range of functions available on a smartphone, high-quality educational apps may not be loaded onto a parent's smartphone or used during any JME. Therefore, the same findings may not occur when a smartphone is the media used in JME. It is not yet known in an experimental setting whether more natural parent use of a smartphone that creates JME, i.e., taking photos, can also have beneficial effects on language in comparison to smartphone technoference.

In addition to the mechanisms involved in language development discussed so far (and addressed in Chapter 1 - social gaze, parent responsiveness, and JME), this chapter considers two additional features of parent-child interactions which facilitate language development: parents' use of language and infant vocalisations. I now address each of these in the context of parent smartphone technoference.

4.1.3 Technoference and Parent Language

Technoference may affect language development by disrupting the parent's role as a conversational partner. For example, in a longitudinal study on mothers and their infant under 1 year, Holmgren et al. (2025) found that mothers who spent the lowest amount of time on digital media used more descriptive language than mothers who spent more time on digital media. Studies which focused specifically on smartphones as the cause of technoference similarly found technoference to disrupt parents' verbal interactions (Kelly & Ocular, 2021; Radesky et al., 2015). At present, it is difficult to draw firm conclusions on the relationship between smartphone technoference and how parents use language during parent-child interactions, due to the lack of consistency in how technoference and parents' language are measured across studies (this is further explored in Chapter 7). Similarly, a range of measurements have been used to assess parents' language including, recording the frequency of verbal interactions initiated by the parent, contingent verbal responses by the parent to their child, the range of vocabulary used, the number of words spoken, and parent use of questions (Charman et al., 2000; Ewin, Reupert, McLean, et al., 2021; Gaudreau et al., 2021; Holmgren et al., 2025; Kelly & Ocular, 2021; Lederer et al., 2022; Radesky et al., 2015). Without standardised measures across studies, it creates a challenge when trying to understand the exact impact of

technoference on parent use of language. This is a particular issue if the effects are sensitive to the type of smartphone technoference the parent engages in.

4.1.3 Technoference and Infant Vocalisations

Infant vocalisations are an important part of the development of expressive language (Werwach et al., 2021). This is partly because of the social interaction that occurs between the parent and the vocalising infant; infants produce more complex vocalisations if their parent responds contingently to their vocalisations (Goldstein et al., 2003). Findings from Goldstein et al. (2009) identify that 5-month-old infants increase vocalisations during the still face episode. Similar findings, a reduction in positive vocalisations and an increase in negative vocalisations, are reported when parents use a phone during the 'still face' phase (Myruski et al., 2017; Stockdale et al., 2020) (see Section 1.2.1 and 1.5.2, Chapter 1). Together these findings suggest that infants are aware from an early age that their vocalisations elicit a response in their communicative partner. While studies using a modified SFP indicate that technoference does have an impact on infant vocalisations, due to the strict experimental setup, e.g., the parent not being allowed to interact with their infant during phone use and the absence of toys (Stockdale et al., 2020), these findings are unlikely to reflect regular smartphone technoference in everyday parent-infant interactions where the parent can potentially switch their attention between their child and smartphone (Hiniker et al., 2015). Although, this is not always what parents do and depends on the way the phone is used (Radesky et al., 2014). This highlights the importance of studying technoference in naturalistic home environments, where contextual factors may shape the impact of smartphone use on infant vocalisations.

4.1.4 The Current Study

The two studies presented in this chapter aimed to explore the impact of parent smartphone technoference on precursors to language development and language outcomes in young children. This aim is based on the extant research reviewed in this chapter (and Chapter 1), which suggests that: 1) smartphone technoference can disrupt features of parent-child interactions which facilitate language development, 2) technoference can disrupt language learning by disrupting the parent's role as a conversational partner and by disrupting infant vocalisations, 3) JME may have positive effects on language.

To explore these aims, this chapter addresses three issues with the literature to date. First, studies measuring social gaze, parent responsiveness, and JME have either used natural observations or have been conducted in controlled settings in the laboratory. Whilst naturalistic observations are more likely to reflect parents' and children's natural responses to technoference, intricacies may be missed as the interactions are not recorded. On the other hand, in a laboratory setting the interactions can be video recorded and coded, increasing the reliability of measurements of the interaction, however the interactions are less natural, i.e. the parent being completely unresponsive. Second, to date, no research has compared different types of smartphone technoference and parent-child interactions. Some tasks may be more absorbing than others, and absorption has been found to relate to less responsive caregiving than intermittent device use (Vanden Abeele et al., 2020). Third, there is a need to explore the cumulative effects of parent smartphone technoference on parent responsiveness. Cross-sectional research, as with observations and laboratory experiments, only provide data on how responsive a parent is in that one context and occurrence. Likely, any relationship between

technoference and parent responsiveness is cumulative. Study 2a will address the first two gaps, by comparing parents using the smartphone to take photos in comparison to a call, in the home environment. These functions of the phone were selected over silent text-based activities (such as text messaging or social media) for two reasons. First are the communicative demands that the phone use places on the user, which may feasibly differentially affect the parent-child interaction. Taking photos of the infant draws on the visual attention of both the infant and the parent, creating an opportunity for JME. In contrast, making a call requires overt communicative linguistic interruption whereby the user directs language to the recipient on the phone, possibly negatively impacting on the language used in the live dyadic interaction. Study 2a also manipulated call modality, allowing for a comparison between a phone call which places demands on language but not visual attention, and a video call which places demand on visual attention and verbal communication. Second, as revealed in Study 1, some phone functions are more likely to occur when parents are not engaged with their child. Video calls were found to be more likely to occur during engagement with the child and a phone call and taking photos occurred similarly between levels of engagement. Thus, the inclusion of these activities reflects the type of phone-based interruptions that an infant is likely to experience in the home. Study 2b addresses the third gap, by asking parents to self-report on general levels of smartphone technoference and parent responsiveness.

4.2 Study 2a

Study 2a was conducted with parents and their 9- to 10-month-old infants to test how parent smartphone use during parent-infant interactions might affect features of the social interaction which aid language development (social gaze, infant

expressions, infant vocalisations, parent responsiveness, and parent use of language). This age group was selected as gaze following – a fundamental characteristic of dyadic interactions - is established by 8 months of age (Gredebäck et al., 2010) and consistently used in 9-month-olds (De Groote et al., 2007). Moreover, as technoference in parents has been found to increase with infant age between 2 to 7 months (Krogh et al., 2021), by the age of 9 months it is likely that infants will have relatively extensive experience of technoference. In addition, around the age of 9 months, infants move from sensorimotor manipulation to focus on objects (Tamis-LeMonda et al., 2002), which creates more opportunities for shared interactions that can be disrupted by technoference. Nine- to 10-month-old infants are also still at an age where they require parent support, making technoference more salient. By 13 months of age, parents are less likely to perform behaviours for their child and more likely to use verbal direction (Power, 1985), therefore any parent smartphone use may be less disruptive to the intricacies of the interaction than in younger children.

Study 2a addresses two key research questions: 1) How does parent smartphone technoference impact parent-infant interactions? 2) Does the way the smartphone is used have different effects on parent-infant interactions? As previously discussed, there is a lack of research exploring technoference in the child's home environment. As much of the daily routines which facilitate face-to-face interactions occur in the home, Study 2a took place in the infants' homes to better reflect natural play interactions. Parents were asked to play with their infant across three different conditions: 1) using their smartphone to take photos during the play interaction, 2) using their smartphone to make either a video or phone call during the play interaction, and 3) uninterrupted play. Based on the previous literature (Elias et

al., 2020; Lederer et al., 2022; Nomkin & Gordon, 2021; Radesky et al., 2014; Stockdale et al., 2020; Tonga, 2023; Vanden Abeele et al., 2020), it is hypothesised that:

H1a) Infant gaze towards the parent, parent gaze towards the infant, and mutual gaze between the parent and infant will be reduced during parent-child interactions when the parent uses a smartphone (to make a call or to take photos) in comparison to uninterrupted play.

H1b) Infants will exhibit a greater duration of spontaneous expressions when the parent uses a smartphone (to make a call or to take photos) in comparison to uninterrupted play.

H1c) Parents will make fewer contingent responses, and a higher proportion of non-contingent, and non-responses to their infants' expressions, when using a smartphone (to make a call or to take photos) in comparison to uninterrupted play.

H1d) Parent language directed towards the infant will be less frequent, whereas infants will make more vocalisations, when the parent uses a smartphone (to make a call or to take photos) in comparison to uninterrupted play.

H2) The type of smartphone use (condition 1: photos, condition 2: phone call or video call) will affect the amount of time that parents gaze to the infant, infants gaze to parent, the dyad spend in mutual gaze, infants and parents direct gaze to the phone, and that parents spend speaking to the infant. The type of smartphone use will also affect the number of contingent parent responses, and the frequency of infant vocalisations. As type of phone use has not been directly compared in research, it is not possible to predict the direction of the results.

4.3 Method

4.3.1 Participants

Due to a lack of literature exploring the impact of different types of smartphone technoference on the parent-child interaction, it was difficult to use previous effect sizes in identifying a sample size with suitable power for the current study. To determine the current sample size, experimental studies testing key measures in Study 2a (social gaze, parent responsiveness, and parent use of language) within the context of parent smartphone technoference were consulted. Experiments measuring social gaze have been conducted on 3-5-month-olds (Inoue et al., 2021), 3-6-month-olds (Nomkin & Gordon, 2021), and 6-month-olds (Dinzinger et al., 2025), with sample sizes of 13, 20, and 65 participants respectively utilising a within participant design. Experiments measuring parent use of language on children aged 2-5-years have yielded sample sizes of 24 and 33 participants in within participant designs and 57 participants in a between participant design (Ewin, Reupert, McLean, et al., 2021; Lederer et al., 2021; Gaudreau et al., 2021). Two experiments have tested parent responsiveness, one study included a sample of 52 5-6-month-olds in a within participant design (Mikić et al., 2025) and one included a sample of 54 20-22-month-olds in a between participant design (Konrad, Hillmann, et al., 2021). As the sample sizes varied across studies and because the age of the sample in these studies differed to the age of the infants in Study 2a, the effect sizes were also considered. Where reported, effect sizes in these technoference experiments were medium to large (ηp^2 = .12, .50, .78, and .83; η2 = .43). Given the limited directly comparable evidence, a target of 40 dyads was chosen, consistent with the mid-range of sample sizes in these studies.

Fifty-nine parent-infant dyads were ultimately recruited. Infants were aged 9-10 months (M_{age} = 294.86 days, *SD* = 21.42 days) and 32 were female. No dyads were excluded, but data was removed for some dyads during the analysis. Details about data exclusion are provided in the results. As the sample was recruited online, dyads resided in different countries. The majority were from the U.S (81%), the remaining dyads were from Great Britain (14%), Canada (<1%), and Denmark (<1%). 24% of parents were aged between 22-29 years-old, 71% were 30-39 years old, and <1% were aged 40-44 years. 93% of infants lived in a two-parent family. 47% of infants did not have siblings, and 46% of infants had 1 or 2 siblings. Further characteristics of the parents are shown in Table 4.1. The parents were predominantly White (80%) and 88% of the sample were educated to at least a bachelor's degree. The average household income was $106,250 (*SD* = $53,340.54).

Parent-infant dyads were recruited by emailing parents who had signed up to a university database to participate in child development research, and advertisements were also shared via social media. Parents who were already signed up to participate via the Children Helping Science website received automated emails if their infant was eligible to participate. All infants were full-term; parents received either a £5 or $5 Amazon voucher for participating in the study. The University Ethics Committee approved this research (ETH2021-1866) and informed consent was gathered online prior to participation in the study.

Table 4.1

Characteristics of the Sample

Ethnicity	**N (percentage)**
Asian	4 (7)
Black	2 (3)
Hispanic	2 (3)
White	47 (80)
Not stated	4 (7)
Education	**N (percentage)**
GCSE (or equivalent)	3 (5)
A Levels (or equivalent)	2 (3)
Bachelor's degree	19 (32)
Master's degree	22 (37)
PhD	5 (8)
Other postgraduate qualification	6 (10)
Not stated	2 (3)

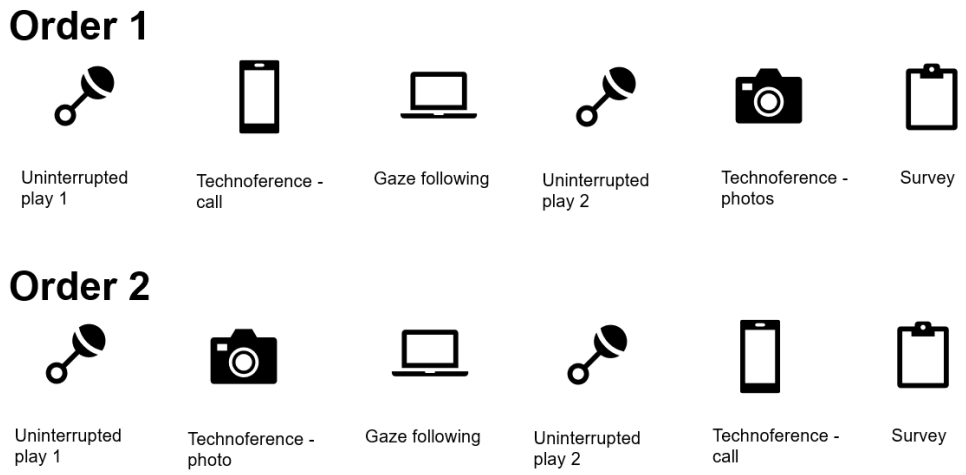
4.3.2 Design and Variables

The experiment utilised a within participant design comparing four conditions which included two uninterrupted play periods (uninterrupted 1, uninterrupted 2) and two technoference conditions (photo, call). To examine the effect of call modality, the call condition included a nested between participant manipulation (phone call vs. video call). Each condition lasted 3 minutes. Uninterrupted play occurred twice, first at baseline (uninterrupted 1) and again after the first technoference interruption (uninterrupted 2). Technoference occurred twice, once when the phone was used to

take photos of the infant (photo) and again to make either a phone call or video call (call). The presentation order of the two technoference conditions was counterbalanced. Thirty participants completed the call condition first (Order 1: Uninterrupted 1, call, gaze following task, uninterrupted 2, photos, survey), whereas 29 dyads completed the photo condition first (Order 2: Uninterrupted 1, photos, gaze following task, uninterrupted 2, call, survey). See Figure 4.1 for an overview of the possible order of experimental conditions.

Figure 4.1

Possible Order of Experimental Conditions



Several dependent variables were measured in this study: parent language (naming or non-naming), parent responsiveness, parent gaze to infant, parent gaze to phone, mutual gaze, infant gaze to parent, infant gaze to phone, infant vocalisations, infant spontaneous expression (expressive or fussy). Each outcome was measured via observation, and the operationalisation of each variable is described in the Section 4.3.6. Gaze following was also measured to be included in the analysis as a covariate.

4.3.3 Apparatus

The experiment was hosted via the online platform Children Helping Science (https://childrenhelpingscience.com/). Parents create an account with Children Helping Science and can participate in a range of studies which match their child's age. Participation occurred in their own homes and access to a computer/laptop with a webcam was required. As the researcher, I inputted the computer code for the study, allowing the study to run independently via the website without any live researcher input or interaction during participation.

4.3.4 Measures

Parents completed an online survey through Qualtrics, which assessed their smartphone use. The questionnaire was a shortened version of that used in the study reported in Chapter 3.

General Smartphone Use

General smartphone use includes parents' smartphone use both when they are, and when they are not, with their child. Two items from Appendix D (17 and 18), and described previously in Chapter 3, assessed frequency and duration of smartphone use.

Three items, also used in Chapter 3 (question 19– Appendix D), distinguished between parents' smartphone use whilst engaging with their child and smartphone use that occurs when not engaging with their child. Item one asked participants "How often do you use your smartphone when your child is sleeping/napping?",item two asked "How often do you use your smartphone when your child is awake, and you are not actively engaging with them?", and item three asked "How often do you use your smartphone when your child is awake, and you are actively engaging with

them?". Measurement was on a five-point Likert scale; "Always", "Most of the time", "About half the time", "Sometimes", and "Never".

Parents were asked how they used their phone both when engaged with their child and not actively engaged with their child. This item was amended from the original survey in Chapter 3, which listed 26 different uses of a smartphone (including the option of 'other'). These 26 uses were narrowed down, with those uses that were infrequently reported when engaged with the child being omitted. Based on the analysis from the study reported in Chapter 3, any activity that had an estimate greater than 0.7 (out of 4), in the direction of suggesting the activity occurred more when interacting with their child, was retained. This left 9 activities: controlling smart devices, exercise, monitoring health, monitoring children, making phone calls, taking photos, playing games, making video calls, and other.

Technoference Measure

One measure of technoference (taken from Chapter 3) was included, which asked parents, "How often do you use your smartphone when your child is awake, and you are actively engaging with your infant?" Measurement was on a five-point Likert scale; "Always", "Most of the time", "About half the time", "Sometimes", and "Never".

JME

One item, also used in Chapter 3, asked parents if they interact with their child when their child uses a smartphone (item 24 – Appendix D).

Child Smartphone Use

Two items taken from Chapter 3 asked parents whether their child shows an interest in their smartphone and whether the parent lets their child use their smartphone (items 22 and 23 – Appendix D).

Gaze Following Task

The gaze following task was included to rule out developmental differences in baseline gaze following, which was deemed necessary as one of the planned dependent variables was infant gaze following during the dyadic interaction. However, as discussed in Section 4.3.5, it was not possible to measure gaze following during the interaction in practice.

After the first technoference condition, infants viewed 8 gaze following trials. In each trial a female model looked to a toy positioned either on their left or right. All gaze following trials were video recorded and coding was completed offline (see Section 4.3.6). For each trial, the direction of an infant's first gaze shift was recorded if the infant initially focused on the model during the first second of the trial, prior to the model turning their head. Trials were scored as 'correct' (+1) if the infant shifted their gaze matching the model's head turn, or 'incorrect' (-1) if the infant's gaze shifted to the non-target toy (Brooks & Meltzoff, 2005). Infants who did not fixate initially or fixated without making a subsequent gaze shift were recorded as 'non looking' (0). An overall baseline gaze following score was calculated as the sum across all 8 trials, the possible range for this score was -8 (all incorrect looks) to +8 (all correct looks) (Brooks, 2014). For trials marked as 'correct', reaction time to follow the model's gaze (Byers-Heinlein et al., 2021) and fixation time on the correct object were both recorded in milliseconds (Farroni, Massaccesi, et al., 2004). The total gaze following score (-8 to +8) served as the planned covariate in the mixed model ANCOVAs.

4.3.5 Procedure

Parents participated in the study at a time of their choosing, by selecting the study via the Children Helping Science website. After selecting the study, parents configured their camera, read a consent form, and gave brief, recorded, verbal consent. Subsequent screens gave parents further information about the study and an overview of what would happen throughout the study. At this stage parents were informed that the baby did not need to be present yet.

Written instructions guided parents as to how the camera should be set up. An image was also displayed to signal what was, and was not appropriate, and where the parent and baby should be in the screen. The instructions stated that an area needed to be setup to facilitate play and include any toys and objects that would be necessary to interact with their baby. The webcam was required to be positioned to ensure that both the baby and the parent were in the recording and that both of their faces could be seen. An additional screen was shown to parents to allow them to review their setup and see their webcam view before commencing with the study. When parents were ready, they moved the study on by selecting a button on the screen.

Parents were then instructed to play and interact with their baby as they usually would (uninterrupted play 1) for a three-minute period whilst the webcam recorded their interaction. Parents started the recording by clicking a button on the screen, a sound played at the end of the three-minute period to signal the end of the recording.

Parents had to select a button to proceed to the next screen where they were advised that the baby could take a break if needed and were informed about the next part of the study. Parents next completed one of the two technoference conditions.

For technoference via photos, parents were instructed to use their smartphone to take photos of their baby and to share photos with their baby as they usually would when interacting with their infant. Before starting the recording, another opportunity was given to check the positioning of the webcam. As before, parents clicked a button to start the recording and a sound played to signal the end of the recording and interaction period. For technoference via a call, parents were randomly allocated to either make a phone call or a video call whilst interacting with their infant. They were instructed to contact the individual they would call before starting the recording to ensure that they were free and willing to take the call. Parents were instructed to start the recording once the recipient was on the phone and to discuss the most recent television programme/film they had watched and/or book they had read, whilst interacting with their infant as they usually would when making a call in that way. As before, a sound signalled the end of the recording period.

Parents were again given the opportunity to give their infant a break if needed and were then instructed to position their infant in a highchair or on their lap facing the computer screen. To assess infants' ability to gaze follow, infants were shown a 10 second video of a White female model wearing a white top who was sat behind a table, the table had one toy positioned either side of the model. At the beginning of the video the model looked directly at the camera, smiled and said, 'Hi baby', as communicative cues can facilitate gaze following (Senju & Csibra, 2008). The model then turned her head and eyes to look at either the left- or right-hand toy. The two plastic toys were identical in shape and size but differed in colour. The model turned silently, without any further emotional expression and held her gaze on the toy for five seconds (Caron et al., 2002). She then turned her head and eyes back to a central position, facing the camera, whilst remaining silent and expressionless. Eight

trials were presented, four looking to the left and four looking to the right. The order was randomised for each infant. Parents were asked to close their eyes whilst their infant completed these trials (Caron et al., 2002) but were given the opportunity to preview a video under the instruction that the infant does not view the preview. During the trials, parents were able to pause the video if their infant needed to be resettled. If this happened, the paused video returned to the beginning upon resuming the trial.

Parents then moved to the next set of instructions where they were given the opportunity to give their infant a break if needed. When ready, parents completed uninterrupted play 2. The instructions and task for uninterrupted play 2 were identical to uninterrupted play 1.

After a further opportunity to allow their infant a break, parents completed the remaining technoference condition. Once complete, parents then clicked a button to be taken to the final part of the study.

On the final screen participants received a written debrief and were directed to complete a short questionnaire in Qualtrics (www.qualtrics.com).

In each of the technoference conditions and uninterrupted play 2, I planned to assess gaze following during natural play and to see if this differed across play conditions. To do this, 20 seconds after the recording had begun a sound of chimes would signal the parent to turn their head and eyes to look at the computer screen. On the screen was an image of a colourful animal. There were four different animal images and the order in which these appeared was randomised for each trial. Parents were required to look at the image until it disappeared, at which point they were to continue to interact with their baby in the way they had previously been instructed (uninterrupted play, photos, or call). In each three-minute observation the

noise would sound every 40 seconds, and the image remained for 5 seconds, resulting in four periods of gaze following in each observation. However, this manipulation was not effective as the chimes also grabbed the attention of the infant to look to the source of the noise i.e. the laptop/computer. Therefore, although many infants did direct their attention to the screen, alongside their parent, they were not doing so due to gaze following but because of the chimes. Consequently, this manipulation did not allow for testing gaze following as designed and was omitted from any analysis.

4.3.6 Coding Scheme

The three-minute play interactions recorded behaviours from the infant and the parent. These behaviours were parent language (naming or non-naming), parent responsiveness, parent gaze to infant, parent gaze to phone, mutual gaze, infant gaze to parent, infant gaze to phone, infant vocalisations, infant spontaneous expressions (expressive or fussy). Any behaviour that was not part of a social interaction was not coded (Tomasello & Todd, 1983). For example, if the parent was talking to the recipient on the phone (as in the call condition), the speech was not coded as it was not part of the interaction with the infant.

Data was coded offline using ELAN (2023) by myself and seven students. I trained the students to implement the coding scheme on a subset of the behaviours, rather than each coder coding all behaviours. Three students coded social gaze, infant vocalisations, and parents use of language, three students coded infant expression and parent contingency. This created two groups of coders. To assess the ICC, 26% of the videos in each group of coders were coded by all students and compared using a two-way, average measurement agreement model. One student coded gaze following, to assess the ICC, I reviewed a random sample of 20% of

videos that the student had already coded. The ICC for each of the behaviours was deemed to have good reliability if it was above 0.75, as per Koo and Li (2016).

Gaze: Eye gaze between infant and parent was coded separately for each member of the dyad. The duration of the parents' gaze to the infant's face/eyes were recorded (ICC = .84), as was the duration of the infant's gaze to the parent's face/eyes (ICC = .92). Mutual gaze, where both the infant and parent are focused on each other's face/eyes at the same time was also coded for duration (ICC = 1). In addition, in the two interactions where parents were asked to use their phone (to take photos and make a call), infant eye gaze (ICC = .76) and parent eye gaze (ICC = .88) towards the phone was further coded for the duration of looking.

Spontaneous expression: A spontaneous expression is one that is initiated by the infant, not prompted by the parent, and could be vocal or physical. Spontaneous expression was coded based on Nicely et al. (1999) as either expressive or fussy. Expressiveness included the infant demonstrating any positive expressions of pleasure or need. For example, if the infant spontaneously picks up a toy and puts it in their mouth, this would not be coded. However, if the infant picks up the toy and waves it up and down, this would be coded. Vocal spontaneous expressions included any non-prompted vocalisations, which could be positive or neutral. Infant fussiness included any negative expressions such as crying, these could be physical or verbal and may or may not be directly signalled to the parent. Inter rater reliability was good (ICC = .87).

Contingency: To identify a contingent response from the parent, first any spontaneous expressions from the infant were coded. For each spontaneous expression, if the parent responded to the expression within five-seconds (Tamis-LeMonda et al., 2001) this response was recorded and was identified as either

matching the infant's expression or not matching it. The parent's response was deemed as matching if it matched the medium, or needs of the infant's expression. For example, if the infant reaches for a toy and the parent responds by passing it to them, this is contingent. If the parent responds by talking to the infant about something unrelated to the toy, this is not contingent. The parent's response was also coded as matching if it matched the emotion of the infant's expression. For example, if the infant made positive vocalisations and the parent vocalised in a positive tone, this would be contingent. If the parent responded in a neutral tone, this would be non-contingent. If the parent did not respond to the infant's expression within 5 seconds, or the parent behaviour was already ongoing, rather than in response to the expression, this was coded as a non-response. If the infant made another expression within the 5-second parent response time frame, before the parent had responded, this was coded as no response. The number of contingent, non-contingent, and non-response was recorded for each dyad in each of the four play interactions. As the number of responses is dependent on the infant's expressions, for the analysis the proportion of each response was calculated from the total number of responses within each three-minute observation period. Inter-rater reliability for contingent responses was excellent (ICC = .98), and good for both non-contingent responses (ICC = .73), and non-response (ICC = .81). Whilst the ICC for non-contingent responses was below 0.75, I deemed 0.73 acceptable due to the subjective nature of having to infer what the infant was communicating to decipher whether the parent had been non-contingent. There were not enough instances of infant fussiness in the sampled videos to report the ICC for infant fussiness.

Infant vocalisations: Based on the coding scheme used by Chang et al. (2016), an infant vocalisation was any non-distress vocal sound, this did not include

organic sounds such as burps, neither did this include cries or grunts. Vocalisations were coded for the precise duration they occurred. A break of 500ms or more between vocalisations, signalled the start of a new vocalisation. If the break was less than 500ms, coding continued through the break. Inter-rater reliability was good (ICC = .79).

Parent language: All utterances and non-linguistic vocalisations e.g., gasps directed to the infant were coded for the precise duration they occurred. A break of 500ms or more between vocalisations, signalled the start of a new vocalisation. If the break was less than 500ms, coding continued through the break. Utterances were classified as naming (e.g. “look at the rattle”) or non-naming (e.g., “bah, bah”, “you like that don’t you?”) (Chang et al., 2016). As each vocalisation was coded for its duration, to be classified as naming, only one naming word was required to be present during each period of vocalisation. Inter-rater reliability was excellent for naming (ICC = .92) and non-naming (ICC =.94).

Gaze following: All gaze following videos were coded by a rater who was unaware of the direction the model turned to. Inter-rater reliability was moderate to good (ICC = 0.68 for looking direction, ICC = 0.72 for reaction time, and ICC = 0.87 for fixation time). The lower than anticipated ICC is partly due to not being able to see the screen the infant was looking at during coding. This allowed for some subjectivity in interpreting whether the infant was looking to the left or right side of the screen.

4.3.7 Data Analysis

To test H1 and H2 (Sections 4.4.2 and 4.4.3), all data was checked for normality by visual inspection using QQ plots and Shapiro-Wilk's test. Levene’s test was applied to ascertain homogeneity of variance between the four play conditions

(uninterrupted 1, uninterrupted 2, call, photo) and Box's M-test to assess homogeneity of covariances between the video call and phone call conditions. If these assumptions were met, a two-way mixed ANOVA was applied to analyse the data and post hoc analysis using paired t-tests with Bonferroni correction were applied. However, where the assumptions were not met, a robust two-way mixed ANOVA was applied on 20% trimmed means, using the R package WRS2 (Mair & Wilcox, 2020). Post hoc tests when using a two-way mixed ANOVA on 20% trimmed means were computed with the rmmcp() function which uses Hochberg's approach to control for the family-wise error (Mair & Wilcox, 2020). Visual representations of data did not differentiate between the two different call types (video or phone), unless the ANOVA revealed a significant effect of type of call. If the gaze following data met the assumptions, an ANCOVA was applied to include gaze following score (-8 to +8) as a covariate. If these assumptions were not met, gaze following score was assessed separately.

4.4 Results

Data analysis was conducted in R version 4.4.2.

4.4.1 Parent Smartphone Use

I first explored the survey data to ascertain how parents of 9-10-month-olds use their phone. Two parents did not complete the survey and are omitted here. Parents' self-reported phone use can be seen in Table 4.2. Most parents reported checking their smartphone between 3-9 times per hour (62%) and using their smartphone for 3-4 hours per day (51%).

Table 4.2

Percentages of Duration and Frequency of Smartphone Use

Frequency	**N (percentage)**
0-2 times an hour	7 (12)
3-5 times an hour	22 (39)
6-9 times an hour	13 (23)
10-12 times an hour	10 (18)
13-15 times an hour	3 (5)
More than 15 times an hour	2 (3)
Duration	**N (percentage)**
Less than 60 minutes per day	1 (2)
1-2 hours per day	12 (21)
3-4 hours per day	29 (51)
5-6 hours per day	11 (19)
7-8 hours per day	3 (5)
Over 9 hours per day	1 (2)

Figure 4.2 displays the various ways that parents use their smartphones during different levels of engagement with their infant. As data was ordinal, Wilcoxon Signed Rank Test with Bonferroni correction was applied to see which activities parents were more likely to use their smartphone for when engaged with their infant in comparison to when they were not engaged with their infant. Parents were significantly more likely to use their smartphone to play games, $z = -5.44$, $p < .001$, $r = 0.52$, control smart devices, $z = -5.26$, $p < .001$, $r = 0.55$, monitor health, $z = -6.01$, $p = .03$, $r = 0.41$, and monitor their child (e.g., nap times), $z = -5.64$, $p = .04$, $r = 0.38$,

when they were not engaged with their child compared to when they are engaged with their infant. No other significant differences were found (see Table 4.3).

Figure 4.2

Portion of Daily Smartphone Use by Activity and Level of Engagement With Child

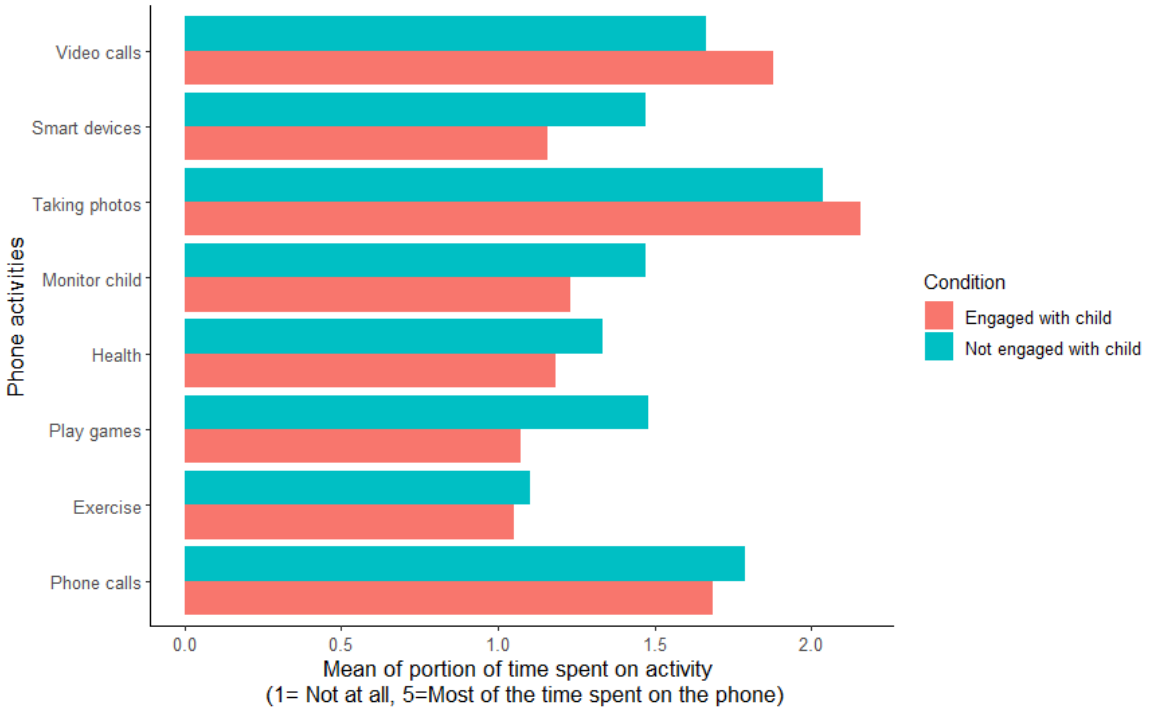


Table 4.3

Wilcoxon Signed-Rank Statistics Comparing Each Type of Smartphone Use by Parent When Engaged With Their Infant or Not Socially Engaged With Their Infant

Activity	**Engagement**	***M***	***SD***	***z***	***p***	***p adjusted***	**Effect size (r)**
Phone calls	Engaged	1.67	0.69	-5.76	0.19	n.s	0.16
	Not engaged	1.79	0.62				
Exercise	Engaged	1.05	0.23	-6.46	0.15	n.s	0.23
	Not engaged	1.11	0.31				

Playing games	Engaged	1.07	0.26	-5.44	<.001	<.001	0.52
	Not engaged	1.48	0.85				
Monitoring	Engaged	1.23	0.50	-5.64	<.001	.04	0.38
child	Not engaged	1.48	0.73				
Monitoring	Engaged	1.19	0.44	-6.01	<.001	.03	0.41
health	Not engaged	1.33	0.61				
Taking photos	Engaged	2.16	0.82	-5.89	0.24	n.s	0.13
	Not engaged	2.04	0.71				
Controlling	Engaged	1.16	0.37	-5.26	<.001	<.001	0.55
smart devices	Not engaged	1.48	0.63				
Making video	Engaged	1.88	0.95	-6.00	0.06	n.s	0.19
calls	Not engaged	1.67	0.74				

Parents also reported on how often they used their phone when their child was asleep, their child was awake and not engaged with them, and when their child was actively engaged with them. See Table 4.4 for the means and standard deviation. A Kruskal-Wallis test, for ordinal data, found a significant difference in the frequency of parents' smartphone use across levels of engagement with their child, $H(2) = 89.7$, $p < .001$, $\eta^2 = .52$. Post hoc comparisons using Dunn's test with Bonferroni correction showed that parents used their phone more when their infant was asleep compared to when their infant was awake but not actively engaged with them ($z = -4.51$, $p < .001$) and compared to when actively engaged with the infant ($z = -9.47$, $p < .001$). Parents also used their smartphones more when their infant was awake but not actively engaged with them, compared to active engagement ($z = 4.95$, $p < .001$).

Table 4.4

Means and Standard Deviations of Smartphone Use by Level of Engagement With Their Infant (1 = Everyday, 5 = Occasionally Or Never)

Level of engagement	***M (SD)***
Infant asleep	2.11 (0.82)
Infant awake but not socially engaged	3.04 (0.80)
Parent actively engaged with child	3.93 (0.63)

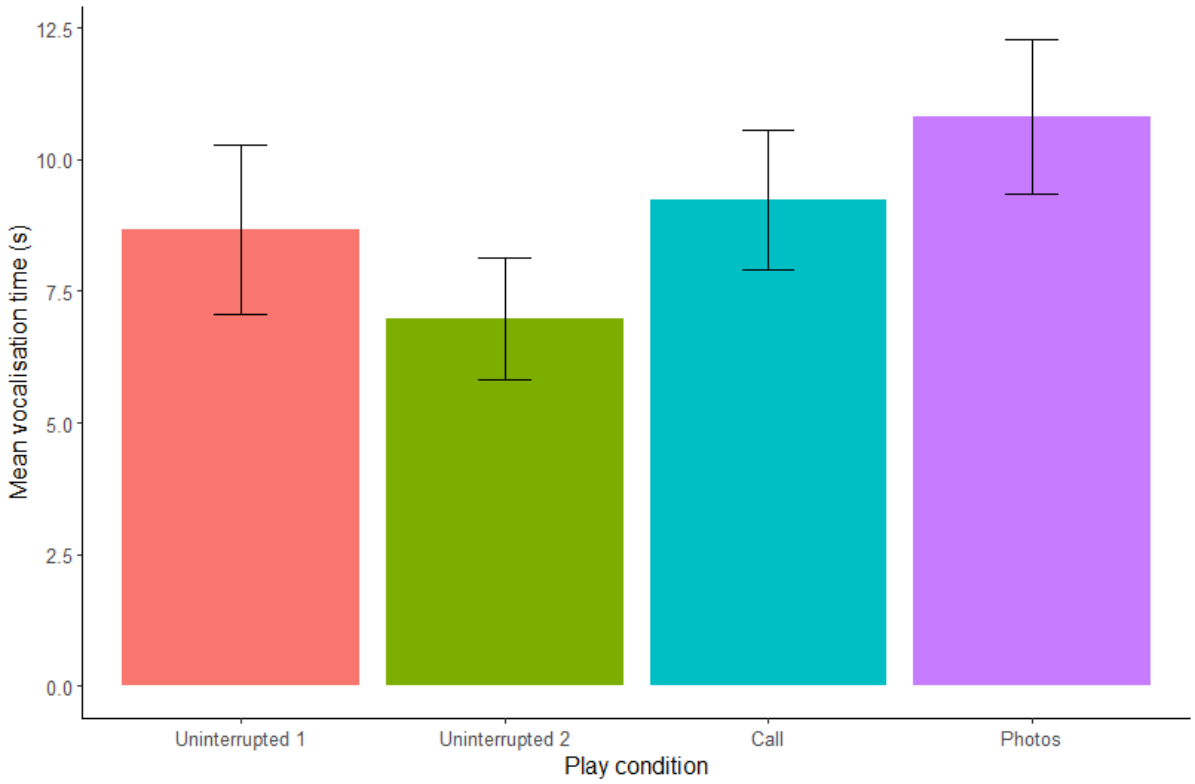
4.4.2 Parent-Infant Interactions – Infant Behaviours

Infant behaviours consisted of infant vocalisations, spontaneous expression, infant gaze to the parent and phone, and mutual gaze.

Infant vocalisations: Frequency of infant vocalisations was compared across the four play conditions (uninterrupted 1, uninterrupted 2, call, photo). The data met the assumptions for a two-way mixed ANOVA, with play conditions as the within factor and the two call conditions (phone, video) as the between factor. Of note is that infants did not spend very long making vocalisations with a range of 6.91 seconds – 11.2 seconds across all conditions (Figure 4.3). The two-way mixed ANOVA showed no main effect of play condition, $F(3, 146) = 2.44$, $p = .08$, $\eta^2 = 0.017$, no main effect of type of call, $F(1, 57) = 0.31$, $p = .58$, $\eta^2 = 0.003$, and no interaction between play condition or type of call, $F(3, 146) = 0.21$, $p = .86$, $\eta^2 = 0.001$.

Figure 4.3

Infant Vocalisations Across Play Conditions



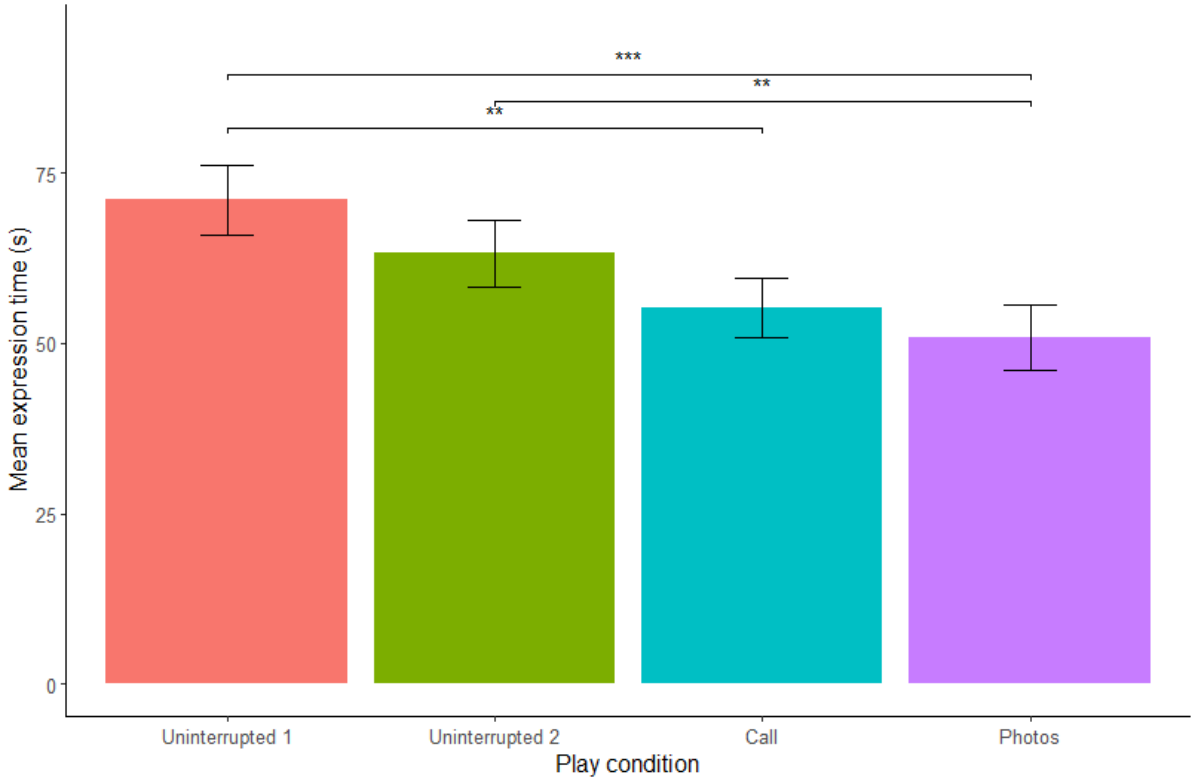
Spontaneous expression: Infant expression and fussiness were analysed separately.

Duration of infant expression was compared across the four play conditions (uninterrupted 1, uninterrupted 2, call, photo), with call condition (phone, video) as a between factor (see Figure 4.4). The data did not meet the assumptions for a two-way mixed ANOVA as Shapiro-Wilk's test identified data to be not normally distributed for participants allocated to the phone call condition when taking photos ($p < .05$) and for participants allocated to the video call condition during uninterrupted 1 ($p < .05$). Levene's test revealed homogeneity of variance for uninterrupted 1 ($p = .11$), uninterrupted 2 ($p = .58$), photo ($p = .13$), but not call ($p < .001$). Box's M-test

indicated the call data also violated homogeneity of covariances ($p < .001$). A robust two-way mixed ANOVA on 20% trimmed means found no main effect of type of call (phone, video), $Q(1, 28) = 1.65$, $p = .21$, $\eta^{2\,(robust)} = 0.06$, and there was no interaction between play conditions and type of call, $Q(3, 26) = 0.398$, $p = .76$, $\eta^{2\,(robust)} = 0.04$. The main effect of play condition was significant, $Q(3, 26) = 9.13$, $p < .001$, $\eta^{2\,(robust)} = 0.51$. Post hoc tests revealed that infants spent more time being expressive during uninterrupted 1 ($M = 71.1_{seconds}$, $SD = 39.6_{seconds}$) than when parents used the phone to make a call ($M = 55.2_{seconds}$, $SD = 32.7_{seconds}$), $z = 11.92$, $p < .01$, and when parents used the phone to take photos ($M = 50.8_{seconds}$, $SD = 36.9_{seconds}$), z = 20.28, $p < .001$. Infants also spent more time being expressive during uninterrupted 2 ($M = 63.2$ seconds, $SD = 37.2$ seconds) than when parents used their phone to take photos, $z = 14.79$, $p < .01$. There was no significant difference between the two uninterrupted play conditions ($z = 7.12$, $p = .11$), the two technoference (call, photo) conditions ($z = 4.56$, $p = .23$), or between uninterrupted 2 and when parents used their phone to make a call ($z = 6.25$, $p = .14$).

Figure 4.4

Infant Expression Across Play Conditions



Infants did not spend much of each three-minute play period being fussy (Table 4.5) and 18 participants did not demonstrate any fussiness throughout the experiment. The data for infant fussiness was not normally distributed, as assessed by Shaprio-Wilk's, $p < .001$ for all play conditions across both phone conditions, subsequently a robust two-way mixed ANOVA was applied on 20% trimmed means. There was no main effect of type of call (phone, video), $Q(1, 28) = 0.84$, $p = .37$, $\eta^{2\,(robust)} = 0.03$, no main effect of play condition, $Q(3, 22) = 1.76$, $p = .18$, $\eta^{2\,(robust)} = 0.19$, and no interaction between play conditions and type of call, $Q(3, 22) = 0.17$, $p = .92$, $\eta^{2\,(robust)} = 0.02$.

Table 4.5

Means and Standard Deviations of Length of Time Infants Spent Being Fussy Across Each Play Condition and Between Each Call Condition

Play condition	**Call condition**	***M (s)***	***SD***
Uninterrupted 1	Phone call	1.07	3.39
	Video call	1.41	2.83
Uninterrupted 2	Phone call	0.91	2.48
	Video call	2.98	6.16
Photos	Phone call	10.5	22.7
	Video call	8.40	15.7
Call	Phone call	7.16	21.3
	Video call	5.5	10.5

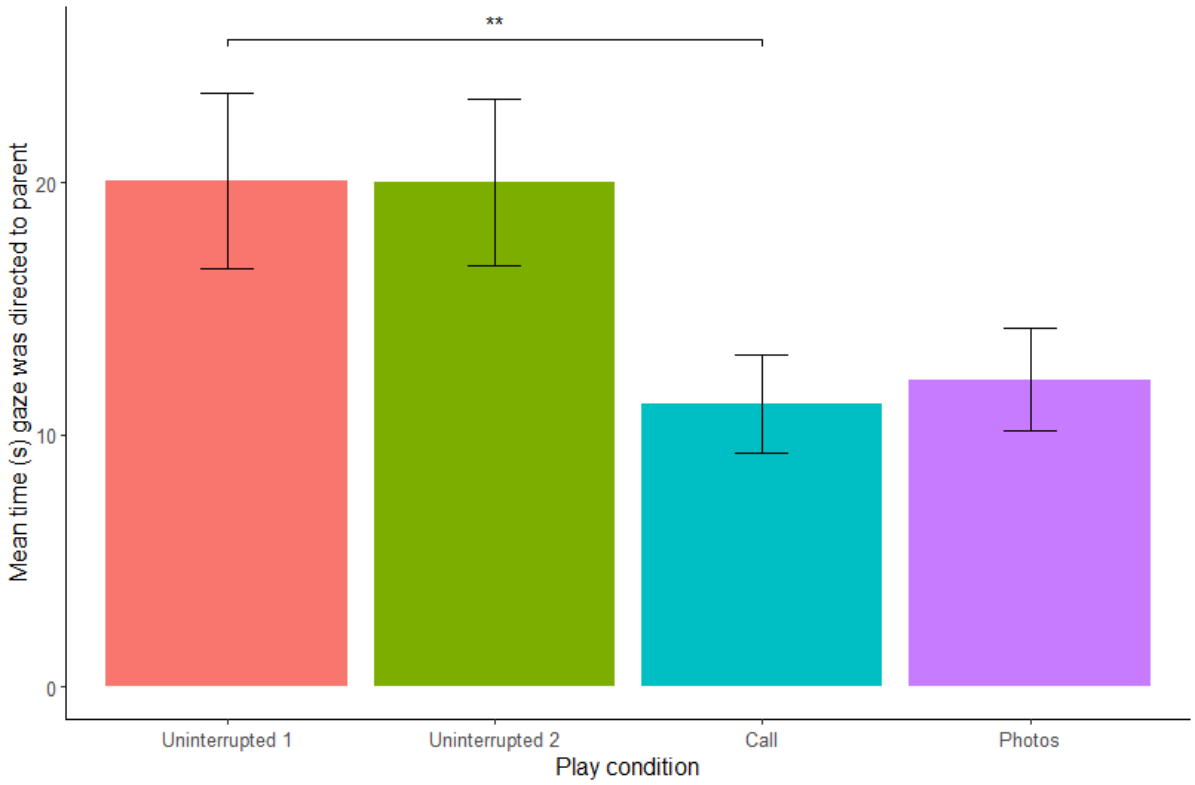
Infant gaze: Infant gaze directed to the parent was analysed separately to infant gaze directed towards the phone. One participant's data was removed from the call condition, as the dyad were not facing each other, and the phone was out of the view of the camera.

The data for infant gaze to parent was not normally distributed, as assessed by Shapiro-Wilk's, $p < .001$ for all play conditions across both phone conditions. Levene's test revealed homogeneity of variance for uninterrupted 1 ($p = .12$), uninterrupted 2 ($p = .44$), and photo ($p = .16$), but not for call ($p < .05$). Consequently, I applied a robust two-way mixed ANOVA on 20% trimmed means to infant gaze toward the parent and explored gaze following separately. There was no main effect of type of call (phone, video), $Q(1, 29) = 1.08$, $p = .31$, $\eta^{2\,(robust)} = 0.04$, and no interaction between play conditions and type of call, $Q(3, 25) = 2.48$, $p = .08$, $\eta^{2\,(robust)}$

= 0.23. The main effect of play condition was significant, $Q(3, 25) = 3.84$, $p = .02$, $\eta^2_{(robust)} = 0.32$. Post hoc tests revealed that infants spent more time looking at their parent during uninterrupted 1 ($M = 20.1$ seconds, $SD = 26.5$ seconds) than when parents used the phone to make a call ($M = 11.2$seconds, $SD = 14.8$seconds), $z = 6.18$, $p < .01$. No other significant differences were found. Figure 4.5 displays the frequency of gaze by play condition and call condition.

Figure 4.5

Infant Gaze to Parent Across Play Conditions



To test whether gaze following score was associated with infant gaze to parent, Kendall's Tau was applied. The data violated the assumptions for a linear regression, as it was not normally distributed as assessed via visual inspection of a QQ plot and Shapiro Wilk's (W = 0.67, $p < .001$). It was not appropriate to use

Spearman's Rho as the data had too many ties. The relationship between gaze following score and infant gaze to parent was not significant, $\tau = 0.068$, $p = .15$.

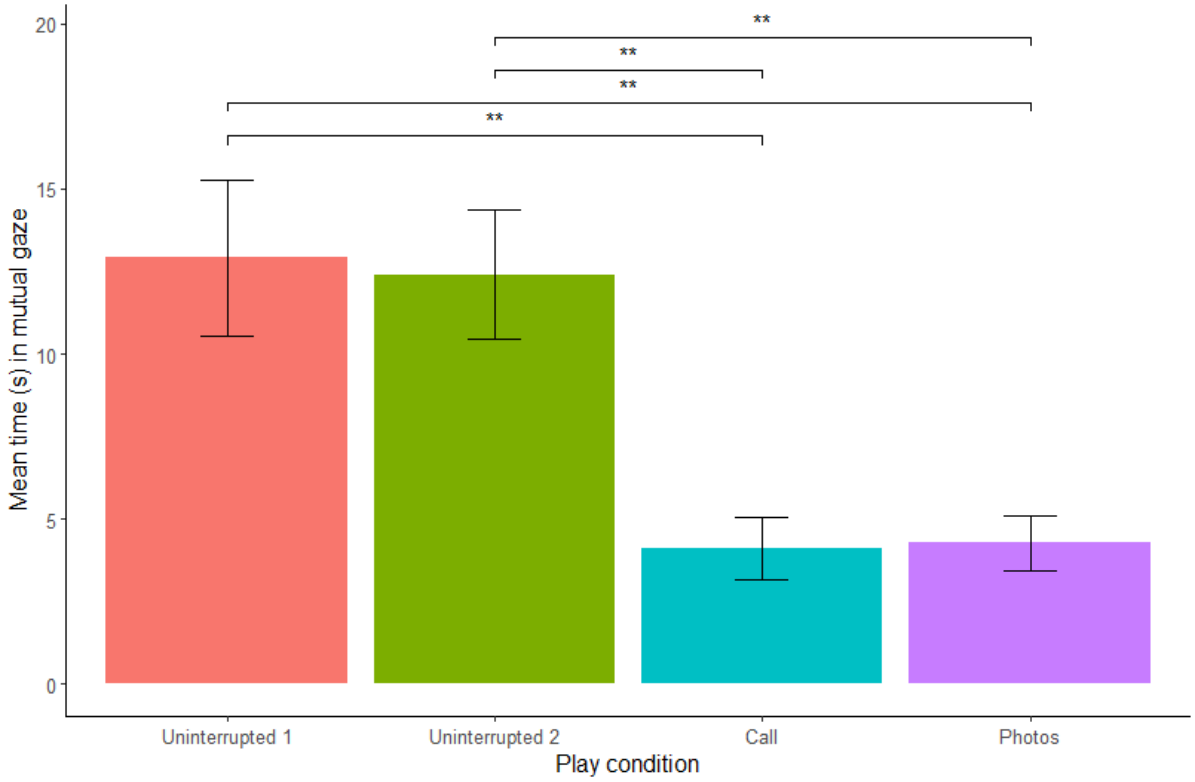
In the two technoference play conditions, infants' gaze to the smartphone was measured. This data violated the assumptions necessary for parametric testing. In the call play condition, the data was not normally distributed as visually assessed via a QQ plot and Shapiro Wilk's test ($p < .001$). Levene's test also identified the call play condition as violating homogeneity of variance ($p < .05$). A robust two-way mixed ANOVA on 20% trimmed means revealed no main effect of type of call (phone, video), $Q(1, 24) = 3.43$, $p = .08$, $\eta^{2\,(robust)} = 0.13$, and no interaction between play conditions and type of call, $Q(1, 26) = 1.48$, $p = .23$, $\eta^{2\,(robust)} = 0.05$. The main effect of play condition was significant, $Q(1, 26) = 52.95$, $p = < .001$, $\eta^{2\,(robust)} = 0.67$. Infants spent more time looking at the phone when parents used the phone to take photos ($M = 69.5_{seconds}$, $SD = 36.6_{\,seconds}$) than when parents used the phone to make a call ($M = 24.8_{\,seconds}$, $SD = 36.2_{\,seconds}$). To test the relationship between gaze following score and looks to the phone, Kendall's Tau was applied. As with the data for gaze to parent, the data violated the normality assumption (Shapiro Wilk's, $p < .001$) and there were too many ties in the data to use Spearman's Rho. The relationship between infant gaze following score and the amount of time they looked at the phone was not significant, $\tau = 0.014$, $p = .83$.

Mutual gaze: One dyad's data was removed from the call play condition, as the dyad were not facing each other. The data violated the assumption of normality as assessed by Shaprio Wilk's ($p < .001$ for all conditions) and Box's M-test indicated the call data did violate homogeneity of covariances ($p < .001$). A robust two-way mixed ANOVA on 20% trimmed means revealed no main effect of type of call (phone, video), $Q(1, 30) = 0.15$, $p = .70$, $\eta^{2\,(robust)} = 0.11$, and no interaction between play

conditions and type of call, $Q(3, 26) = 1.26$, $p = .31$, $\eta^{2\,(robust)} = 0.15$ (Figure 4.6). The main effect of play condition was significant, $Q(3, 26) = 10.31$, $p = < .001$, $\eta^{2\,(robust)} = 0.55$. Post hoc tests showed dyads spent more time engaged in mutual gaze during uninterrupted 1 ($M = 12.9_{seconds}$, $SD = 18$ seconds) than when parents used the phone to make a call ($M = 4.09$ seconds, $SD = 7.23$ seconds), $z = 5.27$, $p < .01$, and when parents used to phone to take photos ($M = 4.26$ seconds, $SD = 6.34$ seconds), $z = 5.12$, $p < .01$. Dyads also spent more time engaged in mutual gaze during uninterrupted 2 ($M = 12.4$ seconds, $SD = 15$ seconds) than when parents used the phone to make a call, $z = 6.10$, $p < .01$, and when parents used the phone to take photos, $z = 5.20$, $p < .01$. There was no significant difference between the two uninterrupted play conditions ($z = -0.08$, $p = .95$), or the two technoference conditions ($z = -0.38$, $p = .61$).

Figure 4.6

Mutual Gaze Between the Dyad Across Play Conditions



4.4.3 Parent-Infant Interactions - Parent Behaviours

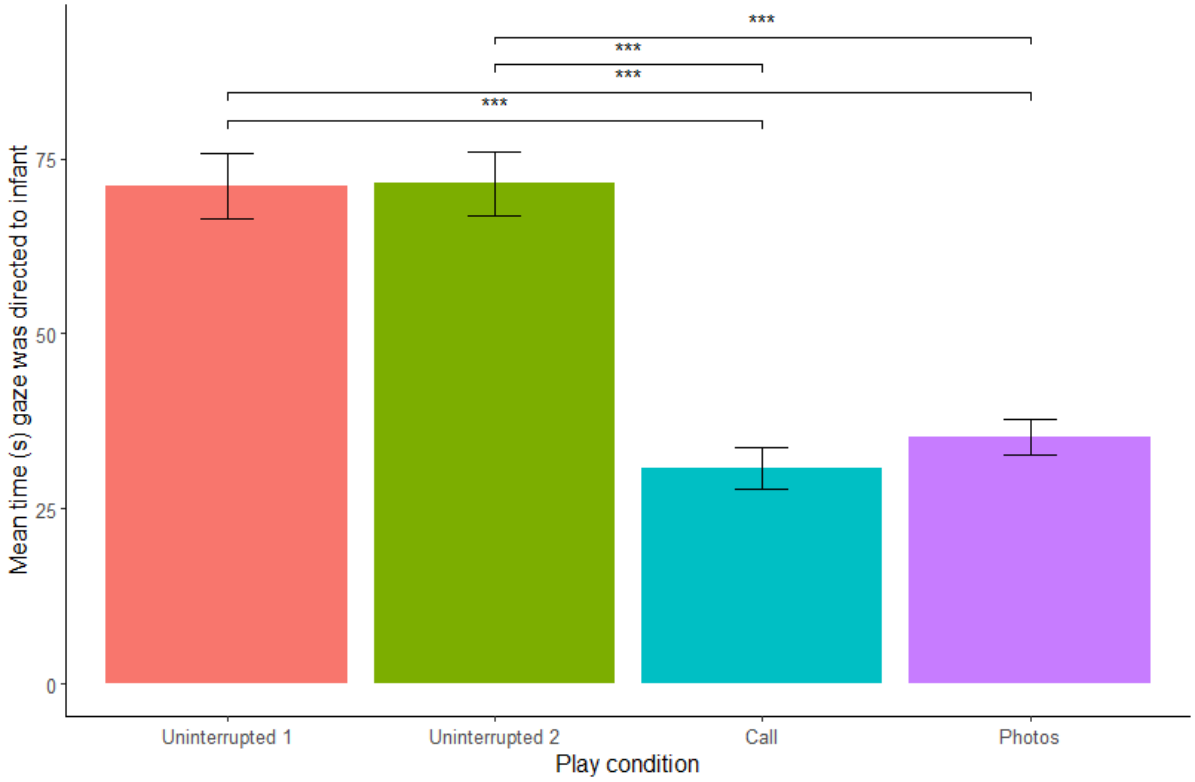
Parent behaviours consisted of gaze to the infant, gaze to the phone, use of language, and response to the infants' expressions.

Parent gaze: Parent gaze directed to the infant was analysed separately to parent gaze directed to the phone. One participant's data was removed from the call condition, as the dyad were not facing each other, and the phone was out of the view of the camera.

A two-way mixed ANOVA was applied, parent gaze to their infant was compared across the four play conditions (uninterrupted 1, uninterrupted 2, call, photo) as the within participant factors, and the call conditions (phone, video) as the between participant factor. The two-way mixed ANOVA showed no main effect of type of call, $F(1, 56) = 0.97$, $p = .33$, $\eta^2 = 0.008$, and no interaction between play condition or type of call, $F(3, 168) = 1.42$, $p = .24$, $\eta^2 = 0.013$ (Figure 4.7). A significant main effect of play condition was found, $F(3, 168) = 48.83$, $p < .001$, $\eta^2 = 0.31$. Post hoc analysis showed that parents spent more time looking at their infant's face during uninterrupted 1 ($M = 71.1_{seconds}$, $SD = 36.1_{seconds}$), compared to when the phone was used to make a call ($M = 30.8_{seconds}$, $SD = 22.7_{seconds}$), $t = -8.35$, $p < .001$, and when parents used the phone to take photos ($M = 35.3\ seconds$, $SD = 19.3\ seconds$), $t = 8.20$, $p < .001$. Parents also looked more to their infant during uninterrupted 2 ($M = 71.5\ seconds$, $SD = 35\ seconds$) compared to when they used their phone to make a call, $t = -8.73$, $p < .001$, and when the phone was used to take photos, $t = -7.74$, $p < .001$. There was no significant difference between the two technoference conditions ($t = -1.28$, $p = 1$) or the two uninterrupted conditions ($t = -0.07$, $p = 1$).

Figure 4.7

Parent Gaze to Infant Across Play Conditions

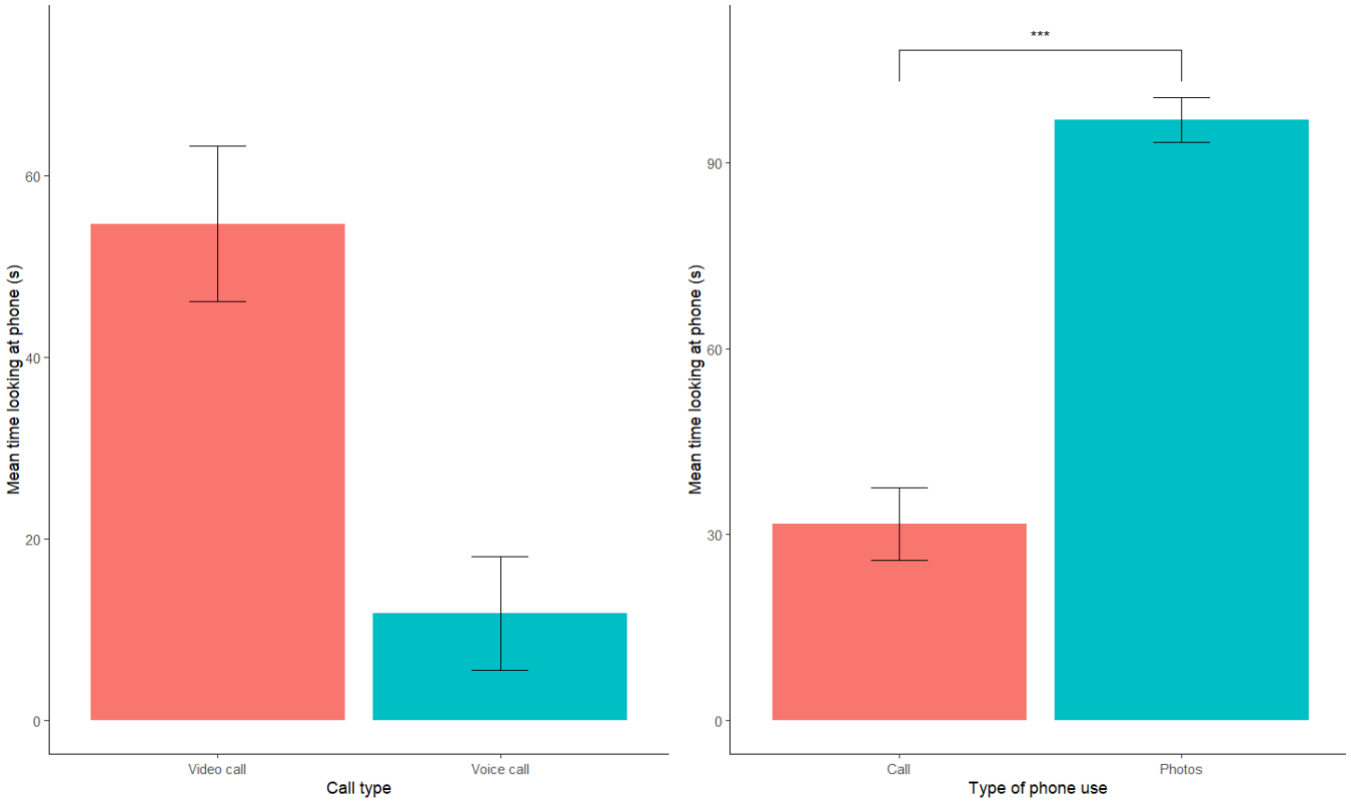


Parents' gaze to the smartphone was measured in each technoference condition (call, photos). The data for parents' gaze to the phone violated the assumptions necessary for parametric testing. In the call condition, the data was not normally distributed as assessed by Shapiro Wilk's test ($p < .001$) and a QQ plot. Levene's test also identified the call play condition as violating homogeneity of variance ($p < .05$). A robust two-way mixed ANOVA on 20% trimmed means was applied, the within participant factor was the type of phone use (photo vs. call), and the between factor was whether participants made a phone or video call. The interaction between type of call and how the phone was used was significant, $Q(1, 21) = 7.15$, $p = .014$, $\eta 2^{(robust)} = 0.25$ (see Figure 4.8). Parents looked at their phone for longer ($M = 79.3_{seconds}$, $SD = 44.2_{seconds}$) when it was used to make a video call

than when it was used to make a voice call (M = 51.3$_{seconds}$, SD = 50.6$_{seconds}$), Q(1, 21) = 22.80, p < .001, η2 $^{(robust)}$ = 0.52. Parents looked at their phone for longer when using the phone to take photos (M = 97.0$_{seconds}$, SD = 27.9$_{seconds}$) than when using the phone to make a call (M = 31.7$_{seconds}$, SD = 44.8$_{seconds}$), Q(1, 21) = 108.87, p < .001, η2 $^{(robust)}$ = 0.84.

Figure 4.8

Parent Gaze to Phone Across Type of Call and Type of Phone Use



Parent use of language: First I analysed the total time parents directed utterances towards their infant. To do this, I summed the duration of naming and non-naming utterances in each play condition and applied a two-way mixed ANOVA, with play condition as the within participant factor, and call condition as the between participant factor. This revealed no main effect of type of call, F(1, 57) = 0.01, p =

.92, η^2 = <.001, and no interaction between play condition or type of call, $F(3, 149) = 0.82$, $p = .47$, $\eta^2 = 0.006$. A significant main effect of play condition was found, $F(3, 149) = 124.81$, $p < .001$, $\eta^2 = 0.49$. Post hoc analysis showed that parents had a shorter duration of utterances when the phone was used to make a call ($M = 13.4_{seconds}$, $SD = 20.4_{seconds}$), compared to when the phone was used to take photos ($M = 80.4_{seconds}$, $SD = 27.6_{seconds}$), $t = -15.2$, $p < .001$, and during both uninterrupted 1 ($M = 75.9_{seconds}$, $SD = 35.7_{seconds}$), $t = -12.7$, $p < .001$, and uninterrupted 2 ($M = 79.5_{seconds}$, $SD = 30.4_{seconds}$), $t = -16.1$, $p < .001$. There were no other significant differences.

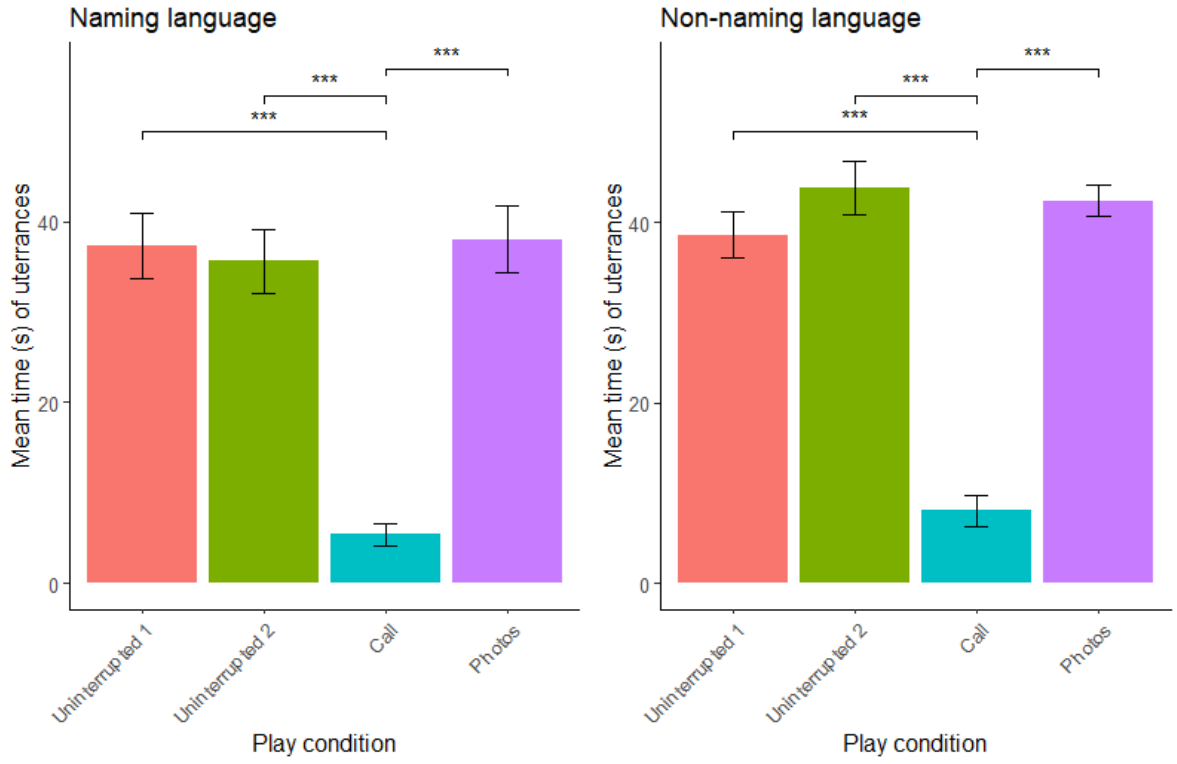
Next, I separately analysed naming language and non-naming language. Figure 4.9 displays each of these. Parent naming language was analysed using a two-way-mixed ANOVA (the within factor was play condition and the between factor call condition) which showed a main effect for play condition, $F(3, 171) = 38.33$, $p < .001$, $\eta^2 = 0.24$. There was no main effect of type of call, $F(1, 57) = 0.11$, $p = .74$, $\eta^2 = 0.001$, and no interaction between play condition or type of call, $F(3, 171) = 0.18$, $p = .91$, $\eta^2 = 0.001$. Post hoc analysis showed parents had a shorter duration of utterances when the phone was used to make a call ($M = 5.4_{seconds}$, $SD = 9.51_{seconds}$) compared to when the phone was used to take photos ($M = 38_{seconds}$, $SD = 28.3_{seconds}$), $t = -8.55$, $p < .001$, during both uninterrupted 1 ($M = 37.3_{seconds}$, $SD = 27.9_{seconds}$), $t = -9.59$, $p < .001$, and uninterrupted 2 ($M = 35.6_{seconds}$, $SD = 26.9_{seconds}$), $t = -9.15$, $p < .001$. There were no other significant differences.

Following, I analysed parent non-naming language. Mauchly's Test revealed a violation of the sphericity assumption ($W = 0.79$, $p < .05$), therefore Greenhouse-Geisser epsilon correction was applied to the ANOVA. A two-way-mixed ANOVA (the within factor was play condition and the between factor call condition) revealed no

main effect of type of call, $F(1, 57) = 0.095$, $p = .76$, $\eta^2 = <.001$, and no interaction between play condition or type of call, $F(3, 151) = 1.14$, $p = .33$, $\eta^2 = 0.011$. A significant main effect of play condition was found, $F(3, 151) = 72.65$, $p < .001$, $\eta^2 = 0.41$. Post hoc analysis showed parents had a shorter duration of utterances when the phone was used to make a call ($M = 8.04_{seconds}$, $SD = 13.3_{seconds}$), compared to when the phone was used to take photos ($M = 42.4_{seconds}$, $SD = 13.6_{seconds}$), $t = -16.4$, $p < .001$, and during both uninterrupted 1 ($M = 38.6_{seconds}$, $SD = 19.7_{seconds}$), $t = -9.77$, $p < .001$, and uninterrupted 2 ($M = 43.9_{seconds}$, $SD = 22.5_{seconds}$), $t = -12.0$, $p < .001$. There were no other significant differences.

Figure 4.9

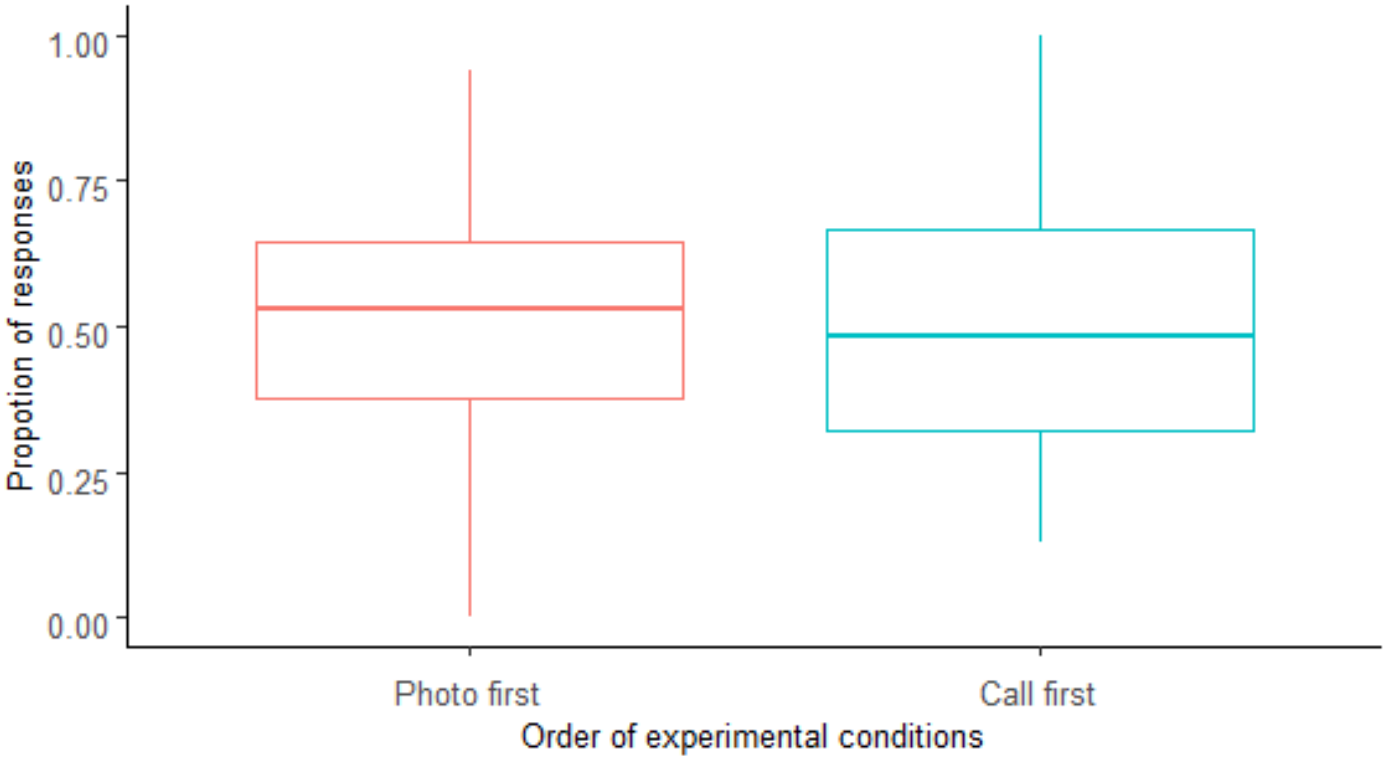
Parent Duration of Language Across Play Conditions



Parent contingency: A two-way mixed ANOVA compared the proportion of contingent responses across the four play conditions (uninterrupted 1, uninterrupted 2, call, photo) as the within factors and the call condition (phone, video) as the between factor. There was no main effect of type of call, $F(1, 57) = 0.067$, $p = .78$, $\eta^2 = < .001$, and no interaction between play condition or type of call, $F(3, 171) = 1.33$, $p = .23$, $\eta^2 = 0.010$. A significant main effect of play condition was found, $F(3, 171) = 64.56$, $p < .001$, $\eta^2 = 0.33$. Post hoc analysis showed a larger proportion of contingent responses were given during uninterrupted 1 ($M = 0.62$, $SD = 0.25$) than during uninterrupted 2 ($M = 0.5$, $SD = 0.23$), $t = 3.95$, $p < .01$, when the phone was used to make a call ($M = 0.22$, $SD = 0.16$), $t = -12.8$, $p < .001$, and when the phone was used to take photos ($M = 0.39$, $SD = 0.21$), $t = 7.16$, $p < .001$. A larger proportion of contingent responses were also given during uninterrupted 2, compared to both when the phone was used to make a call ($t = 9.87$, $p < .001$), and when the phone was used to take photos ($t = -3.65$, $p < .01$). Parents also made a larger proportion of contingent responses when using the phone to take photos in comparison to using the phone to make a call ($t = -6.27$, $p < .001$). Possibly the difference between uninterrupted 1 and uninterrupted 2 was a result of engaging with one type of technoference over another between the two uninterrupted play sessions (see Figure 4.1). To test this, an unrelated t-test compared the proportion of contingent responses in uninterrupted 2, between parents who used to phone to make a phone call after uninterrupted 1 *(*$M = 0.51$, $SD = 0.22$*),* to parents who used the phone to take photos after uninterrupted 1 *(*$M = 0.49$, $SD = 0.24$). Figure 4.10 displays the distribution of data, no significant difference was found, $t(56) = -0.18$, $p = 0.86$, $d = -0.05$.

Figure 4.10

Proportion of Contingent Responses During Uninterrupted 2 by Order of Experimental Conditions



Proportion of non-contingent responses were compared using a two-way mixed ANOVA. Play condition was a within participant factor (uninterrupted 1, uninterrupted 2, call, photo) and call was a between participant factor (phone, video). There was no main effect of type of call, $F(1, 57) < .001$, $p = .99$, $\eta^2 = < .001$, and no interaction between play condition or type of call, $F(3, 171) = 0.375$, $p = .77$, $\eta^2 = 0.004$. A significant main effect of play condition was found, $F(3, 171) = 3.84$, $p < .05$, $\eta^2 = 0.04$. Post hoc analysis showed parents gave a larger proportion of non-contingent responses when the phone was used to take photos ($M = 0.13$, $SD = 0.12$), in comparison to uninterrupted 2 ($M = 0.07$, $SD = 0.09$), $t = 3.74$, $p < .01$. No other significant differences were found.

Finally, the proportion of potential responses to infants' expressions which did not elicit a response from the parent (no response) across the four play conditions (uninterrupted 1, uninterrupted 2, call, phone) were compared using a two-way mixed ANOVA, with call as a between factor. There was no main effect of type of call, $F(1, 57) = 0.22$, $p = .64$, $\eta^2 = .002$, and no interaction between play condition or type of call, $F(3, 171) = 1.93$, $p = .13$, $\eta^2 = 0.016$. A significant main effect of play condition was found, $F(3, 171) = 55.47$, $p < .001$, $\eta^2 = 0.32$. Post hoc analysis revealed a larger proportion of potential responses were non-responses when the phone was used to make a call ($M = 0.67$, $SD = 0.20$), in comparison to uninterrupted 1 ($M = 0.27$, $SD = 0.21$), $t = 15.5$, $p < .001$, uninterrupted 2 ($M = 0.43$, $SD = 0.24$), $t = 7.43$, $p < .001$, and when the phone was used to take photos ($M = 0.48$, $SD = 0.21$), $t = 5.97$, $p < .001$. A larger proportion of potential responses were also non-responses when the phone was used to take photos in comparison to uninterrupted 1, $t = -6.86$, $p < .001$. Parents also did not make a response significantly more during uninterrupted 2 than in uninterrupted 1, $t = -4.51$, $p < .001$. There was no significant difference between uninterrupted 2 and using the phone to take photos, $t = 1.55$, $p = .77$. To see if this difference was related to order of technoference conditions, an unrelated t-test compared the proportion of non-responses during uninterrupted 2, between parents who used the phone to make a phone call after uninterrupted 1 ($M = 0.43$, $SD = 0.21$), and parents who used the phone to take photos after uninterrupted 1 ($M = 0.43$, $SD = 0.27$). Figure 4.11 displays the distribution of data, no significant difference was found, $t(54) = 0.03$, $p = 0.98$, $d = -0.008$. Figure 4.12 displays parents' responses across all conditions.

Figure 4.11

Proportion of Potential Responses That Did Not Elicit a Response During Uninterrupted 2 by Order of Experimental Conditions

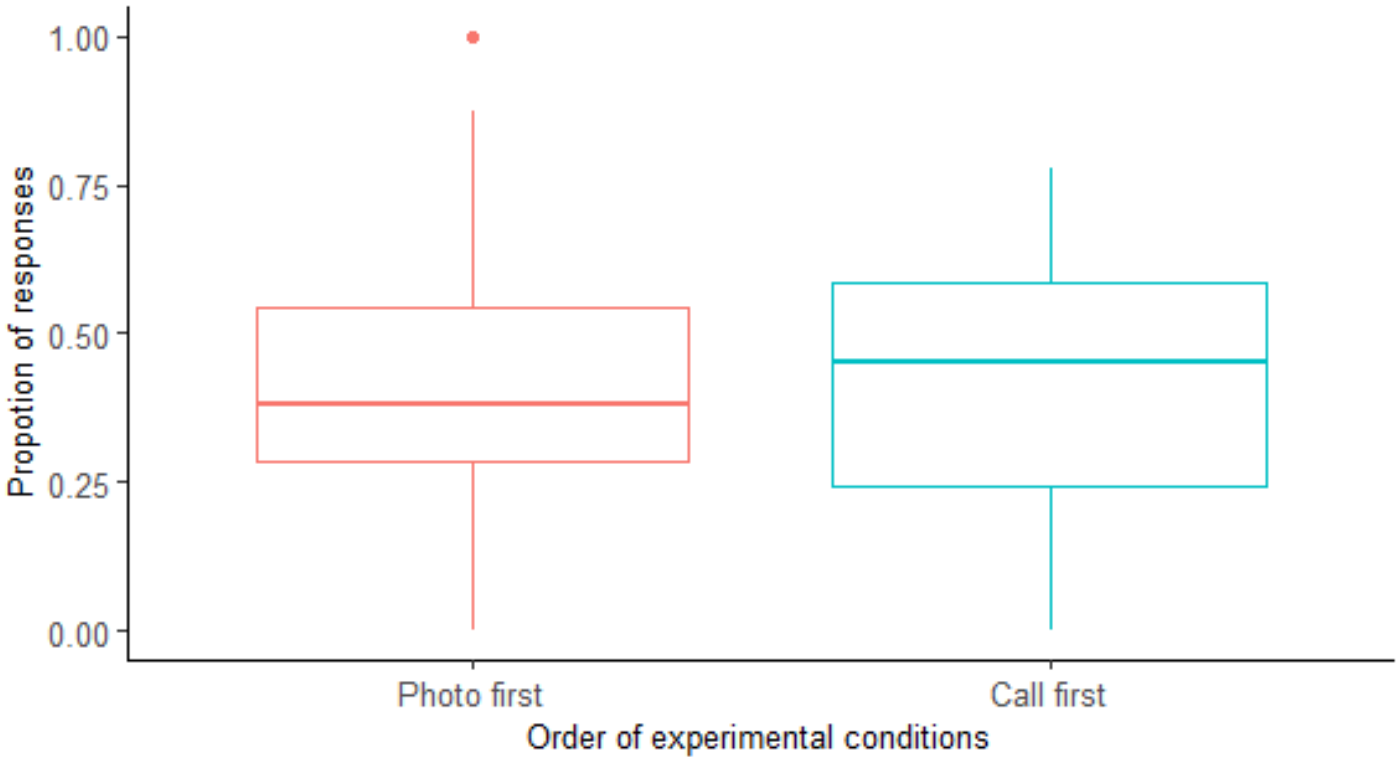
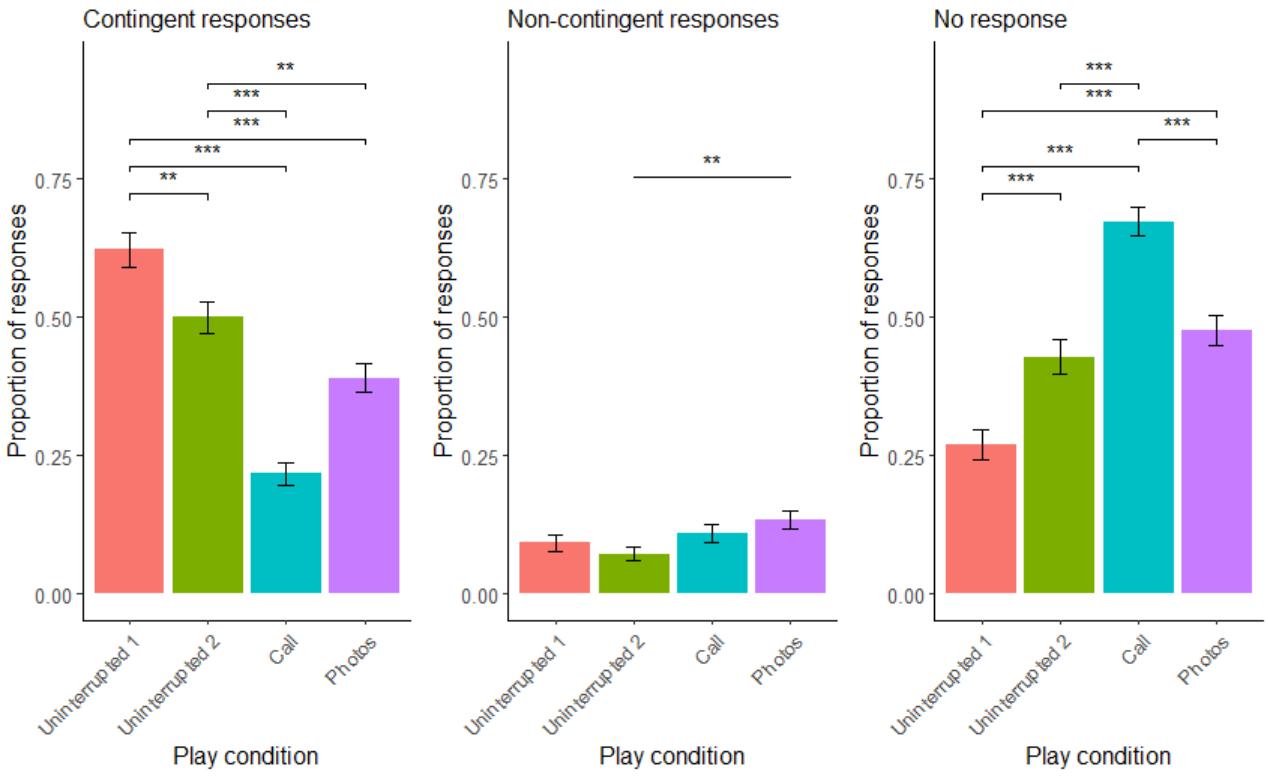


Figure 4.12

Parent Responses to Infants' Expressions Across Play Conditions



4.5 Discussion

Study 2a investigated the effects of parent smartphone technoference on parent–infant interactions, including whether these effects differ by type of phone use. Consistent with H1, parent smartphone technoference did affect several aspects of the parent-infant interaction. Infants spent more time looking to their parent during the first uninterrupted play session in comparison to when parents used their smartphone to make a call (H1a). The dyad spent more time engaged in mutual gaze during the first uninterrupted play session than when parents used their phone to make a call or take photos (H1a). Infants made more positive expressions during the first uninterrupted play session than either technoference conditions (call,

photos), but there was no difference in frequency of fussiness between the uninterrupted play sessions and the technoference play sessions (H1b). Technoference had no effect on infant vocalisations (H1c). Parents' behaviour was also impacted by their smartphone use. Parents' gaze to their infant was reduced when parents used their phone to make a call or to take photos in comparison to uninterrupted play (H1a). Furthermore, parents directed less language (both naming and non-naming) towards the infant when making a phone call in comparison to uninterrupted play (H1d). Parents' responses to infants' spontaneous expression were affected by technoference (H1c). While contingent responsiveness declined between the first and second uninterrupted play sessions, parents remained more responsive in both sessions in comparison to when technoference occurred via a call or photos. Non-contingent responses occurred more often when parents used their phone to take photos in comparison to the second uninterrupted play session. Parents did not respond to infants' spontaneous expressions more frequently when using the phone to make a phone call in comparison to the two uninterrupted play sessions, and when using the phone to take photos in comparison to the first uninterrupted play session (H1g).

H2 predicted that the type of smartphone use (call vs. photos) would have different effects on the parent-infant interaction. This hypothesis was partially supported. Infants looked to the smartphone more frequently when parents used the phone to take photos in comparison to making a call. Parents' behaviour was also affected by type of phone use. Firstly, parents directed less language towards their infant when using the phone to make a call in comparison to using the phone to take photos. Second, parents directed more gaze to the phone when using the phone to take photos than when using the phone to make a call. When making a call, parents

looked at their phone for longer during the video call in comparison to a phone call. Third, parents responded to infants' spontaneous expressions with a contingent response more often when using the phone to take photos than to make a call. Fourth, parents failed to respond to infants' spontaneous expression more often when using the phone to make a call than when using the phone to take photos.

Study 2a provides detail on how technoference may disrupt the parent-child interaction involved in language development. Study 2b builds on Study 2a by addressing three key issues. 1) Study 2a did not measure language outcomes in children meaning it is not possible to determine whether the disruption to parent-child interactions affect language development. 2) Due to the experimental manipulation, Study 2a did not account for natural, regular smartphone technoference. 3) As infants in Study 2a were aged 9-10-months, it was not possible to reliably measure JME, as children at this age will not all have developed secondary intersubjectivity (Trevarthen, 1979). I therefore conducted a survey with parents (Study 2b) that measured child language outcomes, natural parent smartphone technoference, and JME in older children (12-18 months). Measuring social gaze and parent use of language are not suited to self-report, therefore Study 2b only focused on parent responsiveness as a precursor to language development, which parents can more easily report on.

4.6 Study 2b

Study 2b included a sample of 12-18-month-olds. This age group was chosen as parent responsiveness changes across developmental periods. For instance, mothers name more objects in response to 14-month-olds pointing behaviour than to 8-month-olds (Gros-Louis et al., 2014). This is further demonstrated in research which found that imitation and expansions predict language outcomes at 13 months

but not 9 months, whereas mother's affirmations and descriptions predict language outcomes at 9 months but not 13 months (Tamis-LeMonda et al., 2001). Changes in parent responsiveness likely occur due to changes in the child's communication skills. For example, children's object exploration declines between 10-to-14 months, whereas vocalisations and bids to the mother increase during this age (Bornstein et al., 2008). These findings suggest that during the second year, use of language from both the child and parent become more prevalent, rendering this age group more suitable for testing the general association between technoference, parent responsiveness, and language outcomes than younger children (as used in Study 2a) which require high levels of hands-on parent support. A validated self-report measure of responsiveness, the Parent Responsiveness Scale (Anikiej-Wiczenbach & Kaźmierczak, 2021), was used to provide a general measure of parent responsiveness, as opposed to measuring responsiveness in a one-off observation. Similarly, a validated measure of language, the UK Communicative Development Inventory (Alcock et al., 2020), was used to gather a detailed measure of language as opposed to the number of words or utterances in a one-off observation.

Based on previous literature (Abels et al., 2018; Corkin et al., 2021; Elias et al., 2020; Hiniker et al., 2015; Lederer et al., 2022; Medawar et al., 2023; Nakagawa et al., 2019; Ochoa et al., 2021; Paoletti et al., 2025; Reed et al., 2017), I hypothesised that:

H3) Parents who reported being more responsive would also report reduced smartphone technoference.

H4) The more frequently technoference occurred, the lower the language outcomes in the child.

H5) Children whose parents reported more consistent shared phone use (“yes” or “sometimes”) would show greater language outcomes than children whose parents did not engage in shared phone use (“no”).

An exploratory analysis also tested three further associations. 1) The relationship between parent smartphone use and engagement level with their child. 2) Whether there was a relationship between technoference and the child’s smartphone use. 3) The association between shared phone use (JME) and level of parent responsiveness.

4.7 Method

4.7.1 Participants

One hundred and thirty-four parents of children aged between 12 and 18-months took part in this study. A power analysis on G*Power for each hypothesis. As H2 and H3 predicted linear associations between continuous variables, these were planned to be tested using linear regression. Based on a medium effect size (f^2 = .15) and a power of .80, G*Power identified a required sample size of 55 for these hypotheses. H5 compared language outcomes between three groups (parents reporting “yes” versus “sometimes”, or “no” to engaging in shared phone use), an ANOVA was the planned analysis to test for a difference between frequency of shared phone use. G*Power identified a sample size of 126, based on a medium effect size of 0.28 and a power of 0.8. Due to limited research in this area, a medium effect size was deemed most suitable for this study. Participants were recruited through social media and the Essex Babylab database. The University ethics committee approved this research (ETH2021-0352), and informed consent was gained at the beginning of the survey.

The characteristics of the sample are shown in Table 4.6. The survey was mostly completed by the child's mother (99%). The primary parent was either the mother (69%) or both the mother and the father (31%). On average the parent completing the questionnaire was 34.04 years old (*SD* = 5.35 years). 63% were married and 30% were cohabiting, the rest were single or separated. Most of the parents were White (90%), employed either full time (25%) or part time (49%) and had achieved a bachelor's degree (37%) or a postgraduate degree (33%). The average household income was £68,145 (*SD* = £33,232.25).

The average age of the children whom parents completed the survey in relation to was 13.42 months (*SD* = 1.64 months). 50% of the children were male, 86% were White and 9% were mixed race. One child had Cerebral Palsy, and another had a heart defect, the remaining sample (99%) had no diagnosed disorder.

Table 4.6

Characteristics of the Sample

Primary caregiver	**N (percentage)**
Mother	93 (69)
Father	0 (0)
Mother and father	41 (31)
Ethnicity	**N (percentage)**
White	121 (90)
Black	1 (<1)
Asian	5 (4)
Mixed	5 (4)
Other	1 (<1)

Prefer not to answer	1 (<1)

Employment	**N (percentage)**
Employed full time	33 (25)
Employed part time	66 (49)
Homemaker	19 (14)
Student	4 (3)
Unemployed	3 (2)
Other	9 (7)

Education	**N (percentage)**
GCSE (or equivalent)	6 (4)
A Levels (or equivalent)	35 (26)
Bachelor's degree	49 (37)
Master's degree	21 (16)
PhD	11 (8)
Other postgraduate qualification	12 (9)

4.7.2 Measures

Participants completed an online survey through Qualtrics, which assessed their smartphone use, their child's language, the parent's level of responsiveness to their child, and JME. The survey included the same questions to measure general phone use as described in Study 2a, with the addition of two technoference measures, a language measure, and a parent responsiveness measure.

Technoference Measures

Three measures of technoference were included. The first asked parents “How often do you use your smartphone when your child is awake, and you are actively engaging with your infant?” Measurement was on a five-point Likert scale; “Always”, “Most of the time”, “About half the time”, “Sometimes”, and “Never”.

The second item was taken from Corkin et al. (2021) and asked parents “How often do you consciously decide not use your smartphone when with your child and then turn it off or put it away for a while?”. Parents could respond “Everyday”, “Several times a week”, “Once a week”, “Once every two weeks”, and “Occasionally or never”.

The final measure of technoference was the parents’ score on the DISRUPT scale, a previously validated measure of technoference (McDaniel, 2021) (see Appendix A) and asked participants to rate four items, e.g., “During the time I spend with my child I feel like I use my phone or other mobile device too much”. Responses are on a six-point Likert scale; “Strongly disagree” to “Strongly agree”. Cronbach’s alpha for the DISRUPT was 0.81, indicating strong reliability. This measure is slightly lower than in the initial validation (ranging from 0.83-0.91) (McDaniel, 2021), but higher than other literature which has applied the DISRUPT e.g., McDaniel, Pater, et al. (2023) where Cronbach’s alpha for fathers was 0.74 and 0.77 for mothers.

Language Measure

Parents completed the UK Communicative Development Inventory (UK-CDI) (Alcock et al., 2020) (see Appendix C) which assesses language development in 8–18-month-olds. Parents identify which words their child can either understand or understand and say (Cronbach’s alpha = 0.98), which communicative gestures their child can do, e.g., shaking their head to indicate ‘no’ (Cronbach’s alpha = 0.71) and which actions their child can do, e.g., feeding a doll with a spoon (Cronbach’s alpha

= 0.87). The Cronbach's alpha in this study are slightly below the literature at .99, .99, and .98, respectively (Alcock et al., 2020).

Parent Responsiveness

The Parent Responsiveness Scale (PRS) (Anikiej-Wiczenbach & Kaźmierczak, 2021) was completed by parents to assess how sensitively the parent responds to their child's needs (see Appendix D). The scale includes thirteen statements, e.g. "I react immediately when my baby cries" to which parents respond on a 7-point scale from 'Completely disagree' to 'Completely agree' and is designed to be used with parents of children aged 0-18-months old. Cronbach's alpha was 0.8, similar to previous literature, e.g. Anikiej-Wiczenbach et al. (2024), where Cronbach's alpha was 0.87 for women and 0.82 for men.

4.7 Results

All data analysis was conducted in R version 4.2.3. As much of the data was ordinal, a Spearman's rank correlation was conducted to explore the relationship between general smartphone use (frequency of phone use per hour, phone duration, phone use when the child is asleep, phone use when the child is awake but the parent is not engaged with them), child phone use, shared phone use, technoference (consciously deciding to put the phone away when with the child, DISRUPT score, frequency of smartphone use when engaged with the child), parent responsiveness and language outcomes (words and child's use of gestures) (Table 4.7). Due to the limited previous literature in the field, conservative *p* values were used to assess significance.

Measures of general parent smartphone use correlated with each other. The frequency parents checked their smartphone positively correlated with the amount of time per day parents used their smartphone, $r_s(134) = .45$, $p < .001$. The frequency

with which parents used their smartphone when their child was asleep, was negatively correlated with the amount of time per day they generally use their smartphone for, $r_s(134) = -.29$, $p < .001$. The amount of time per day parents used their smartphone when their child was awake and not actively engaged with them was positively correlated with smartphone use when the child was asleep, $r_s(134) = .26$, $p < .001$, but negatively correlated with duration of smartphone use in an average day, $r_s(134) = -.32$, $p < .001$, and daily frequency of smartphone checks, $r_s(134) = -.27$ $p < .001$. Two measures of technoference were correlated with each other; a significant negative correlation was found between scores on the DISRUPT and how often parents used their smartphone when actively engaged with their child, $r_s(134) = -.38$, $p < .001$.

Table 4.7

Correlations Between Independent and Dependent Variables, and Covariates

	1	2	3	4	5	6	7	8	9	10	11	12
1. Phone checks per hour	-											
2. Phone duration	0.44 ****	-										
3. Phone use when child asleep	-0.12	-0.29 ****	-									
4. Phone use when child awake	-0.27 ****	-0.32 ****	0.26 ****	-								
5. Child phone use	0.02	-0.05	-0.02	0.04	-							
6. Shared phone use	0.09	-0.04	0.18 ***	<0.01	-0.18 ***	-						
7. Put phone away	0.14	0.12	0.11	-0.18	-0.09	0.05	-					

(1=everyday, 5=never)	**			***								
8. Phone when engaged	-0.20 ***	-0.35 ****	0.26 ****	0.47 ****	<0.01	0.11	-0.09	-				
9. DISRUPT	0.24 ****	0.32 ****	-0.28 ****	-0.54 ****	0.04	-0.01	0.13 *	-0.38 ****	-			
10. Responsiveness	0.07	0.05	-0.04	0.02	-0.02	-0.01	-0.15 **	0.11 *	-0.06	-		
11. Words	-0.07	-0.16 **	0.17 ***	0.06	<0.01	-0.08	0.03	0.04	-0.19 ***	0.09	-	
12. Gestures	-0.10	-0.23 ****	0.21 ***	0.14 *	0.04	-0.14 **	-0.01	0.13 *	-0.19 ***	0.07	0.76 ****	-

Note. Values represent r_s.

The following conservative *p* values were used to assess significance * $p < .20$, ** $p < .10$, *** $p < .05$, **** $p < .01$

4.7.1 Technoference vs. General Smartphone Use

Responses were compared to test whether there was a difference between how frequently parents use their phone when their child is asleep, the child is awake, but the parent is not engaging with the child, and when the parent is actively engaged with their child. As responses were ordinal, a cumulative link model (CLM) was applied using the ordinal package (Christensen, 2018) and the significance of the effects of the independent variable was tested with an analysis of deviance approach. The means and standard deviations can be seen in Table 4.8. There was a significant main effect of level of engagement with the child and smartphone use, $X^2(2) = 284.54$, $p < .001$, $R^2_{Nag} = 0.54$. Post hoc comparisons using the Tukey HSD test indicated that parents were significantly less likely to use their phone when they are engaged with their child, than when their child is awake, but they are not engaged with them ($z = -8.31$, $p < .001$), or when their child is asleep ($z = -12.51$, $p < .001$). Parents were also significantly less likely to use their smartphone when their child is awake, but they are not engaged with them, compared to when their child is asleep ($z = -7.97$, $p < .001$).

Table 4.8

Means and Standard Deviations of Smartphone Use by Level of Engagement With the Child (1 = Everyday, 5 = Occasionally Or Never)

Level of engagement	***M (SD)***
Child asleep	2.22 (0.95)
Child awake but not engaged	3.24 (0.83)
Parent actively engaged with child	4.25 (0.64)

4.7.2 Exploratory Question 1: How Do Parents Use Their Phone?

As the data was ordinal, Wilcoxon Signed-Rank Tests with Bonferroni correction were conducted to compare whether parents used their phones differently when they were actively engaged with their child compared to when their child was awake and not engaged with them across all eight activities in the survey (see Table 4.9). Parents spent more time making phone calls, z = -4.0, p < .001, r = 0.03, playing games on their smartphone, z = -3.4, p < .01, r = 0.29, monitoring their health, z = -4.45, p < .01, r = 0.38, monitoring their child's use of technology, z = -3.3, p < .01, r = 0.28, and controlling smart devices, z= -3.3, p < .01, r = 0.29, when they were not actively engaged with their child compared to when they were actively engaged with their child (Figure 4.13). No other significant differences were found.

Table 4.9

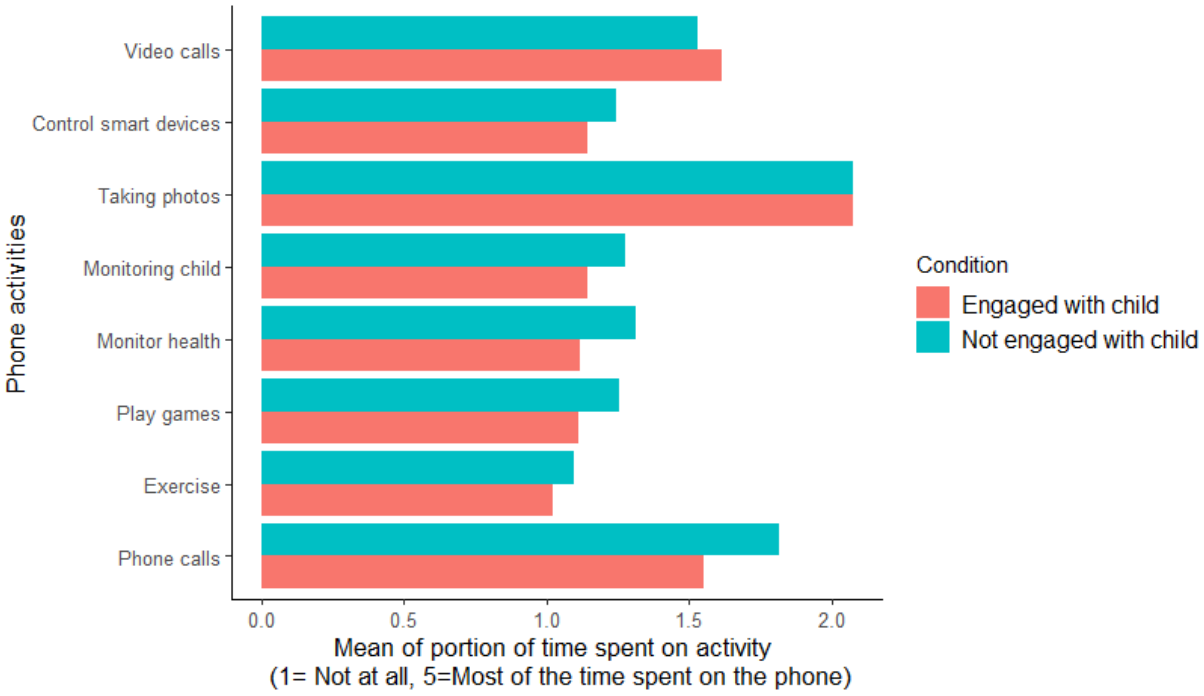
Results of Wilcoxon Signed Ranks to Examine the Difference Between Types of Smartphone Use When Parents Are, and Are Not, Actively Engaged With Their Child

Activity	Engagement	*M*	*SD*	*z*	*p*	*p* adjusted	Effect size (r)
Phone calls	Engaged	1.55	0.66	-4.0	<.001	.008*	0.34
	Not engaged	1.81	0.71				
Exercise	Engaged	1.02	0.19	-2.50	.010	ns	0.22
	Not engaged	1.10	0.37				
Playing games	Engaged	1.11	0.40	-3.40	<.001	.008*	0.29
	Not engaged	1.25	0.56				
Monitoring child	Engaged	1.14	0.48	-3.27	.001	.009*	0.28
	Not engaged	1.28	0.59				
Monitoring health	Engaged	1.12	0.43	-4.45	<.001	.008*	0.39

	Not engaged	1.31	0.57				
Taking photos	Engaged	2.07	0.69	-.035	.972	ns	0.02
	Not engaged	2.07	0.60				
Controlling smart devices	Engaged	1.14	0.35	-3.30	<.001	.008*	0.29
	Not engaged	1.25	0.45				
Making video calls	Engaged	1.61	0.83	-1.22	.22	ns	0.05
	Not engaged	1.53	0.68				

Figure 4.13

Portion of Daily Smartphone Use by Activity and Level of Engagement With Child



4.7.3 Exploratory Question 2: Technoference and Children's Smartphone Use

Three measures of technoference were assessed in the survey, 1) whether parents consciously put their smartphone away when they were with their child, 2)

the score on the DISRUPT scale, and 3) whether the parent used their smartphone when they were engaged with their child. Due to non-normal distributions, both consciously putting the smartphone away and use of the smartphone when engaged with the child, were transformed to categorical data for this analysis. For consciously deciding to put the smartphone away, due to very few responses in these categories, “once a week”, “once every two weeks”, and “occasionally or never” were grouped together to form one category ‘once a week or less’. ‘Several times a week’ and ‘everyday’ remained as two separate categories. For the variable of using the smartphone when engaged with the child, no parents reported that they ‘always’ do this. Due to low responses to ‘most of the time’ and ‘about half the time’, these were grouped together to make a new category of ‘half of the time or more’. The remaining two categories ‘sometimes’ and ‘never’ remained as they were. A chi-square test of independence showed that there was no significant difference between whether parents consciously put the smartphone away when with the child and the child’s use of a smartphone, $X^2(4, N=134) = 1.90$, $p = .75$, Cramer’s $V = 0.08$. The chi-square test of independence also found no significant relationship between how frequently parents use their smartphone when they are engaged with their child and the child’s use of a smartphone, $X^2(4, N=134) = 1.53$, $p = .82$, Cramer’s $V = 0.08$. Binary logistic regression revealed no significant association between the parent’s score on the DISRUPT scale and the child’s use of the smartphone, $X^2(1) = 0.06$, $p = .81$, Nagelkerke $R^2 = 0.001$.

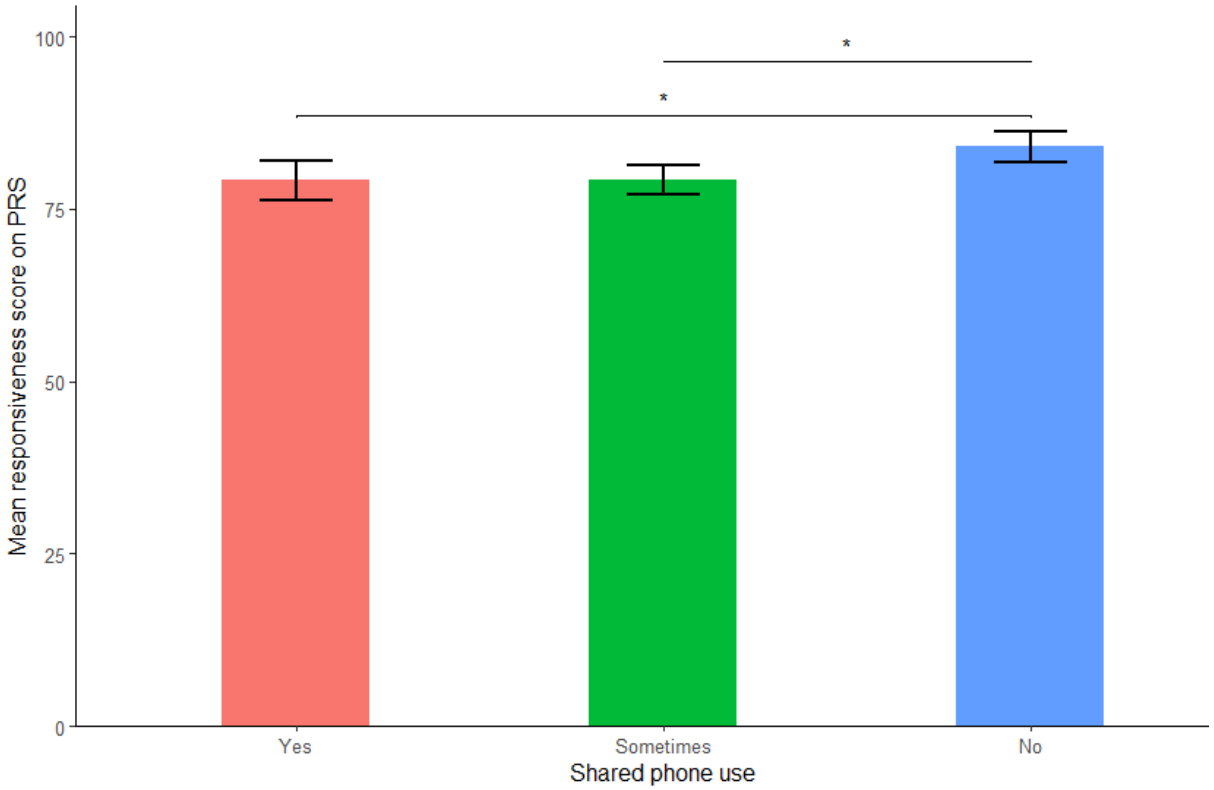
4.7.4 Exploratory Question 3: Shared Phone Use and Parent Responsiveness

Shared phone use was categorised as ‘yes’, ‘no’, or ‘sometimes’. Any response which identified the child does not use the phone were dropped from this analysis. The assumptions of normality and homogeneity of variance were satisfied,

as assessed by Shapiro-Wilk test (W = 0.98, p = .26) and Levene's test (p = .41). A one-way ANOVA revealed a significant effect of joint smartphone use on responsiveness, $F(2, 74) = 4.12$, p = .02, η^2 = .10. Pairwise comparisons (Figure 4.14) using Tukey HSD revealed that parents who do not use their smartphone with their child had higher levels of responsiveness (M = 84, SD = 4.30) than parents who reported co-using their smartphone with their child (M = 79.2, SD = 7.23, p = .034), and parents who sometimes sit with their child and engage in shared smartphone use, (M = 79.2, SD = 5.88, p = .027).

Figure 4.14

Comparison of Level of Parent Responsiveness Dependent on Whether Parents Co-Use Their Smartphone With Their Child

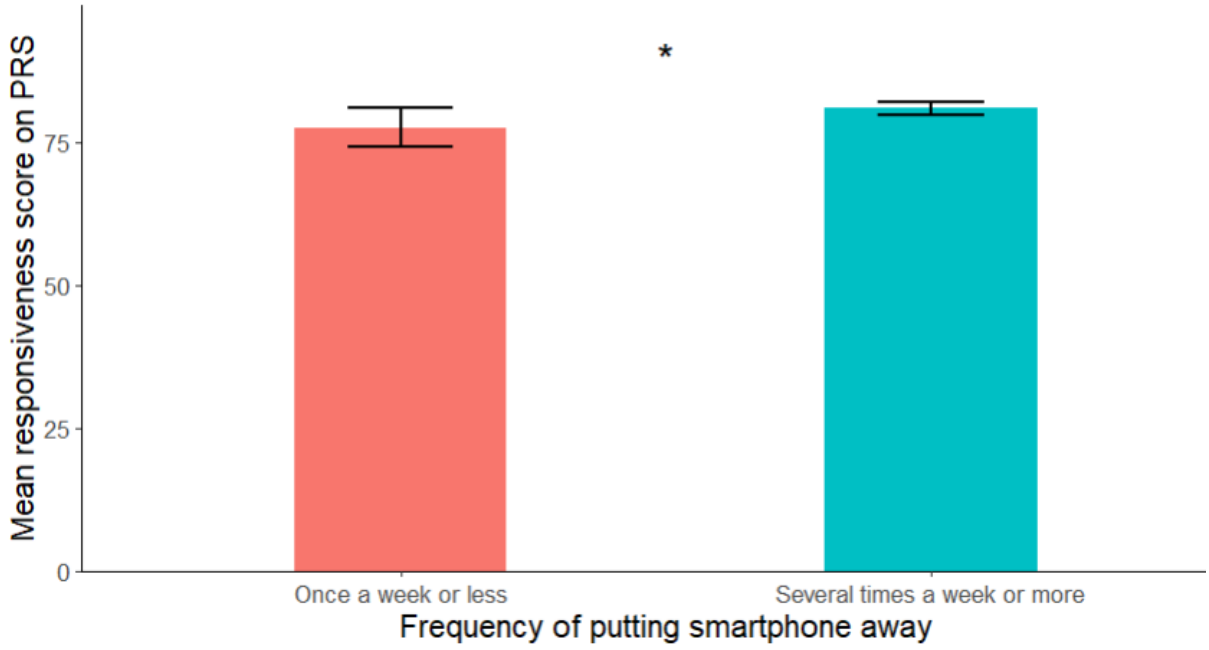


4.7.5 Hypothesis 3: Technoference and Responsiveness

The correlation matrices revealed an association between technoference and responsiveness, suggesting that the more frequently parents put their smartphone away when with their child the higher level of responsiveness, $r_s(134) = -.22$, $p < .05$. This relationship was further explored. The Shapiro-Wilk test was used to assess normality of these two variables. Neither responsiveness (W = 0.95, $p < .001$) or consciously putting the smartphone away were normally distributed (W = 0.69, $p < .001$). Responsiveness had a negative skew, with most parents scoring high in responsiveness. Putting the phone away was positively skewed, with more parents selecting that they consciously put their smartphone away when with their child ‘everyday’ or ‘several times a week’. This variable was transformed for the analysis into two categorical variables, ‘several times a week or more’, which included the ‘everyday’ and ‘several times a week’ response, all other responses were grouped together to form ‘once a week or less’. As responsiveness was not normally distributed, a Mann Whitney test was applied. Parents who put their phones away several times a week or more had significantly higher levels of responsiveness (M = 80.9, SD = 6.16) than parents who consciously put their phone away once a week or less (M = 77.5, SD = 8.10), $z = -1.98$, $p < .05$, $r = 0.17$ (Figure 4.15).

Figure 4.15

Comparison of Parent Responsiveness Dependent on How Frequently Parents Put Their Smartphone Away



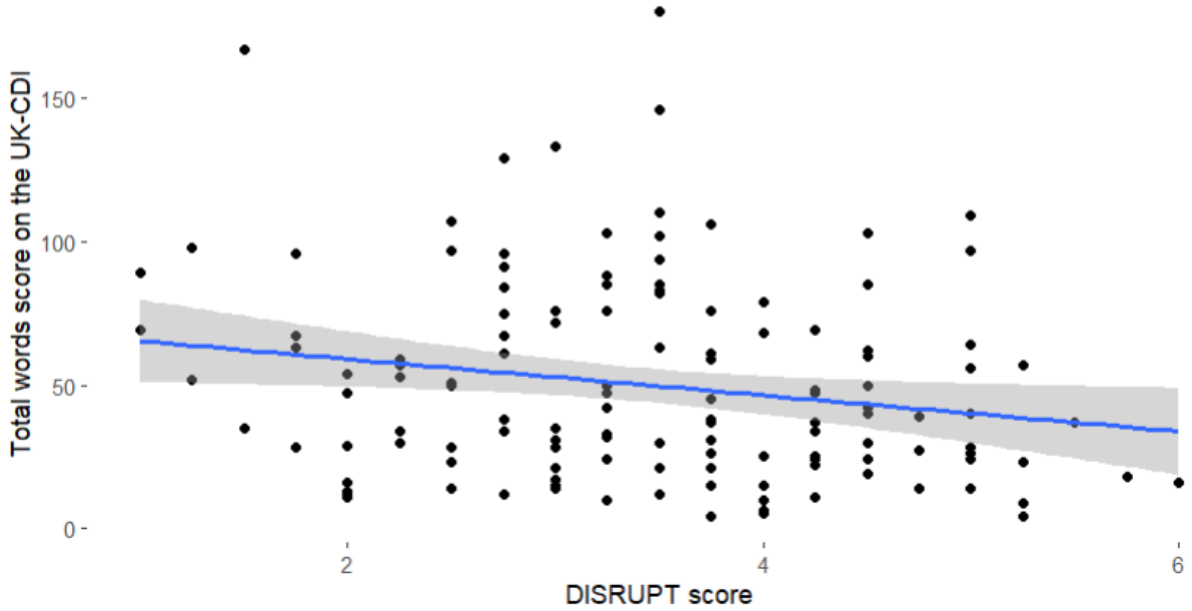
4.7.6 Hypothesis 4: Technoference and Language Outcomes

Based on the correlation matrices, the score on the DISRUPT was the only measure of technoference associated with words (produced and understood), $r_s(134) = -.20$, $p < .05$), and was therefore selected for further analysis. A Shapiro-Wilk's test revealed that the total words (understood and produced) was positively skewed ($W = 0.91$, $p < .001$). To account for this, the DISRUPT data was standardised (converted to Z scores). As child age could predict language outcomes, a hierarchical regression model entered child age in Step 1. Five participants were removed from these analyses due to missing data for child age. Child age significantly predicted language outcomes, $F(1, 127) = 16.34$, $p < .001$, $R^2 = .114$. In Step 2, the standardised DISRUPT score was entered, this did not significantly improve model fit beyond age alone, $F(1, 126) = 3.49$, $p = .064$, $R^2 = .024$. In the full model, DISRUPT

was not a significant predictor of total words when controlling for age, $t(126) = -1.87$, $p = 0.64$, though the direction of the effect (negative) is consistent with the hypothesis relationship (Figure 4.16).

Figure 4.16

The Association Between Parents' Score on the DISRUPT and Words Produced and Understood by the Child

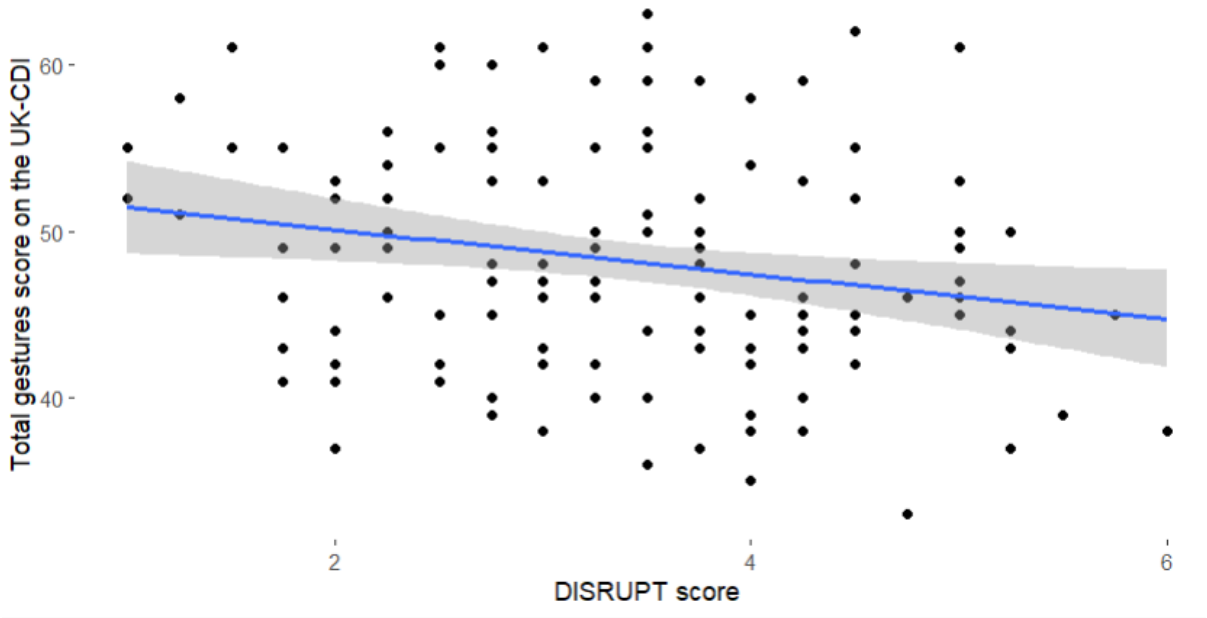


Two measures of technoference in the correlation matrices were associated with the child's use of gestures, the DISRUPT score, $r_s(134) = -.21$, $p < .05$, and use of the smartphone when actively engaged with the child, $r_s(134) = .17$, $p < .10$; these were selected for further analysis. A Shapiro-Wilk test revealed a negative skew for use of phone when engaged with the child ($W = 0.73$, $p < .001$), with more participants selecting 'never' or 'sometimes'. Only nine participants selected any of the other options, therefore the analysis was conducted on 'always', 'most of the time', or 'half the time or less'. Use of gestures was normally distributed for each of these levels, as assessed by Shapiro-Wilk's test ('Always' $p = .21$, 'Most of the time' $p = .29$, 'Half

of the time or less' p = .19). Levene's test revealed homogeneity of variance (p = .10), therefore a one-way ANOVA was applied. There was no significant main effect of parents using their smartphone when engaged with their child and the child's use of gestures, $F(2, 131) = 1.18$, p = .31, $\eta^2 = 0.02$. A hierarchical linear regression was applied to test whether the DISRUPT score predicted the child's use of gestures above any effects of child age. Preliminary analysis of the model showed the assumptions for a linear regression were met but for consistency across models, standardised DISRUPT scores were included. Child age was entered in Step 1 and significantly predicted total gestures, $F(1, 127) = 24.68$, $p < .001$, $R^2 = .163$. DISRUPT score was entered in Step 2 and improved the model fit beyond age alone, $F(1, 126) = 4.72$, $p = .032$, $R^2 = .030$. In the full model, DISRUPT significantly predicted total gestures when controlling for age, $t(126) = 2.17$, p = .032 (Figure 4.17).

Figure 4.17

The Association Between Parents Score on the DISRUPT and Gestures Produced and Understood by the Child



4.7.7 Hypothesis 5: JME and Language

A Kruskal-Wallis test was analysed to test whether there were differences in the number of communicative gestures a child uses depending on whether parents engage in shared smartphone use with their child. Participants who did not let their child use their phone were removed for this analysis. Scores on gestures for each level of shared smartphone use were normally distributed for 'no' (p= .14) and 'sometimes' (p = .40), but not for 'yes' (p = .03), as assessed by Shapiro-Wilk's test, therefore a Kruskal-Wallis test was applied. There was not a significant effect of shared smartphone use on the amount of communicative gestures a child uses, $X^2(2) = 0.23$, p =.89, $\eta^2 = -0.03$. A Kruskal-Wallis test was also conducted to see if shared smartphone use affected the child's production and comprehension of words, as a Shapiro-Wilk's test identified two levels of shared phone use that were not normally distributed ('No' $p < .001$, 'Sometimes' $p = .11$, 'Yes' $p < .001$). There was not a significant main effect of whether parents engaged in shared smartphone use with their child and the child's language, $X^2(2) = 0.62$, $p = .74$, $\eta^2 = -0.01$.

4.8 Discussion

The first aim of Study 2b was to explore whether technoference is related to parent responsiveness and child language development, as well as testing whether JME can enhance language development. The results of the survey revealed that higher levels of responsiveness were associated with parents making a conscious effort to put their smartphone away (H3). Technoference was found to be negatively associated with gestures (H4), but JME had no effect on language (H5). The second aim was to explore 1) the relationship between parent smartphone use and engagement level with their child, 2) whether there was a relationship between technoference and the child's smartphone use, 3) the association between shared

phone use (JME) and level of parent responsiveness. Parents reported higher overall smartphone frequency when not interacting with their child; notably, no specific type of phone was reported as being more common during periods of engagement than during non-engagement. There was no relationship between technoference, and children's smartphone use. Higher levels of parent responsiveness were found for parents who did not engage in shared smartphone use with their child. The three exploratory questions are discussed next.

4.8.1 Exploratory question 1 – How Do Parents Use Their Smartphones?

The literature to date does not provide a clear picture of parent smartphone use when engaged with their child (see Chapter 3, Section 3.4.2). Consistent with Study 1, parents reported being more likely to use their smartphone whilst the child was asleep, or not engaged with the parent, than during a dyadic interaction. These findings suggest that despite concerns over parent smartphone use, parents are mindful of their phone use when interacting with their child. This may be because parents feel guilty for using their smartphone around their child (Garg, 2021) and have therefore implemented strategies to avoid using their smartphone when with their child (Bury et al., 2020). Alternatively, the demands of childcare may render smartphone use impractical, but technoference can occur without direct phone use. For example, parents can be cognitively distracted by their phone e.g., hearing a notification but being unable to check their device. This study asked parents about their phone use when engaged with their child and outside of parent-child interactions but did not assess whether parents were thinking about their phone use during, and outside of, dyadic interactions. If parents are physically using their phone less during interactions with their child, cognitive technoference could be higher. Conceivably, cognitive technoference could impact the parent-child interaction in a

similar way to other non-physical distractions such as maternal depression (Field, 2010).

Smartphones have a range of functions which require different demands from the user. To truly understand the potential effect of technoference on the parent-child interaction, we need to have a better understanding of *how* parents are using their smartphones when engaged with their child. In this study, parents did not identify any function of phone use as being more likely to occur when engaged with their child than when not engaged with their child. These findings differ to those in Study 1 (Chapter 3), where parents reported being more likely to use their smartphone to control smart devices, take photos, make video calls, and to take photos when engaged with their child. Given the wide range of functions on a smartphone, it is somewhat unsurprising that no clear pattern of phone use by parents when engaged with their child has emerged (Corkin et al., 2021; Garg, 2021; Hiniker et al., 2015; Mangan et al., 2018). The lack of consistency in findings across studies, can also be explained by how smartphone use is measured. For example, both Study 2b and Corkin et al. (2021) provided parents with a list of potential smartphone uses to select from, but the lists provided differed, whereas other studies have acquired more open responses from parents via interviews and diaries (Garg, 2021; Hiniker et al., 2015).

4.8.2 Exploratory Question 2: Is There a Relationship Between Technoference and Children's Smartphone Use?

No relationship was found between parents' levels of technoference and their child's independent smartphone use, which contrasts with research showing parent's screen time is associated with child screen time (Lauricella et al., 2015). The majority (over 94%) of parents in this sample did allow their child to use their phone. One

simple reason for the lack of association found may be that if the child is using the parent's phone, the parent is unable to use it. Additionally, parents' views on child smartphone use were not measured. This is important because parents who view screen time positively have children who engage in more screen time (Lauricella et al., 2015). Possibly the parents in this sample have positive views on child smartphone use, given that less than 5% of parents in this study reported that their child never uses their smartphone independently. This is interesting, as 55% of the sample reported that their child does not show an interest in the smartphone when their parent is using it. If children are not consistently showing an interest in the smartphone when it is present, it is curious that nearly all parents let their child use their smartphone and suggests it may be the parent, not child, who is initiating the child's smartphone use. Indeed, Marsh et al. (2015) found that the decision for children under 5 to use tablets was primarily initiated by the parent, potentially becoming a parenting aid and an integral part of the daily routine (Bar Lev et al., 2018), regardless of the parent's attitudes towards the effects of media on their child (Bar Lev & Elias, 2020). Maybe technoference was not found to be related to children's smartphone use because children's smartphone use is influenced by the complex intricacies of family life rather than parent smartphone use.

4.8.2 Exploratory Question 3: Is Parent Responsiveness Related to JME?

This study sought to explore whether JME is related to responsiveness. JME involves the parent engaging with their smartphone with their child, which has been found to facilitate positive interactions between the dyad (Floegel et al., 2021). Co-using media with a child is influenced by parent age, with younger parents more likely to co-use media, and by the amount of time the parent spends with the child, with the more time together facilitating more periods of co-use (Connell et al., 2015).

In this study, parents who reported that they did not co-use their smartphone with their child had significantly higher levels of self-reported responsiveness than parents who did use their smartphone with the child. Moreover, parents who put their phones away more frequently were more responsive, indicating that it may be that responsive parents put their phone away more frequently, which limits opportunities for JME.

Understanding the reasons why parents choose to co-use their smartphone or not, as well as knowing what the child is allowed to do on the smartphone, is necessary to try to make sense of these findings. Parents who do not use the smartphone with their child may be allowing their child to use the phone independently for a range of reasons such as, entertaining the child whilst the parent completes chores (Bar Lev et al., 2018), as an educational aid (Thompson et al., 2023), or to distract the child (Floegel et al., 2021). This may allow for the parent to maintain levels of responsiveness, as the device use has met a need, saving the parent time/resources. To further understand these findings, it is necessary to understand the frequency of JME episodes and how the smartphone is used during JME.

4.9 General Discussion

With technology being ever present in parent-child interactions, it is important to understand what impact, if any, this may have on these interactions. These two studies contribute to the literature by furthering our knowledge on how parent smartphone technoference may affect important precursors to language development, and language outcomes in children. The experiment used in Study 2a showed that parent smartphone technoference does disrupt parent-infant interactions. When parents used a smartphone during the interaction, infants were

more expressive and looked less to their parent than when play was uninterrupted. When using a smartphone, parents looked at their infant less, directed less language towards their infant, made fewer contingent responses to their infant's expressions, and were more likely to not respond at all to their infant's expressions, than when play was uninterrupted. Parents, but not infants, behaviour was affected differently depending on the way the phone was used. When using the phone to make a call, parents were less likely to direct language towards their infant and were more likely to fail to respond to their infant's expressions than when using a phone to take a photo. When using a phone to take a photo, parents responded contingently more often to their infant's expressions, and spent longer looking at the phone than when using the phone to make a call. Study 2b sought to extend Study 2a by measuring language outcomes in relation to smartphone technoference, accounting for natural parent smartphone technoference and JME. Study 2b extended some of the findings of Study 2a, finding reduced responsiveness in parents who put their phone away less frequently. Technoference was found to be negatively associated with language outcomes, specifically gestures, whilst JME was not associated with language outcomes. Together, these two studies suggest that parent smartphone technoference affects features of parent-child interactions which are precursors for language development in children, namely parent responsiveness, parent use of language, and social gaze, and is also related to some language outcomes in children. Whether the disruption to these precursors mediates the relationship between parent smartphone technoference and language is still unclear.

4.9.1 Technoference and Language

In line with previous research (Corkin et al., 2021; Reed et al., 2017), technoference was negatively associated with gestures in Study 2b. However, this

relationship was dependent on how technoference was measured and was only found when measuring technoference via the DISRUPT, but not when parents were asked how frequently they consciously put their smartphones away when with their child. These inconsistencies may be explained by the different measures assessing different elements of technoference. For example, consciously putting the phone away does not remove cognitive distraction, i.e. thinking about the phone, but this is captured in the DISRUPT. Moreover, both measures capture the parent's perspective, but not how the child perceives the disruption, which may shape how technoference affects language development. A child is unlikely to be aware that a parent is cognitively distracted by their phone, whereas direct phone use is likely more obvious to the child. Study 2a allowed for parent smartphone use to be manipulated in a manner that the infant would notice and measure the effects on the infant during the interaction, finding that infants gazed to their parent less, but had increased levels of spontaneous expression during smartphone technoference in comparison to uninterrupted play. These changes in behaviour suggest infants do have some awareness of the interruption, reinforcing the need for a clearer conceptualisation of technoference (Frackowiak et al., 2024).

Infant social gaze is an important precursor for language development (see Chapter 1, Section 1.4). As the first study to experimentally test the effects of smartphone technoference on infant gaze in the home environment, these findings build on previous research revealing that infants' social gaze is disrupted in naturalistic play by smartphone technoference (Tonga, 2023). Why might infants gaze less at their parent during smartphone technoference? One possibility is that infants' gaze is affected by the parent looking at the phone. However, whilst parents regulate their gaze to the infant dependent on the infants' gaze, i.e., if the infant

stops looking at the parent, the parent stops looking at the infant, infants do not regulate their gaze in response to their parents' gaze (Kahya et al., 2022). Put simply, infants maintain a regulated pattern of gaze which is not influenced by the gaze of their parent. In addition, infants rarely look to their parent's face during naturalistic interactions (Deak et al., 2014), particularly if infants are free to roam (Franchak et al., 2016), reinforcing that infants do not lead in gaze behaviour. Another possibility is that the change in infants' gaze is related to emotional regulation. As discussed in Chapter 1, parent smartphone technoference causes a 'still face' in the user (Konrad, Berger-Hanke, et al., 2021), and infants display similar patterns in response to this as in the classic still-face paradigm (SFP), i.e. a decreased in gaze towards the parent (Stockdale et al., 2020; Tidemann & Melinder, 2022). Possibly, in this study, infants were responding to the still face with reduced gaze to the parent, as opposed to the smartphone technoference directly.

Parent social gaze is also important for developing social competence in the infant, signalling a readiness to interact (Senju & Csibra, 2008). Study 2a revealed that parents' social gaze was also disrupted by smartphone technoference, supporting prior evidence that smartphone technoference disrupts parents' gaze to the infant (Elias et al., 2020; Nomkin & Gordon, 2021; Radesky et al., 2014). Similarly, mutual gaze was more frequent when play was uninterrupted in comparison to when parent smartphone technoference occurred. This is likely led by parents' gaze behaviour, as parents tend to spend more time looking to the infant during a social interaction. Mutual gaze therefore occurs when the infant looks to the parent, who is already looking to the infant (Northrup & Iverson, 2020). The explanation for the effect of smartphone use on parents' gaze to the infant is perhaps more straight forward. Using a mobile phone requires that the user looks at the

device to interact with it and in some cases to unlock the phone to use it. Thus, opportunities to direct gaze towards the infant are displaced towards the phone. Although, another possibility is that parents were diligently adhering to the study instructions to use their phone during the two technoference play periods. Subsequently, parents' visual attention was on the phone rather than their infant. In contrast, real world phone use is more autonomous, allowing the parent the flexibility to alternate their gaze between their phone and their child (Amery, Danby, & Brereton, 2026).

In line with previous research (Abels et al., 2018; Elias et al., 2020; Hiniker et al., 2015; Lederer et al., 2022; Mikić et al., 2025; Nakagawa et al., 2019; Ochoa et al., 2021), smartphone technoference was associated with reduced parent responsiveness in Study 2a and Study 2b. These findings may be due to absorption in the smartphone, which reduces responsiveness to the child (Vanden Abeele et al., 2020). Results from Study 2a support this, showing that parent contingency varied by task; specifically, parents were more responsive when using the phone to take photos than when making a call. This suggests that the nature of the task may moderate the relationship between technoference and responsiveness. Taking photos may allow for intermittent engagement, which aligns with recent findings from Amery, Danby and Brereton (2026) that a mother was able to use her phone and respond to her infant's bids for attention, without becoming absorbed in the phone. However, in Study 2b, the direction of the association between responsiveness and technoference cannot be established, due to the correlational nature of the findings. For example, as there are individual differences in responsiveness (Bigelow & Power, 2014), it is possible that parents who are already engaged in higher levels of responsive parenting, choose to put their smartphone away to avoid the phone

distracting them from social interactions with their child. Indeed, some parents implement specific strategies to minimise distraction from their smartphone, such as turning off notifications (Johnson, 2017). Similarly, less responsive parents may be more likely to use their smartphones when engaged with their child. Thus, the association may reflect smartphone use as a feature of reduced responsiveness, rather than smartphone use reducing responsiveness. There may also be a reciprocal relationship between the two. Alternative explanations for this relationship include the infants' developmental progression and maternal depression (Golds et al., 2024). Golds et al. (2024) found that most mothers engage in low levels of smartphone use, have high levels of responsiveness, low levels of depression and anxiety, and low levels of concern over their infant's development. Where phone use is high and responsiveness low, mothers also have increased levels of depression and anxiety or increased concerns over their infant's development. Together these findings suggest that the relationship between smartphone use and responsiveness may not be direct and may instead be embedded within broader family context.

Opportunities for parents to respond to their infant are dependent on the infant directing communication to the parent. In contrast to previous literature that infants make more bids for their mother's attention when she uses a smartphone in comparison to uninterrupted interactions (Krapf-Bar et al., 2022; Myruski et al., 2017), infants in Study 2a made more positive spontaneous expressions during uninterrupted play in comparison to when play was interrupted by smartphone technoference. The difference in findings may be due to the methodology used. Study 2a encouraged parents to continue to interact with their infant as they usually would during phone use, but Krapf-Bar et al. (2022) did not provide mothers with instructions regarding interacting with their infant during phone use, and Myruski et

al. (2017) instructed the mother to be unresponsive to the infant whilst using the phone. Possibly removing the parent from the interaction can explain the difference in findings; infants may have made more bids for attention during smartphone use as the mother being unresponsive was unusual, as opposed to responding to the smartphone use per se. Further research is needed exploring natural parent smartphone technoference, that is familiar to the infant, and its impact on parent responsiveness.

As JME has the potential to initiate joint attention, which is important for language development (Carpenter et al., 1998; Markus et al., 2000; Tomasello & Farrar, 1986; Tomasello & Todd, 1983), it was anticipated that JME may be related to language development. However, Study 2b found no evidence that JME has any effect on language outcomes and fails to provide support for previous research reporting JME as being beneficial for language (Corkin et al., 2021; Medawar et al., 2023). One reason for the lack of consistency across studies may be because the current measures of JME do not consider the wide range of potential ways that a dyad can engage in JME on an electronic device. For example, the measure of JME both in Study 2b and in Corkin et al. (2021) was rather broad, simply asking parents how often they engage in the device together as opposed to capturing what activities the dyad engage in during JME. As smartphones are multi-functional, JME can encompass a range of potential interactions. For instance, passively watching a video together may create a different shared experience in comparison to playing a digital game together, or video calling a close relative. Although Medawar et al. (2023) gathered more detail on JME such as asking parents about conversations during and after media use, they also did not ask parents what they do during JME. Measuring the specific activity during JME is important as the relationship between

smartphone JME and language may be dependent on the intricacies of the dyadic interaction during JME. An activity which is too absorbing for either, or both, of the dyad may prevent JME from being a truly shared experience (Ewin, Reupert, & McLean, 2021). However, structured digital activities provide promising results for JME and shared engagement. For example, electronic book reading has been found to increase parent language in comparison to traditional book reading (Lauricella et al., 2014). Arguably, the current measures of JME which do not identify the type of JME, or allow for differentiation between structured and unstructured JME, may not have identified any nuances in the relationship between JME and language.

4.9.2 Technoference and Parents' Use of Language

Study 2a's findings are in line with previous literature that parent smartphone technoference negatively affects parents' use of language during parent-child interactions (Gaudreau et al., 2021; Kelly & Ocular, 2021; Radesky et al., 2015). In Study 2a parents directed language to their infants less frequently when using a smartphone during play, compared to uninterrupted play. This pattern of findings remained for both naming language and non-naming language, suggesting that smartphone technoference disrupts infant directed language. Of consideration, is that in Study 2a, parents were instructed as to how to use their phones, yet, during natural interactions parents make a choice as to whether they use their phone or not. The reasons for using the phone may influence the extent to which parents' use of language is disrupted by the phone. For example, parents report feeling less guilt using their smartphone if the availability norm is high i.e., they perceive they are expected to respond to calls/messages quickly, whereas guilt was higher if there was goal conflict between smartphone use and everyday tasks (Halfmann et al., 2025). In Study 2a, the availability norm was high as parents were instructed to use their

phone in a specific way for a fixed duration. It may be that if parents are not feeling guilt for their phone use, that they are less concerned with monitoring the quality of their interaction with their infant. Indeed, in U.S. restaurants, parents who used their phone had higher levels of engagement with their child after engaging in phone use which was higher than their typical use (Linder et al., 2022). This suggests that parents do compensate for smartphone technoference. Future research is needed to explore whether parents' use of language is disrupted to the same extent when phone use is natural.

4.9.3 Technoference and Infant Vocalisations

Contrary to the prediction that infants would make more vocalisations when parents use their smartphone during play, Study 2a found no difference in the duration that infants were vocal during uninterrupted play in comparison to play disrupted by smartphone use. It is curious that infants did not increase vocalisations during periods of parent smartphone use, as parents responded less contingently in Study 2a when using their phone. Research has previously found that infants adjust their vocalisations to the parents' social feedback. Contingent, but not non-contingent, feedback increases the quality and quantity of infant vocalisations (Goldstein et al., 2003). Although, in Study 2a parents' general responsiveness was measured, not specifically their vocal contingency, which may explain why contingency was affected but not infant vocalisations. These findings are also in contrast to research showing that negative affect (including vocalisations) increased, and positive affect (including vocalisations) reduced, when parents used their phone in a modified SFP (Myruski et al., 2017; Stockdale et al., 2020). Methodological differences may explain why Study 2a did not support these previous findings. Rather than a still face, smartphone use in Study 2a reflected more natural phone

use. As infants build their understanding of social exchanges through early experiences (Feldman, 2007), infants in contemporary society may build a template of social interactions that include phone use. Tronick (1989) states that infants who do not experience repair after miscoordination during a social interaction are less likely to seek to repair the social interaction. This is supported by research from Elmlinger et al. (2023) who found that infant vocalisations during the still face increased if parents had previously responded contingently during a social interaction. This may explain why infants' vocalisations did not change when parents used their phone in Study 2a. Put simply, infants are used to experiencing smartphone technoference and therefore do not seek to repair the interaction via vocalising, as they have learned this does not work. The unusualness of a 'still face' may not follow this pattern, as the infants do not have a template of a still face during social interactions, and therefore increase vocalisations to reengage the parent. Second, how the smartphone was used varied across studies, Myruski et al. (2017) instructed parents interact with the device, but not how, Stockdale et al. (2020) instructed parents to use their phone as they usually would, and Study 2a specified phone use. Whilst not significant, parents in Study 2a reported making video calls and taking photos more often when engaged with their child, in comparison to not engaged with their child. If phone use in Study 2a, to make calls and take photos, reflects infants' natural exposure to smartphone technoference, this may explain the difference in findings. As previously stated, perhaps infants have adapted their understanding of social interactions to include phone use, and possibly specific types of phone use. Future research should further explore whether phone use which more closely reflects parents everyday phone use when with their infant has different effects on infant vocalisations. Last, infant vocalisations were not measured

consistently. Myruski et al. (2017) measured vocalisations as part of positive and negative affect, Stockdale et al. (2020) measured the presence or absence of infant vocalisations, whilst Study 2a measured the duration of vocalisations. It is possible that the duration of vocalisations could be similar to Stockdale et al. (2020). It would be beneficial in future studies to measure both the amount and duration of infant vocalisations.

4.9.4 Type of Smartphone Use

Study 2a tested whether the way in which a parent uses their smartphone when with their infant has different effects on the parent-infant interaction. Parents were asked to use their smartphone in two different ways, to take and share photos with their infant and to make either a phone or video call. How the phone was used affected the infants' and parents' gaze directed towards the phone. Both parents and infants looked longer at the phone when it was used to take photos in comparison to when it was used to make a call. For the parents, but not the infants, the type of call also affected gaze to the phone. Parents looked longer to the phone when it was used to make a video call than when it was used to make a voice call. Parent use of language and responsiveness also varied depending on how the phone was used. Parents used less language directed to their infant when making a call in comparison to taking photos, the type of call (video or phone call) did not influence the amount of language parents directed to their infant. Parents did not respond to their infants' expressions more frequently when using the phone to make a call than when using the phone to take photos. Taken together, these findings suggest that how the phone is used affects the parent more than the infant during parent-infant interactions. I explore these findings further below.

To the best of my knowledge, only one other study has measured infants' gaze towards the phone during parent smartphone technoference. However, Tonga (2023) found that infants did not look to their mother's hands more when she had something in the hands (either a phone or paper), whereas this study found that infants do look to the phone when it is used to take photos. The difference in findings is likely because parents used the phone to complete a questionnaire (Tonga, 2023), this is an individual task which does not involve the infant, similar to the call task in Study 2a. Yet, when parents in Study 2a used their phone to take photos, they made attempts to gain their infant's attention to look towards the phone and showed the photos on the phone to the infant whilst simultaneously talking about the photos. Interacting with the infant and phone in this way, has the potential to lead to JME. This line of argument warrants further experimental exploration, whereby JME is measured across different types of phone use.

The findings that parents' behaviour is affected by how the phone is used replicates and extends previous findings from Radesky et al. (2014) showing that parents' gaze towards their phone is dependent on type of phone use and is less likely to occur for phone calls. Study 2a adds to these findings, showing that type of call matters and that video calls, unsurprisingly, demand more of the parents' gaze than phone calls. Despite guidance in the U.S to not expose infants to media before the age of 2, parents report regular use of video calls with their 6-24-month-olds (McClure, 2015). In Study 2a, although not significant, parents reported being more likely to use their phone to make video calls when engaged with their infant, than when not engaged with their infant. If video calling is common among parents, and using the phone in this way demands more of the parents' gaze, it is important to consider the effects of video calling on infant development. Despite in Study 2a

infants not looking longer at the phone during video calls in comparison to a phone call, previous research shows that infant engagement in video calls can have beneficial outcomes. For example, during video calls with grandparents, infants as young as 8-months old can engage in joint visual attention with the grandparent (McClure et al., 2018; Myers et al., 2024) and video calls are positively associated with communicative development (Paoletti et al., 2025).

Study 2a provides novel insight into how the way in which the phone is used influences parents' use of language. Previous research shows that smartphone use disrupts parents' language input during interactions with their child (Radesky et al., 2015), and that non-digital disruptions have similar effects on parents' use of language as smartphone technoference (Chamam et al., 2024; Ewin, Reupert, & McLean, 2021; Gaudreau et al., 2021; Lederer et al., 2022). This would suggest that all distractions are equal. However, Study 2a's findings suggest that distractions are not equal, as parents used less infant directed language when making a call in comparison to taking photos. To the best of my knowledge, this is the first study to experimentally manipulate smartphone technoference by asking parents to take photos to assess the effects on parent language. Therefore, future research should compare parent language input when the phone is used to take photos in comparison to non-digital play. An additional consideration is whether the quality of parent language is affected by the type of phone use. Whilst quantity of parent language input is related to child language development, quality of input has a larger effect, which increases as the child gets older (Anderson et al., 2021). Study 2a only assessed quantity, not quality, of parent use of language. Whether type of phone use affects the quality of language requires future consideration.

Parents were less likely to not respond to their infants' expressions when using the phone to take photos in comparison to making a call. This may be due to the demands that each type of phone use make on the parent. Although, Study 2a also found that parents spent more time looking at their phone when using the phone to take photos than when using the phone to make a call. It is curious that parents were more likely to not respond to their infant when making a call, even though they looked to their phone less than when taking photos. However, there was no difference in parents' gaze to their infants between the two types of phone use, which suggests using the phone to take photos did not displace gaze towards the infant. Possibly parents were shifting their gaze between the phone (when taking photos) and their infant, which allows the phone to become a shared object of attention, and as discussed in Chapter 1 (Section 1.5.2) can create periods of joint attention (Ochoa et al., 2021). When infants pay attention to an object, it facilitates contingent interactions between the parent and the infant (Masek et al., 2021). This may explain why when using the phone to take photos, parents were less likely to not respond to their infants' expressions, as the parents' attention may have been on the infant alongside the phone. Indeed, my findings that parents made more contingent responses when taking photos in comparison to making a call and responded non-contingently more frequently when using the phone to make a phone call in comparison to using the phone to take photos, support this line of argument. Together, these findings suggest that using the phone to make a phone call reduces responsiveness in comparison to using the phone to take photos. When speaking on the phone, a new social partner is introduced to the interaction, it may be the social disruption as opposed to the phone use which is driving these findings. However, a social disruption per se cannot explain why parents were less contingent when

making a call, as Krapf-Bar et al. (2022) found mothers were less likely to respond to infants' bids for attention when using the phone in comparison to a face-to-face social disruption. Therefore, there may be something unique about social interactions on the phone. Although, Krapf-Bar et al. (2022) asked mothers to use their phone to answer questions, unlike Study 2a where the phone was used to make a call. Radesky et al. (2014) found levels of absorption with the phone to be increased when using the phone for typing or swiping in comparison to phone calls, which may explain the findings from Krapf-Bar et al. (2022). Possibly parents were less responsive when using the phone for a typing task than a social disruption, because of the demands of the task. Whether a call and a social disruption are similar in their influence on parents' non-response to infants' expressions, is not yet known.

4.9.5 Conclusions, Limitations, and Suggestions for Future Research

This study had several limitations. First, Study 2a used a novel platform (Children Helping Science), where parents were in their own homes without the presence of the researcher. This resulted in some lack of standardisation across participants. For example, when making a call (voice or video) some parents put their phone on the floor or on a surface, rather than holding the phone. This enabled these parents to carry on manipulating toys using both hands, which may have buffered against any effects of call technoference, as parent hand actions facilitate infant visual attention to an object (Suarez-Rivera et al., 2019). Future research could compare whether holding a phone as opposed to positioning the phone elsewhere when making a call, has differing effects on the parent-infant interaction. Second, as the environment in Study 2a was not controlled, there were variations in whether other people were present during the experiment. In some instances,

siblings spoke to the parent during the study. In these cases, parents were consistent in asking the siblings to not disrupt them as they were completing a study. However, the presence of the sibling may have affected outcomes measured in the study, e.g., gaze to infant/parent, or language directed to the infant. Although, this reflects technoference outside of the laboratory, where a parent-infant dyad are not in a distraction free environment, and may provide a better representation of the influence of parent smartphone technoference on parent-infant interactions than lab studies (Ewin, Reupert, McLean, et al., 2021; Lederer et al., 2022). To be able to advise parents on smartphone use, we need to have a valid representation of how parents use their phone when with their infant in the home. To test this, future research could conduct observations in the home but without explicit instructions on phone use, to assess the effects of natural smartphone technoference. Third, the survey in Study 2b had a limited number of responses as to how the smartphone was used, and it is therefore possible that it failed to capture how parents are using their smartphone when engaged with their child by omitting options such as to access social media, to check emails, and logging their child's routine. Fourth, both studies were cross-sectional. As technoference, social gaze, JME, and responsiveness are not one-off occurrences, this study does not allow for an understanding of how these variables may interact with each other and subsequently shape child language outcomes over time. Future research would benefit from longitudinal observations in the home, where the effects of technoference and language can be seen during daily routines that children are frequently exposed to across child development. Finally, technoference although there was a significant relationship between technoference and child gestures in Study 2b, the effect was small (R^2 = .030), with technoference accounting for only 3% of the additional

variance beyond age. This suggests the variability in child use of gestures is associated with factors other than technoference, such as child age (which accounted for 16% of the variance). Nevertheless, as smartphone technoference occurs potentially daily, these small effects may accumulate over time. Other potential confounds include parental education and family income. Maternal education has not been found to be associated with technoference (Krogh et al., 2021, McDaniel & Radesky, 2018a), making it less likely a confounder, although it is associated with child language exposure, with higher levels of education associated with more adult speech and more conversational turns (Dwyer et al., 2019). Similarly, children in families of lower SES are more likely to experience less high quality and less high quantity language environments (Schwab & Lew-Williams, 2016). These factors may instead moderate the effects of technoference; as technoference during routine has been shown to be associated with language development in 2-year-olds (Sundqvist et al., 2021), its effects could be compounded in homes where adult speech is already lower. This is an avenue which requires further exploration.

Overall, the two studies presented both add to the literature on parent smartphone technoference. First, parent smartphone technoference affected how both infants and parents behaved during the parent-infant interaction, resulting in lower quality interactions (Study 2a). Importantly, smartphone technoference was not equal in its effects on parent-infant interactions. Across several behaviours, using the phone to make a call was more disruptive than using the phone to take photos. Second, parents who put their smartphones away when with their child and those parents who did not engage in shared smartphone use were more responsive (Study 2b). Parents who are concerned about their smartphone use when with their child could be advised to put their smartphone away during parent-child interactions. The

importance of being mindful of ‘how’ the phone is being used could also be conveyed, with parents encouraged to avoid phone use which removes them from the interaction such a phone calls.

Chapter 5 Study 3 Parent Smartphone Use in Early Word Learning: A Comparison of Technoference, Joint Media Engagement, and Uninterrupted Instruction

5.1 Introduction

The findings from Chapter 4 revealed that parent smartphone technoference disrupts features of parent-infant interactions which facilitate language development in 9–11-month-olds (Study 2a) and is negatively associated with language outcomes in 12-18-month-olds (Study 2b). Joint media engagement (JME) was not related to language outcomes (Study 2b). Although Study 2b did not reveal a relationship between JME and language outcomes in 12-18-month-olds, a novel finding from Study 2a was that the way in which parents use their phone has different effects on parents, but not infants, behaviour. Phone use which led to technoference (a phone call) negatively affected parent responsiveness and parent language input in comparison to phone use which encouraged JME (taking photos). Together these findings suggest that smartphone use which results in JME may be less disruptive to parent-infant interactions than smartphone technoference, but this might not translate to improved language outcomes in children. As discussed in Chapter 4, this finding is contrary to previous research which has found JME to be beneficial for

language development (Corkin et al., 2021; Medawar et al., 2023). Possibly, methodological variations across studies account for this discrepancy; notably, a lack of clear operationalisation of what constitutes JME. Due to the broad functionality of a smartphone, all forms of JME are not equal: some may promote a shared interaction, whilst others may be too absorbing to promote such interpersonal exchange (Ewin, Reupert, & McLean, 2021). To address this, Study 3 compares the effect of parent smartphone use which creates technoference, to parent smartphone use which encourages JME, on children's novel word learning.

Study 3 is a partial replication of an experimental study that tested the effect of technoference on novel word learning in 2-year-olds (Reed et al., 2017). In this study, parents taught their child two novel words, one at a time, each for 60 seconds. One teaching period was interrupted by a phone call for 30 seconds, the other teaching session was uninterrupted. Children were more likely to learn the novel word during the uninterrupted teaching period, suggesting that smartphone technoference may impair language learning. This suggestion is supported by a small body of research (Northcott, 2021; Sundqvist et al., 2021) finding smartphone technoference as being disruptive to language learning. As discussed in Chapter 1, parent responsiveness facilitates language development (Baumwell et al., 1997; Bornstein et al., 2020; Leigh et al., 2011; Tamis-LeMonda et al., 1996). As smartphone technoference reduces parent responsiveness (Abels et al., 2018; Elias et al., 2020; Hiniker et al., 2015; Inoue et al., 2021; Lederer et al., 2022; Mangan et al., 2018; Nakagawa et al., 2019; Wolfers et al., 2020), it may in turn affect language development through disrupting underlying mechanisms including parent contingency during parent-child interactions (Kelly & Ocular, 2021) and the number of questions parents and children ask each other (Gaudreau et al., 2021). Yet,

Gaudreau et al. (2021) found neither parents' nor children's responsiveness to questions was affected by smartphone technoference. Seemingly, technoference may not impact all aspects of conversation. However, several issues across these studies warrant the need for further research. First, Kelly and Ocular (2021) employed a between-participant design but did not randomly allocate whether parents used their phone or not. Whilst this allowed for measures of natural smartphone use, it is possible that parents who choose to use their phones more frequently are less contingent in conversations regardless of whether they are using their phone or not. Second, although Reed et al. (2017) used a within-participant design, the teaching period which was not interrupted by phone use, was not interrupted at all. Possibly, it was the break from teaching rather than use of the phone during the interruption which impaired novel word learning. Third, although Gaudreau et al. (2021) did compare different mediums of interruption (smartphone or pen and paper) during a dyadic interaction, both interruptions involved the same task, i.e., completing a survey. This is an individual task which, regardless of the medium of distraction, places the same demands on the user. Whilst this allows for a comparison between digital and non-digital disruptions, it does not inform as to whether alternative ways of using the phone would have the same effects on parent language use.

Phone use which encourages JME may be less disruptive to language learning. As discussed in Chapter 1, parent smartphone use has to potential to establish joint attention when the phone is used to look at videos/photos or to take photos (Kelly et al., 2023; Ochoa et al., 2021; Radesky et al., 2014). Joint attention facilitates language development (Markus et al., 2000; Tomasello & Farrar, 1986; Tomasello & Todd, 1983), therefore if JME can lead to joint attention it may be less

detrimental to language outcomes than phone use which directs the parent's attention from their child to their phone. Indeed, Corkin et al. (2021) found less frequent parent and infant co-use of screens was associated with lower infant vocabulary in 18-25-month-olds. Notably, much of the research on JME and children's language has been conducted on digital devices other than smartphones e.g. iPads, television, finding increased parent utterances and increased use of new words (Ewin, Reupert, McLean, et al., 2021; Lavigne et al., 2015). To date, research has not experimentally compared smartphones as the digital technology during JME and child language outcomes.

5.1.2 The Present Study

Study 3 was a pre-registered (https://aspredicted.org/m3vg-ndm4.pdf) partial replication of Reed et al. (2017). This study tested whether type of phone use affects word learning, across three experimental conditions: 1) teaching was interrupted by a phone call, 2) teaching was interrupted by shared game play on the phone, 3) teaching was uninterrupted. The addition of a second phone use condition addresses the possibility that the findings from Reed et al. (2017) occurred because of the interruption to teaching, rather than due to the impact of the smartphone, i.e. any interruption could have had the same effects. Indeed, several studies show similar effects on language of both digital and non-digital disruptions (Chamam et al., 2024; Gaudreau et al., 2021), but possibly the demands of the disruption could have different effects. Comparing two different types of smartphone use (phone call vs. shared game play) tests whether the way in which parents use their phone impacts novel word learning, further addressing whether different types of smartphone disruptions are equal, or whether the demands on the user matter. Both uses of the smartphone create an interruption to the teaching, but crucially in different ways. The

phone call limits the parents' opportunities to provide responsive parenting (via technoference), and playing a game together creates an opportunity for JME to occur. It was hypothesised that novel word acquisition would be greatest in the uninterrupted condition, followed by JME, and lowest in the smartphone technoference condition.

5.2 Method

5.2.1 Participants

Sixty-nine caregivers (68 parents, 1 grandparent) (67 females, M_{age} 35.90_{years}, SD = 4.87_{years}) and their typically developing children between the ages of 24 and 30 months (35 males, M_{age} 25.61_{months}, SD = 1.66_{months}) participated in the study. Eight additional children were excluded due to being bilingual (N = 5), because of fussiness (N = 2), and because the caregiver mispronounced one of the words they were teaching (N = 1). This age group was chosen in line with previous research utilising a similar paradigm which demonstrated that children of this age were able to learn novel words from social interactions (Reed et al., 2017; Roseberry et al., 2014). A power analysis on G*Power identified a sample size of 65 participants necessary for an effect size of 0.16, based on the effect size reported by Reed et al. (2017) with a power of 0.8. Participants were recruited from a database of caregivers who had signed up to participate in research with their child. Social media was also used to recruit participants. The university ethics committee approved this research (ETH2122-1304) and informed consent was gathered digitally prior to caregivers arriving at the laboratory. Children received a book as a thank you for their participation in the research.

The characteristics of the sample are shown in Table 5.1. The primary caregiver for most children was the mother (60.9%) or both the mother and the father

(39.1%). Most of the participating caregivers were White (98.6%) and were employed part-time (63.8%) or full-time (18.8%). For 25% of the sample, the highest level of education achieved was a Level 3 qualification, 36% held a bachelor's degree, 20% had achieved a master's degree, 7% had a PhD, and 7% had another form of postgraduate education. The average household income was £68,623 (*SD* = £30,584).

Table 5.1

Characteristics of the Sample

Primary caregiver	**N (percentage)**
Mother	42 (61)
Father	0 (0)
Mother and father	27 (40)
Ethnicity	**N (percentage)**
Mixed	1 (1)
White	68 (99)
Employment	**N (percentage)**
Employed full time	13 (19)
Employed part time	44 (64)
Homemaker	4 (6)
Other	5 (7)
Student	1 (1)
Unemployed	1 (1)
Education	**N (percentage)**
GCSE (or equivalent)	1 (1)

A Levels (or equivalent)	17 (25)
Bachelor's degree	26 (38)
Master's degree	14 (20)
PhD	5 (7)
Other postgraduate qualification	6 (9)

5.2.2 Design and Variables

A within participant design allowed for a comparison between the interruption conditions, interruption via a 30-second phone call (technoference), interruption via 30-seconds shared game play on an app (JME), or no interruption. Caregivers taught three novel words to their child, one at a time. The order of the three teaching conditions was randomised and the order in which the novel words were taught was counterbalanced, this created six possible orders of presentation. 1) The phone call interruption, followed by interruption to teaching via shared game play, and finally no interruption to teaching. 2) The phone call interruption occurring first, followed by no interruption, and lastly interruption via shared game play. 3) Shared game play interruption, followed by the phone call interruption, and lastly no interruption. 4) Shared game play interruption, followed by no interruption to teaching, and finally interruption from a phone call. 5) Uninterrupted play, followed by the phone call interruption, and then interruption via shared game play. 6) Uninterrupted play, followed by interruption via shared game play, and then phone call interruption.

To measure whether the novel words had been learnt, the Intermodal Preferential Looking Paradigm (IPLP) was used (Golinkoff et al., 1987). The IPLP measured children's understanding of the novel word, each of which were a verb, by

presenting children with two video clips side by side. There was one pairing for each novel word, with one of the scenes demonstrating the corresponding action to the novel word (target scene) and the other scene involving an unrelated action (non-target scene). Audio presented alongside the video clips asked the child to find the novel word by looking at it. If the child has learnt the novel word, they were expected to look longer at the target scene than the non-target scene. This is based on extant research which finds children look longer to the target scene for previously learnt language and novel language after teaching (Ambridge & Rowland, 2013). The dependent variable was therefore total looking time to each scene (target and non-target).

5.2.3 Materials

Each child was taught three novel words by their caregiver. These words had been used successfully in previous studies (Reed et al., 2017; Roseberry et al., 2014) and were each demonstrated by the caregiver with the use of a toy (Table 5.2). In some cases (N = 36), the caregiver was inventive in their teaching of the action. For example, one child did not like the doll, so the caregiver bounced the child on their lap to demonstrate ‘blicking’, as well as using the doll. Although this created some variability in the teaching between caregivers, (who anyway still used the toys as instructed for most of the teaching), it ensured the child still viewed the action associated with the novel word.

The scenes used to test the words in the IPLP were edited clips using Sesame Street characters, who were either demonstrating the corresponding action to the novel word or a different action. Both the novel words and the clips were the same as used by Roseberry et al. (2014). The test scenes required the children to extend their knowledge of the novel word to both a new actor (Sesame Street character, not their caregiver) and a new object. For example, the caregiver taught the word ‘frepping’ using a rattle and shaking it side to side. In the Sesame Street clip, Prairie Dawn shakes a box, not a rattle. The only caveat to this, is for those children where the caregiver bounced them on their knee for ‘blicking’ (N = 6) if the child was not interested in the doll as a teaching aid.

Table 5.2

Novel Words Taught in the Study (Roseberry et al., 2014)

Novel word	Action taught to child	Matching action in video (target scene)	Non-matching action in video (non-target scene)
Blicking	Moving a doll up and down i.e. bouncing	Elmo's dad moves baby Elmo up and down on his knee	Cookie Monster's grandma holds baby Cookie Monster in her arms and twists side to side
Frepping	Moving a rattle from side to side i.e. shaking	Prairie Dawn moves a box in her hand from side to side rapidly	Elmo places his hands on a block as he stands up
Meeping	Turning the propellors on a helicopter i.e. turning	Elmo's dad turns the dial on a radio	Baby Cookie Monster runs with a toy airplane in hand

Measures

Caregivers completed a survey to assess their smartphone use and general levels of technoference during daily interactions with their child.

General Smartphone Use

Two items from Appendix D (17 and 18 – previously described in Chapter 3) asked caregivers about the frequency and duration of their smartphone use. One item, used in both Study 1 and 2b (item 19 – Appendix D), asked caregivers about

the frequency of smartphone use in the presence and absence of their child. The final item asked caregivers how they use their phone when not engaged with their child, and how they use their phone when actively engaged with their child, across eight possible uses (previously described in Study 4a).

Technoference Measures

The same three measures of technoference used in Study 2b (and described in Chapter 4), were included in this survey. The first asked caregivers about their phone use when their child was awake and actively engaging with them. The second was taken from Corkin et al. (2021) and asked how often caregivers consciously decided to put their phone away when with their child. The final measure of technoference was the caregivers' score on the DISRUPT (McDaniel, 2021) (see Appendix A).

5.2.4 Procedure

Caregiver Training

When caregivers were invited to the study, they were informed that the study was investigating whether 2-year-olds can be taught a novel word. Before the study began, caregivers were shown an instructional video (lasting 2 minutes, 34 seconds) which involved the researcher identifying each novel word, along with the corresponding toy and action. The video also informed caregivers of the English word for each of the novel words (bouncing, shaking, and turning). This video was sent via email prior to the laboratory visit, and caregivers were instructed not to allow their child to view it or to expose them to the target words before the study begun. Informed consent was also completed online before the visit.

Upon arriving at the laboratory, each caregiver was offered another opportunity to watch the instructional video and to ask any questions about the novel

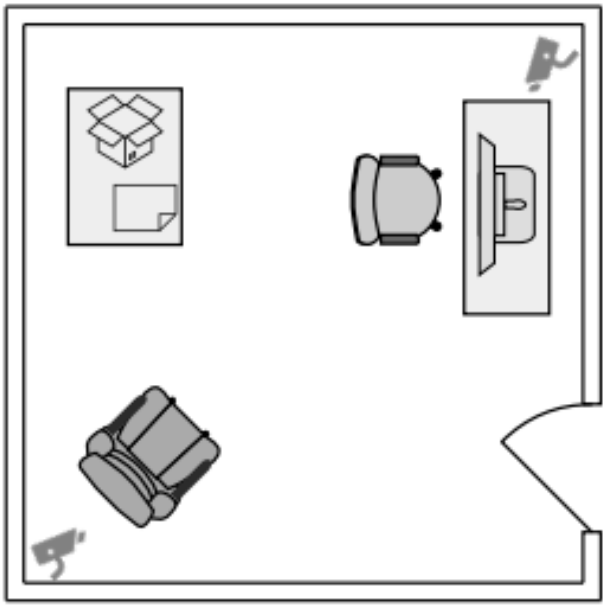
words they were to teach their child. If the caregiver wanted to watch the video again, they watched this on the researcher's iPad using a set of headphones. This ensured the child did not hear the words before the teaching phase. The researcher explained the procedure of the study and reinforced the need to use the actions when teaching each word. Caregivers were told that they would be required to use the smartphone during the study to receive instructions as to when to teach which word, to play the puzzle game with their child, and to speak on the phone with the researcher as they would with a friend about their morning routine. The researcher then gave instructions on how to use the smartphone (Alcatel 5002H_EEA), including how to answer phone calls and how to access and play the puzzle game. The puzzle game was the free version of a Baby Games; learn app. The app includes puzzles of different animals with a variety of different types of puzzles such as matching the shape of the animal to its outline, moving the puzzle pieces to the correct place on an image of an animal, and matching shapes. When one puzzle is complete, the user can move onto another puzzle. Thus, some dyads made further progress in the game than others.

After the training, caregivers and their child were taken to the observation room (Figure 5.2) where they remained for the rest of the study. The room contained two wall mounted cameras in opposite corners. These were able to be controlled from an adjacent monitoring room, where the researcher was positioned during the study. Building blocks, the props needed for teaching the novel words (which were in a separate box out of reach of the child) and a handout which had each of the novel words on with their corresponding action were placed on a table in the corner of the room. Opposite this table, was another table, with a computer monitor on top and an office chair behind. From the adjacent room the researcher could observe the

interaction via a one-way mirror and could both control the stimuli presented on the monitor and the two wall mounted cameras which were recording the session for offline video coding.

Figure 5.1

A Schematic Representation of the Observation Room

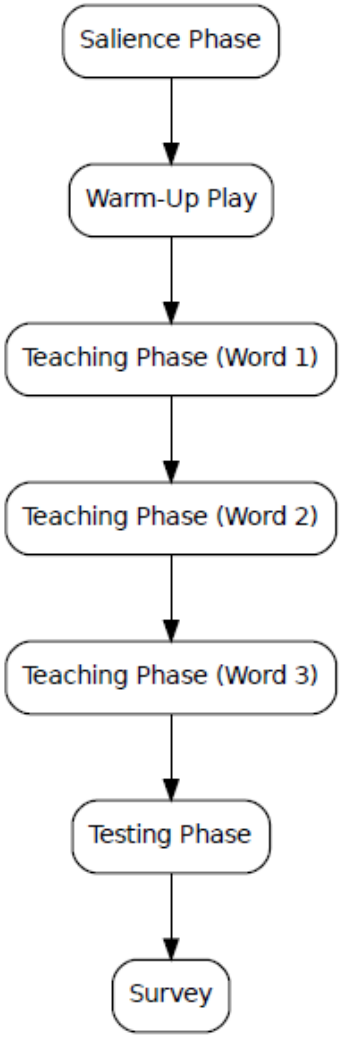


Salience Video

The study contained seven phases which always occurred in the same order (Figure 5.3) and began with a salience phase where children watched the same three videos that they would view again during testing (Table 5.2) to check for preference biases. The audio gave the child general instructions, e.g. “Can you look up? Look up. Look up here”. Each video was 5-seconds long and shown once. Caregivers were instructed to keep their eyes closed whist their child watched the videos to prevent any unintentional cueing. Before presenting each video, a cartoon image of an animal appeared along with a chime noise which served to grab the child’s attention onto the screen.

Figure 5.2

Flow Chart Outlining the Study Design



Warm-up Play

After the salience videos had ended, the researcher phoned the caregiver and asked them to play with the building blocks with their child. The dyad spent 2.5 minutes playing freely with the building blocks, after which the researcher phoned the caregiver again and asked them to tidy the blocks away before teaching the first novel word.

Teaching Phase

Caregivers were instructed to teach either ‘meeping’, ‘frepping’ or ‘blicking’ (order counterbalanced). They were reminded over the phone which toy to use and what the corresponding action was. A pilot study revealed that some children were not receptive to the use of the toys, therefore caregivers were also instructed to emphasise the action and to ‘be creative’ if their child became frustrated with the toy used to demonstrate the action. Sixty seconds were allocated to teaching each novel word, for two of the words there was an interruption (order counterbalanced) and in the control condition the caregiver taught the word for 60 seconds uninterrupted. The timer began when the caregiver first said the novel word being taught.

Phone Call Interruption: After 30 seconds of teaching, the caregiver received a phone call and spoke to the researcher about their morning routine with their child. The phone call lasted 30 seconds. The caregiver was then instructed to continue teaching the novel word that they were teaching before the phone call after hanging up. Another 30 second teaching period followed this, giving a total teaching time of 60-seconds, after which the caregiver received another phone call providing instructions about the next stage.

Game Play Interruption: After 30 seconds of teaching, the caregiver received a phone call and was instructed to stop teaching the novel word and to play the puzzle game on the phone app with their child. Caregivers were encouraged to interact with their child whilst playing the game, this instruction was important as it encouraged JME. After 30 seconds of playing the game, the caregiver received another phone call which instructed them to stop playing the game and to continue teaching the novel word they were teaching before playing the game. Another 30 second teaching period followed this, giving a total teaching time of 60-seconds,

after which the caregiver received another phone call providing instructions about the next phase.

Testing Phase

Once the teaching of the third novel word was complete, the researcher returned to the room and instructed the caregiver to sit their child on their lap again in front of the computer monitor, reminding them to keep their eyes closed when the videos began. As before, the stimuli presentation started with an attention grabber. The videos watched were the same as the ones viewed in the salience trials (one video for each novel word). However, the audio instructions differed to the salience videos, each video was presented four times, rather than once, and each of the four trials served a different purpose.

Following the trial schedule used in previous studies (Reed et al., 2017; Roseberry et al., 2014), there were four trials per word, giving twelve trials in total, each lasting 5-seconds. The four trials included two extension trials, a mutual exclusivity trial, and a recovery trial (see Table 5.3). The extension trials, trials 1 and 2, required the children to extend their knowledge of the novel word to new stimuli. For example, when children were taught the verb ‘frepping’, this action was demonstrated by shaking a rattle side to side. In the extension trials, Prairie Dawn moves a box in her hand from side to side. The audio asked “Where is frepping? Can you find frepping? Look at frepping”. If children have learnt the novel word, they should look to the matching action in the extension trials. The mutual exclusivity trial, trial 3, was included as a stringent test of having learnt the novel word. In this trial the child is asked to find an action that had not been taught during the teaching phase e.g. “Where is glorping? Can you find glorping? Look at glorping”. If children have truly learnt the novel word, it is expected that they will look to the non-matching

action, as they will have learnt that the name for the matching action during the teaching phase and can therefore infer that the non-matching action must be ‘glorping’. The final trial, trial 4, was a recovery trial. Here, children were asked to return their attention to the novel word taught during the teaching phase.

Table 5.3

Presentation of Video Stimuli in the IPLP Testing Phase

Trial	**Type**	**Audio**
1	Extension trial	“Where is (blicking/frepping/meeping), can you find (blicking/frepping/meeping), look at (blicking/frepping/meeping).”
2	Extension trial	“Where is (blicking/frepping/meeping), can you find (blicking/frepping/meeping), look at (blicking/frepping/meeping).”
3	Mutual exclusivity	“Where is (glorping/wezzling/hirshing), can you find (glorping/wezzling/hirshing), look at (glorping/wezzling/hirshing).”
4	Recovery trial	“Where is (blicking/frepping/meeping), can you find (blicking/frepping/meeping), look at (blicking/frepping/meeping).”

The order of trials was the same for each novel word, the two extension trials, followed by the mutual exclusivity trial, and finally the recovery trial. The four trial videos for each novel word were visually identical, only the audio differed, as described in Table 5.3. The non-target scene in the mutual exclusivity trials was

therefore not a novel scene, but the same visual imagery as the target scenes for the extension and recovery trials.

The trial videos were the same as used in previous studies (Reed et al., 2017; Roseberry et al., 2014), but the audio was edited to include an English rather than U.S accent providing the instructions. The target scene appeared on the left for ‘frepping’, right for ‘meeping’, and right for ‘blicking’, as per their presentation in previous studies.

Survey Completion

Once the test videos were complete, the caregiver completed the survey on an iPad. Upon completion, caregivers were verbally debriefed and given the opportunity to ask any questions, the child was given a book for their participation.

5.2.5 Data Analysis

Data coding was completed by the lead researcher offline using ELAN (2023), an open-source coding software. A second independent observer, blind to the experimental hypothesis, was trained by the lead researcher in how to apply the coding criteria and second-coded 20% of the videos. The ICC was calculated for each behaviour coded, using a two-way, average measurement agreement model. Good reliability was found between observers, with the ICC ranging between 0.75-1 across behaviours. The specific ICC for each coding criteria is included in the descriptions below.

For the salience videos, looking time towards what would later be the target scene and non-target scene was measured (ICC = 0.84). In the testing videos, looking time towards the target scene and non-target scene was measured. Following Reed et al. (2017), the looking time for the two extension trials was averaged across the two videos for each child (ICC = 0.84).

During the teaching phase, the number of times the novel word was said (ICC = 0.99) and the amount of time spent teaching (ICC = 0.79) were also coded. Most caregivers did not teach consistently for the duration of the teaching time allocated; therefore, each teaching phase could comprise of a variable number of teaching periods. A teaching period begun when the caregiver said the novel word for the first time. If the child or caregiver directed their attention away from the teaching, that teaching period ended. Coding for time spent teaching resumed when caregivers next said the novel word. When there was an interruption to the teaching (phone call interruption or game interruption), the number of times the novel word was said, and the time spent teaching was recorded separately for both before and after the interruption. From this, a total was also calculated for each interruption condition by adding the before and after totals together.

The child's level of engagement during the teaching was coded on a scale from 0 to 3 (ICC = 0.77). A score of 3 represented high engagement such as repeating the novel word, continuous focus on the teaching, and showing positive affect; 2 represented medium engagement, such as spending at least half of the teaching time engaged in the teaching and the caregiver being able to successfully redirect the child's attention back to the teaching when the child lost interest; 1 represented low engagement, and was demonstrated by the child spending minimal time with the caregiver during the teaching and directing their attention either to other stimuli in the room or choosing to play with the toy in a different way; a score of 0 was applied when the child did not engage in the teaching at all and instead spent the teaching time ignoring the caregiver's attempts to engage them with the toy and teaching, often demonstrating negative affect.

The child's behaviour during each interruption was also coded. During the game interruption, the child engagement was coded on a scale from 0 to 2 where a score of 0 was assigned if the child showed no interest in the game, 2 if they were fully engaged with the game, and 1 if they engaged with the game for some of the interruption time (ICC = 1). In the call interruption, the child was assigned a score of 0 if they waited whilst the parent was on the phone, 1 if they played independently, 2 if they made bids for attention towards the parent, and 3 if the child's behaviour was a mix of making bids, playing and/or waiting (ICC = 0.78).

The time spent in each interruption was also coded (ICC = 0.88). For the phone call, this began when the caregiver started speaking to the researcher about their day and ended when the researcher informed the caregiver 30 seconds was up. There was some variation in timing ($M = 30.34_{\text{seconds}}$, $SD = 2.97_{\text{seconds}}$) depending on if the caregiver stopped speaking straight away at the researcher's cue or continued talking for a little longer. For the game, coding began when the game had loaded, and the caregiver directed the child to the game. Usually this involved the caregiver asking the child to "Choose an animal", which was the first part of the game. Coding ended when the game was interrupted by the incoming phone call for the next set of instructions. There was some variation on timing ($M = 34.28_{\text{seconds}}$, $SD = 4.60_{\text{seconds}}$) dependent on how quickly the phone call connected to stop the game play.

Lastly, the transition time between instructions was also recorded (ICC = 0.99). Caregivers received instructions of which novel word to teach via a short phone call. Transition was measured from the moment this phone call ended until the caregiver first said the novel word. Transition time between interruption and teaching began when the caregiver ended the instruction call which informed them to end the interruption and return to teaching and ended when the novel word was said.

5.3 Results

The rcompanion package (Mangiafico, 2025), the rstatix package (Kassambara, 2023), and the Stats package (R Core Team, 2024) within R (version 4.4.1) were used for the statistical analysis. Due to a technical issue when recording, the sound was not recorded for one dyad, thus there was missing data for teaching input analysis. However, the data was anyway included for the main analysis of looking time in the IPLP.

Caregivers self-reported phone use can be seen in Table 5.4. Most caregivers reported checking their smartphone between 3-9 times per hour (96%) and using their smartphone for 0-4 hours per day (91%).

Table 5.4

Percentages of Frequency and Duration of Smartphone Use

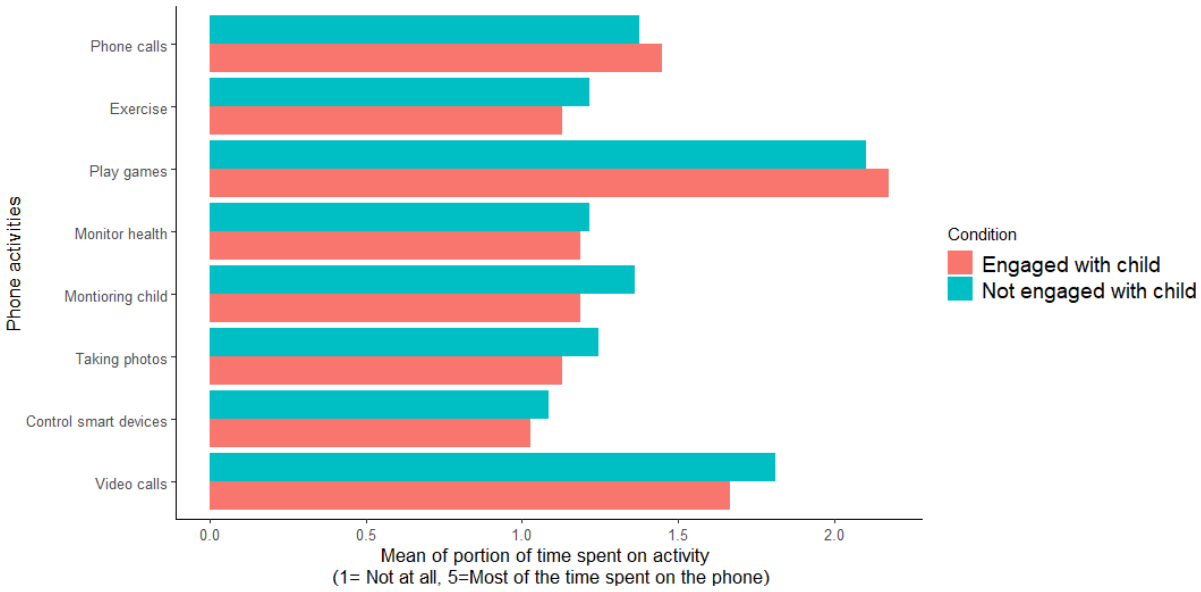
Frequency	**N (percentage)**
0-2 times an hour	0 (0)
3-5 times an hour	35 (51)
6-9 times an hour	31 (45)
10-12 times an hour	3 (4)
13-15 times an hour	0 (0)
More than 15 times an hour	0 (0)
Duration	**N (percentage)**
Less than 60 minutes per day	17 (25)
1-2 hours per day	30 (44)
3-4 hours per day	16 (23)
5-6 hours per day	3 (4)

7-8 hours per day	1 (<1)
Over 9 hours per day	2 (3)

Figure 5.4 displays the various ways that caregivers use their smartphones during different levels of engagement with their child. As data was ordinal, Wilcoxon Signed Rank Test with Bonferroni correction was applied to see which activities caregivers were more likely to use their smartphone for when engaged with their child compared to when they were not engaged with their child. No significant differences were found.

Figure 5.3

Portion of Daily Phone Use by Activity and Level of Engagement With the Child



Despite no differences in types of activities reported in this survey, a Kruskal-Wallis test found a significant difference in the frequency of caregivers' smartphone use across levels of engagement with their child, $H(2) = 93$, $p < .001$, $\eta^2 = .42$. Dunn's test between groups with Bonferroni correction showed that caregivers were more likely to use their smartphone when their child was asleep, compared to when their

child was awake but not engaged with them (z = -3.62, p < .001), or when they were engaged with their child (z = -9.55, p < .001). Caregiver's smartphone use was also more frequent when their child was awake but not engaged with them, compared to when caregivers were engaged with their child (z = 5.93, p < .001). See Table 5.5 for the mean and standard deviation.

Table 5.5

Means and Standard Deviations of Smartphone Use by Level of Engagement With the Child (1 = Everyday, 5 = Occasionally or Never)

Level of engagement	***M (SD)***
Child asleep	2.49 (0.93)
Child awake but not engaged	3.17 (0.82)
Parent actively engaged with child	4.11 (0.53)

5.3.1 Preliminary Analysis

Similar to the analysis conducted by Reed et al. (2017), I began by isolating the independent variable (phone call, game, no interruption) and testing whether there were any other differences between interruption conditions that may impact learning the novel word. This involved testing the frequency of novel word input during teaching, teaching duration, how long caregivers took to return to teaching after the interruption, the child's engagement in the teaching, the child's engagement with the game interruption, and the child's response to the phone call interruption. Each of these is explored below.

5.3.1.1 Frequency of Novel Word Input

The number of times that caregivers said the novel word during teaching was not normally distributed, rendering unsuitable the application of the pre-registered ANOVA. A Friedman test was instead applied. This revealed a significant difference in how frequently the novel word was said during teaching depending on interruption condition, $X^2(2) = 10.9$, $p < .01$, Kendall's W = 0.08. Post hoc analysis using a pairwise Wilcoxon Signed Rank Test with a Bonferroni correction was applied. The novel word was repeated significantly more when teaching was interrupted by a phone call ($M = 16.5$, $SD = 7.69$), than when there was no interruption ($M = 14.2$, $SD = 6.68$), $Z = 1520$, $p = .01$, $r = .36$. There were no significant differences between the number of repetitions of the word when interruption was from a phone call compared to interruption by a game ($M = 16.1$, $SD = 7.40$), $Z = 1208$, $p = .1$, $r = .12$, nor between the game interruption vs no interruption to teaching ($Z = 672$, $p = .22$, $r = .22$).

To see whether interruption condition may have influenced frequency of novel word input, the frequency of repeating the novel word was compared for the teaching periods before and after each period of phone interruption. Since caregivers would not be aware of how the interruption was to occur (if at all) until after it had occurred, comparing frequency after the interruption allowed to investigate whether the type of phone use influences the frequency of novel word input. A paired t-test revealed no significant difference in the number of times the novel word was repeated before the phone call ($M = 8.73$, $SD = 4.54$) compared to the number of times the novel word was repeated after the phone call ($M = 8.13$, SD, 4.39), $t(66) = 1.41$, $p = .16$, $d = .14$. There was also no significant difference in the number of times the novel word was repeated before the game ($M = 8.15$, $SD = 3.69$) compared to the number of times

the novel word was repeated after the game (*M* = 7.86, *SD* = 4.61), *t*(65), 0.64, *p* = .53, *d* = .07.

5.3.1.2 Teaching Duration

To further isolate the independent variable, teaching duration across interruption conditions (no interruption, phone call interruption, game interruption) was compared. Although the same amount of time (60 seconds) was allocated to teaching in the interruption conditions, teaching was not necessarily constant during that time as it was dependent on how the child responded to the caregiver's attempts to teach the novel word. A repeated measures ANOVA revealed a significant difference between interruption condition and teaching duration, $F(2, 134) = 5.11$, $p < .01$, $\eta^2_G = .025$. Post hoc analysis using paired t-tests with Bonferroni correction were applied. The time spent teaching the novel word was significantly longer when a phone call created technoference (*M* = 46.3, *SD* = 14.8) compared to when there was no interruption to teaching (*M* = 40.9, *SD* = 13.7), *t* (67) = 3.18, *p* = .007, *d* = 0.39. There was no significant difference between the amount of time spent teaching between the phone call interruption and the game interruption (*M* = 43.2, *SD* = 13.8), *t*(67) = 1.95, *p* = .17, *d* = 0.24, or when teaching was disrupted by game interruption compared to when there was no interruption to teaching, *t*(67) = -1.30, *p* = .60, *d* = -0.16.

To see whether interruption may have influenced teaching duration, the length of time spent teaching was compared before and after the phone call and the game interruption. A paired t-test revealed no significant difference between teaching duration before the phone call interruption (*M* = 22.9, *SD* = 8.40) compared to the teaching duration after the phone call interruption (*M* = 24.2, *SD* = 7.81), *t*(67) = 1.27, *p* = .21, *d* = .17, and no significant difference in teaching duration before the game

interruption (*M* = 22.6, *SD* = 7.97) compared to teaching duration after the game interruption (*M* = 21.3, *SD* = 7.63), *t*(66) = 1.16, *p* = .25, *d* = .16.

5.3.1.3 Time Taken to Return to Teaching After the Interruption

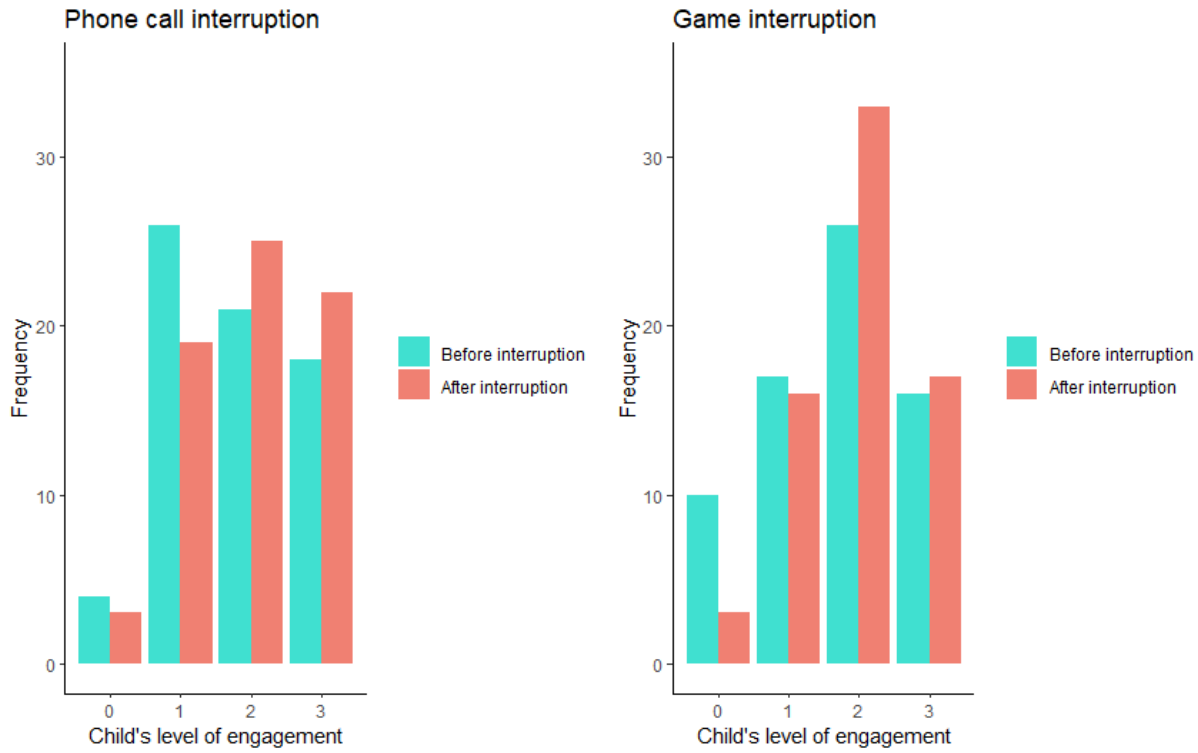
If one type of phone use is more distracting than another, it may take caregivers longer to return to teaching after the interruption has ended. As data was not normally distributed, a Wilcoxon signed-rank test compared the length of time it took caregivers to begin re-teaching the novel word after the researcher signalled the interruption had ended and teaching was to resume. Caregivers took longer to return to teaching the novel word after the game interruption (*M* = 13.6*s*, *SD* = 21.9*s*) in comparison to the phone call interruption (*M* = 7.97*s*, *SD* = 14.4*s*), *W* = 698, *p* = .003, *r* = .35.

5.3.1.4 Child's Engagement in the Teaching

As the rating of children's engagement in teaching was ordinal, a Wilcoxon Signed Rank Test was applied to compare engagement during each interruption. There was no significant difference between the child's engagement in the teaching (Figure 5.5) before the phone call interruption (*M* = 1.94, *SD* = 0.87) and after the phone call interruption (*M* = 1.76, *SD* = 0.94), *W* = 311, *p* = .09, *r* =.21, or before the game interruption (*M* = 1.93, *SD* = 0.81) compared to after the game interruption (*M* = 1.71, *SD* = 1.00), *W* = 313, *p* = .07, *r* = .21.

Figure 5.4

Level of Engagement in Teaching Before and After Each Type of Interruption

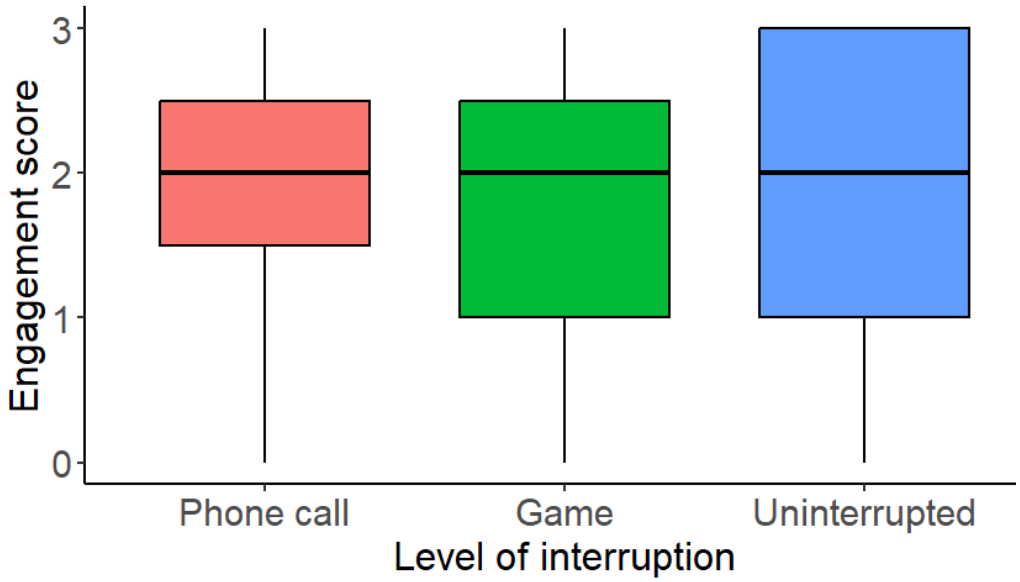


Note. The child's level of engagement was rated from 0 (no engagement) to 3 (high engagement) during the teaching. A rating was applied during teaching before and after the phone call interruption and before and after the game interruption.

Since there was no difference between engagement before and after the interruption, these two ratings were averaged for each participant to give one engagement score for each interruption condition (Figure 5.6). This allowed for comparison of engagement between interruption condition (phone call, game, no interruption). As engagement was ordinal, a non-parametric Kruskal-Wallis test compared level of engagement across interruption condition and found no difference between interruption condition and the level of engagement of the child, $H(2) = 1.13$, $p = .57$, $\eta^2H = .004$.

Figure 5.5

Engagement in Teaching Across Each Interruption Condition



Note. The child's level of engagement was rated from 0 (no engagement) to 3 (high engagement) during the teaching.

5.3.1.5 Child's Response to Interruptions

Most children (N=65) fully engaged with the game during the interruption, only one child did not engage with the game at all, and a few children (N=3) were partially engaged with the game. Due to the homogeneity in response, no further analysis was carried out on this variable.

Children's responses to the phone call interruption were more varied, most children either played independently (N = 27) or varied their response throughout the phone call between waiting, playing, and making bids for attention (N= 23). Some children spent the phone call interruption solely making bids for attention (N = 14) and only N=5 waited patiently for the duration of the phone call. A Kruskal-Wallis test was applied as the data was ordinal, revealing no difference between how the children responded to the phone call interruption dependent on the word taught, $H(2)$

= 0.81, p = .67, η^2H = 0.02. A one-way ANOVA, using the response as a factor with four levels (play, mixed response, bids for attention, waiting patiently) was run to see if level of engagement affected novel word learning. There was no main effect of call reaction on novel word learning, $F(3, 55) = 2.36$, p = .08, η^2G = .11.

5.3.1.6 Salience Preferences

It was necessary to test whether children preferred either scene (target vs. non-target) in each of the videos prior to exploring the looking time in the testing phase. The time children spent looking to what would be the target scene in the testing phase, was divided by total looking time, providing proportional looking time for the analysis (Reed et al., 2017), thus only looking time to the target scence was included in the analysis. A Shapiro-Wilk test revealed looking time for 'meeping' was not normally distributed (W = 0.94, p < .001). Therefore, one-sample t-tests with Bonferroni correction were applied to 'blicking' and 'frepping', and a one-sample Wilcoxon signed-rank test was applied to 'meeping'. There was a preference for the target scene (M = 55.09, SD = 17.46) for 'blicking', $t(66) = -2.39$, p = .02, d = 0.29. There was no preference for the target scene (M = 52.52, SD = 20.16) for 'frepping', $t(66) = -1.03$, p = .31, d = 0.13 and children showed a preference for the non-target scene (M = 66.56, SD = 16.78), W = 226, p < .001, r = .69. for 'meeping'. Any preference for the target scenes for 'frepping' and 'meeping' at testing cannot therefore be attributed to a priori preferences for the features of the target scene.

5.3.2 Interruption and Target Scene Looking

To test whether children had a preference for the target scene, the proportion of looking time to the target scene was calculated by dividing looking time to the target scene by the total looking time for the extension trials across both scenes. Any

trials where children spent the entire looking time attending to one scene were removed (N = 8), as were trials where the caregiver mispronounced the word when teaching (N = 2) or taught beyond the allocated teaching time (N = 1). Each child watched two extension trials which, following Reed et al. (2017), were averaged for each child. If children have can extend the means of the verbs to a new object, the IPLP assumes that children should spend a larger proportion of the looking time viewing the target scene than the non-target scene (Golinkoff et al., 2013).

A one-way repeated measures ANOVA was performed to analyse the effect of interruption condition (phone call, game, uninterrupted) on looking time to the target scene. The means and standard deviations are presented in Table 5.6. The results indicated no significant effect of interruption condition on target scene, $F(2, 120) = 0,12$, $p = .891$, $\eta^2_G = .001$ (Figure 5.7).

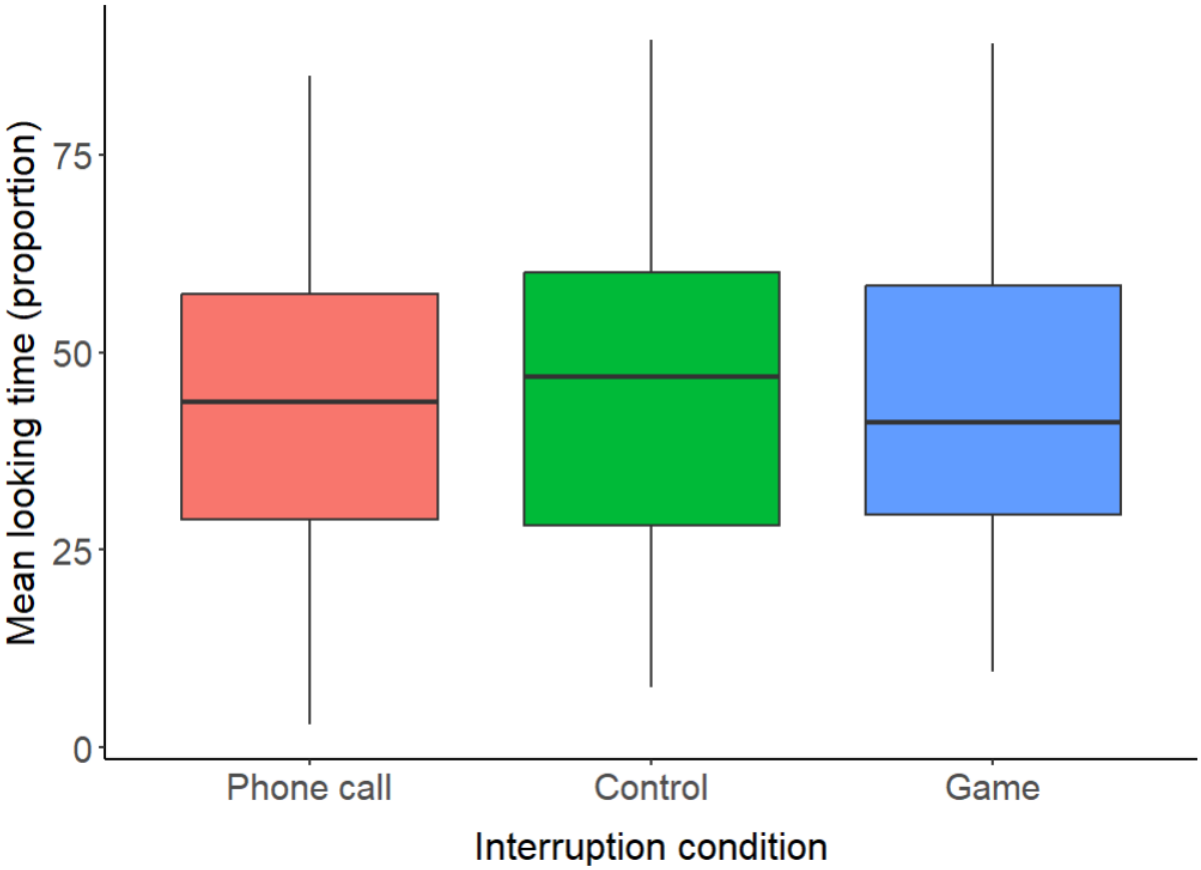
Table 5.6

Means and Standard Deviations of Proportion Looking Time to Target Scene Across Interruption Condition

Scene	**Interruption condition**	***M (SD)***
Target scene	Phone call	43.8 (19.5)
	Game	44.8 (20.2)
	Uninterrupted	44.4 (19.8)

Figure 5.6

Comparison of Looking Time to the Target Scene in the Extension Trials by Teaching Condition



5.3.3 Target vs. Non-Target Scene Preference Within Each Condition

Paired One-sample t-tests with Bonferroni correction, revealed that target looking was significant after the phone call interruption, $t(66) = 2.60$, $p = .035$, $d = -0.32$. There was no preference for target scene, after the game interruption, $t(63) = 2.08$, $p = .126$, $d = -0.26$, and when teaching was uninterrupted, $t(66) = 2.33$, $p = .126$, $d = -0.28$. Before correction, all three conditions were significant ($p = .012$, .023, and .042). The effects were similar in size and direction across conditions, consistent with the ANOVA. The pattern of data suggests a preference for the non-target scene across interruption condition albeit only significant in after the phone call interruption.

To further explore the data, separate one-way ANOVAs tested whether looking time to the target scene was affected by the order of the interruption conditions (phone call interruption, game interruption, uninterrupted), the novel word taught, or total time spent teaching. The order of teaching did not have a significant effect on how long children looked at the target scene, $F(2, 120) = 1.61$, $p = .20$, $\eta^2_G = .02$, but there was a significant effect of the novel word taught, $F(2, 107) = 22.18$, $p < .001$, $\eta^2_G = .20$. Post hoc analysis applied paired t-tests with Bonferroni correction and revealed that children looked significantly longer at the target scene for 'blicking' ($M = 54.5$, $SD = 16.6$) compared to 'frepping' ($M = 45.7$, $SD = 21.1$), $t(60) = 2.62$, $p < .05$, $d = 0.34$, and compared to 'meeping' ($M = 33.2$, $SD = 15.1$), $t(64) = 7.35$, $p < .001$, $d = 0.91$. Children also looked significantly longer to the target scene when they were taught the word 'frepping' compared to 'meeping', $t(63) = 4.46$, $p < .001$, $d = 0.68$. Regression analysis revealed that the total time spent teaching did not predict looking time to the target scene, $F(1, 196) = 2.63$, $p = .11$, $R^2 = .01$.

Due to the differences in looking time to the target scene by novel word during testing, and the a priori preference for the 'blicking' target scene, additional analysis was conducted on the novel words to further understand their potential impact on the results. One-sample t-tests with Bonferroni correction revealed no significant differences across interruption conditions for 'blicking', or for 'frepping'. However, in each interruption condition children looked longer to the non-target scene than the target scene for 'meeping', see Table 5.7.

Table 5.7

Results of Paired T-tests Comparing Novel word, Interruption Condition and Scene

Novel word	**Interruption condition**	**Target looking *M* (*SD*)**	**Statistic**
Blicking	Phone call	52.8 (18)	$t(22) = 0.75$, $p = 1$, $d = 0.16$
	Game	55.9 (18.7)	$t(18) = 1.37$, $p = 11$, $d = 0.31$
	Uninterrupted	54.9 (13.8)	$t(23) = 1.74$, $p = .85$, $d = 0.36$
Frepping	Phone call	44.6 (20.2)	$t(21) = -1.26$, $p = 1$, $d = -0.27$
	Game	49 (22.7)	$t(19) = -0.20$, $p = 1$, $d = -0.04$
	Uninterrupted	43.7 (21.2)	$t(21) = -1.39$, $p = 1$, $d = -0.30$
Meeping	Phone call	33.6 (16)	$t(21) = -4.82$, $p < .001$, $d = -1.03$
	Game	32.9 (11.9)	$t(24) = -7.15$, $p < .001$, $d = -1.43$
	Uninterrupted	33 (18.1)	$t(20) = -4.30$, $p = .003$, $d = -0.94$

5.3.3 Rigorous Testing

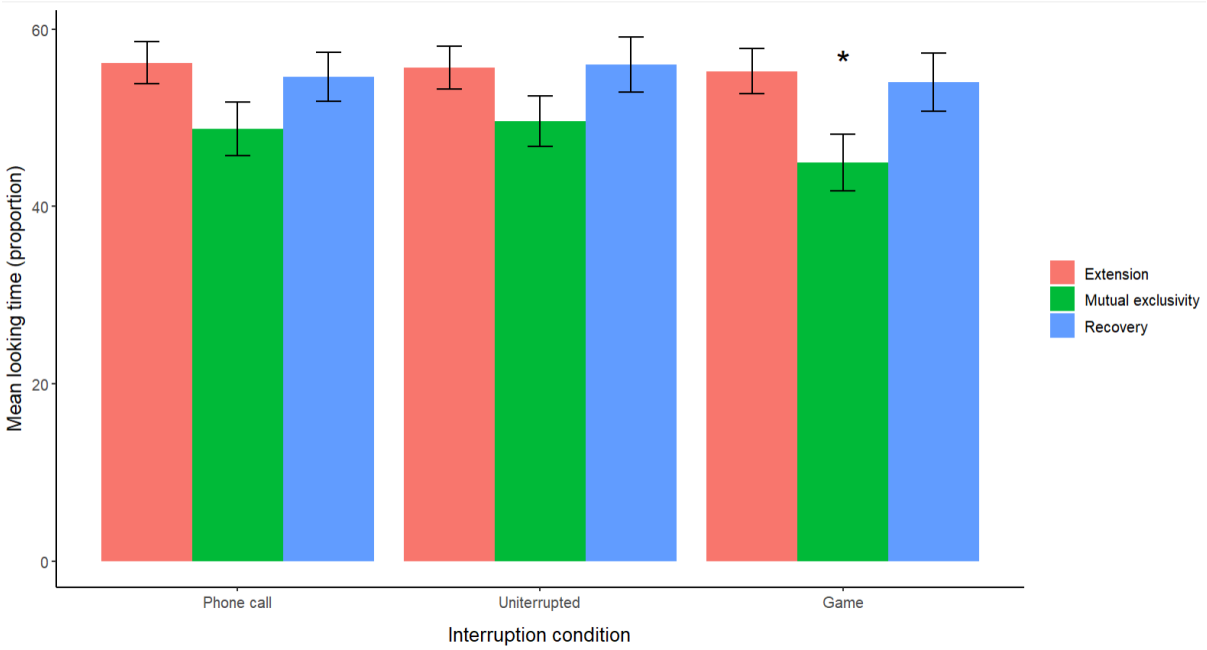
Following the pre-registration, a repeated measures ANOVA was applied for each interruption condition as a stringent test of novel word learning using the following three data points, the average of the two extension trials, the mutual exclusivity trial where children had to extend their learning to a new verb, and the recovery trial. Of interest here is the pattern of results. Comprehension of the verbs is assumed if children look at the target scene in the extension trials, look away from the target scene in the mutual exclusivity trials, and look back to the target scene in the recovery trials. Given the earlier results that children looked longer at the non-target scene (pre-Bonferroni correction), the analysis focused on looking time to this

scene rather than the target scene. As the data was not normally distributed across all measures of novel word learning, Friedman's test was applied instead of an ANOVA. The Friedman test can only test one explanatory variable at a time; therefore, it was necessary to deviate from the preregistration and run three separate Friedman tests, one for each interruption condition (phone call, game, no interruption).

There was a significant difference in preference for scene across trial types for the game interruption, $X^2(2) = 6.26$, $p = .04$, $W = 0.07$, but there were no significant differences between trial type for the phone call interruption, $X^2(2) = 1.11$, $p = .57$, $W = 0.01$, or when teaching was uninterrupted, $X^2(2) = 0.53$, $p = .77$, $W < 0.01$. Despite the non-significance in these two conditions, the direction of looking does follow the expected pattern (see Figure 5.8).

Figure 5.7

Comparison of Looking Time to the Non-Target Scene Across All Three Types of Trial (Extension, Mutual Exclusivity, and Recovery) by Interruption Condition



5.3.4 Exploratory Analysis: Associations Between Parent Phone Use and Child Word Learning

The survey included three measures of technoference: 1) whether caregivers consciously put their phone away, 2) the DISRUPT score, and 3) caregivers' phone use when actively engaged with their child. These measures of technoference were explored using multiple regression to see if they predicted novel word learning. Separate multiple regressions were run for each interruption condition (phone call, game, uninterrupted). None of the measures of technoference predicted novel word learning when teaching was interrupted by a phone call, $F(3, 57) = 0.87$, $p = .46$, $R^2 = -.007$, a game, $F(3, 57) = 1.65$, $p = .19$, $R^2 = .03$, or when teaching was uninterrupted, $F(3, 57) = 1.74$, $p = .17$, $R^2 = .04$.

Three further multiple linear regression models included caregiver's age, household income, and child's gender as further potential predictors of novel word learning across interruption condition (phone call, game, uninterrupted). None of the demographics predicted novel word learning when teaching was interrupted by a call, $F(3, 43) = 0.31$, $p = .82$, $R^2 = -.05$, by a game, $F(3, 43) = 1.02$, $p = .39$, $R^2 = .001$, or when teaching was uninterrupted, $F(3, 43) = 0.002$, $p = .99$, $R^2 = -.07$.

5.4 Discussion

This study sought to further explore the link between smartphone technoference and child language outcomes by considering whether the way in which the smartphone is used, either to reduce parent responsiveness (via a phone call) or to encourage joint attention (via JME through shared game play on the phone), influences the relationship between technoference and language outcomes. Although not surviving Bonferroni correction for multiple comparisons, preference for the non-target scene across interruption condition suggests that children were able

to discriminate between the two scenes in the same way regardless of interruption condition. Contrary to the expected pattern of results using an IPLP, these results suggest that children may have found the non-target action surprising, when presented alongside instructions to look for the novel word, thus explaining the increased looking time to the non-target scene over the target scene. Though, despite children discriminating between the two scenes, Study 3 failed to replicate the findings of Reed et al. (2017), as there was no evidence that type of smartphone technoference affected novel word learning differently, or impaired novel word learning in comparison to uninterrupted teaching; comprehension was equal across each interruption condition.

5.4.1 Interruption to Teaching and Word Learning

The finding that word learning remained consistent regardless of whether teaching was interrupted by parent smartphone use or not, is inconsistent with emerging research suggesting that technoference negatively impacts child language outcomes (Ewin, Reupert, McLean, et al., 2021; Reed et al., 2017; Sundqvist et al., 2021). These findings are surprising, as Study 3 replicated the procedure used by Reed et al. (2017), including using the same novel words (with the addition of one more) and the same videos in the IPLP, however this study failed to replicate their findings that learning of a novel word was impaired by technoference. The present findings do however align with another recent partial replication of Reed et al. (2017). Nguyen (2024) taught 17-19-month-olds two novel nouns, where one of the teaching periods was disrupted by smartphone technoference (via a text message). As with the present study, no difference in word learning was found when the teaching was interrupted by smartphone technoference compared to when the teaching was

uninterrupted. Together, these findings suggest that young children's word learning may not be affected by brief periods of technoference.

One explanation for finding no difference in novel word learning after a period of parent smartphone use in comparison to uninterrupted teaching, is that seeing others using smartphones is so ubiquitous in a young child's life that they may have adapted to be able to still learn despite technoference occurring. As young children are exposed to technoference from birth (Coyne et al., 2022) and mothers report increasing their smartphone use post-partum (McCaleb, 2020), this creates opportunities for young children to potentially experience smartphone technoference for their entire life, giving them ample time to adapt to learning despite smartphone interruptions. This potential adaption by infants is demonstrated in a recent study by Mason et al. (2024) who found that infants were more responsive to their mother (e.g., responding to attempts at feeding, vocalising or smiling in response to the mother's vocalisation) during breastfeeding when the mother used digital media, as opposed to listening to classical music. The suggestion that young children adapt to parent technoference is further supported by Myruski et al. (2017), who found that infants made more bids for their mother's attention when she was using a smartphone, suggesting infants may have an awareness of the need to initiate interactions when a smartphone is in use. Moreover, since the time period that data was collected by Reed et al. (2017), smartphones have continued to develop and become further embedded into our daily lives, and this may explain the difference in findings with the present study. This suggestion is supported by several recent studies which have also found no effects of parent technoference on children on various outcomes including behaviour (Porter et al., 2024), neural activity (Swider-Cios et al., 2024), imitative behaviour (Flatebø et al., 2024), and future attachment

(Coyne et al., 2022). Interestingly, Coyne et al. (2022) found positive outcomes of parent smartphone use, which was related to decreases in future parent-toddler dysfunction, adding further support to the suggestion that children have adapted to interactions which involve technoference. These findings are also in contrast to research suggesting that technoference is equally as disruptive as non-digital disruptions on parent-child interactions (Chamam et al., 2024), maternal responsiveness (Konrad, Hillmann, et al., 2021), and the quality and quantity of language exposure (Ewin, Reupert, McLean, et al., 2021). Although, these studies have not compared the effects of different types of phone use. Future research should further explore whether technoference is still deemed disruptive to young children and if so, whether technoference is a unique type of disruption or whether all disruptions are equally problematic.

Another possibility is that parents have adapted their parenting behaviours due to perceived negative connotations around parent smartphone use (Wolfers et al., 2023) and guilt when using their smartphone during parenting (Garg, 2021). Study 3's findings that caregivers used their smartphone less when engaged with their child than when they were not engaged with their child, demonstrate that parents make conscious decisions around their smartphone use when with their child. This is supported by interviews with Norwegian parents who reported that some situations are not appropriate for smartphone use, such as playing or mealtimes, and reported feeling guilty if they used their smartphone in these occasions (Abels et al., 2024). Yet, many parents did acknowledge that brief smartphone usage, i.e., technoference, is partly acceptable. To minimise the potential for technoference, parents reported implementing explicit strategies to avoid unintentionally using their smartphone, such as deleting distracting apps or

leaving their phone in another room. Having this awareness, may also explain how parents behave in experimental studies. For example, Nguyen (2024) found that children were more likely to learn novel nouns when their parents were told the true purpose of the study, i.e. testing whether texting impacts word learning, in comparison to when the parents were simply told that the study was investigating how children learn words. This suggests that parents may adapt how they interact with their child if they are aware of the possible effect of technoference. Indeed, Linder et al. (2022) found that parents compensated for a period of smartphone technoference by subsequently increasing engagement with their young child after technoference which was higher than their usual phone use. Furthermore, Fusha et al. (2025) found more frequent technoference, in the form of audible notifications and parent phone checking, whilst parents are with their 18-34-month-old was associated with increased self-reported parental warmth. It is possible that in the present study, where caregivers were told that their teaching would be interrupted by a phone call and by playing a game on the smartphone, caregivers became conscious of the quality of their teaching and interactions with their child which buffered against any negative effects of phone use. This may explain why caregivers spent longer teaching when the teaching period was interrupted by a phone call, as potentially they were actively trying to buffer against any negative effects of technoference. Although, my analysis revealed that time spent teaching did not predict novel word learning. Alternatively, being aware that a disruption may occur could have impaired the quality of teaching across all three levels of interruption, as the caregiver may have been cognitively distracted by the potential incoming smartphone interruption (McDaniel, 2021). As the mere presence of a phone is enough to reduce the quality of social interactions (Misra et al., 2016), by reducing feelings of closeness (Lanette,

2018) and affection and responsiveness from parents (Rothstein, 2018), it may be that no difference was found for novel word learning between the three interruption conditions because the smartphone was present throughout and being aware that an interruption was possible affected the interaction (either in a positive or negative way), above experiencing the interruption.

A further consideration is that the interruption conditions may not reflect natural phone use. The teaching period of 60 seconds was focused solely on teaching the novel word and, although the interruption gave a break to the teaching, the teaching itself remained protected from the interruption as across all conditions 60 seconds of phone free time was allocated to teaching. Outside of a controlled task, the parent may continue to engage with same task with their child whilst using their phone (Ewin, Reupert, & McLean, 2021). For example, if the dyad is completing a puzzle and the parent receives a text message, the parent may reply to the text message whilst continuing to engage in the puzzle with their child. In relation to the current study, this would involve the caregivers continuing to teach the novel word whilst simultaneously being interrupted by the smartphone. Had the smartphone interruption flowed more naturally into the teaching periods, this may have had different outcomes on the novel word learning.

The lack of differences between the interruption conditions and any novel word learning cannot be attributed to the child's engagement in the teaching or the child's behavioural response to the interruption condition as there were no differences across the interruption conditions in relation to these variables. Despite caregivers repeating the novel word more when teaching was interrupted by a phone call than by a game or no interruption, the number of times the novel word was repeated during the teaching did not affect children's word learning. Both Nguyen

(2024) and Reed et al. (2017) also found no relationship between repeating the novel word and word learning, yet unlike Nguyen (2024) caregivers in this study did not repeat the novel word more before the interruption than after the interruption. Whilst frequency of input aids word learning, the quality (diversity of vocabulary and complexity of syntax) of parent input is more important than quantity for language learning (Anderson et al., 2021). This can explain why despite caregivers repeating the novel word more frequently in the phone call interruption, there was no beneficial effect of word learning, as each repetition was not adding in quality. Interestingly, Nguyen (2024) found that children were more likely to learn the novel word when parents did not repeat the word during the smartphone interruption (text message), compared to when parents did repeat the novel word whilst using the phone. Whilst this seems counter intuitive, looking at the smartphone whilst repeating the novel noun may create confusion for the child making it difficult to map the new word onto the correct object (Nguyen, 2024). The current study directed parents to not repeat the novel word during the interruption period, which rules out this variable impacting how well the children learnt the novel words.

Interestingly, across all three interruption conditions, children looked longer at the non-target scene than the target scene, in contrast to the expected pattern of IPLP results, although this difference was no longer significant following Bonferroni correction for multiple comparisons. One explanation is that as children differentiated between the two scenes, looks towards the non-target scene may be due to surprise at seeing a scene which does not correspond with the audio: thus, demonstrating learning of the novel word. An alternative explanation is that the IPLP may have underestimated children's word learning due to a lack of speaker consistency. Hollich (2006) found that 23-month-olds successfully identified novel nouns only when the

testing voice matched the teaching voice. It is possible that the difference in teaching voice (i.e. the caregiver) to the speaker during the IPLP hindered the children's ability to demonstrate their understanding in the present study. Future studies could use an alternative task to assess word learning which involves the person who taught the word/s also asking the child to demonstrate learning of the word, for example using a touch screen task (Lo et al., 2021) which has written text on the screen that the parent reads to the child to direct them to select the target word.

Lastly, the difference in findings between the present study and Reed et al. (2017) may be due to slight methodological differences between the two studies. Firstly, the sample used by Reed et al. (2017) was smaller (N=44) than in the present study (N=69) and slightly older (by 1.4 months). Furthermore, the present study included teaching three novel words, in comparison to two in the study by Reed et al. (2017). The children in the current study therefore had to retain the newly learnt words for longer, and failure to retain the learning may explain the difference in results to Reed et al. (2017). This is reinforced in research from Bion et al. (2013), who found that whilst 24-month-olds could map novel words to novel objects during the teaching phases, this learning was not retained in testing trials, whereas 30-month-olds did demonstrate some retention of the novel word. It may be that the children used in the current study were too young (M_{age} = 25.61 months) to successfully retain the three novel words they had been taught. Indeed, during the teaching, many caregivers asked questions to check their child understood the new word e.g., "What am I doing with the ____?", "Can you do _____?" to which most children responded with the appropriate novel word or corresponding action. This anecdotally demonstrated an understanding of the novel word during the teaching, but possibly the children were too young to retain this learning for the IPLP. A caveat

to this, is that Roseberry et al. (2014) did find that 24-30-month-olds could learn the same novel verbs used in the present study with a slightly younger sample (by 0.53 months) than Reed et al. (2017), *but* the children were tested on their learning after being taught two novel words, before then engaging in further teaching. By teaching and testing all three novel words, the current study may have missed any effects of smartphone technoference as the task of retaining three sets of words may have been too challenging for this age group. Future research should test word learning directly after the teaching, and before teaching another novel word, to remove the need for children to retain the new word for so long and to avoid interference between the words being taught. An additional difference is that Study 3 was conducted in the UK, whereas Reed et al. (2017) conducted their research in the U.S. Possibly, cultural differences in parent smartphone use may have some role to play in the difference in findings. Cultural norms may shape practices around smartphone use and technoference in the home (Fulk et al., 1990), which in turn could impact how children respond to technoference during the study. Future research should further explore cultural norms around parent technoference, as this may help to unravel the complex interplay between technoference and child language outcomes.

5.4.2 Type of Phone Use and Word Learning

Based on extant research that maternal responsiveness is important for language development (Bornstein et al., 2020; Tamis-LeMonda et al., 1996) and that technoference disrupts parent responsiveness (Abels et al., 2018; Elias et al., 2020; Hiniker et al., 2015; Inoue et al., 2021; Lederer et al., 2022; Mangan et al., 2018; Nakagawa et al., 2019), the phone call was expected to reduce responsiveness during the interruption and subsequently impair novel word learning in comparison to

no interruption to the teaching or interruption by a game on the phone. Additionally, as young children show an interest in their parent's electronic device use (Radesky et al., 2014) and JME is positively related to language outcomes (Medawar et al., 2023; Sundqvist et al., 2021), the game interruption was expected to be less disruptive to language learning than the phone call. The findings partially supported this prediction; despite no difference in word learning between the two smartphone interruptions, the rigorous test of word learning revealed that children's learning of the novel word was more robust when teaching was interrupted by JME (shared game play on the phone), in comparison to interruption to teaching via technoference (phone call), or non-interrupted teaching.

There are several possible interpretations for the finding that word learning was more robust when teaching was interrupted by JME. Firstly, as joint attention and responsiveness facilitate children's language development (e.g., Baumwell et al., 1997; Bornstein et al., 2008; Tomasello & Farrar, 1986) and specifically learning novel words (Myers et al., 2017; Roseberry et al., 2014), JME via the game play which encouraged joint attention and parent responsiveness, may have aided learning of the novel word. This is deemed the most likely explanation. An alternative explanation is that possibly a 30-second break during the teaching provided children with longer time to process the word, however as the same robustness of learning was not found when a phone call interrupted the teaching, this seems unlikely. Finally, nearly all children were engaged in the game on the phone and child engagement may have aided robust word learning. Yet, as children have been found to focus on the device and not the parent (Ewin, Reupert, & McLean, 2021), and novel word learning in 20-month-olds is not affected by engagement (Wei et al., 2019), this explanation is doubtful.

5.4.3 Limitations

Despite replicating Reed et al. (2017) there are several limitations that should be noted. Firstly, the teaching was not consistent across caregivers. Whilst this provided more naturalistic interactions between caregivers and their child, it meant that children were experiencing different levels of quality in the teaching as caregivers took different approaches. Some explained clearly what the word meant whilst demonstrating the action, others said the word alongside demonstrating the action but without any explanation. Some caregivers made the teaching more engaging, e.g. “can you frep up high?”, whereas others rarely let their child engage with the toy and were more directive in their teaching, which could have affected learning of the novel word (Corkin et al., 2021). Whilst the frequency of input and time spent teaching was accounted for, the quality of the teaching was not measured which may have impacted how well children learnt the novel words. Future studies should factor in quality of teaching into the analysis, or similar to Roseberry et al. (2014), control for teaching variation by using video recordings of the teaching.

Secondly, due to the nature of the task some aspects of the study varied across dyads. For example, as instructions were given via a phone there was variation in how long the smartphone took to connect and in how long caregivers took to answer the call. When teaching was interrupted by the game, some parents continued to engage with the child whilst the game app was opening, whereas others did not engage with the child until the game was open and ready to play. The continued interaction may signal a general level of responsiveness in the caregiver or reflect how distracted they were by the smartphone, both of which could influence how disruptive the technoference was for novel word learning (Baumwell et al., 1997;

Reed et al., 2017). It would be beneficial in future studies to factor in any interactions during transitions between tasks into the analysis.

5.4.2 Conclusion and Implications

This study adds to the literature by identifying the complex relationship between parent smartphone technoference and child language outcomes. Interruption to a caregiver-child interaction does not automatically lead to negative outcomes for learning new words, but that is not to say that we should be advocating parent smartphone use during parenting. Instead, it is important to find a balance in advising parents around smartphone use, to ensure that any smartphone use is brief and in moderation without increasing feelings of guilt in parents for engaging in brief smartphone technoference.

Chapter 6 Study 4 Disruption in Adult-Infant Interaction: An fNIRS Study of Neural Responses to Smartphone vs. Book Engagement

6.1 Introduction

In Chapter 5, disruptions to teaching (phone call or shared phone use) did not affect children's learning of a novel word compared to uninterrupted teaching. These findings suggest that parent smartphone use does not disrupt short-term observable learning outcomes. However, behavioural measures, such as learning, or parent-infant behaviour during the interaction (as in Study 2a), do not capture potential underlying neural changes associated with parent smartphone technoference. Study 4 addresses this by examining the effects of adult smartphone technoference on neural activity. Building on Study 2a, which showed that parents directed more social gaze toward their infant during uninterrupted play than during phone use (phone call and taking photos), this study tests whether disruptions to social gaze disruption are associated with changes in infant neural activity.

Chapter 1 reviewed in detail the importance of eye gaze as an ostensive signal in developing social communication in the early years (Stephenson et al., 2021), creating opportunities for social interactions, and for ensuring that the intended recipient is aware that the communication is directed to them (Csibra, 2010). An understanding of ostensive signals in infancy represents the beginnings of

the development of a network of brain regions that facilitate complex social interactions, often termed the social brain (Adolphs, 1999). This network of brain regions primes infants for social interactions when they enter the world, as evidenced from a large body of research exploring early development and the social brain (see Grossmann (2015)). The social brain continues to undergo structural development into adolescence and changes significantly between adolescence and adulthood (Blakemore, 2008; Mills et al., 2014), facilitating humans' social communication.

The ability to detect direct gaze is central to social communication in both adults and infants. In studies with adults, direct gaze signals interest from the other member of a social interaction, signals the start and end of a speaking turn during an interaction, and promotes feelings of closeness (Ellsworth & Ross, 1975; Ho et al., 2015; Stass & Willis Jr, 1967). Given the crucial role of gaze for social communication, it is not surprising that several studies have found distinct patterns of neural activation in adults depending on whether gaze is direct or averted. Increased activation in response to direct gaze, but not averted gaze, has been found in ventral occipitotemporal cortices around the fusiform gyrus, the amygdala, the fusiform gyrus, the right paracingulate cortex, the left temporal pole, the dorsal medial prefrontal cortex, and the Superior Temporal Sulcus (STS) (George et al., 2001; Kampe et al., 2003; Pelphrey et al., 2004; Schilbach et al., 2006). These findings suggest neural sensitivity to direct gaze in adults.

Infants too are sensitive to direct gaze. As discussed in Chapter 1, infants prefer faces with direct gaze compared to averted gaze (Farroni, Johnson, et al., 2004; Farroni, Massaccesi, et al., 2007; Farroni et al., 2006). At a neural level, the infant brain recruits many of the same brain areas during social communication as

adults (Kosakowski et al., 2022). Studies using electroencephalography (EEG) report a peak in the N290 component, and increased gamma activity, in response to direct versus averted gaze in 4-month-olds for upright faces (Farroni, Johnson, et al., 2004; Grossmann et al., 2007). Similar findings are reported in studies using functional near infrared spectroscopy (fNIRS) in infants between the ages of 4-to-7-months. In response to direct versus averted gaze, an increased haemodynamic response has been found in several brain areas including the right superior posterior temporal cortex, the right fronto-polar cortex, the left dorsal prefrontal region, the prefrontal cortex, the frontal and temporal cortices, and the anterior superior temporal cortex (Grossmann & Johnson, 2010; Grossmann et al., 2008; Grossmann et al., 2010; Lloyd-Fox et al., 2015; Urakawa et al., 2015). Together, the evidence suggests that infants, similarly to adults, are sensitive to direct gaze and several brain regions are involved in identifying the presence of direct gaze.

Technoference has the potential to disrupt social gaze, as use of a smartphone largely demands that the user looks at the phone (Bury et al., 2020), potentially disrupting eye gaze to a social partner. As discussed in Chapter 1, a small body of research has observed the impact that parent smartphone technoference has on eye gaze between young children and their parents. These studies have demonstrated that parent smartphone technoference reduces looking time to the infant during feeding (Inoue et al., 2021) and leads to parents turning their bodies away from their child (Elias et al., 2020). Study 2a similarly found that parents looked to their infant more when not using a smartphone. Type of smartphone use can affect the direction of gaze, parents making phone calls have been found to maintain eye gaze with their child, but not when engaged in swiping tasks on the phone (Radesky et al., 2014). However, Study 2a found no difference in parents' eye gaze to the

infant when using the phone to make a call in comparison to using the phone to take photos. Taken together, these tentative findings suggest that parent smartphone technoference can disrupt parents gaze to their child, but it is unclear whether type of smartphone use moderates this relationship.

Parent-child interactions are also susceptible to disruption from non-digital sources such as in-person social interruptions (Vanden Abeele et al., 2020), which may affect eye gaze in a manner similar to smartphone use. To the best of my knowledge, only one study has compared disrupted eye gaze between digital and non-digital disruption, finding that 2-6-month-old infants direct less gaze to the parent during both distraction types than they do during free play (Tonga, 2023). However, a small number of studies have compared digital and non-digital distractions on other outcomes including maternal responsiveness, maternal use of language and children's bids for attention, reporting no differences on these outcomes regardless of the medium of the interruption (Ewin, Reupert, McLean, et al., 2021; Gaudreau et al., 2021; Konrad, Berger-Hanke, et al., 2021; Lederer et al., 2022), even when an adult directs ostensive signals to the child prior to each disruption (Flatebø et al., 2024). Taken together, these results suggest that smartphone technoference may be as disruptive to the parent-child interaction as non-digital interruptions such as magazine reading. Nonetheless, a recent fNIRS study comparing story reading using a traditional book versus screen-based visuals, found that 36-to-72-month-olds showed increased activation in the temporoparietal junction only during the book reading condition (Pecukonis et al., 2025). Whilst this study did not test a disruption per se, it suggests that young children may be sensitive to screen vs. non-screen interactions. However, there were differences in the delivery of the story reading

which may explain the results, as the screen-based condition used a prerecorded audio, whereas the book-reading condition relied on live reading.

Emerging research has begun to explore the influence of technoference on neural activity. EEG has been used to compare smartphone technoference to dyadic play in an adapted still face paradigm (SFP) with 9-month-olds (Swider-Cios et al., 2024). In this study, the dyad played for 2-minutes, followed by 2-minutes where the mother looks at her smartphone without making any interaction with the infant, before then reengaging with the child. Whilst Swider-Cios et al. (2024) found a behavioural change during the smartphone disruption, with infants displaying increased negative affect, there was no change in neural activity during this period. Although these findings suggest that neural processes may not be sensitive to technoference, it is important to consider that the mother looked at the smartphone continuously for 2 minutes - a duration that likely does not reflect typical, brief instances of technoference. However, van den Heuvel et al. (2026) found decreased brain to brain coupling between infants aged 4-12 months and their mother during the smartphone still face in comparison to free play, suggesting technoference can affect neural processes. In another EEG study, Zivan et al. (2022) found higher mother-child neural synchrony when mothers read their 2-3.5-year-olds a story uninterrupted compared to regular interruptions by a smartphone. These findings suggest technoference can disrupt neural activity when an ongoing interaction is disrupted regularly for short periods. However, without a non-digital disruption for comparison it cannot be concluded that technoference is unique in its ability to reduce mother-child synchrony, and possibly a non-digital disruption could have the same effects. However, there is tentative evidence using a modified SFP that smartphone technoference has a different effect on other physiological processes in

comparison to non-digital distractions. Nazzari et al. (2025) found that interactions interrupted by either smartphone technoference, or a pen-and-paper task led to increased negative affect in 3-5-month-olds. However, only the smartphone condition was associated with a decreased in forehead temperature during the interruption, suggesting a stress response. Dinzinger et al. (2025) found cardiac arousal increased in response to smartphone disruption in comparison to baseline. Respiratory sinus arrhythmia (RSA) was lower (indicating poorer stress regulation) during smartphone disruption in comparison to the still face phase. Taken together these findings suggest infants aged 6 months and under have different physiological responses to smartphone disruption than to non-digital disruptions. Whether neural activity differs between smartphone technoference and non-digital disruptions is not yet known.

6.1.2 The Present Study

The current study aimed to address existing gaps in the literature by using fNIRS to test whether the infant brain responds differently to averted gaze during a social interaction due to smartphone technoference versus non-digital disruption. The brain areas of interest in this study were the prefrontal cortex, the temporal cortex, and parietal cortex (incorporating the STS), as these areas are associated with sensitivity to direct gaze in both adults and infants (Grossmann, 2015; Grossmann et al., 2008; Kampe et al., 2003; Lloyd-Fox et al., 2015; Pelphrey et al., 2004). Ostensive signals of eye gaze and infant directed speech (IDS) are most effective as communication cues when they occur together as opposed to each independently (Guellai & Streri, 2011), therefore the current study had adult models singing nursery rhymes using IDS whilst periodically averting their gaze to either a smartphone or a book. The adult model was passive when looking at the

smartphone/book rather than engaging with the object. While I acknowledge that natural use of a smartphone is unlikely to be passive, with the user likely to be swiping, typing or talking into the phone, as the first study to experimentally compare averted gaze during a social interaction due to smartphone technoference versus non-digital disruption, passive use of both objects allowed for a clear comparison of the effect of the object as opposed to how the objects were used.

6.2 Study 4a

A pilot study involving adult participants was conducted prior to the study with infants for two primary reasons. One, as the first study to experimentally manipulate adult eye gaze to compare digital and non-digital disruptions, Study 4 used novel stimuli. It was therefore necessary to assess the effectiveness of the stimuli in generating a canonical response. However, the haemodynamic response in infants does not always show a canonical response (Issard & Gervain, 2018), unlike adults, deeming an adult sample more suited to piloting. Second, without previous research evidencing neural processes in the infant brain in response to different type of disruptions, it was not possible to predict the likely outcome. For a difference in neural processing to occur, it was anticipated that an understanding that a smartphone is a different type of disruption to a book is necessary; a distinction that infants are unlikely to have yet developed. Adults, however, understand that smartphone use during social interactions is not socially acceptable (Leuppert & Geber, 2020). If the type of disruption does affect neural processing, logically this would be more likely to be present in adults who understand the social norms around smartphone technoference. Thus, the adult pilot study allows for a tentative exploration of whether an understanding of social norms surrounding smartphone technoference is a perquisite for differential neural responses to digital versus non-

digital disruptions. Based on this line of reasoning, I predicted that there would be a significant difference in adult's neural activity in the prefrontal cortex, and across the temporal and parietal cortex when viewing a social interaction where direct gaze is interrupted by a smartphone compared to a book (H1).

6.3 Method

6.3.1 Participants

Twenty-seven participants participated in the study (all biologically female, one identified as non-binary). Of these, seven (26%) were excluded due to technical issues (N = 2), falling asleep during the stimuli presentation (N = 3), and poor signal quality, defined as 30% or more of the channels removed during preprocessing (N = 2). The final sample analysed included 20 participants (M_{age} 23.95_{years}, SD = 8.56_{years}). Due to the exploratory nature of this study, it was decided to only include females to control for gender, which has been shown to influence 'phubbing' (phone snubbing) behaviour (Escalera-Chávez et al., 2020) and a power analysis was not conducted.

Characteristics of the sample are shown in Table 6.1. Eighty-five percent of the sample were White, 10% were Asian and 5% were Black. Most participants were psychology students (80%) with a Level 3 qualification (75%) who participated for course credit. No reimbursement was offered to non-students. The University Ethics committee approved this research (ETH2223-2521) and informed consent was gathered digitally prior to participants arriving at the laboratory.

Table 6.1

Characteristics of the Sample

Ethnicity	**N (percentage)**
Asian	2 (10)
Black	1 (5)
White	17 (85)
Employment	**N (percentage)**
Employed full time	1 (5)
Employed part time	3 (15)
Student	16 (80)
Education	**N (percentage)**
GCSE (or equivalent)	1 (5)
A Levels (or equivalent)	15 (75)
Bachelor's degree	1 (5)
Master's degree	2 (10)
PhD	1 (5)

6.3.2 Design and Variables

A within participants design was applied, allowing for a comparison between the response to smartphone technoference and a non-digital disruption (book) within participants. Participants viewed videos of female Caucasian adults singing nursery rhymes. In the technoference condition, the social partner averted their gaze to a smartphone during the singing. In the non-digital disruption condition, the social partner averted their gaze to a book during the singing. To measure how participants responded to the two different types of interruptions, changes in the concentration of

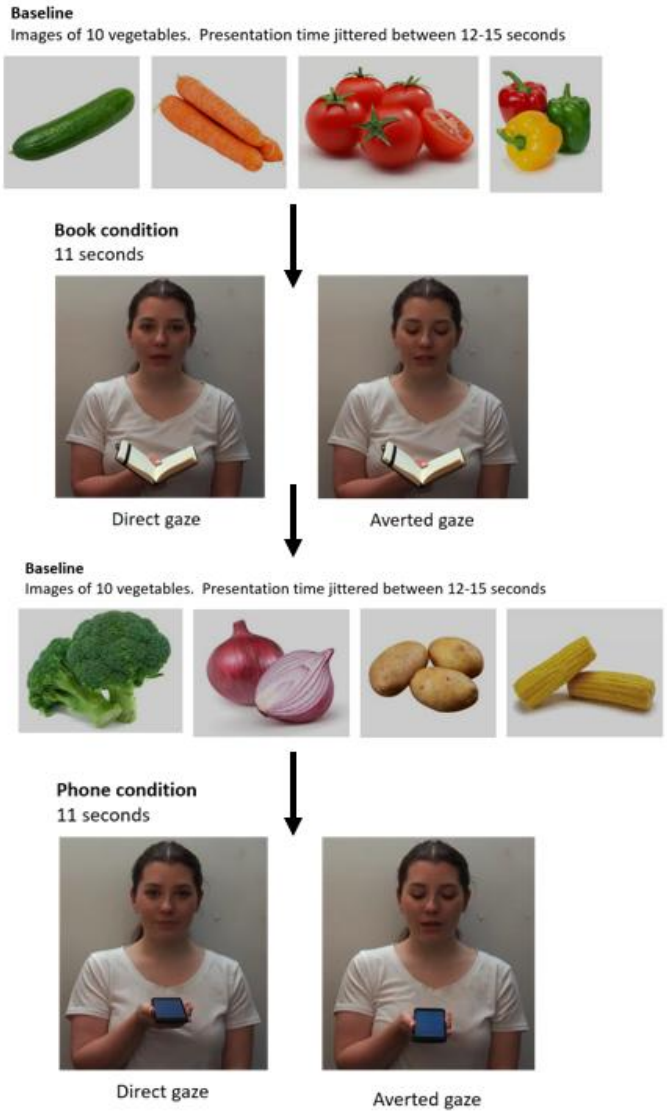
oxygenated haemoglobin (HbO_2) and deoxygenated haemoglobin (HHb) were measured using a NIRS system across 18 channels.

6.3.3 Stimuli

In each experimental trial participants viewed a video of an adult singing a nursery rhyme whilst their eye gaze was disrupted by looking down towards a smartphone or to a book. In between the presentation of each experimental trial, still images of vegetables were presented (Figure 6.1).

Figure 6.1

An Example of the Experimental Design



Note. The experimental design alternated between coloured images of vegetables (presented between 12-15 seconds) and a video of a model singing (presented for 11 seconds). The disruption trial alternated between averting gaze to a smartphone or a book after each baseline trial.

Each experimental trial consisted of a female Caucasian adult singing one of three nursery rhymes (Humpty Dumpty, Row Your Boat, Five Little Ducks) using IDS for 11 seconds. Each of the four female models sung all three songs, both when holding a smartphone and when holding a book, wearing a white t-shirt with their hair tied back. This resulted in 12 videos per condition. During the 11-second duration, the model begun with direct gaze towards the camera and then averted their gaze by looking down to the object they were holding and then returned their gaze to the camera. In every trial, the model looked to the interrupting object three times, 1-second into the trial, 4-seconds into the trial, and 8-seconds into the trial. Models were asked to sing as they would to a baby, this resulted in individual variability in tone which is reflective of experiences in the real world when hearing the same song via multiple adults and media. To generate a baseline response, full colour non-social still images of vegetables were presented between trials. The duration of these varied between 12-15 seconds, to reduce the likelihood of an anticipatory response to the baseline stimuli (Lloyd-Fox, 2020). Participants were presented with 24 trials, viewing all variations of model, song, and condition. Stimuli presentation always began with the baseline images. The order of presentation was pseudo randomised to allow for a different order of stimuli presentation for each participant, but with the interruption alternating between the smartphone and book for each trial.

The pseudo randomisation also ensured that the same adult was not being presented consecutively.

6.3.4 Measures

Demographic data on age, gender, ethnicity, education, employment, current relationship status, and whether the participant was a parent or not were collected. General smartphone use and phubbing[4] were also measured.

General Smartphone Use

Similar to previous studies in this thesis, items 17 and 18 from Appendix D asked about frequency and duration of smartphone use. Two items asked participants about their smartphone use when actively engaged in a social interaction and when not actively engaged with another person. These two items were amended from item 19 (Appendix D) and asked participants "Thinking about your phone use over the last 24 hours, identify how long you engaged with each of the following when using your phone when you were <u>not</u> actively engaging with another person". The second item omitted the word 'not'. Participants could respond "I did this almost the entire time I used my phone", "I did this for about half the time I spent on my phone", "I did this for less than half of the time I spent on my phone", or "Not at all".

Phubbing Behaviour

I amended an item previously used in Study 2b and Study 3 (originally taken from Corkin et al. (2021)) to ask participants "How often do you consciously decide

[4] Phubbing is a portmanteau of phone and snubbing and is the act of using one's phone during a social interaction, snubbing the social partner (Chotpitayasunondh & Douglas, 2016). Unlike technoference, phubbing refers only to mobile phone use and is more commonly used in the adult literature than technoference. See Frackowiak, et al. (2024). for a discussion of these terms.

not to use your smartphone during social interactions, and then turn it off or put it away for a while?" Participants could respond "Everyday", "Several times a week", "Once a week", "Once every two weeks", or "Occasionally or never".

The Generic Scale of Phubbing (GSP) (Chotpitayasunondh & Douglas, 2018b) (see Appendix E) is a 15-item measure of an individual's phubbing behaviour in social interactions, measuring four elements of phubbing behaviour, nomophobia (e.g., "I feel anxious if my phone is not nearby"), interpersonal conflict (e.g., "I get irritated if others ask me to get off my phone and talk to them"), self-isolation ("I feel content when I am paying attention to my phone instead of others"), and problem acknowledgement ("I find myself thinking "just a few more minutes" when I am using my phone"). Participants respond on a seven-point Likert scale, from 1 (*never*) to 7 (*always*). Cronbach α in this study was .88, lower than the original validation (Cronbach = .93) (Chotpitayasunondh & Douglas, 2018b), however still showing a strong degree of internal consistency.

Being Phubbed

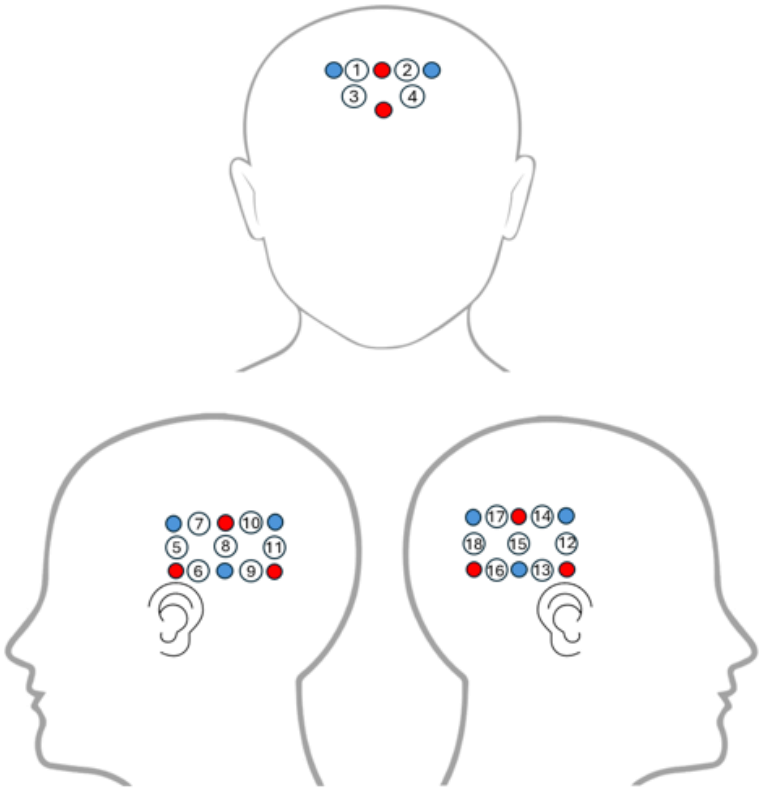
The Generic Scale of Being Phubbed (GSBP) (Chotpitayasunondh & Douglas, 2018b) (see Appendix F) is a measure of an individual's experience of being phubbed in social interactions. Twenty-two items measure three elements of being phubbed, perceived norms (e.g., "Others place their phones where they can see them"), feeling ignored (e.g., "Others would rather pay attention to their phones than talk to me") and interpersonal conflict (e.g., "Others use their phones even though they know it irritates me"). Participants respond on a seven-point Likert scale, from 1 (*never*) to 7 (*always)*. Cronbach α in this study was .93, similar to the original validation (Cronbach = .96) (Chotpitayasunondh & Douglas, 2018b).

6.3.5 NIRS Recording

Adults wore portable fNIRS headgear using the NIRx NIRSport system which contained 8 sources and 8 detectors attached to an easycap, forming 16 channels. This system uses continuous wavelengths at 760nm and 850nm to detect changes in HbO_2 and HHb. The channels were positioned on the prefrontal cortex (PFC), the temporal lobe, central area, temporoparietal junction (TPJ), and the parietal lobe, based on the 10-10 system (Figure 6.2) positioned at 2cm intervals. Before the study began, head measurements were taken to align the headgear with the 10-10 coordinates.

Figure 6.2

Illustrative Example of the Approximate Placement of the Sources and Detectors



Note. The red dots represent sources, and the blue dots represent detectors. The white circles represent the approximate placement of the channels.

6.3.6 Procedure

Upon arrival to the laboratory, participants completed an online consent form using the researcher's iPad. The testing room contained a computer monitor and the fNIRS equipment, the researcher was positioned opposite to the participant behind a partition so that the participant could not see the researcher during the presentation of the stimuli. The researcher proceeded to explain the procedure and participants were told they would be shown various images and videos via the computer monitor. The researcher, or an assistant, took head measurements of the participant to allow for the correct size cap to be used. Participants were then given the opportunity to ask any questions before the researcher placed the fNIRS headgear onto the participant's head. Once the headgear was positioned on the participants head and the signal optimisation had been checked, the researcher instructed participants to sit as still as possible whilst viewing the stimuli. The computer presented the stimuli using MATLAB, and a HP laptop recorded the NIRS output. During the presentation of the stimuli, all digital devices were turned off and placed in a box out of the participants line of sight and the light in the room was turned off. A camera on top of the computer monitor recorded where participants were looking. After viewing all 24 trials participants were asked to complete a questionnaire via an iPad which measured their experiences of phubbing.

6.3.7 Data Analysis

Data was exported in .nirs format and transferred into .snirf when uploaded into Homer3, a MATLAB toolbox, which was used to preprocess and process the data. Preprocessing was conducted to remove any extraneous noise from the raw data (Pinti et al., 2019). First the raw fNIRS data was converted into optical density data. Channels with a low signal to noise ratio were discarded using the Homer3 hmrR_PruneChannels function and setting the “dRange” to 0.01 to 10 and “SNRthresh” to 2. Motion artifacts were identified using the Homer3 function hmrRMotionArtifactByChannel. Following other research which has applied a combination of motion correction techniques (Bonzano et al., 2023), the Homer3 functions hmrR_MotionCorrectSpline (p=0.99) and hmrR_MotionCorrectWavelet (iqr = 0.5) were applied. Next, the data was band-pass filtered (0.01 -2Hz) (Burns et al., 2018) to filter out unwanted frequency noise. Lastly, data was converted to relative concentrations of HbO_2 and HHb using hmrROD2_conc with a path length factor of 6 based on Duncan et al. (1995).

Following preprocessing, data was visually inspected by channel across participants to check channels with any unusual pattern of results, such as not following the typical haemodynamic response. No channels were identified and therefore no further action was taken. Any channels identified as having poor signal quality during preprocessing were also removed (N = 2 channels on one participant), but the rest of the data was retained if the total number of channels removed from the participant was less than 30%. Table 6.2 includes the useable data rate by channel and condition for the remaining 20 participants. One participant (5%) had at least one channel removed.

Table 6.2

Useable Data Rate by Channel and Condition for the Adult Sample

Condition	Total trials shown	Number of trials excluded	Trials retained	Mean valid trials per participant
Phone	240	0	240	12
Book	240	0	240	12

Channel	Phone: participants with useable data, N (%)	Book: participants with useable data, N (%)
1	20 (100)	20 (100)
2	20 (100)	20 (100)
3	20 (100)	20 (100)
4	20 (100)	20 (100)
5	20 (100)	20 (100)
6	19 (95)	19 (95)
7	20 (100)	20 (100)
8	20 (100)	20 (100)
9	20 (100)	20 (100)
10	20 (100)	20 (100)
11	19 (95)	19 (95)
12	20 (100)	20 (100)
13	20 (100)	20 (100)
14	20 (100)	20 (100)
15	20 (100)	20 (100)
16	20 (100)	20 (100)

17	20 (100)	20 (100)
18	20 (100)	20 (100)

Note. Channels were excluded by participants, rather than by condition.

This data set was used in two different ways: 1) to allow for a comparison between baseline and the experimental conditions, 2) processed further for statistical analysis (see below).

The preprocessed data was analysed using a general linear model (GLM). In the GLM the boxcar function represents the entire time course of stimuli presentation and is convolved with the canonical hemodynamic response function (HRF) (Pinti et al., 2017; Uga et al., 2014). The GLM was chosen for this study because it considers the entire time series and is therefore more statistically powerful than the often-used block averaging approach (Pinti et al., 2019). In Homer3, the GLM uses the time before stimulus presentation as the baseline regressor, and the two interruptions (smartphone and book) were added as regressors. The GLM was applied from stimulus onset until 7 seconds after (18 seconds in total). A modified gamma function and its derivative with a square-wave duration was applied for the HRF. The parameters basis was set to idxBasis=3. The output provided two betas for each haemodynamic species (four in total). For each species, there was one beta for the gamma and one for the derivate. As we did not have a specific hypothesis for the derivative, the beta for the gamma was used for the subsequent data analysis. This data set was used to make comparisons across channels and experimental conditions.

6.4 Results

All analyses were carried out in RStudio 2024.04.2.

6.4.1 Descriptive Statistics

Participants self-reported smartphone use can be seen in Table 6.3. Most participants checked their smartphone 3-9 times an hour (60%), used their smartphone for 3-6 hours per day (65%) and made a conscious effort to put their phone away once a week (40%).

Table 6.3

Percentages of Duration and Frequency of Smartphone Use and Consciously Putting the Smartphone Away

Frequency	**N (percentage)**
0-2 times an hour	2 (10)
3-5 times an hour	4 (20)
6-9 times an hour	8 (40)
10-12 times an hour	1 (5)
13-15 times an hour	2 (10)
More than 15 times an hour	3 (15)
Duration	**N (percentage)**
Less than 60 minutes per day	1 (5)
1-2 hours per day	4 (20)
3-4 hours per day	7 (3)
5-6 hours per day	6 (30)
7-8 hours per day	2 (10)

Over 9 hours per day	0

Consciously putting phone away	**N (percentage)**
Occasionally or never	7 (35)
Once a week	8 (40)
Once every two weeks	3 (15)
Several times a week	1 (5)
Everyday	1 (5)

Figure 6.3 displays the various ways that participants use their smartphones during different levels of social engagement with others. As the data was ordinal, the Wilcoxon Signed-Rank Test with Bonferroni correction was applied to examine which activities participants were more likely to use their smartphone for when socially engaged with others, compared to when not socially engaged with others. Participants spent more time making phone calls and video calls when not socially engaged compared to when they were socially engaged. No other significant differences were found (see Table 6.4).

Table 6.4

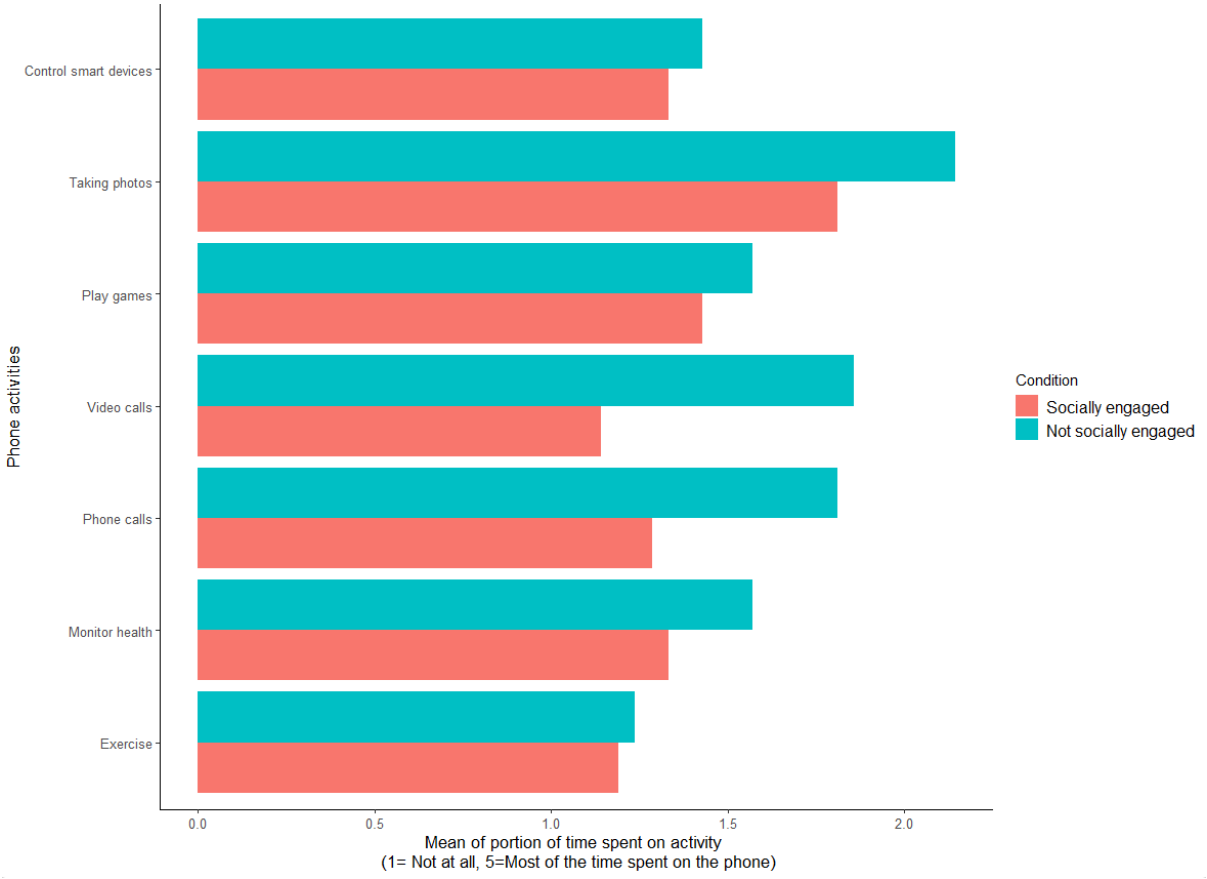
Wilcoxon Signed-Rank Statistics Comparing Each Type of Smartphone Use When Socially Engaged With Others or Not Socially Engaged With Others

Activity	**Engagement**	***M***	***SD***	***z***	***p***	***p* adjusted**	**Effect size (r)**
Phone calls	Engaged	1.30	0.47	3.051	.002	*	0.67
	Not engaged	1.80	0.62				
Exercise	Engaged	1.20	0.52	0.577	.564	ns	0.13
	Not engaged	1.25	0.55				

Playing games	Engaged	1.45	0.76	1.134	.257	ns	0.25
	Not engaged	1.60	0.82				
Monitoring health	Engaged	1.35	0.67	1.890	.059	ns	0.42
	Not engaged	1.60	0.59				
Taking photos	Engaged	1.80	0.77	1.807	.071	ns	0.47
	Not engaged	2.15	0.59				
Controlling smart devices	Engaged	1.35	0.59	1	.317	ns	0.22
	Not engaged	1.45	0.69				
Making video calls	Engaged	1.15	0.37	2.714	.007	*	0.67
	Not engaged	1.90	0.91				

Figure 6.3

Portion of Daily Smartphone Use by Activity and Level of Social Engagement



6.4.2 Quality Checks

The pre-processed data was used to inspect changes in HbO_2 and HHb across a 17-second-long epoch, starting 2 seconds before the onset of each trial and ending 4 seconds after trial offset. The 2 second duration prior to stimulus onset (baseline) was subtracted from this 17-second window. The remaining 15 second window was further separated into five 3-second epochs to allow for comparison between baseline HRF and interruption (phone vs. book), by the main effect of time. The purpose of this quality check was to identify channels that showed either a significant HbO_2 increase and/or a significant HHb decrease from baseline across the 15 second epoch. The two interruptions (phone vs. book) were averaged

together for each participant within channels, following the approach taken by other studies using fNIRS (Fiske et al., 2022; Lloyd-Fox et al., 2015; Lloyd-Fox et al., 2018).

A channel-by-channel analysis was applied to identify channels which demonstrated a significant haemodynamic response from baseline over time, using repeated measures ANOVAs with time (0-3 seconds, 3-6 seconds, 6-9 seconds, 9-12 seconds and 12-15 seconds) as a within participant factor. Channels that revealed a significant main effect of time for both HbO_2 (Table 6.5) and HHb (Table 6.6) were selected for further analysis.

Table 6.5

Results of ANOVA Testing Main Effect of Time on HbO2 Concentration on Adults' Data

	Left hemisphere				Right hemisphere			
	Channel	*F*	*p*	η2G	Channel	*F*	*p*	η2G
Prefrontal cortex	1	7.795	< .001**	0.16	2	21.216	< .001**	0.32
	3	21.450	< .001**	0.24	4	23.346	< .001**	0.40
Temporal and parietal cortex	5	5.560	< .001**	0.12	12	2.805	< .05*	0.06
	6	7.660	< .001**	0.15	13	5.95	< .001**	0.12
	7	5.998	< .001**	0.14	14	3.771	< .05*	0.08
	8	2.698	< .001*	0.07	15	2.786	< .05*	0.07
	9	10.935	< .001**	0.24	16	6.116	< .001**	0.13
	10	4.227	< .001*	0.09	17	2.248	.07	0.06
	11	12.427	< .001**	0.30	18	7.364	< .001**	0.21

Note * = significant at $p < .05$, ** = significant at $p < .001$ after applying the Benjamini-Hochberg procedure for controlling the false discovery rate.

After applying the Benjamini-Hochberg procedure for controlling the false discovery rate, a significant difference in the haemodynamic response to the social stimuli in comparison to the baseline was found across 17 channels. The grand averaged time courses of the haemodynamic changes in HbO_2 for the significant channels are shown in Figure 6.4.

Figure 6.4

Group Averaged HbO_2 Responses to the Baseline and Each Type of Interruption for Adults

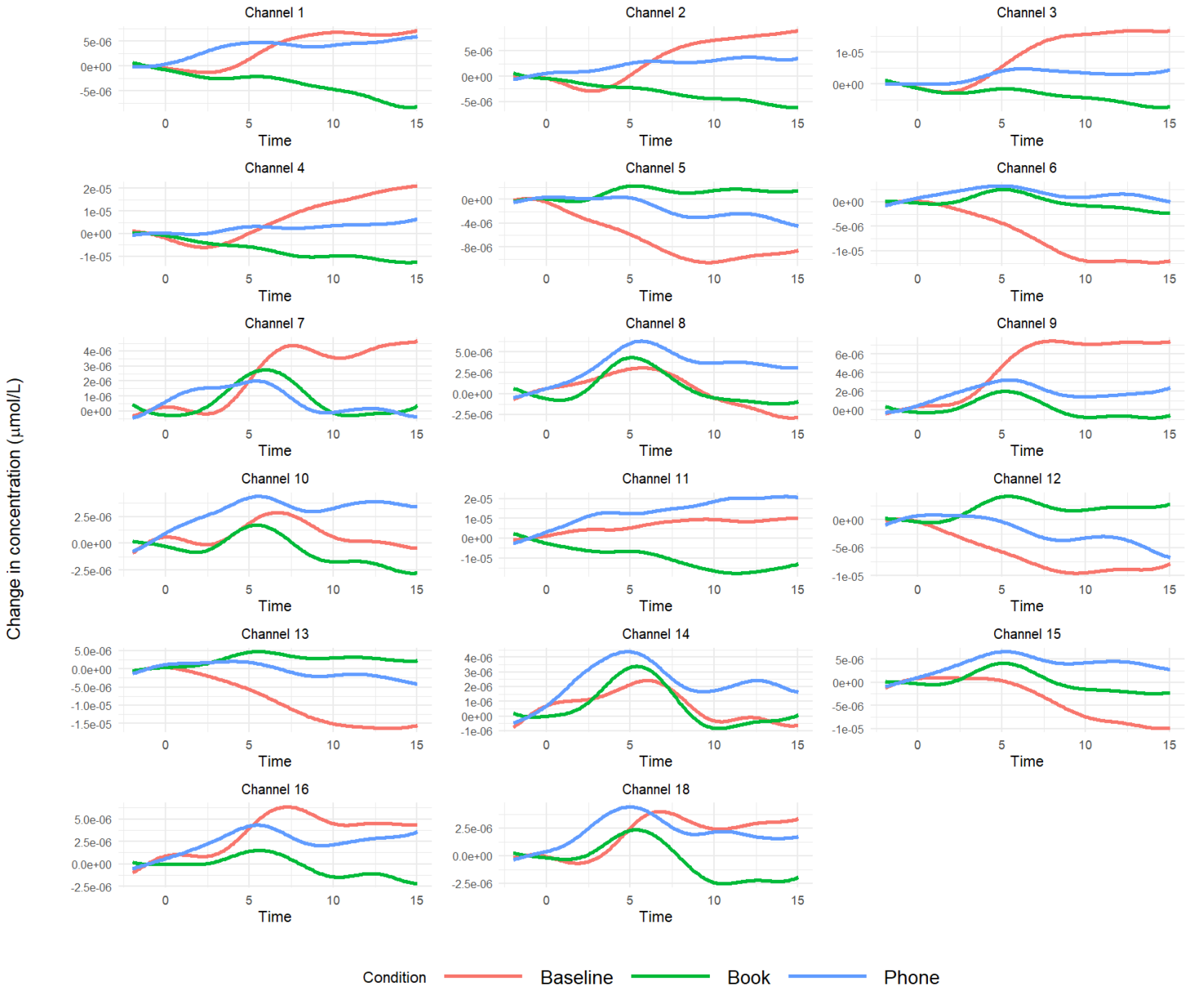


Table 6.6

Results of ANOVA Testing Main Effect of Time on HHb Concentration on Adults' Data

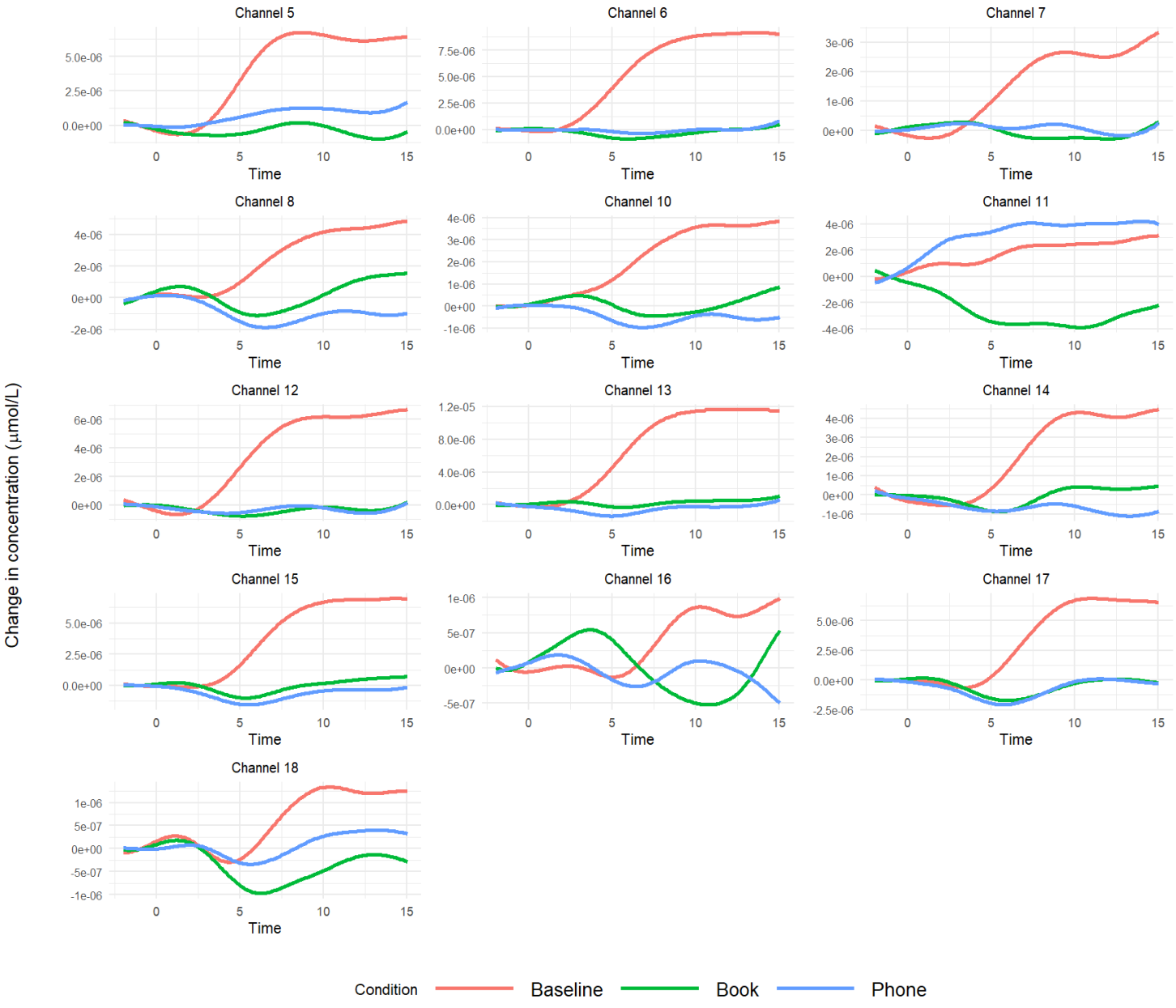
		Left hemisphere				**Right hemisphere**		
Prefrontal cortex	Channel	*F*	*p*	η2G	Channel	*F*	*p*	η2G
	1	1.952	.11	0.02	2	0.873	.48	0.01
	3	2.162	.08	0.03	4	2.011	.10	0.04
Temporal and parietal cortex	5	8.195	.001**	0.15	12	12.221	.001**	0.19
	6	25.792	.001**	0.36	13	25.81	.001**	0.34
	7	9.574	.001**	0.18	14	16.825	.001**	0.245
	8	30.058	.001**	0.4	15	27.308	.001**	0.37
	9	1.387	.25	0.03	16	3.358	.001*	0.05
	10	23.211	.001**	0.29	17	20.289	.001**	0.31
	11	9.365	.001**	0.12	18	5.858	.001**	0.11

Note * = significant at *p*< .05, ** = significant at *p*< .001 after applying the Benjamini-Hochberg procedure for controlling the false discovery rate.

After applying the Benjamini-Hochberg procedure for controlling the false discovery rate, a significant difference in the haemodynamic response to the social stimuli in comparison to the baseline was found across 12 channels. The grand averaged time courses of the haemodynamic changes in HHb for the significant channels are shown in Figure 6.5.

Figure 6.5

Group Averaged HHb Responses to the Baseline and Each Type of Interruption for Adults



6.4.3 Pre-Registered Analysis

My pre-registration (https://aspredicted.org/5jsj-3zbm.pdf) planned to use a linear mixed model. However, the decision to use a GLM (for the previously mentioned strengths) resulted in one beta value per condition for each participant and each haemoglobin species. This rendered a linear mixed model no longer appropriate, as the data for each trial was not available, which is necessary to appropriately apply a linear mixed model (Meteyard & Davies, 2020). Therefore, a two-way ANCOVA was applied using the GLM betas for each haemoglobin species to examine the effects of interruption type (phone vs. book) and channel on HRF, after controlling for GSP score and GSBP score. There was no significant main effect of distraction type on HbO_2, $F(1, 640) = 0.309$, $p = .58$, $\eta^2G < .001$, and the interaction between distraction type and channel on HbO_2 was also not significant, $F(16, 640) = 0.811$, $p = .67$, $\eta^2G = .02$. Similarly, the ANCOVA revealed a non-significant effect of distraction type on HHb, $F(1, 488) = 0.041$, $p = .84$, $\eta^2G < .001$, and no significant interaction between distraction type and channel on HHb, $F(12, 488) = 0.350$, $p = .98$, $\eta^2G = .009$.

6.5 Discussion

The aim of this exploratory study was to examine whether the areas of the adult brain recruited in social cognitive tasks distinguish between an interruption to direct gaze caused by a smartphone compared to a book. Contrary to H1, regardless of the type of interruption (smartphone or a book) no difference was found in either HbO_2 or HHb. Whilst adults are able to differentiate between direct and averted gaze at a neural level (George et al., 2001; Kampe et al., 2003; Pelphrey et al., 2004; Schilbach et al., 2006), to the best of my knowledge no studies in adults have explored this in the context of technoference. These findings therefore provide novel

evidence of the potential impact of smartphone technoference on neural processing of social cues.

Given that smartphone used during social interactions is associated with negative social norms (Leuppert & Geber, 2020) and can lead to negative mood and feelings of ostracism (Knausenberger et al., 2022), I predicted that adults would recognise the medium of the interruption and show a different neural response to the smartphone compared to the book. However, no difference in neural response was found between the two objects. There are several potential explanations for these results. The negative effects of smartphone technoference are stronger the more frequently smartphone technoference occurs (Hales et al., 2024; Knausenberger et al., 2022) and if the smartphone technoference occurs for trivial rather than important reasons (McDaniel & Wesselmann, 2021). Firstly, smartphone technoference in this study was both frequent (3 times in 11 seconds) and trivial (a brief glance to the phone), thus one might expect the smartphone technoference to elicit a different neural response to the book. However, the interruption to gaze caused by the book was equally frequent (3 times in 11 seconds) and as trivial (a brief glance to the book) as the smartphone. Therefore, as each interruption was matched for frequency and trivialness, the interruption to social interaction was the same, possibly this is why neural activity was similar for both interruptions. As opposed to my prediction that adults would focus on the object and the social norms associated with smartphone technoference, the features of the disruption may have been the crucial aspect of the interruption. An alternative explanation centres around high familiarity with smartphone technoference (Al-Saggaf & MacCulloch, 2018). Thus, the familiarity of adults with smartphone technoference may account for the lack of difference observed between the two interruptions in the present study. This

explanation is indirectly supported by research finding no association between smartphone technoference and relationship satisfaction or friendship satisfaction (Çizmeci, 2017; Stevic & Matthes, 2023). On the other hand, it is unlikely that adults are familiar with social interactions being disrupted by a book. If familiarity with the interruption was to account for the similarity in neural activation between interruption types, a difference in neural activity would be expected due to the book interruption being more unusual than the smartphone. The current novel findings provide a basis for future research to explore this relationship further.

6.6 Study 4b

Despite the non-significant findings in adults in Study 4a, the pre-registration plan proceeded with the infant study. Study 4b followed the same experimental design as Study 4a, comparing neural activity in the prefrontal cortex, temporal cortex, and parietal cortex (incorporating the STS) in response to smartphone technoference and a non-digital disruption (a book) (George et al., 2001; Grossmann & Johnson, 2010; Grossmann et al., 2008; Grossmann et al., 2010; Kampe et al., 2003; Lloyd-Fox et al., 2015; Pelphrey et al., 2004; Schilbach et al., 2006; Urakawa et al., 2015). Based on research showing that physiological responses are sensitive to smartphone technoference (Dinzinger et al., 2025; Nazzari et al., 2025), it was hypothesised that neural activity in the prefrontal cortex, and across the temporal and parietal cortices will differ when gaze is averted to the phone in comparison to a book (H2a). Alternatively, as the data from the adult sample, alongside other evidence, demonstrates similar effects on behaviour due to digital and non-digital disruptions (Ewin et al., 2021; Flatebø et al., 2024; Gaudreau et al., 2021; Konrad et al., 2021; Lederer et al., 2022), it is possible that there would be a non-significant difference in infant's neural activity when viewing a social interaction where direct

gaze is interrupted by a smartphone compared to a book (H2b). Given the limited evidence base, these two hypotheses were tested against each other. Either outcome carries value: a distinct neural response would support the idea that smartphones pose a unique threat to infant social engagement, while a null result would suggest that disruption to gaze itself, rather than its digital origin, is the more important factor to address.

6.7 Method

6.7.1 Participants

Fifty-five 6.5-7.5-month-old infants participated in this study. Of these, seven (13%) were excluded due to poor signal quality, defined as 30% or more of channels with poor signal (n = 6), and experimental error (n = 1, see exclusion criteria) leaving a final sample of 48 infants (27 females, M_{age} 213.08_{days}, SD = 8.13_{days}). A power analysis using G*Power identified a sample size of 41 participants necessary for an effect size of 0.50 and a power of 0.8. Due to the novel stimuli in the current study, the effect size was selected based on the average effect size across previous fNIRS studies on infants which measured activity in the temporal and prefrontal cortices in response to social communication (partial η2 = 0.332 and d > 0.84) (Grossmann & Johnson, 2010; Grossmann et al., 2008). Infants were recruited by contacting parents who had signed up to a university database to participate in research with their child. Social media was also used to recruit parents. The University Ethics Committee approved this research (ETH2223-2151) and informed consent was gathered online prior to arrival at the laboratory.

The characteristics of the sample are shown in Table 6.7. The primary caregiver for most of the infants was the mother (77%) and the infants were predominantly White (92%). Most of the participating parents were employed full-

time (63%) or part time (17%). Seventy three percent of the sample were educated to at least a bachelor's degree and the average household income was £81,609 (*SD* = £34,990).

Table 6.7

Characteristics of the Sample

Primary caregiver	**N (percentage)**
Mother	37 (77)
Mother and father	11 (23)
Ethnicity	**N (percentage)**
Mixed	4 (8)
White	44 (92)
Employment	**N (percentage)**
Employed full time	30 (63)
Employed part time	8 (17)
Homemaker	3 (6)
Maternity leave	3 (6)
Self-employed	4 (8)
Education	**N (percentage)**
GCSE (or equivalent)	4 (8)
A Levels (or equivalent)	9 (19)
Bachelor's degree	19 (40)
Master's degree	8 (17)
PhD	4 (8)
Other postgraduate qualification	4 (8)

6.7.2 Design and Stimuli

The same design and stimuli used with the adult sample were implemented with the infant participants.

6.7.3 Measures

General Smartphone Use

Parents' general smartphone use was measured using the same four items as Study 3 (Chapter 5). Two items asked parents about frequency and duration of their smartphone use. One item asked parents about the frequency of smartphone use in the presence and absence of their child. The fourth item asked parents how they use their phone when not engaged with their child and how they use their phone when actively engaged with their child across eight possible uses (previously described in Study 4a).

Technoference Measures

Parents completed the same three items previously described in Study 2b (Chapter 4) and Study 3 (Chapter 5). One item asked parents about the frequency of their smartphone use when actively engaging with their child. The second asked parents how often they consciously put their phone away when with their child (Corkin et al., 2021). The Distraction in Social Relations and Use of Parent Technology (DISRUPT) scale (McDaniel, 2021) measured cognitive technoference.

6.7.4 NIRS Recording

The NIRx NIRScout system was used to detect changes in HbO_2 and HHb across 8 sources and 8 detectors attached to an easycap. The formation of the sources and detectors was the same as for the adults (Figure 6.2). Before the study began, head measurements were taken of head circumference (*M* = 44.23cm, *SD* =

1.13cm), ear to ear (*M* = 23.77cm, *SD* = 1.64cm), forehead width (*M* = 17.19cm, *SD* = 2.91cm), and nasion to inion (*M* = 25.01cm, *SD* = 1.91cm), to align the headgear with the 10-10 coordinates. These measurements alongside photographs of the infant's head whilst wearing the headgear were used for approximate determination of underlying cortical regions.

6.7.5 Procedure

Upon arrival to the laboratory, parents and their infant were taken to a reception room. Most parents had completed online consent prior to arrival at the laboratory, any parents who had not signed consent were asked to do this in the reception room using the researcher's iPad. The researcher proceeded to explain the procedure. Parents were told that their infant would sit on their lap facing a computer monitor whilst wearing the fNIRS headgear and were asked to refrain from interacting with their child whilst the stimuli were presented. The researcher, or an assistant, took head measurements of the infant to allow for the correct size cap to be used. Parents were then given the opportunity to ask any questions and to feed their baby before moving to the testing room.

The testing room contained the fNIRS equipment, a computer monitor, and a swivel chair. Parents were asked to sit on the chair with the infant on their lap, whilst the researcher positioned the fNIRS headgear onto the infant. An assistant was present to help to distract the infant during this process for most participants. Once the headgear was positioned on the infant's head and the signal optimisation had been checked, the parent and infant were turned to face the computer monitor. To avoid any light interference, the researcher turned off the light as they left the room. Parents were instructed to sit as still as possible whilst viewing the stimuli and all digital devices were turned off and placed in a box out of the infant's and parent's

line of sight. Videos were presented until the infant had seen 24 videos (12 in each condition), or until they lost interest or became fussy. On average, infants watched 7.52 trials (*SD* = 2.49) when the adult model was holding a book and 7.27 trials (SD = 2.63) when the adult model was holding a phone.

After completion, the researcher took photos of the placement of the NIRS headgear. The headgear was then removed, and parents and infants returned to the reception room, where the parent completed the survey on the iPad before being verbally debriefed and given the opportunity to ask any questions. The infant was given a book for their participation.

6.7.6 Exclusion Criteria

The exclusion criteria followed Filippetti et al. (2023) and data was excluded from further analysis based on the following:

- Infant refusing to wear the NIRS cap (none excluded).
- Trials where the infant was heavily fussy or distressed (none excluded).
- Parental interference, where the parent interferes with the infant whilst the infant is watching the stimuli (none excluded).
- Poor signal quality, whereby 30% or more of the channels have a poor signal (six excluded).
- Experimental error, such as failure to record the NIRS data or video footage or incorrect placement of the source-detector montage (one excluded).
- The infant did not attend to 60% of the trial and watch at least two of the three looks away, assessed by looking time to the screen (none excluded).
- The infant did not attend to at least 30% of the baseline stimuli (none excluded).
- Viewing fewer than three trials per condition (none excluded).

6.7.7 Data Analysis

Offline video coding of looking time was completed by the lead researcher using ELAN (2023), an open-source coding software. Infant looking time to the stimuli and away from the stimuli was recorded. Following the exclusion criteria, any trials where the infant was not looking at the stimuli for at least 60% of the trial duration and did not view at least two of the actors' averted gazes, were removed prior to preprocessing.

As with the adult analysis, data was first exported in .nirs format and transferred into .snirf when uploaded into Homer3 to conduct preprocessing. First, the light intensity data was converted to optical density. Channels with a low signal to noise ratio were discarded using the Homer3 hmrR_PruneChannels function and setting the "dRange" to 0.01 to 10 and "SNRthresh" to 2. Motion artifacts were identified using the Homer3 function hmrRMotionArtifactByChannel. Following other research which has applied a combination of motion correction techniques (Bonzano et al., 2023), the Homer3 functions hmrR_MotionCorrectSpline (p=0.99) and hmrR_MotionCorrectWavelet (iqr = 0.5) were applied. Next, the data was band-pass filtered (0.01 - 0.80Hz) (Filippetti et al., 2023) to filter out unwanted frequency noise. Lastly, data was converted to relative concentrations of oxygenated and deoxygenated hemoglobin using hmrROD2_conc with a path length factor of 5.1 (Duncan et al., 1995).

Prior to further processing, data was visually inspected by channel across participants. Any channels which had an unusual pattern of results, such as not following the typical haemodynamic response, were explored in more detail at the participant level to see if one infant was driving this pattern. This resulted in one infant's data being removed from channel 10, and another infant's data being

removed from channels 16 and 18. To account for the potential effects of removing these channels, the analysis was run with and without these three data points and the findings remained the same in both analyses. Table 6.8 includes the useable data rate by channel and condition for the remaining 48 participants. Fourteen infants (29%) had at least one channel removed.

Table 6.8

Useable Data Rate by Channel and Condition for the Infant Sample

Condition	Total trials shown	Number of trials excluded	Trials retained	Mean valid trials per participant
Phone	398	49	349	7.27
Book	403	42	361	7.52

Channel	Phone: participants with useable data, N (%)	Book: participants with useable data, N (%)
1	46 (95.8)	46 (95.8)
2	46 (95.8)	46 (95.8)
3	44 (91.7)	44 (91.7)
4	46 (95.8)	46 (95.8)
5	45 (93.8)	45 (93.8)
6	46 (95.8)	46 (95.8)
7	48 (100)	48 (100)
8	47 (97.9)	47 (97.9)
9	46 (95.8)	46 (95.8)

10	46 (95.8)	46 (95.8)
11	44 (91.7)	44 (91.7)
12	46 (95.8)	46 (95.8)
13	48 (100)	48 (100)
14	47 (97.9)	47 (97.9)
15	46 (95.8)	46 (95.8)
16	46 (95.8)	46 (95.8)
17	47 (97.9)	47 (97.9)
18	47 (97.9)	47 (97.9)

Note. Channels were excluded by participants, rather than by condition.

Following the approach taken with the adult sample, this data set was used in two different ways: 1) to allow for a comparison between baseline and the experimental conditions, 2) to input into the GLM.

A GLM approach was applied to analyse the infant data from stimulus onset until 7 seconds after (18 seconds in total). A modified gamma function and its derivative with a square-wave duration was applied for the HRF. The parameters basis was set to idxBasis=3. The beta for the gamma was used for the subsequent data analysis. This data set was used to make comparisons of haemodynamic concentration between experimental conditions across channels.

6.8 Results

All analyses were carried out in RStudio 2024.04.2.

6.8.1 Descriptive Statistics

Parents self-reported smartphone use can be seen in Table 6.9. Most parents checked their smartphone 3-9 times an hour (78%), used their smartphone for 1-4

hours per day (83%) and made a conscious effort to put their phone away everyday (54%).

Table 6.9

Percentages of Frequency and Duration of Parents' Smartphone Use and Consciously Putting the Smartphone Away

Frequency	**N (percentage)**
0-2 times an hour	8 (17)
3-5 times an hour	21 (44)
6-9 times an hour	15 (31)
10-12 times an hour	4 (8)
13-15 times an hour	0 (0)
More than 15 times an hour	0 (0)
Duration	**N (percentage)**
Less than 60 minutes per day	2 (4)
1-2 hours per day	16 (33)
3-4 hours per day	24 (50)
5-6 hours per day	4 (8)
7-8 hours per day	2 (4)
Over 9 hours per day	0 (0)
Consciously putting phone away	**N (percentage)**
Occasionally or never	6 (13)
Once a week	2 (4)
Once every two weeks	0 (0)
Several times a week	14 (29)

Everyday	26 (54)

Parents were asked how often they used their smartphone across three different levels of engagement with their child; when their child is asleep, awake but not engaging with them, and during social engagement. As responses to this question were ordinal, Friedman's test with Bonferroni correction was applied to compare frequency of smartphone use across each level of engagement, revealing a significant difference in smartphone use across levels of engagement, $X^2(2) = 76.2$, $p < .001$, Kendall's W = 0.74. Post hoc pairwise Wilcoxon signed ranks tests revealed parents were more likely to report using their smartphone when their child was asleep ($M = 3.92$, $SD = 0.92$) compared to when they were awake but not engaging with them ($M = 2.69$, $SD = 0.80$), $Z = 33$, $p < .001$, $r = .78$. Parents reported using their smartphone more when their child was asleep in comparison to when they were actively engaging with their child ($M = 1.73$, $SD = 0.57$), $Z = 0$, $p < .001$, $r = .88$. Parents also reported using their smartphone more often when their child was awake but not engaging with them compared to when parents were actively engaging with their child, $Z = 630$, $p < .001$, $r = .83$.

Parents reported on the different ways in which they use their smartphone across different levels of engagement with their child (Figure 6.6). As the data was ordinal, the Wilcoxon Signed-Rank Test with Bonferroni correction was applied to see which activities parents were more likely to use their smartphone for when engaged with their child, compared to when not engaged with their child. Parents spent more time playing games when not engaged with their child compared to when they were engaged with their child. No other significant differences were found (see Table 6.10).

Figure 6.6

Portion of Daily Smartphone Use by Activity and Level of Engagement With Child

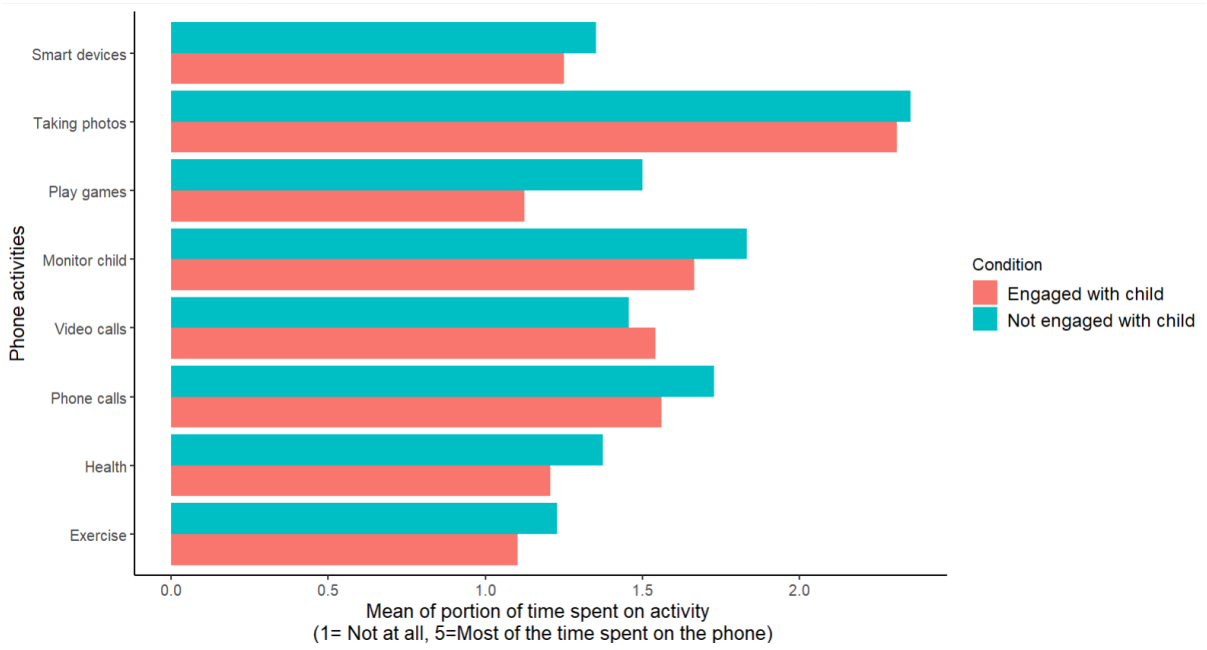


Table 6.10

Wilcoxon Signed-Rank Statistics Comparing Each Type of Smartphone Use When Engaged With Child or Not Socially Engaged With Child

Activity	Engagement	*M*	*SD*	*z*	*p*	*p* adjusted	Effect size (r)
Phone calls	Engaged	1.56	0.62	32.5	.01	ns	0.20
	Not engaged	1.72	0.71				
Exercise	Engaged	1.10	0.52	0	.02	ns	0.35
	Not engaged	1.23	0.59				
Playing games	Engaged	1.13	0.53	0	.001	.009*	0.52
	Not engaged	1.50	0.85				
Monitoring child	Engaged	1.67	0.83	19.5	.05	ns	0.28
	Not engaged	1.83	0.88				

Monitoring health	Engaged	1.21	0.58	13	.02	ns	0.33
	Not engaged	1.38	0.57				
Taking photos	Engaged	2.31	0.85	105.5	.72	ns	0.04
	Not engaged	2.35	0.60				
Controlling smart devices	Engaged	1.25	0.60	8	.16	ns	0.21
	Not engaged	1.35	0.60				
Making video calls	Engaged	1.54	0.65	50.5	.36	ns	0.09
	Not engaged	1.46	0.65				

6.8.2 Quality Checks

The pre-processed data was used to inspect changes in HbO_2 and HHb across a 17-second-long epoch, starting 2 seconds before the onset of each trial and ending 4 seconds after trial offset. The 2 second duration prior to stimulus onset (baseline) was subtracted from this 17-second window. The remaining 15 second window was further separated into five 3-second epochs to allow for comparison between baseline HRF and interruption (phone vs. book), by the main effect of time. Following the approach taken in other infant fNIRS studies (de Klerk et al., 2018; Filippetti et al., 2023; Lloyd-Fox et al., 2015; Lloyd-Fox et al., 2018; Pirazzoli et al., 2019) and with the adult data, a channel-by-channel analysis using repeated measures ANOVAs with time (0-3 seconds, 3-6 seconds, 6-9 seconds, 9-12 seconds and 12-15 seconds) as a within participant factor was applied. Channels which revealed a significant main effect of time (see Tables 6.11 and 6.12) were retained for further analysis.

Table 6.11

Results of ANOVA Testing Main Effect of Time on HbO2 Concentration on Infants' Data

	Left hemisphere				Right hemisphere			
	Channel	*F*	*p*	η2G	Channel	*F*	*p*	η2G
Prefrontal	1	9.912	< .001**	0.61	2	6.003	< .001**	0.32
	3	20.252	< .001**	0.12	4	10.52	< .001**	0.04
Temporal and parietal cortex	5	19.961	< .001**	0.16	12	11.536	< .001**	0.09
	6	19.041	< .001**	0.18	13	21.307	< .001**	0.14
	7	3.201	< .05*	0.02	14	4.988	< .001*	0.03
	8	23.791	< .001**	0.13	15	14.426	< .001**	0.09
	9	2.249	.07	0.02	16	6.663	< .001**	0.06
	10	3.528	< .001*	0.01	17	3.658	< .05*	0.02
	11	1.133	.34	0.004	18	1.328	.26	0.02

Note * = significant at $p < .05$, ** = significant at $p < .001$ after applying the Benjamini-Hochberg procedure for controlling the false discovery rate.

After applying the Benjamini-Hochberg procedure for controlling the false discovery rate, a significant difference in the haemodynamic response to the social stimuli in comparison to the baseline was found across 15 channels. The grand averaged time courses of the haemodynamic changes in HbO_2 for the significant channels, with the three previously identified data points removed, are shown in Figure 6.7.

Figure 6.7

Group Averaged HbO_2 Responses to the Baseline and Each Type of Interruption for Infants

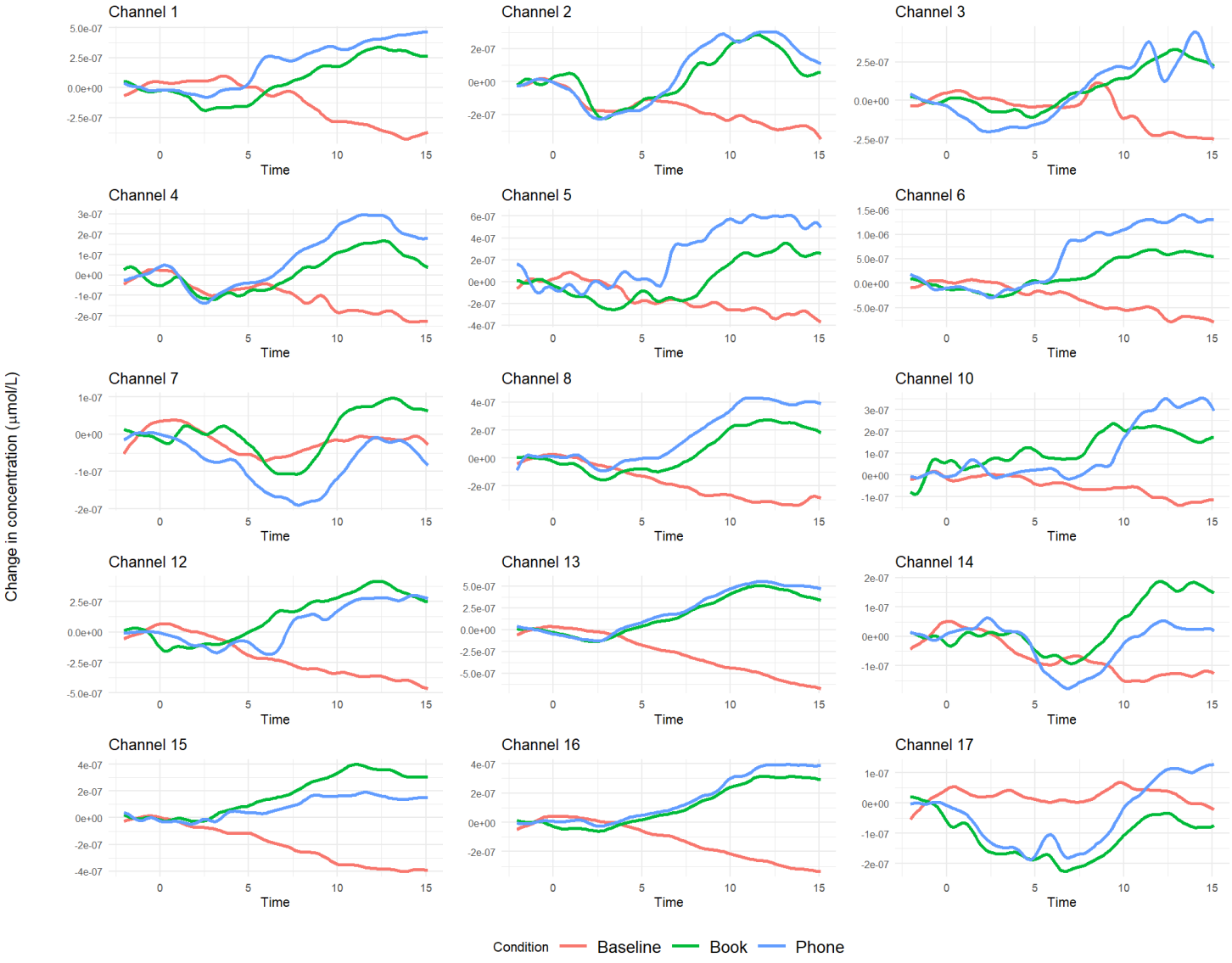


Table 6.12

Results of ANOVA Testing Main Effect of Time on HHb Concentration on Infants' Data

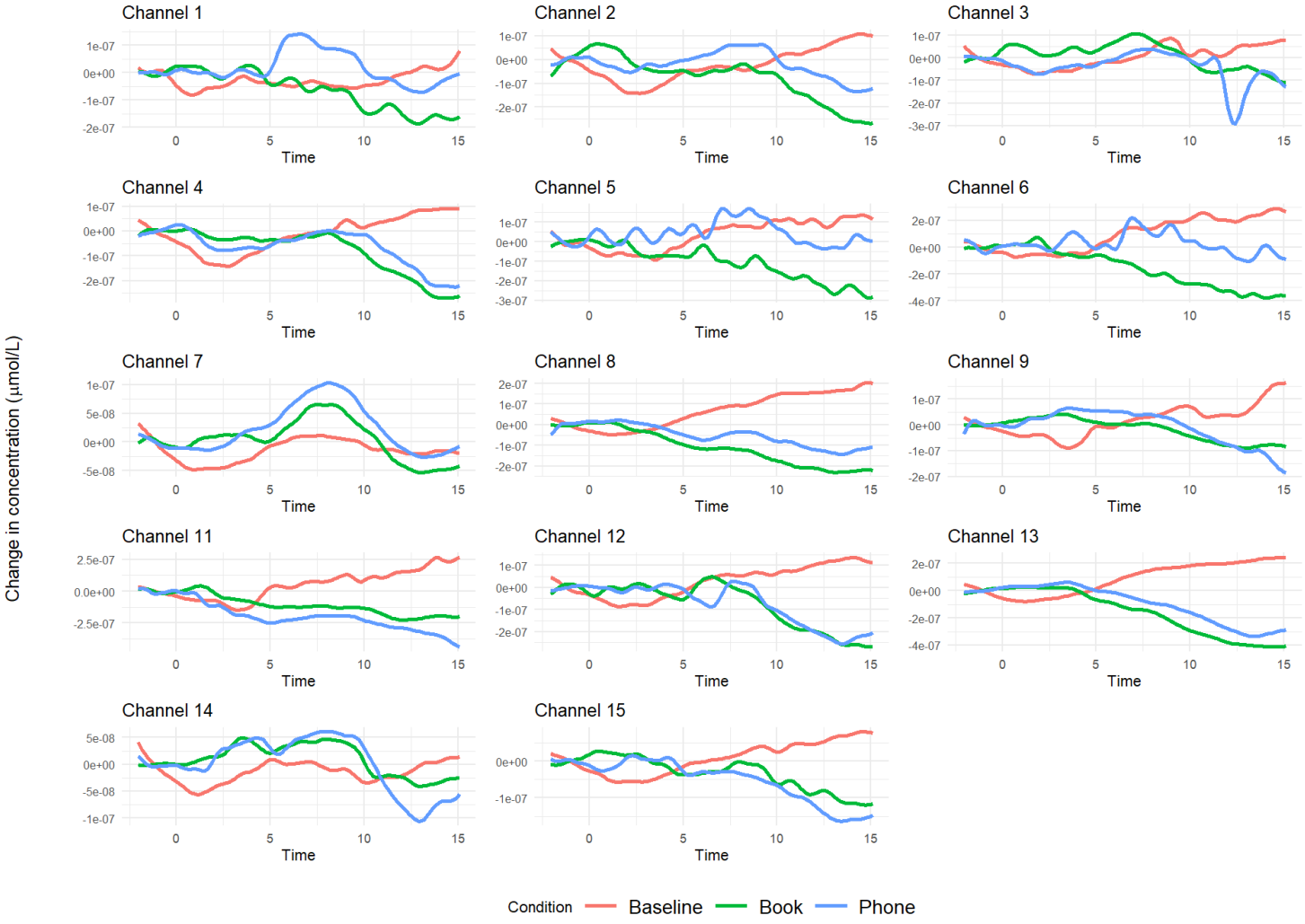
	Left hemisphere				Right hemisphere			
	Channel	*F*	*p*	η2G	Channel	*F*	*p*	η2G
Prefrontal	1	2.634	< .05*	0.11	2	6.109	< .001**	0.03
	3	5.043	< .001**	0.03	4	12.847	< .001**	0.04
Temporal and parietal cortex	5	5.635	< .001**	0.05	12	10.623	< .001**	0.09
	6	5.761	< .001**	0.06	13	46.631	< .001**	0.21
	7	7.898	< .001**	0.04	14	5.061	< .001**	0.03
	8	18.65	< .001**	0.06	15	10.842	< .001**	0.05
	9	6.836	< .001**	0.03	16	1.971	0.10	0.03
	10	2.021	0.09	0.01	17	1.941	0.11	0.01
	11	5.169	< .001**	0.01	18	0.861	0.49	0.01

Note * = significant at *p*< .05, ** = significant at *p*< .001 after applying the Benjamini-Hochberg procedure for controlling the false discovery rate.

After applying the Benjamini-Hochberg procedure for controlling the false discovery rate, a significant difference in the haemodynamic response to the social stimuli in comparison to the baseline was found across 14 channels. The grand averaged time courses of the haemodynamic changes in HHb for the significant channels, are shown in Figure 6.8.

Figure 6.8

Group Averaged HHb Responses to the Baseline and Each Type of Interruption for Infants



6.8.3 Pre-Registered Analysis

As with the adult data, a two-way ANCOVA was applied to each haemoglobin species, using the GLM betas, to examine the effect of interruption type (phone vs. book), and channel, on HbO_2 after controlling for DISRUPT score. There was no significant main effect of type of interruption on HbO_2, $F(1, 1359) = 0.458$, $p = .99$, $\eta^2G < .001$, and no significant interaction between of type of interruption and channel

on HbO_2, $F(14, 1359) = 0.347$, $p = .99$, $\eta^2G = .004$. The main effect of type of interruption on HHb was also not significant, $F(1, 1263) = 0.019$, $p = .89$, $\eta^2G < .001$, and neither was the interaction between type of interruption and channel on HHb, $F(13, 1263) = 0.098$, $p = 1$, $\eta^2G = .001$. The removal of three data points during visual inspection did not affect the overall outcomes of either ANCOVA.

6.9 Discussion

This pre-registered study sought to ascertain whether the neural responses of 6.5-to-7.5-month-old infants differed when eye gaze during a social interaction was interrupted by either a smartphone or a book. As predicted by H2b, the analysis revealed no difference in either HbO_2 or HHb between the two types of interruption.

One possible explanation for the findings is that the same neural mechanisms are involved in the processing of ostensive signals, whatever modality they occur (Parise & Csibra, 2013). Infants are born with a preference for direct gaze (Farroni et al., 2002), suggesting an innate sensitivity to eye contact. As the stimuli in the present study involved the adult model utilising direct and averted gaze with both types of interruption, the effects of the gaze aversion may occur regardless of the object gaze is averted to, as it is the aversion that is important rather than the reason for the averted gaze. Alternatively, as each model engaged in direct gaze, it is possible that the presence of direct gaze elicited neural activity, an effect which is well established (Grossmann & Johnson, 2010; Grossmann et al., 2008; Grossmann et al., 2010; Lloyd-Fox et al., 2015; Urakawa et al., 2015). Therefore, the occurrence of the averted gaze intertwined with direct gaze, as opposed to being presented in isolation, as in previous research, may not have impacted the ongoing neural activity in response to direct gaze. In other words, due to an innate sensitivity to direct gaze (Farroni, Massaccesi, et al., 2004), the addition of brief instances of averted gaze

within the same interaction does not disrupt the effects of direct gaze on neural activity. This can explain why despite previous research showing distinct neural activation for direct versus averted gaze (Grossmann & Johnson, 2010; Grossmann et al., 2008; Grossmann et al., 2010; Lloyd-Fox et al., 2015; Urakawa et al., 2015), the present study did not find a difference between the types of interruption; as gaze was impacted similarly for both objects.

With limited research exploring the impact of technoference on neural activity, the findings from the present study add to the literature by being the first to show that the cause of a social interruption does not affect neural responses to disruption to a social interaction involving direct gaze. Previous research found no change in neural activity in response to technoference via the SFP, despite there being behavioural differences, including increased negative affect (Swider-Cios et al., 2024). Unlike Swider-Cios et al. (2024), the present study builds on these findings through the comparison between the type of interruption, rather than comparing interruptions to natural parent-infant interactions. However, Study 4b did not include a control condition in which the interaction is uninterrupted. The rationale for this was to maximise the number of experimental trials infants attended to. Infant attrition is high in fNIRS research and one reason for this is infants' limited attention span (Baek et al., 2023). Had a control condition have been included, it is possible infants would not have viewed enough trials in each condition for their data to be included, which would reduce statistical power. However, without a control condition, it remains unclear whether either object is processed as an interruption to the social interaction. Future research should utilise alternative experimental designs, e.g., repetition suppression, to allow for this comparison.

Previous studies have tended to use still faces as social stimuli (e.g., Grossmann and Johnson (2010)) which does not reflect the nuances of a dynamic social interaction. The present study sought to present a more realistic social interaction, using a video of an adult. Subsequently, the stimuli included other features of social communication in addition to eye gaze, notably IDS. If IDS as an ostensive signal elicits increased neural activity in regions associated with social cognition (Zangl & Mills, 2007), it may be that the disruption to direct gaze does not change this process. Indeed, Puce et al. (1998) found the STS was involved in processing both gaze and mouth movements independently. Furthermore, Parise and Csibra (2013) found that the number of ostensive cues is not important in eliciting neural activation in 5-month-olds, although this is at odds with Lloyd-Fox et al. (2015) who found that enhanced brain activation occurred in 6-month-olds when IDS and direct gaze occurred together as opposed to either individually. Nevertheless, in this study both direct gaze and IDS were present, thus in both interruptions the singing may have confounded any effects of media of interruption.

6.10 General discussion

Direct eye gaze as an ostensive signal is well established in infants (Çetinçelik et al., 2021; Csibra, 2010) and is a key feature of social interactions between adults (Hillen et al., 2015; Ho et al., 2015; Kuhn et al., 2009; Liang et al., 2021). In both adults and infants, direct gaze is related to neural activation in the social brain (Grossmann & Johnson, 2010; Grossmann et al., 2008; Grossmann et al., 2010; Kampe et al., 2003; Kosakowski et al., 2022; Lloyd-Fox et al., 2015; Pelphrey et al., 2004; Schilbach et al., 2006; Urakawa et al., 2015). Whilst tentative findings demonstrate that smartphone technoference can disrupt eye gaze (Elias et al., 2020; Inoue et al., 2021; Radesky et al., 2014), at the time of writing,

experimental work is yet to explore whether disruption to direct gaze caused by smartphone technoference affects neural activation. The current study tested whether any effects of smartphone gaze disruption on neural activation are unique to the smartphone or whether another type of interruption, i.e., a book, could have the same effect. I found no difference for adults or infants in either HbO_2 or HHb in the prefrontal cortex or across the temporal and parietal cortex when viewing a social partner who interrupts eye contact by averting her gaze towards a smartphone compared to a book. These findings did not support H1 that there would be a significant difference in adult's neural activity (HbO_2 and HHb). H2 was supported, which predicted there would not be a significant difference in infant's neural activity (HbO_2 and HHb) regardless of whether direct gaze is interrupted by a smartphone compared to a book.

Perhaps it is not surprising that the type of distraction did not affect the neural response. Whilst many studies report increased activation across several areas of the brain in response to direct compared to averted gaze (George et al., 2001; Grossmann et al., 2008; Grossmann et al., 2010; Kampe et al., 2003; Pelphrey et al., 2004; Schilbach et al., 2006), some studies report mixed findings (Pageler et al., 2003; Wicker et al., 1998), suggesting that not all brain areas involved in the social brain are sensitive to direction of gaze. This lack of consistency over which areas of the brain are activated in response to direct gaze is shown across several studies that report activation across the fusiform gyrus, paracingulate cortex, left temporal pole, STS, dorsal medial prefrontal cortex, right superior posterior temporal cortex, right front-polar cortex, and the dorsal prefrontal region (George et al., 2001; Grossmann et al., 2008; Grossmann et al., 2010; Kampe et al., 2003; Pelphrey et al., 2004; Schilbach et al., 2006). These differences are likely to be related to the stimuli

and paradigms used (Itier & Batty, 2009). It may be that with different stimuli and/or a different paradigm a difference in neural response between type of distraction would be observed. It would be beneficial for future studies to compare the cause of distraction across various experimental designs, e.g. repetition suppression, alternating/non-alternating designs (Issard & Gervain, 2018) to see if the null findings are due to experimental design or, because regardless of the type of distraction, brain areas related to processing social cognition are activated. In addition, much of the previous literature involves *either* direct or averted gaze, however depending on the brain area involved, direct gaze can be processed differently. For example, although the amygdala activation was not measured in this study, Hooker et al. (2003) found that the amygdala displayed stronger activation when direct gaze never occurred, compared to when direct gaze occurred on 40% of trials. Hooker et al. (2003) suggest that the amygdala may play a role in monitoring gaze, explaining the increased activity when no gaze had been detected as the amygdala was remaining vigilant for direct gaze. Thus, the inclusion of both direct and averted gaze in this study may help explain the diverging results compared to the previous literature which has isolated gaze direction.

It is interesting that the same results were found in both infants and adults, although the underlying mechanisms underlying these trends are likely distinct. Unlike infants, adults have experience of both using their smartphone during a social interaction and being the social partner when someone else is using their smartphone (Chotpitayasunondh & Douglas, 2016). Moreover, adults recognise smartphone use during social interactions as rude (Al-Saggaf & O'Donnell, 2019) and as less acceptable in one-to-one interactions than in group settings (Leuppert & Geber, 2020). With this sophisticated understanding of smartphone technoference, it

could be expected that, because of their experience, adults may view the smartphone interruption as different to the interruption via the book. On the other hand, 6.5-7.5-month-old infants may be familiar with seeing mothers use a smartphone from birth (Coyne et al., 2022) but will not yet understand the functions of a smartphone or the social norms around smartphone use. It would therefore have been reasonable to assume that there may be a difference between how infants and adults process smartphone technoference. One explanation as to why both age groups did not differentiate between the object causing the distraction at a neural level, is that the human brain has evolved to detect the direction of another person's gaze (Baron-Cohen, 1995; Emery, 2000; Kobayashi & Kohshima, 1997). Given the recent emergence of digital technology, responses to the smartphone are likely learnt via environmental experience, as opposed to being an evolved response. In this study, because the direction of gaze was identical for both the smartphone and the book, the similarity in brain activation in response to each interruption may be due to an evolved response to gaze. Therefore, the observed brain activation occurred due to the pattern of gaze regardless of the cause of distraction. This is supported by studies which find infants have an innate preference for the eyes (Farroni et al., 2002) and show activation in the same areas of the brain as adults for social information (Grossmann & Johnson, 2007), suggesting the human brain is adapted to respond to ostensive signals such as the eyes. Following this line of argument, it is also possible that whilst a difference is not seen in brain activity, the autonomic nervous system (ANS) may respond to the distinctiveness of the distraction. Measures of the ANS including heart rate (Ishikawa & Itakura, 2019; Ishikawa et al., 2022), facial temperature (Ioannou et al., 2014), and skin conductance (Nichols & Champness, 1971; Ruuhiala, 2007) are sensitive to direction

of gaze. To date, three studies have investigated the ANS and smartphone technoference in young children, reporting physiological changes in the ANS during smartphone technoference (Dinzinger et al., 2025; Nazzari et al., 2025; Porter et al., 2024). However, only one of these studies made a comparison to a non-digital interruption. It would therefore be beneficial for future research to further explore the role of the ANS in relation to the cause of distraction during a social interaction. An alternative explanation for the results of this study, is that the activation in the areas of the brain measured (the prefrontal, temporal and parietal cortices) was not influenced by the cause of the distraction but potentially other areas are. Consistent with this argument, prior research indicates that smartphone technoference can affect emotion. For example, adults report feeling ostracised when a social partner uses their phone during a social interaction (Knausenberger et al., 2022) and infants demonstrate increased negative affect and decreased positive affect in response to smartphone technoference (Stockdale et al., 2020). As fNIRS measures activity in the cortex rather than sub-cortical regions, which play a key role in processing emotions (e.g., Yip et al., (2004)), it is possible that, had this study measured the activity in the deeper regions of the brain, a different pattern of results would have been found. Future studies should utilise alternative neuroimaging techniques to allow for the exploration of the relationship between sub-cortical areas and type of distraction.

The design of this study had several strengths. Firstly, unlike previous studies investigating gaze direction which tend to use static and sometimes computerised faces (e.g., Grossmann & Johnson (2010)), this study used a dynamic video recording of a real-life adult model. The way in which stimuli is presented can impact responses during a social interaction. For example, more attention is paid to dynamic

stimuli compared to static stimuli (Smith & Mital, 2013) and when computerised stimuli are used direct gaze does not affect skin conductance, whereas live stimuli do (Ruuhiala, 2007). Using a dynamic scene in this study allowed for a balance between portraying a realistic social interaction, whilst also being able to control the interactions to ensure that the averted gaze was standardised across both interruptions. Secondly, the use of a GLM has several benefits over block averaging which is often used in fNIRS infant research, including a consideration of the time course strengthening statistical power (Pinti et al., 2019). The GLM also models the HRF and assumes a pre-defined haemodynamic response. Although this response is still largely unknown in infants and could even differ across areas of the brain (Pinti et al., 2019) or due to the complexity of the stimulus (Issard & Gervain, 2018), several studies do reveal a haemodynamic response in infants younger than the sample in the current study (Grossmann & Johnson, 2010; Lloyd-Fox et al., 2015; Lloyd-Fox et al., 2009), suggesting that the GLM was likely suitable to be applied in this study.

There are several limitations with the study that should be noted. Firstly, the stimuli used in the study, despite being a dynamic social partner, did not fully represent a genuine live interaction. In each video the adult model sung to the social partner but being a pre-recording any responses from the social partner, e.g., vocalisations, smiles, were not acknowledged. Secondly, the adult model briefly looked down to the smartphone but did not use or engage with the smartphone in any way. Whilst this allowed for standardisation with the book manipulation, it does not reflect how the phone is likely to be used in a genuine interaction. The stimuli therefore lacked ecological validity and had the interaction been live or involved realistic interaction with the smartphone and the book, the results may have differed.

Third, because the task a participant engages in can affect the neural activity observed (Itier & Batty, 2009), using a novel paradigm and stimuli meant it was difficult to know how participants would respond. For example, tasks which require active engagement from adult participants, such as identifying the direction of the gaze (Bristow et al., 2007; Hooker et al., 2003) or identifying the gender of the face (George et al., 2001), report differences in neural activity in response to direct versus averted gaze. Whereas, tasks where participants are required to remain passive, as in the current study, report similar neural activation between direct and averted gaze (Wicker et al., 1998). It is possible that participants' passive engagement with the stimuli in the current study reduced the impact of the interruption, resulting in no observable effect on gaze behaviour. It would be beneficial in future studies to directly compare different tasks that adult participants complete whilst viewing direct versus averted gaze. Fourth, some adult participants anecdotally reported that they assumed the actor was looking down to remind themselves of the lyrics to the nursery rhymes. This creates a justification for the averted gaze and therefore the averted gaze may be less likely to be seen as a disruption by adults to the social interaction, but instead a necessary part of the interaction. In addition, the stimuli used in the study were purposely designed to be engaging for infants by using IDS to sing nursery rhymes. It is also possible that the adult participants found the infant directed stimuli novel and did not necessarily focus on the model in the same way that they would have the stimuli been age appropriate. An interaction that was tailored to adults may have yielded different results. Therefore, the observed neural responses may not necessarily be related to the distraction but instead due to the novelty of the task. Fifth, participants may not have instantly distinguished between the book and the smartphone. To allow for control, both items were of a similar size,

and both were black. Although each was angled in the video so that the screen/paper could be seen, the visual similarity between the two objects may have been too subtle for participants to initially notice if their gaze was not on the object. Having the adult use each item in a more obvious way would help disentangle whether the visual similarity between the two items confounded the results, or whether the object causing the interruption was indeed not important. Finally, there was not an established social interaction prior to the disruption. Each trial was 11 seconds long and after the first second, the adult model averted their gaze to the object in their hand. Whilst this initial second would have grabbed the participant's attention, it is unlikely to be long enough to establish a social interaction, with studies on joint attention requiring at least 3 seconds of joint engagement to be classified as an interaction (Tomasello & Todd, 1983). Therefore, it is possible that the participants did not necessarily deem the averted gaze to the phone/book as an interruption to a social interaction, which may explain why a difference between the two objects was not found.

6.10.1 Conclusion

The purpose of the current study was to examine whether adults and 6.5-7.5-month-olds have different neural responses when a social interaction was interrupted by two different media: a smartphone or a book. These two studies found that neither adults or infants had a different neural response when a social interaction was disrupted by a smartphone compared to a book, suggesting that the brain does not distinguish between what is causing disruption to social communication. As the first study to experimentally test the cause of a social interruption on neural mechanisms, the findings should be treated with caution. Future research should build on these

findings by isolating IDS, extending the design to separate direct and averted gaze and varying the response measured to move beyond neural responses.

Chapter 7 General Discussion and Conclusions

7.1 Introduction

From birth, infants are inherently social, showing sensitivity to eye gaze and faces (Batki et al., 2000; Farroni, Massaccesi, et al., 2004; Farroni et al., 2006), supporting early engagement with parents. Parent-child interactions which are high quality, including periods of joint attention and responsiveness to the child's verbal expressions, shape children's emerging language outcomes (Baldwin et al., 1996; Rocha et al., 2020; Tamis-LeMonda et al., 2014; Tamis-LeMonda et al., 2001; Tomasello & Farrar, 1986). Reasonably, disruptions to parent-infant interactions could affect language outcomes, specifically if these interruptions disrupt social gaze, joint attention, or parent responsiveness. A common disruption is parent smartphone use. Parents report using their smartphone for around 4 hours per day and checking their phone about 60 times a day (Yuan, 2019). It is therefore not surprising that there are concerns at a national level over parent smartphone use, which may disrupt parent-infant interactions (Alaimo, 2025; Coulson, 2024; Wales & Waldinger, 2025). Research exploring the relationship between technoference, disruptions to parent-infant interactions from technology (McDaniel & Coyne, 2016), and child outcomes is growing. However, this research covers a broad range of developmental outcomes (Golds et al., 2025; Mason et al., 2024; McDaniel et al., 2018; McDaniel et al., 2024) and there is still a lack of research exploring the effect on child language development. In addition, the emerging research in the field is being met with an increasing ubiquity of smartphone usage (Ofcom, 2025) and as

smartphones are becoming omnipresent in the fabric of family life, there is a critical need for further research exploring the relationship between smartphone technoference and child language development and the underlying mechanisms in this relationship.

The main goal of this thesis was to examine the relationship between parent smartphone technoference and child language outcomes, including how technoference may influence processes which shape language development; social gaze, joint attention, and parent responsiveness. Based on the literature review presented in Chapter 1, I addressed three broad research questions (RQ):

RQ1: Parent smartphone use:

1) How do parents use their smartphone according to the level of active engagement with their child?

RQ2: Underlying mechanisms (gaze, joint attention, parent responsiveness):

2a) Does parent smartphone use affect the dyadic interaction?

2b) Do different types of parent smartphone use differentially affect dyadic interactions?

2c) Does smartphone related gaze disruption elicit different neural responses compared to a non-digital disruption?

RQ3: Outcomes (child language):

3a) Is parent smartphone technoference associated with child language outcomes?

3b) Does type of parent smartphone use differentially affect child language outcomes?

To address these questions, I conducted four studies, presented in Chapters 3 (Study 1), 4 (Studies 2a and 2b), 5 (Study 3), and 6 (Studies 4a and 4b). A summary of the key findings is presented in Table 7.1.

Table 7.1

Overview of Each Study in This Thesis and Their Findings

	Study	Participants	Methods	Findings
Chapter 3	Study 1	Parents of children under the age of 2 years	Self-reported measures of smartphone use	Parents were more likely to use their smartphone when their child were asleep and least likely to use their smartphone when they were engaging with their infant. When parents were engaged with their child, they were more likely to use their smartphone to make video calls than when not engaged with their child. No difference in frequency of use when parents are engaged with their child compared to not engaged with their child was found for using the phone to make phone calls, monitor children, and monitor health.

Chapter 4	Study 2a	Infants aged 9-10 months and a parent	Experiment in the home environment delivered online Independent variable = technoference condition (call, photos, uninterrupted interaction) Dependent variable = infant gaze, vocalisations, and expression. Parents gaze, use of language, and responsiveness to infant expressions	Infants made more positive spontaneous expressions, spent more time looking to their parent, and made more positive expressions during uninterrupted play sessions in comparison to when parents used their phone to make a call or to take photos. Technoference did not affect infant fussiness or infant vocalisations. Parents spent less time looking at their infant and engaged in less mutual gaze during technoference than during uninterrupted play. Parents directed less speech toward the infant during a phone call than during either uninterrupted play or taking photos on the phone. Contingency was highest during uninterrupted play and making a call resulted in parents more often not responding to their infant's expressions. Type of phone use (call vs. photos) affected infants' gaze to the phone, parents' gaze to the phone, parents' use of language and parents' responsiveness.

	Study 2b	Parents of children aged 12-18-months	Self-reported phone use, technoference, joint media engagement (JME), responsiveness, and child language	Technoference was negatively associated with gestures. JME had no relationship with language. Higher levels of parent responsiveness were associated with parents putting their phone away more often. Parents who do not engage in JME had higher levels of responsiveness than parents who engage in JME.
Chapter 5	Study 3	24–30-month-olds	Experiment conducted in the laboratory Independent variable = interruption to teaching (JME, phone call, no interruption) Dependent variable = novel word learning	The type of interruption to the teaching had no effect on novel word learning in children, but the expected looking preference for novel word mapping was only significant after interruption by JME (a game on the phone) than a phone call or no interruption.
Chapter 6	Study 4a	Female adults	Experiment conducted in the laboratory Independent variable = (phone interruption, book interruption) Dependent variable = neural activity	The type of interruption had no effect on neural activity.

	Study 4b	6.5-7.5-month-olds	Experiment conducted in the laboratory Independent variable = (phone interruption, book interruption) Dependent variable = neural activity	The type of interruption had no effect on neural activity.

The studies presented in Table 7.1 were discussed in detail in their respective chapters. The remainder of this chapter will first discuss the findings of these studies collectively in relation to the RQs and wider literature, and then their general limitations. This chapter ends by providing suggestions for future research and considering potential practical implications of the findings.

7.2 General discussion

7.2.1 Parent Smartphone Use (RQ1)

Whilst the main goal of this thesis was to examine the relationship between parent smartphone technoference and child language outcomes, it also sought to further knowledge of parents' general smartphone use and when they are with their children. Specifically, the first research question was *How do parents use their smartphone according to the level of active engagement with their child?* Obtaining accurate data on parent smartphone use presents methodological constraints. Research has tended to use passive mobile sensing (McDaniel et al., 2024; Tharner et al., 2022; Yuan, 2019) and parent self-report (Corkin et al., 2021; McDaniel, 2021; Ventura et al., 2020). As discussed in Chapter 2, parent self-report can lack validity as parents tend to underreport their smartphone use (Yuan, 2019), whereas passive mobile sensing provides an objective measure of phone use. Passive mobile sensing also has the advantage of being unobtrusive to parents, however, it relies on compatible operating systems on phones and provides overall phone use as opposed to phone use when engaged with the child, i.e., technoference. To achieve the latter, parents need to complete self-report to identify the times during each day they were with their child, which may not provide an accurate measure.

Given the absence of a robust measure to gather valid data on parent smartphone use when with their child, it is not surprising that parent phone use varies across studies. In studies utilising passive mobile sensing to measure smartphone usage in parents of children under 1-year-old, smartphone use during the time spent with their child ranges from 14% of the time to 27% on average (McDaniel, Pater, et al., 2023; Tharner et al., 2022). Studies which gather parent self-report show parents spend between 10.21 – 11.88 minutes per hour using their phone when with their child aged under 3 years (Corkin et al., 2021; Fusha et al., 2025). Data on parent smartphone use are likely influenced by the age of the child, the year the data was collected, and individual differences. First, younger children who are not yet mobile and are predominantly milk fed may allow for increased phone use in comparison to mobile toddlers. Second, conceivably, as the functionality of mobile phones change, so may parents' use of them. This makes it difficult to compare data gathered in 2016-17 (Tharner et al., 2022) before generative AI, personal agents (e.g. Siri), digital wallets, and digital keys, to phone use in 2026. Third, parents are not a homogenous group, with smartphone use in parents of 1-12-month-olds ranging from low (spending 13% of their child time on their phone), to moderate (spending 28% of their child time on their phone), or high (spending 50% of their child time on their phone) (McDaniel et al., 2024).

To address some of these issues, the studies in this thesis measured parents' smartphone use utilising the same self-report items (described in Chapter 3) in each study. Standardisation of the items across each study helps to address whether child age is a possible influencing factor on parent smartphone use. Second, in this thesis, data collection occurred across a five-year period; 2020 (Study 1), 2021-2025 (Study 2a), 2022-2023 (Study 2b and Study 3), and 2024-25 (Study 4b), controlling for

some of the variation in smartphone functionality over time. However, notably the use of self-report does not provide fully valid data due to the previously mentioned issue of the challenges with accurately recalling all phone use. Table 7.2 summarises the frequency and duration of parent smartphone use in a 24-hour period across these studies.

Table 7.2

Frequency and Duration of Parent Smartphone Use Across Study 1 – Study 4b

Frequency							
	Age of child	**0-2 times an hour**	**3-5 times an hour**	**6-9 times an hour**	**10-12 times an hour**	**13-15 times an hour**	**More than 15 times an hour**
Study 1	Under 2 years	21%	44%	24%	7%	4%	0%
Study 2a	9-10 months	12%	39%	23%	28%	5%	3%
Study 2b	12-18 months	19%	48%	17%	10%	3%	2%
Study 3	24-30 months	0%	51%	45%	4%	0%	0%
Study 4b	6.5-7.5 months	17%	44%	31%	8%	0%	0%
Mean		14%	45%	28%	11%	2%	1%
Duration							
	Age of child	**Less than 60 minutes per day**	**1-2 hours per day**	**3-4 hours per day**	**5-6 hours per day**	**7-8 hours per day**	**Over 9 hours per day**
Study 1	Under 2 years	< 1%	35%	44%	18%	< 1%	0%
Study 2a	9-10 months	1%	21 %	51%	19%	5%	2%
Study	12-18	4%	32%	49%	14%	<1%	<1%

2b	months						
Study 3	24-30 months	25%	44%	23%	4%	1%	3%
Study 4b	6.5-7.5 months	4%	33%	50%	8%	4%	0%
Mean		7%	33%	43%	13%	3%	1%

Table 7.2 shows that on average, parents check their phone 3-5 times an hour. This was the highest frequency of phone checking across all age ranges studied. Most parents reported using their phone for 3-4 hours per day, except for parents of 24-30-month-olds, where the highest average duration of use was lower at 1-2 hours per day. This descriptive data shows some consistency in parent self-reported phone use but does not differentiate between times when parents are engaged with their child or not. As described in Chapter 3, parents were asked about their phone use when engaged with their child, when their child is present but not engaged with them, and when their child is asleep. Regardless of the age of the child, parents in all studies reported using their phone less often when actively engaged with their child than when not engaged with their child. In Chapter 4, I suggested that this can be explained by parent guilt and/or the demands of childcare. First, parents report feeling guilt around their smartphone use (Garg, 2021; Halfmann et al., 2025; Wolfers et al., 2023), implementing strategies to deter from phone use when parenting (Bury et al., 2020; Garg, 2021). As parent phone use during time spent with their child has been found to be relatively low (Abels et al., 2018; Hiniker et al., 2015), it suggests that technoference may be relatively infrequent during dyadic interactions. Future studies may want to compare the effects of technoference in families that vary in the frequency of smartphone

disruption in the home. Second, when engaged with the child, a parent is involved in a variety of interactions, some are play based whereas others form part of daily routines e.g. mealtimes. Many of these require the use of both hands, reducing opportunities to use the phone. Although, wireless headphones do allow for the parent to engage in phone calls, or listen to audio e.g., music or podcasts, without using their hands. Nevertheless, phone use may be low because the nature of the task, and the child, demands the parents' attention. A further consideration is the socioeconomic status (SES) of the parent. In this thesis, the sample was fairly homogenous (discussed further in Section 7.3.1) which may explain the similarity in patterns of phone use. Parents of lower SES use their phone more often when parenting (Garg, 2021) but are also more likely to engage in JME than parents of higher SES (Garg & Sengupta, 2019), whilst middle-class parents report feeling guilty for technology use around their child (Garg & Sengupta, 2019). It would be beneficial for future studies to recruit diverse samples to allow for further comparisons on the relationship between SES and technoference.

7.2.2 Eye Gaze Direction (RQ2)

This thesis assessed the relationship between eye gaze and technoference in two studies (2a and 4b) to address RQ2. In Study 2a, I experimentally manipulated parent smartphone use to assess the effect on both parent and infant gaze during a dyadic interaction.

As a primary ostensive signal, eye gaze signals a social partner's intent to engage, and infants interpret these signals as indicating intention to communicate (Csibra, 2010). When an adult shifts their gaze from their social partner to elsewhere, it signals to the social partner to also look in that direction. Gaze following occurs when the social partner follows this shift in gaze (Del Bianco et al., 2019).

The ability to follow another's gaze is an important precursor to language development (Brooks & Meltzoff, 2005). For gaze following to occur in infants, a parent needs to first direct their gaze towards them. Smartphone technoference may disrupt this process, as parents avert their eye gaze to their phone and away from the child, when using their phone (Elias et al., 2020; Inoue et al., 2021; Nomkin & Gordon, 2021; Radesky et al., 2014). Study 2a extends these previous research findings, showing that parents spent longer time looking at their infant when play was uninterrupted by phone use, in comparison to when using the phone to either take photos or to make a call[5]. Parents also looked at their phone for longer when using it to take photos than to make a call. A video call maintained more of the parents' gaze towards the phone than a phone call. These findings are in line with previous studies which show that parents' gaze to their infant is reduced when using a phone (Dinzinger et al., 2025), but that parents can continue to direct their gaze to their child when making a phone call in comparison to other uses of the phone (Radesky et al., 2014). At the time of writing, this is the second study (after Dinzinger et al. (2025)) to experimentally manipulate parent smartphone use and record the interaction to reliably measure parent gaze. These controlled studies build on observational research which also reports parents averting their gaze from their child to their phone (Elias et al., 2020). However, both in my study and in the study by Dinzinger et al. (2025) parents were directed as to how to use their phone. Possibly, this influenced gaze direction as parents followed instructions to use their phone. It is therefore pertinent that future research measures natural smartphone technoference but given the difficulty in reliably recording gaze in a naturalistic observation, it is important to record these interactions either in the home or the laboratory.

[5] 'Calls' in the context of Study 2a combines video and phone calls. Reference to only one of these types of calls is identified explicitly as either 'phone call' or 'video call'.

For eye gaze to function as an ostensive signal, the infant must be aware that they are the target of the parent's visual attention. Indeed, infants do not follow the gaze of an adult if it is not preceded by gaze directed towards them (Senju & Csibra, 2008). Furthermore, extant research shows that infants can distinguish between direct and averted gaze (Farroni et al., 2002; Farroni, Massaccesi, et al., 2004; Farroni et al., 2006; Farroni, Menon, et al., 2007; Hood et al., 2003), suggesting that they are indeed sensitive to the direction of another person's gaze. As parents look to their phone when using it, as evidenced in Study 2a, this averted gaze may in turn affect infant's gaze to the parent. Study 2a supports this assumption as infants looked less to their parent's face when their parent used their phone to make a call than when play was uninterrupted. Although parents looked to the infant less when taking photos than when play was uninterrupted, taking photos did not impact infants' gaze to their parent. Infants did, however, look more to the phone when it was used to take photos than when it was used to make a call. As parents also looked at the phone for longer when taking photos, it suggests that the dyad may be engaged in JME. However, without directly measuring whether this increased gaze occurred at the same time, this suggestion is tentative. Future research should measure shared attention on the phone across different device use to see if taking photos on the phone can encourage JME during natural interactions.

Eye gaze was also central to RQ2c, which asked *Does smartphone related gaze disruption elicit different neural responses compared to a non-digital disruption?* To test this, Study 4b measured neural activity in infants when viewing a model averting their gaze from the infant to either a smartphone or a book. Based on the established literature that infants are sensitive to gaze direction (Farroni et al., 2002; Farroni, Massaccesi, et al., 2004; Farroni et al., 2006; Farroni, Menon, et al.,

2007; Hood et al., 2003), it was anticipated neural responses would not differ as both disruptions involved averted gaze. The findings of Study 4b supported this assumption: regardless of the cause of distraction, there was no difference in either oxyhemoglobin (HbO_2) or deoxyhemoglobin (HHb) in 6.5-7.5-month-olds or in a sample of adults (Study 4a), tentatively suggesting that the disruption to direct gaze, rather than the reason for that disruption, may be driving the results. These findings are consistent with the literature showing that both infants and adults demonstrate a different neural response to direct versus averted gaze (Farroni, Massaccesi, et al., 2004; George et al., 2001; Grossmann & Johnson, 2007, 2010; Grossmann et al., 2008; Grossmann et al., 2010; Kampe et al., 2003; Lloyd-Fox et al., 2015; Pelphrey et al., 2004; Schilbach et al., 2006; Urakawa et al., 2015). However, it would be premature to conclude that all disruptions are equal, as in Study 4 the adult model interacted with the book and phone in the same way; specifically averting gaze. As previously stated, phone use does not always result in averted gaze (Radesky et al., 2014) and future studies should compare the effect of different ways of using the phone on neural activity.

7.2.3 Joint Attention and JME (RQ3b)

In this thesis, I proposed two different ways that parent smartphone use may affect joint attention. First, smartphone use may disrupt joint attention if parents miss infant cues whilst looking at their devices (Davidovitch et al., 2018; Krapf-Bar et al., 2022; Lederer et al., 2022; Ochoa et al., 2021; Radesky, 2015). Alternatively, smartphone use could initiate joint attention when a parent and their child are both engaged with the device (i.e., JME) (Amery, Danby, & Brereton, 2026; Ochoa et al., 2021; Radesky et al., 2014). As joint attention plays a central role in language development (Markus et al., 2000; Tomasello & Farrar, 1986; Tomasello & Todd,

1983), smartphone use which leads to JME may be less disruptive to language development than smartphone use which disrupts the initiation of joint attention.

Following this reasoning, RQ3b, (*Does type of parent smartphone use differentially affect child language outcomes?*) was tested in Study 2b and Study 3. Study 3 experimentally manipulated whether parents used their phone to encourage JME (shared game play on the phone) or to reduce responsiveness (a phone call). The findings on parent responsiveness are discussed in 7.2.4. Parents taught their child three novel words, one of the teaching periods was interrupted by JME, one by reducing responsiveness, and one teaching period was uninterrupted. If JME can encourage joint attention, word learning would be expected to be increased when shared game play interrupted the teaching period in comparison to a phone call. Study 3 did not find support for this assumption. In Chapter 5, I suggest that one reason for the similar findings following JME, technoference, and no interruption is because infants are exposed to smartphones from birth (Coyne et al., 2022) and may have adapted to learning in the presence of smartphone use. This is a line of reasoning supported by recent research, which also found no effects of parent smartphone technoference on a range of behavioural outcomes (Coyne et al., 2022; Flatebø et al., 2024; Porter et al., 2024; Swider-Cios et al., 2024) including language (Nguyen, 2024). If familiarity indeed plays a role, it would be pertinent for future research to test the effects of JME in a sample of children from ‘screen free’ households, or from homes where parents are very careful about phone use. If, as suggested, infants have adapted to frequent smartphone exposure, we may expect to see a different pattern of results in those children with less experience of adult phone use.

An interesting finding in Study 3 was that looking time preference associated with novel word mapping was only statistically significant when teaching was interrupted by JME, in comparison to a phone call, or uninterrupted teaching. It is conceivable that JME may have encouraged joint attention which aided this looking preference. However, as joint attention was not measured in Study 3, this interpretation should be treated with caution. In addition, these findings contradict those of Study 2b which found no relationship between JME and child language. Given these mixed findings and previous research showing that JME can be beneficial for language development (Corkin et al., 2021; Medawar et al., 2023), further investigation is warranted. As both Corkin et al. (2021) and Medawar et al. (2023) used parent self-report to gather data, methodological differences are unlikely to explain the difference in findings with Study 2a. Perhaps the child's age is a moderating factor in this relationship, as those studies which found JME to be beneficial to language (Study 3, Corkin et al. (2021) and Medawar et al. (2023)) included children who were between 18-36 months whereas in Study 2b the children were aged 12-18 months. Possibly, children younger than 18 months do not have the necessary technical skills to navigate the device and parents may provide technical support over talking about the content during JME. In addition, the language skills of the child may shape the language input from the parent. Older children who can form sentences may ask questions about what is happening on the phone. Since two-word sentences do not develop until approximately 18-months-old (Goldin-Meadow & Butcher, 2003), younger children have limited expressive language to verbally prompt parental language during JME. Whether age does moderate the relationship between JME and language is an avenue which requires further exploration. The recent development of the Joint Media Engagement Scale (Koch et al., 2025) would

allow for standardised comparisons across age groups differentiating between cognitive scaffolding, which serves to enhance children's understanding of the media, affective scaffolding, referring to emotional states of the child or characters in the viewed material, and technical scaffolding, helping with the practicalities of using the device.

7.2.4 Parent Responsiveness (RQ2)

When a parent responds to an infant's attempts to initiate joint attention (IJA) promptly, contingently, and appropriately, they are demonstrating responsiveness (Bornstein et al., 2008; Tamis-LeMonda et al., 2014). Responsiveness aids language development by 1) helping to facilitate joint attention between the parent and child, aiding word mapping (by labelling objects an infant is already attending to), and 2) facilitating scaffolding of language to match the child's developmental level (Bornstein et al., 2008; Donnelly & Kidd, 2021; Olson et al., 2015; Tamis-LeMonda et al., 2014; Wasik & Jacobi-Vessels, 2017; West & Iverson, 2017). In Chapter 1, I presented extant evidence demonstrating the importance of parent responsiveness for child language development and proposed that as parent smartphone technoference can disrupt responsiveness (Abels et al., 2018; Elias et al., 2020; Mangan et al., 2018; Mikić et al., 2025; Nakagawa et al., 2019; Rothstein, 2018; Wolfers et al., 2020), it may also be damaging for language development. To explore these ideas, RQ2a and RQ2b tested parent responsiveness in Studies 2a and 2b.

Study 2b focused specifically on the relationship between parent smartphone technoference and parent responsiveness, gathering data via self-report. Perhaps unsurprisingly, responsiveness was found to be related to parent smartphone use: parents who made a conscious effort to put their phone away when with their child were also more responsive. Similarly, in Study 2a parents were more responsive to

their infant's spontaneous expressions when they were not using their phone during play, in comparison to when they did use a phone during play. These findings follow a growing body of research reporting that parents are less responsive to their child when using their phone (Abels et al., 2018; Elias et al., 2020; Mangan et al., 2018; Mikić et al., 2025; Nakagawa et al., 2019; Rothstein, 2018; Wolfers et al., 2020). Many of these studies observed parent smartphone use in settings such as food outlets and playgrounds. Away from the home, the child may interact less with the parent, making use of the facilities, e.g. the play equipment. This, alongside general distractions in a busy setting, may compound the effects of smartphone technoference on responsiveness. Study 2a's findings therefore make an important addition to the literature. As the first study to experimentally manipulate parent smartphone use during face-to-face play in the home, these findings demonstrate that parent smartphone use is associated with reduced responsiveness when children are in close proximity to their parent and when in an environment with minimal novel distractions.

Study 2a showed that, regardless of whether parents made a call or took photos with the phone during play with their infant, the amount of time infants spent being expressive did not differ. Thus, parents had equal opportunity to respond to their infant's behaviour across both uses of the phone. However, parents made more contingent responses when using the phone to take photos in comparison to making a call and were more likely to not respond to infants' expressive behaviour when making a phone call than when using the phone to take photos. These findings extend previous research which has shown that parents miss their child's bids for attention and take longer to respond when using a phone (Abels et al., 2018; Hiniker et al., 2018; Mikić et al., 2025), by finding that the multifaceted nature of the phone

matters and how the phone is used differentially affects responsiveness. These findings are important in light of recent studies reporting that parent smartphone use was as equally disruptive to parent responsiveness as non-digital distractions (Chamam et al., 2024; Lederer et al., 2022) and suggest that all distractions may not have similar effects. Instead, the demands of the distraction may be important. Indeed, parents in the research from both Lederer et al. (2022) and Chamam et al. (2024) were asked to complete a non-digital task that required them to focus attention on the task (magazine reading and a pen and paper task). A call may make similar demands on the user, diverting attention to the conversation rather than the infant. However, using the phone to take photos requires the parent shifts their attention between the phone and their infant, creating more opportunities to notice the infants' expressive behaviour, which may be why parents were more responsive when taking photos of their infant in comparison to making a call. Nevertheless, as parents' gaze to their infant did not differ when taking photos or making a call (as discussed in 7.2.2), parents lack of response cannot be explained due to failure to see the infants' expressive behaviours. If this were true, I would expect parents to look at their infant for longer when using the phone to take photos than when using the phone to make a call. One possibility is that infants' expressive behaviours may differ depending on how the parent is using the phone. Study 2a did not differentiate between types of expressive behaviour; however, evidence suggests that when infants use multiple modalities (e.g., gaze, touch) parents are likely to respond regardless of their phone use (Abels et al., 2018). Possibly, when parents took photos on the phone, infants elicited more modalities due to being integrated into the phone use. Future research should examine whether characteristics of infants'

expressive behaviour differ according to the specific smartphone task a parent is engaging in.

7.2.5 Language Development (RQ3)

In this thesis, I have presented research which demonstrates that eye gaze, joint attention, and parent responsiveness are important precursors to the development of language in young children. The studies in this thesis have shown that parent smartphone technoference is associated with social gaze and parent responsiveness during parent-child interactions, but that JME (which could lead to joint attention) was not related to language outcomes. However, as we proposed in Morris et al. (2022), it is also possible that parent smartphone technoference can have a direct effect on language outcomes, which was the basis of RQ3a: *Is parent smartphone technoference associated with child language outcomes?*

Study 2b tested RQ3a via a survey and found levels of parent smartphone technoference were negatively associated with child gestures. These findings are in line with the research presented in Chapter 1 which showed that phone use is negatively associated with language outcomes (Corkin et al., 2021; Paoletti et al., 2025; Reed et al., 2017). One explanation for these results, is that parent smartphone use negatively affects parents' use of language during parent-child interactions. This suggestion is consistent with both previous literature (Gaudreau et al., 2021; Kelly & Ocular, 2021; Mikhelson et al., 2024; Radesky et al., 2015) and the findings from Study 2a that parents directed language to their infant less often when using a smartphone during play, in comparison to uninterrupted play; although infant vocalisations were unaffected by phone use. In Chapter 4, I suggested that infants' expectations of dyadic interactions may include parent phone use. Possibly the lack of change in vocalisation during parent phone use, could indicate that infants did not

vocalise to repair to interaction, as they have learnt that this repair attempt is ineffective. Parents on the other hand, may divert attention to the demands of the task on the phone, leaving less attentional resources available for language use directed to the child. This argument is corroborated by the findings that type of phone use was associated with parent language. In Study 2a, parents directed less language to their infant when using the phone to make a call in comparison to taking photos. Thus, the phone per se does not influence parent's use of language, but the demands of the task on the phone may do. A phone call requires the user to direct their attention to the person they are communicating with on the phone, whereas taking photos allows the parent to switch attention between looking to the phone and the child (Amery, Danby, & Theobald, 2026).

The relationship between parent smartphone technoference and child language outcomes is not however this straightforward. Several studies have found no relationship between parent smartphone technoference and child language outcomes (Nguyen, 2024; Sundqvist et al., 2021), Study 3 similarly found that whether the teaching period was interrupted by parent phone use, or uninterrupted did not differentially affect novel word learning. Additionally, most studies are cross sectional, measuring child language outcomes at one time point. A recent longitudinal study revealed that whilst parent technoference is negatively associated with child language outcomes at 1-year-old, this pattern of results was not maintained one year later (Coyne et al., 2026). Possibly, children aged 24-30-months (as in Study 3) may be less susceptible to brief periods of technoference than younger infants. Given that word learning develops rapidly during a child's second year (Bloom, 1976; Mayor & Plunkett, 2010), it may be possible that as the child's language skills develop, technoference is less detrimental to the child's vocabulary.

This would explain the discrepancy in findings between Study 2b, where 12-18-month-olds were studied, and the findings from both Study 3 and Coyne et al. (2026).

7.3 Limitations[6]

Limitations specific to each study are discussed within the relevant chapters. Here, I consider broader limitations that apply across the thesis.

7.3.1 Sample

Recruiting parents to participate was a challenge. Each study had a narrow age range, further reducing the pool of potential participants. For all studies, recruitment largely relied on the Essex Babylab database. Parents who are interested in potentially participating in research with their child sign up to the database and researchers from the Babylab contact the parents when a study meeting their child's age range is available. This created several issues with the sample. First, parents who sign up to the database are usually recruited via attendance to a narrow range of parent and baby groups in the local area. Second, of those who do signup, upon making contact very few parents respond and subsequently participate. For this thesis, some parents responded to say they were a screen free family and therefore declined to participate, which also limited the pool of participants. In addition, across all studies the sample was largely homogenous, whereby most parents were White, mid to high SES, and highly educated. Study 2a was the only caveat, where participants were largely from the U.S., due to the study being hosted online on an American platform. Despite this, the sample were also

[6] Section 7.3.3 is adapted from Morris, A. J., Filippetti, M. L., & Rigato, S. (2022). The impact of parents' smartphone use on language development in young children. *Child Development Perspectives, 16*(2), 103-109. https://doi.org/10.1111/cdep.12449

mostly White, held at least a bachelor's degree, with a household income above the U.S. national average. The narrow sample limits the generalisability of the findings in the thesis, and it is important that future studies seek to recruit more diverse samples.

7.3.2 Conceptualising Technoference

A limitation of this thesis, and the research into technoference and language development more broadly, is the lack of consistency in how technoference is conceptualised and subsequently operationalised in research. Swit et al. (2026) propose the Technoference Pathway Model, which identifies three distinct types of technoference (distraction, interruption, and disruption) each having different outcomes on parents and children. Distractions are internally driven, occurring when a parent voluntarily chooses to engage in their smartphone, without an external prompt. An interruption is an external event which demands attention, such as notifications or phone calls from the smartphone. Both distractions and interruptions are brief and require the parent's attention, but Swit et al. (2026) claim that interruptions are more likely to break a dyadic interaction. Disruptions are defined as smartphone use that causes sustained or repeated breakdowns to the dyadic interaction. Disruptions are deemed most detrimental to the parent-child relationship and child outcomes, as recovery to the interaction is less likely to occur. In comparison, distractions and interruptions do allow for recovery to the interaction, due to their brief nature, which can re-establish the connection between the dyad. As each type of technoference conceptually differs, how each should be measured in research also differs (Swit et al., 2026).

Applying the Technoference Pathways Model, to this thesis, highlights technoference was conceptualised slightly differently across studies. Studies 1 and

2b utilised self-report and included questions measuring distraction. Study 4 differed in that parents did not participate in the study and technoference was artificially created via a pre-recorded video. The video involved the adult model making brief looks towards the phone, without an external cue and would therefore also constitute measuring distraction. Studies 2a and 3 directed parents as to when and how to use their smartphone, thus whilst the external cue did not come in the form of a notification, the device use was not internally driven and was thus measuring interruption. This creates problems when comparing the findings from across the studies, as they are measuring different constructs.

7.3.3 Measuring Technoference

As previously noted, technoference is not easily defined. This creates a challenge when designing studies to measure technoference. Central to technoference is that it interrupts social interactions (McDaniel & Coyne, 2016). However, smartphones are multifaceted and each task on a smartphone may make different demands of the user (Kildare & Middlemiss, 2017). This is problematic when seeking to draw comparisons across studies. In this thesis, smartphone technoference was measured differently in each study (as mentioned in the previous section). Broadly these measures applied self-report or experimental manipulation of smartphone use. I next consider the limitations of each of these approaches.

Technoference was measured via three different self-report measures. One measure of technoference was included in each study, which asked parents to report on their smartphone use when actively engaged with their child. This question was designed for this thesis. The question asked parents to think about a regular day when responding to this question, subsequently this question is susceptible to recall and availability bias. Specifically, parents may over-rely on salient or recent

episodes, such as days with above average usage rather than reporting accurate usage. The second measure was a question taken from Corkin et al. (2021) which asked parents how often they consciously put their phone away when with their child. This measure was used in Study 2b, Study 3, and Study 4b. However, measuring this behaviour on a scale fails to consider the context in which this behaviour occurs. For example, whether a parent intentionally puts their phone away may depend on situational factors such as work commitments or whether they are the sole caregiver on the given day. The third measure of technoference was the Distraction In Social Relations and Use of Parent Technology (DISRUPT) (McDaniel, 2021), which was applied in Studies 2b, 3, and 4b. There are several issues with measuring technoference in this way. Firstly, the phrasing of the statements in the DISRUPT are framed in a negative light. Because parents can feel guilt over smartphone use when parenting (Garg, 2021; Halfmann et al., 2025; Wolfers et al., 2023), this judgemental phrasing may lead to socially desirable responses whereby lower technoference is reported than occurs. Indeed, most parents under-report smartphone use when with their child (Kelly & Ocular, 2021). Using passive sensing apps (e.g., Yuan (2019)) can overcome issues of social desirability but still require the parent to identify accurately at which points during the day they were engaged with their child. A further consideration is whether smartphone use is the most effective measure of technoference. A recent study showed that how mothers feel about their smartphone use was related to quality of interactions with their 2-month-old, but perceived technoference and smartphone use measured via passive sensing was not (Ventura et al., 2025). Second, whilst self-report may capture the extent to which a parent engages in smartphone technoference, it does not allow for a distinction between types of smartphone use which, as discussed at length in this

thesis, may have different effects on the parent and child. Last, parents reporting on their own phone use necessitates a level of insight which may be compromised by the often-subconscious nature of smartphone use. For example, brief checks of the phone, or gaze shifts towards the phone may go unnoticed by parents and subsequently not reported.

Studies 2a, 3, and 4b each experimentally manipulated smartphone technoference. This approach overcomes the issues with measuring technoference via self-report, but in turn raises different challenges. First, the manipulation of smartphone use differed across studies. Technoference involved a 3-minute call (phone or video) to a friend/family member in Study 2a, a 30-second phone call with the researcher in Study 3, and gaze averted intermittently to a phone, which was not actively used, in Study 4b. This variation is also common in the literature, where parents have been asked to use the phone in various ways including to make a phone call (Reed et al., 2017), complete a survey (Gaudreau et al., 2021), and respond to a text message (Nguyen, 2024). Although this variation reflects natural phone use which is multifaceted, this inconsistency across studies makes it difficult to compare findings because how the smartphone is used may moderate the effect of technoference on precursors to language development and language outcomes. Second, while directing parents as to how to use the phone allows control over technoference to a certain extent, it is unlikely to capture the complexity of parents' smartphone use. The limited and controlled nature of smartphone activity in the studies in this thesis, only includes a very narrow range of ways to interact with the phone which are unlikely to capture naturalistic smartphone use. Central to naturalistic smartphone use are incoming notifications which are unexpected and tend to be responded to immediately, interrupting current activities (Heitmayer &

Lahlou, 2021). However, Heitmayer and Lahlou, (2021) also found that many users mute or restrict access to their phones, and that checking is driven more by habit (around every 5 minutes) than by notifications. Habitual use as a feature of technoference was not addressed in this thesis and experimental manipulation does not capture these nuances in phone use and therefore any findings may not reflect the true relationship between technoference and parent-child interactions. Another consideration is that there are differences in naturalistic smartphone use across parents. McDaniel et al. (2024) identify five user types which vary according to the amount of time spent using their phone and the types of activities the phone is used for. A central distinction in these user types is using the phone primarily for social media, gaming, or messaging. Although Study 3 included game interaction, this was a game aimed at young children rather than adults and is therefore unlikely to reflect natural game interaction and the demands this places on users. Messaging and social media use were not included as technoference manipulations in this thesis, which limits the applicability to naturalistic smartphone use. Last, parents have volunteered their time to participate in the study and are therefore willing participants who follow instructions. Parents may subsequently focus more on the task using the phone than they would if they were in control of their phone use in a natural setting. Alternatively, as parents know they are in a study they may overcompensate for any phone use e.g. with increased responsiveness, which may not reflect natural phone use.

To address these difficulties, researchers should combine multiple measures of parents' smartphone use, such as natural observations in the home, self-report questionnaires, and objective techniques e.g., passive sensing applications. This approach is fundamental to developing experiments that can manipulate

technoference in a valid way to gain a true understanding of its impact on language outcomes.

7.4 Suggestions for Future Research

While this thesis adds to the literature on parent smartphone use and language development in young children, there are many gaps in this emerging field which warrant further study. Based on the discussions throughout this thesis, I propose that further research should focus on the following key areas which are explored in more detail in the section below.

1. The reasons why parents use their smartphone and whether these reasons moderate the relationship between parent smartphone technoference and child language development.
2. Take a longitudinal approach from birth to four years to identify age-related changes to both parent smartphone technoference and children's language development.
3. Examine in more detail, natural parent phone use in the home and the effect this has on parent-child interactions.
4. Consider advancements in technology both to smartphones, and to other devices such as smartwatches, to ensure research is a valid reflection of technoference.

7.4.1 Why Parents Use Their Smartphones[7]

In examining technoference and language, it is important to disentangle issues surrounding *why* parents use their smartphone around their children because

[7] Section 7.4.1 and 7.4.2 are adapted from Morris, A. J., Filippetti, M. L., & Rigato, S. (2022). The impact of parents' smartphone use on language development in young children. *Child Development Perspectives, 16*(2), 103-109. https://doi.org/10.1111/cdep.12449

this may moderate the effect of technoference on language acquisition. The reason a parent chooses to use their smartphone when engaged with their child may reflect other variables in the home, such as requests from family members (Garg, 2021). Technoference itself may be a moderator in language development, rather than a causal factor. In one study, parents who used their smartphone as a means of escape reported more parenting stress than parents who did not (Torres et al., 2021). Since parents' perception of their children (e.g., as having a difficult temperament) is one of the reasons for parent smartphone use during family mealtimes (Radesky et al., 2018), challenges in establishing a caregiving relationship may explain why some parents use their smartphone when with their child.

Smartphones may also play a role in reducing parent stress by providing emotional and instrumental support related to parenting via searching for information or seeking social support (Wolfers, 2021); in one study, seeking social support reduced feelings of loneliness in mothers (Coyne et al., 2022). Parents who are less stressed may have interactions with their children that are more conducive to responsiveness and joint attention. It is not known whether the same conclusions would be drawn from direct measurements of technoference as opposed to general parent smartphone use. Researchers should investigate why parents use their smartphones when with their child and explore the direction of the relationship between parenting stress and technoference to ascertain whether technoference affects language outcomes causally.

7.4.2 The Need for Longitudinal Research

Research on technoference and language is predominantly cross-sectional, which prevents observing the effects of technoference on language development as

they unfold over time. While parents may respond less to their child in a one-time observation (e.g., Elias et al., 2020), single time points may not be representative of regular technoference. Thus, longitudinal research is essential to investigate the impact of technoference on later language outcomes. Longitudinal studies that have measured technoference in children from birth to age 5 are sparce. Most have focused on a wider range of devices than just smartphones as sources of technoference and nonlanguage outcomes (e.g., child behaviour, see McDaniel and Radesky (2018a)). The recent publication from Coyne et al. (2026) is the first longitudinal study to my knowledge to focus only on smartphones as the source of technoference and language outcomes. These longitudinal studies highlight the complexities of the relationship that cross-sectional studies cannot capture. For example, one study found different results at the cross-sectional level compared to the longitudinal data (Coyne et al., 2022) and, as stated previously, another study found the effect of smartphone technoference on the child's language did not remain at the one year follow up (Coyne et al., 2026). These findings reinforce the need for longitudinal work that captures more effectively the ongoing effects of technoference on language. As proposed, examining longitudinal trajectories of technoference during parent-child interactions can help us understand its effect on social gaze, parent responsiveness, and joint attention, and how these affect subsequent language development.

7.4.3 Technoference in the Home

Much of the research into parent smartphone technoference and language has taken place in experimental (Ewin, Reupert, McLean, et al., 2021; Gaudreau et al., 2021; Lederer et al., 2022; Nguyen, 2024; Reed et al., 2017) or natural settings (Abels et al., 2018; Elias et al., 2020; Kelly & Ocular, 2021). Although some recent

studies have conducted research in the home (Holmgren et al., 2025; Mikhelson et al., 2024; Paoletti et al., 2025), only one has focused specifically on smartphone use (Mikhelson et al., 2024). Experimental settings allow for establishing causality between technoference and language, however the novel setting and stipulated phone use is unlikely to represent the conditions in which young children are regularly exposed to parent smartphone technoference. For example, when parents are not directed to use their phone in a set way for an experiment, they are able to shift attention between their infant and phone (Amery, Danby, & Brereton, 2026). This lack of ecological validity limits the generalisability of the findings. On the other hand, observations in natural settings do reflect natural phone use. However, the researcher is unlikely to be able to see what the parent is doing on their phone and being unable to record the observation is likely to mean intricacies in behaviours are missed. Parents may take their child to settings outside of the house more frequently because they can use their smartphone to multitask (such as checking work emails) without having to stay at home (Bury et al., 2020). This would lead to technoference appearing more common in a setting away from the home, than it may be when at home. As young children spend a significant proportion of their time with their parent in the home, it is likely that most of their exposure to parent smartphone technoference occurs within the home. It is therefore crucial that future research studies parent smartphone technoference within the home environment to develop a true picture of the role technoference plays in dyadic interactions.

7.4.4 Advancement in Technology

One of the challenges in studying the influence of technology use on behaviour is that technology is continually developing. As discussed earlier in this chapter, in the past 10 years the functionality of smartphones has developed to now

include generative AI and personal agents. If the reasons a parent uses their phone matter (see Section 7.4.1), the addition of features which may be embedded into daily routines is crucial to address. In particular, parents are increasingly using parenting apps to support with infant care such as breastfeeding, tracking infant feeding and development (David et al., 2024; Virani et al., 2021), which may increase phone use during infant routine. It is pertinent that future studies do not treat all phone use as equal and consider how changes in technology may impact how parents use their smartphones and whether this in turn impacts children's developmental outcomes.

In addition to smartphones, smartwatches also continue to develop their features. In Chapter 1, I explained my reasoning for focusing on smartphones as the form of technoference in this thesis. These reasons included their portability, functionality, and the small screen which is designed for one user. A smartwatch has all these features too. A smartwatch is arguably more portable than a phone, as it is attached to the wrist. The screen is also smaller than a phone, reducing opportunities for JME. Although functionality on a smartwatch is not as efficient as a phone, most watches include many of the same features, albeit these may be more difficult to use due to the small screen, which may result in briefer interruptions than a phone. A smartwatch is, however, hands free, which allows the user to avert gaze to the watch without having to stop what they are doing. For example, a parent reading to their child could angle their wrist and avert their gaze in response to a notification, whilst continuing to hold the book. These differences may result in 'interruptions' from smartwatches as being the form of disruption, as opposed to 'distraction' or 'disruption'. Conceivably, being able to see notifications on a smartwatch, may also reduce smartphone use. Study 1, conducted in 2020, found

only 22% of parents owned a smartwatch. However, smartwatch and wearable technology ownership in 25-49-year-olds (those most likely to be parents of young children) increased to 41% in January 2026 (YouGov, 2026). At the time of writing, there are no studies which have explored smartwatches as a form of parenting technoference. Natural observations would provide a sensible starting point to ascertain whether smartwatches do create technoference when parenting.

7.5 Implications for Practice

It is hoped that the findings from this thesis will not only lead to continued research in this field but will also be useful to both practitioners and parents trying to navigate phone use in an increasingly digital world. Although there is still much to uncover on the complexities of parent smartphone technoference and child language outcomes, the findings from this thesis could contribute to the advice and support offered to parents on their smartphone use.

It is not practical to advise parents to not use their smartphones. First, this target is likely to be perceived as unachievable given how smartphones are integrated into daily life. Indeed, an intervention to encourage parents to decrease their screen use for an hour a day saw reductions in the first week, but this change did not maintain across the four-week intervention (McDaniel, Rasmussen, et al., 2023). Second, parents already feel guilt and conflict about smartphone use when with their child (Garg, 2021; Halfmann et al., 2025; Radesky et al., 2016; Wolfers et al., 2023), unachievable targets are likely to increase these feelings of guilt and internal tensions. Finally, smartphone use during parenting can have positive effects on the parent when used to seek social support (Torres et al., 2021). Advising a smartphone ban would also reduce any positive effects they may have. Realistic and

practical advice is needed to guide parents on their smartphone use, without demonising smartphone use.

Based on the findings in this thesis, parents could be encouraged to be aware of their smartphone use when parenting and advised to avoid phone use which is likely to remove their attention from their child e.g., phone calls. This advice can be extended to all disruptions to parent-child interactions, based on Study 4b that digital and non-digital interruptions did not have different effects on infant neural activity. If parents do need to use their phone, they can be advised to keep use brief and be mindful to return to the interaction with their child as soon as the phone use has terminated. Last, parents could be advised to have designated phone free time throughout the day, which can be achieved by consciously putting the phone away during face-to-face interactions with their child such as floor play.

7.6 Concluding Remarks

The studies conducted in this thesis examined the relationship between parent smartphone technoference and child language outcomes, including precursors to language development. Whilst further research is necessary to understand the complexities of parent smartphone technoference, the findings of this thesis provide further insight on parent smartphone technoference and child language.

This thesis revealed that parents use their smartphone less often when engaged with their child in comparison to when they are not engaged with their child. Parent smartphone technoference was found to disrupt social gaze during parent-child interactions. Both parent gaze to their infant and the infant's gaze to their parent was disrupted by parent smartphone technoference. Type of phone use mattered; parents' gaze was more disrupted when using the phone to take photos

whereas infants looked at their parent less when the parent used a phone to make a call than when play was uninterrupted. Smartphone use which disrupted gaze did not affect infant neural activity differently to a non-digital disruption. Consistent with previous literature, parent smartphone use was found to reduce parent responsiveness, although these effects were less pronounced when parents used their phone to take photos in comparison to making a call. These findings suggest that parent smartphone technoference can be disruptive to social gaze and parent responsiveness, but that different types of phone use may have different effects on the interaction.

Inconsistencies were found when exploring the impact of parent smartphone technoference on child language. In one study, I found that parent smartphone use did not negatively impact the learning of novel words, but that phone use which encouraged JME resulted in more robust word learning. However, in another study, increased technoference was associated with reduced use of words and gestures in children. Parent's use of language was affected by their phone use, with a phone call being more disruptive to language directed to the child than using a phone to take photos. These inconsistencies in findings, both in this thesis and in the wider literature, highlight the need for further research in the field.

To conclude, the work contained within this thesis provides insights into the potential effects of parent smartphone technoference on language outcomes in children. I hope that this thesis will be useful to researchers for further investigations into how technoference shape early language development, in a world where smartphones are becoming increasingly integrated into family life.

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Appendix A

Distraction In Social Relations and Use of Parent Technology (DISRUPT)

Please rate your level of agreement with the following statements

Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	2	3	4	5	6

During time I spend with my child…

1. … I find myself thinking about what I could be doing on or messages/notifications I might receive on my phone or mobile device.
2. … I find it difficult to stay away from checking my phone or mobile device.
3. … I feel like I use my phone or other mobile device too much.
4. … there are times that I could play with or interact with my child, but I am on my phone or mobile device instead.

Appendix B

Parental Responsiveness Scale (PRS)

Please read the following statements carefully and determine to what extent each of them reflects your relationship with your child. For each statement, please indicate with an X whether you:

1. Completely disagree
2. Disagree
3. Partially disagree
4. Difficult to say
5. Partially agree
6. Agree
7. Completely agree

1. I pay attention to the objects my child points at and I turn my head in the direction they are pointing.
2. I react immediately when my baby cries.
3. When my baby cries, I try to console them by touching, stroking, or hugging.
4. I reciprocate my child's smile.
5. I make contact with my child when I see that they want it.
6. When my child is frightened by a loud noise, I immediately try to stop the sound.
7. I know when my child is sleepy and I immediately try to arrange a place for them to rest.
8. When my child is shy in front of or afraid of a new person, I do not force them to engage and I give them time to get used to the new person (or 'adapt').

9. When some specific type of play with a child makes them happy, I try to repeat it as often as possible.
10. I know when my child feels physical discomfort and I try to help them.
11. I name items that my child points at.
12. When my child initiates play, I encourage and facilitate it.
13. When I talk to my child, I adjust the volume and tone based on their response.

Appendix C

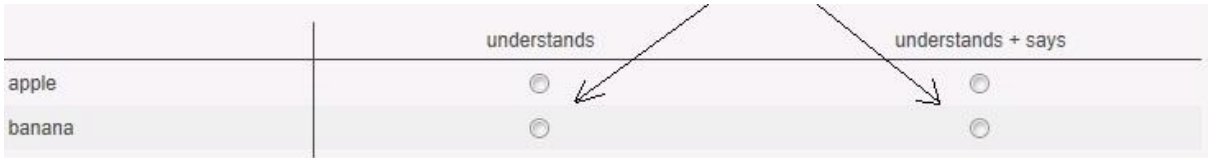
UK Communicative Development Inventory (UK-CDI)

The following questions ask about your child's language development.

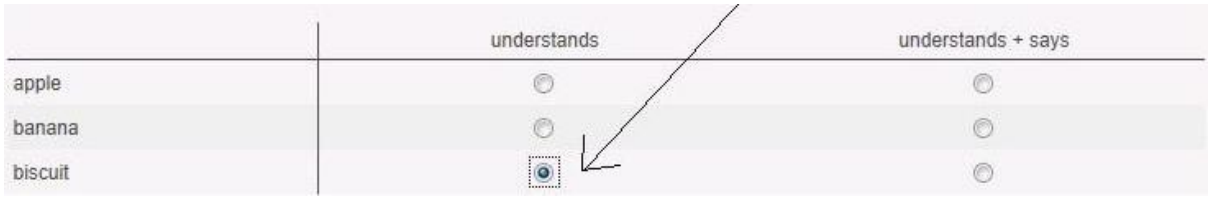
Here is a list of words children may know. It is a large inventory of words used by many different children across a wide age range, so do not worry if your child knows only a few of them at the moment!

Instructions

1. If your child **does not yet understand or say the word**, leave the circles blank.



2. If your child **understands a word but doesn't say the word**, mark like this:



3. If your child **understands and also says** the word, mark like this:



Please only include words your child says on their own (e.g. not when you ask them to “say train”).

Give your child credit for using different words with the same meaning. If your child understands or says a

different word please still fill in the appropriate circle. Please include:

Different words (e.g. "baby" for "doll")

- Local or dialect words (e.g. "bairn" for "baby")
- Family names (e.g. "nana" for "grandma")
- Baby-talk words (e.g. "goggy" for "dog")

Please do **not** include foreign words (e.g. “aqua” for “water”).

If a word refers to a person/people mark the word even if your child only says the name of the person (e.g. “Adam” for “baby”).

WORD LIST

Please mark the circles next to the words your child **understands** or **understands and says** below.

Remember to give your child credit for using **different** or **local** words with the same meaning.

	Understands	Understands + says
Meow	☐	☐
Woof	☐	☐
Yum	☐	☐

Quack	☐	☐
Dog	☐	☐
Cat	☐	☐
Bird	☐	☐
Lion	☐	☐
Butterfly	☐	☐
Cow	☐	☐
Car	☐	☐
Tractor	☐	☐
Aeroplane	☐	☐
Pushchair	☐	☐
Book	☐	☐
Teddy	☐	☐
Balloon	☐	☐
Bubble	☐	☐
Milk	☐	☐
Banana	☐	☐
Yoghurt	☐	☐
Apple	☐	☐
Cake	☐	☐
Chips	☐	☐
Sausage	☐	☐

Nose	☐	☐
Eye	☐	☐
Hand	☐	☐
Finger	☐	☐
Arm	☐	☐
Belly button	☐	☐
Nappy	☐	☐
Shoes	☐	☐
Hat	☐	☐
Jumper	☐	☐
Pyjamas	☐	☐
Bed	☐	☐
Door	☐	☐
Downstairs	☐	☐
Settee/sofa	☐	☐
Table	☐	☐
Bottle	☐	☐
Phone	☐	☐
Toothbrush	☐	☐
Cup	☐	☐
Bowl	☐	☐
Hoover	☐	☐

Park	☐	☐
Flower	☐	☐
Moon	☐	☐
Slide	☐	☐
Grandma	☐	☐
Grandpa	☐	☐
Mum	☐	☐
Dad	☐	☐
Baby	☐	☐
Own name	☐	☐
Hello	☐	☐
Bye	☐	☐
Peek-a-boo	☐	☐
Thank you	☐	☐
Goodnight	☐	☐
Yes	☐	☐
Nap	☐	☐
Clap hands	☐	☐
Cuddle	☐	☐
Kiss	☐	☐
Splash	☐	☐
Tickle	☐	☐

Sleep	☐	☐
Sing	☐	☐
Draw	☐	☐
Blow	☐	☐
Catch	☐	☐
Dance	☐	☐
Eat	☐	☐
Give	☐	☐
All gone	☐	☐
Gentle	☐	☐
Hot	☐	☐
Cold	☐	☐
Naughty	☐	☐
Dirty	☐	☐
What	☐	☐
Night	☐	☐
You	☐	☐
Mine	☐	☐
Under	☐	☐
In	☐	☐
More	☐	☐
Again	☐	☐

ACTIONS AND GESTURES

When infants are learning to communicate they often use gestures to get a message across. For each of the gestures below, please mark the actions that you have seen your child do or **try** to do.

Gestures

	Not yet	Sometimes	Often
Points (with arm and index finger extended) at some interesting object or event	☐	☐	☐
Waves byebye on his or her own when someone leaves	☐	☐	☐
Shakes head "no"	☐	☐	☐
Gestures "hush" by placing finger to lips	☐	☐	☐
Shrugs to indicate "all gone" or "where did it go"	☐	☐	☐

Actions

	No	Yes
Plays chasing games	☐	☐

	☐	☐
Sings		
	☐	☐
Dances		
	☐	☐
Clap hands		
	☐	☐
Comb or brush own hair		
	☐	☐
Put on a hat		
	☐	☐
Put on a necklace, bracelet, or watch		
	☐	☐
Blow to indicate something is hot		
	☐	☐
Put telephone to ear		
	☐	☐
Push toy car or truck		
	☐	☐
Throw a ball		
	☐	☐
Stir pretend liquid in a cup or pan with a spoon		
	☐	☐
Pretend to ‘drink’ from a cup or other object		
	☐	☐

Put a toy or doll to bed	☐	☐
Feed a toy or doll with a spoon	☐	☐
Brush/comb a toy or doll's hair	☐	☐
Push a toy/doll in a pram/buggy	☐	☐
Kiss or hug a toy or doll	☐	☐
Sweep with a real or toy broom or mop	☐	☐
"Read" (opens book, turns page)	☐	☐
Hoover (using a real object or toy)	☐	☐
Play a musical instrument (e.g. piano, trumpet, with a real or pretend instrument)	☐	☐
Write with a real or pretend pen, pencil, or marker	☐	☐
Pretend to or really put on glasses		

Appendix D

Study 1 Questionnaire

Demographics

Questions about yourself. The following questions are aimed at gathering demographics data. This data is typically collected in research studies to make sure the participants who took part in the study are representative of the target population (UK). While some of the questions may feel a little intrusive, the data gathered will not be used to identify any of the participants.

Q1. How old are you? _____

Q2. Gender

- Male
- Female

Q3. What is your ethnicity?

- White
- Black/African/Caribbean/Black British
- Asian or Asian British
- Mixed/Multiple Ethnic Group (e.g. White and African)
- Arab
- Other, please specify _____
- Prefer not to answer

Q4. Which of these options best describes your current relationship/living arrangements?

- Married or in a civil relationship
- Single
- Cohabiting (i.e., living with a partner without being married/civil partnered)
- Separated or divorced
- Widowed
- Prefer not to answer

Q5. Person completing this questionnaire

- Mother
- Father
- Other (please specify) _____

Q6. Who is the primary caregiver of the child/children in the household, i.e., the person who spends most time with the child or takes care of the child on a daily basis?

- Mother
- Father
- Both Mother and Father
- Other (please specify) _____

Q7. Total family income per year _____

Q8. Education

Please specify which of the following have been completed and give details where necessary.

Please tick all the boxes that apply.

- Primary school
- Secondary school
- GCSEs. How many?

  _____
- A-levels. How many?

  _____
- University: First degree. Which subject?

  _____
- University: Postgraduate degree. Which subject?

  _____
- Any specialist training completed. Please give details
- _____

Q9. Employment at present

- Employed full-time
- Employed part-time
- Retired
- Homemaker
- Student
- Unemployed
- Other (please specify) _____
- Prefer not to answer

<u>Information on child under 2</u>

When you answer the questions in the survey, you are asked to do this with your youngest child (who should be under the age of 2) in mind. Please answer the questions below in relation to your youngest child.

Q10: Gender

- Male
- Female
- Not known

Q11. Birth date (dd/mm/yyyy) _____

Q12. Child's ethnic origin

- White British
- Irish
- Any other White background, please write in _____
- Mixed
- Asian, Asian British, Asian English, Asian Scottish or Asian Welsh
- Black, Black British, Black English, Black Scottish or Black Welsh
- Chinese, Chinese British, Chinese English, Chinese Scottish, Chinese Welsh
- Any other ethnic background, please write in _____

Q13. Has the child been diagnosed with any disorder?

- Yes
- No

Q14: If Yes, please give details _____

Details of other children in the household

Q15: How many other children (under 5 years) live in the household? _____

Q16. How many other children (aged 5 -18 years) live in the household? _____

Smartphone use

Q17. In a regular day, how many times per hour do you usually check your smartphone?

- 0-2 times an hour
- 3-5 times an hour
- 6-9 times an hour
- 10-12 times an hour
- 13-15 times an hour
- More than 15 times an hour

Q18. In a regular day, how long do you generally use your smartphone for in a day?

- Less than 60 minutes per day
- 1-2 hours per day
- 3-4 hours per day
- 5-6 hours per day
- 7-8 hours per day
- Over 9 hours per day

Q19. Answer the following questions with your youngest child (under the age of 2) in mind and in relation to a regular day.

	Always	Most of the time	About half the time	Sometimes	Never
How often do you use your smartphone when your child is sleeping/napping?	☐	☐	☐	☐	☐
How often do you use your smartphone when your child is awake, and you are not actively engaging with them? For example (but not limited to), the infant is playing independently, watching television, interacting with another family member.	☐	☐	☐	☐	☐
How often do you use your smartphone when your child is awake, and you are actively engaging with your infant? For example (but not limited to) when playing a game	☐	☐	☐	☐	☐

together, looking at a book together, exploring toys together.

Q20. Thinking about your phone use over the last 24 hours, identify how long you engaged with each of the following when using your phone when your youngest child was asleep or they were awake but not actively engaging with you.

	Not at all	I did this for less than half of the time I spent on my phone	I did this for about half of the time I spent on my phone	I did this almost the entire time I used my phone
To organise daily life e.g. calendar, shopping list, online banking, pay bills	☐	☐	☐	☐
To get information about current events	☐	☐	☐	☐
To text with friends and family members	☐	☐	☐	☐
To make phone calls with friends and	☐	☐	☐	☐

family members				
To make video calls with friends and family members	☐	☐	☐	☐
To read and/or send non-work related emails	☐	☐	☐	☐
To access social media	☐	☐	☐	☐
To play games	☐	☐	☐	☐
To study/work	☐	☐	☐	☐
To take/view/order photos	☐	☐	☐	☐
To watch educational resources/access educational apps/learn another language	☐	☐	☐	☐
To research information about your child's	☐	☐	☐	☐

development				
To read/contribute to parent forums	☐	☐	☐	☐
To research general information as you think of it (but not specific to your child) e.g. looking up recipes	☐	☐	☐	☐
To shop/research products to buy	☐	☐	☐	☐
To monitor health e.g. access health and fitness advice, track your health, track calorie consumption	☐	☐	☐	☐
To watch and participate in an exercise video/class	☐	☐	☐	☐
To access reward apps e.g. Boots Advantage Card,	☐	☐	☐	☐

Costa Coffee

To use Google Maps	☐	☐	☐	☐
To stream films/TV series (e.g. via Netflix, Amazon Prime, YouTube)	☐	☐	☐	☐
To monitor your child/ren e.g. use of technology, nap times, feeding times	☐	☐	☐	☐
To listen to music/podcasts/audio books	☐	☐	☐	☐
To read eBooks	☐	☐	☐	☐
To access childcare information (e.g. Tapestry)	☐	☐	☐	☐
Controlling other smart devices (e.g. heating, speakers)	☐	☐	☐	☐
Other (please	☐	☐	☐	☐

specify)

Q21. Thinking about your phone use over the last 24 hours, identify how long you engaged with each of the following when using your phone when your youngest child was awake and actively engaging with you.

	Not at all	I did this for less than half of the time I spent on my phone	I did this for about half of the time I spent on my phone	I did this almost the entire time I used my phone
To organise daily life e.g. calendar, shopping list, online banking, pay bills	☐	☐	☐	☐
To get information about current events	☐	☐	☐	☐
To text with friends and family members	☐	☐	☐	☐
To make phone calls with friends and family members	☐	☐	☐	☐
To make video calls with friends and	☐	☐	☐	☐

family members				
To read and/or send non-work related emails	☐	☐	☐	☐
To access social media	☐	☐	☐	☐
To play games	☐	☐	☐	☐
To study/work	☐	☐	☐	☐
To take/view/order photos	☐	☐	☐	☐
To watch educational resources/access educational apps/learn another language	☐	☐	☐	☐
To research information about your child's development	☐	☐	☐	☐
To read/contribute to parent forums	☐	☐	☐	☐

To research general information as you think of it (but not specific to your child) e.g. looking up recipes	☐	☐	☐	☐
To shop/research products to buy	☐	☐	☐	☐
To monitor health e.g. access health and fitness advice, track your health, track calorie consumption	☐	☐	☐	☐
To watch and participate in an exercise video/class	☐	☐	☐	☐
To access reward apps e.g. Boots Advantage Card, Costa Coffee	☐	☐	☐	☐
To use Google Maps	☐	☐	☐	☐

To stream films/TV series (e.g. via Netflix, Amazon Prime, YouTube)	☐	☐	☐	☐
To monitor your child/ren e.g. use of technology, nap times, feeding times	☐	☐	☐	☐
To listen to music/podcasts/audio books	☐	☐	☐	☐
To read eBooks	☐	☐	☐	☐
To access childcare information (e.g. Tapestry)	☐	☐	☐	☐
Controlling other smart devices (e.g. heating, speakers)	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐

Q22. Does your youngest child show an interest in and try to interact with the smartphone when *you* are using it?

- Yes
- No
- Sometimes

<u>Child smartphone use</u>

Q23. Do you let your youngest child use your smartphone independently?

- Yes
- No
- Sometimes

Q24. Do you sit with your youngest child and interact with the smartphone when *they* are using it?

- Yes
- No
- Sometimes
- They do not use my smartphone

Q25. Do you currently own a smartwatch (e.g. Apple, Samsung)?

- Yes
- No

Q26. Please describe the main way/s you use your smartwatch.

_____

Appendix E

Generic Scale of Phubbing

We would like you to think about your mobile phone use during your face-to-face social interactions with others.

Think about your social interactions on the whole (e.g., with friends, acquaintances, family, your partner) and the extent to which the following statements apply to you.

In my face-to-face social interactions with others ….

1. I feel anxious if my phone is not nearby
2. I cannot stand leaving my phone alone
3. I place my phone where I can see it
4. I worry that I will miss something important if I do not check my phone
5. I have conflicts with others because I am using my phone
6. People tell me that I interact with my phone too much
7. I get irritated if others ask me to get off my phone and talk to them
8. I use my phone even though I know it irritates others
9. I would rather pay attention to my phone than talk to others
10. I feel content when I am paying attention to my phone instead of others
11. I feel good when I stop focusing on others and pay attention to my phone instead
12. I get rid of stress by ignoring others and paying attention to my phone instead
13. I pay attention to my phone for longer than I intend to do so
14. I know that I must miss opportunities to talk to others because I am using my phone
15. I find myself thinking “just a few more minutes” when I am using my phone

Responses are on a 7-point Likert scale of “Never”, “Rarely”, “Occasionally”, “Sometimes”, “Frequently”, “Usually”, “Always”.

Appendix F

Generic Scale of Being Phubbed

We would like you to think about others' mobile phone use during your face-to-face social interactions with others.

Think about your social interactions on the whole (e.g., with friends, acquaintances, family, your partner) and the extent to which the following statements apply to you.

In my face-to-face social interactions with others ….

1. Others seem to check their phones for messages and social media updates
2. Others seem to be using their phones to go online
3. Others place their phones where they can see them
4. Others seem worried that they will miss something important if they do not check their phones
5. Others seem like they lose awareness of their surroundings because of their phone use
6. Others seem like they have a difficult time putting their phones down
7. Others seem like they cannot stand leaving their phones alone
8. Others seem like they are “in their own worlds” using their phones
9. Others seem anxious if their phones are not nearby
10. Others pay attention to their phones rather than talking to me
11. Others would rather pay attention to their phones than talk to me
12. Others seem like they get rid of boredom by paying attention to their phones instead of me
13. Others seem like they feel content when they are paying attention to their phones instead of me

14. Others pay attention to their phones rather than focusing on me
15. Others seem like they get rid of stress by paying attention to their phones instead of me
16. Others seem like they feel good when they stop focusing on me and pay attention to their phones instead
17. Others shift their attention from me to their phones
18. I tell others that they interact with their phones too much
19. I have conflicts with others because they are using their phones
20. I find myself thinking “I've had enough” when others are using their phones
21. Others use their phones even though they know it irritates me
22. Others seem like they get irritated if I ask them to get off their phones and talk to me

Responses are on a 7-point Likert scale of “Never”, “Rarely”, “Occasionally”, “Sometimes”, “Frequently”, “Usually”, “Always”.