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Early media exposure

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Early media exposure

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Editorial: Early media exposure

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Editorial on the Research Topic
Early media exposure

Introduction

The ever-evolving landscape of digital media now encompasses many novel ways for young children to watch, play, and engage. Just over a decade ago, ground-breaking work was focused primarily on television and videos as the main format of audiovisual media use among children. This work generally converged on associations between greater TV duration and less optimal child developmental outcomes such as language and cognition (Madigan et al., 2020). However, contrary to this deficit perspective, high-quality media content has been found to have a positive impact on children's social-emotional development, language, and cognition (Huston et al., 2014; Mares and Pan, 2013).

Regardless of the veracity of arguments over the positive and negative developmental impacts of exposure to audiovisual media, it is increasingly apparent that the substantial differences between traditional TV and the current digital landscape call for contemporary perspectives to ensure the generalizability of established findings. Television can be turned off, has finite programming, and is fixed in location. In contrast, newer forms of digital media are constantly on, have boundless and personalized content, and are highly portable. These diverse characteristics can make digital media study and translation more challenging (Barr et al., 2020). Furthermore, caregivers and parents are also likely to have their own devices and digital media use patterns (McDaniel and Radesky, 2018). Therefore, more precise approaches to address the diversity of the digital ecology, including caregivers' device use, and the impact on young children's wellbeing are needed. No singular approach is likely to capture every aspect of the digital media environment. However, the field is moving toward multi-faceted measurement approaches to understand the duration/frequency, content, and context of digital media use. This eBook, titled "Early Media Exposure" highlights the collective field's progress toward aligning digital media research with the realities of modern family media ecology. These 15 published works offer key insights into family media ecology, highlighting the duration/frequency, content, and context of digital media use which shape children's wellbeing.

Duration and frequency of digital media use

Sticca et al. conduct an ambitious scoping review of the digital media effects on children's developmental outcomes, focusing on infants and preschoolers. They find that digital media use overall continues to have weak to null associations with less optimal sleep, language, and cognition. They summarize stronger associations between digital media use overall and social-emotional development (Sticca et al.).

However, the relationships between digital media and development are not always straightforward, depending on the type of digital media used and the age of the child. For instance, Mortimer et al. leverage a longitudinal study to examine tablet use during infancy and associations with executive functioning, finding that infant tablet use is not significantly associated with poorer EF, at least up to preschool-age. Sanchez-Bravo et al. also find null cross-sectional associations during this infancy period between screen exposure, sleep quality, and language development, suggesting more work to characterize infant development and screen exposure may be warranted, especially longitudinally.

These works also include an international lens on the impact of digital media use on children's development. For instance, Fekonja et al. find null associations between digital media use and toddler language development among toddlers in Slovenia, possibly related to low average toddler exposure to electronic media. Future work might include additional countries and cultures, where digital media use habits and exposures might vary and where the socioecological systems that shape digital media use might also vary tremendously. Such work would shed light on potential policy-level or cultural approaches to shaping digital media habits and outcomes.

Content

Given the ability to create and upload user-generated content, digital media content is growing increasingly saturated. In order to break through the market, content creators now may need to use more emotionally affective, catchy, or dramatic tactics in order to catch users' attention (Radesky et al., 2024). The quality of digital media now may have greater variability compared to the past when digital media was primarily consumed from major networks. This eBook highlights the varied ways in which online content might shape children's outcomes.

Online harm is unfortunately quite common. Gath and Swit's work highlights that approximately one quarter of New Zealand children have experienced online harm before the age of 8 and that children with behavioral difficulties or personal devices are more likely to experience online harm. In turn, online harm is adversely associated with greater depressive symptoms (Gath and Swit). This work converges with another article in this Research Topic finding that device ownership predicts exposure to violent content among young children, suggesting that device ownership might be one way to modify content quality (Henderson et al.). Henderson et al. also find that young children are exposed to violent and inappropriate content on YouTube, with younger infants (0–12 months of age) having increased risk of exposure to violent content than toddlers.

However, the implications of Henderson et al.'s work for young children may be unclear, as infants and young toddlers may exhibit a video-deficit effect, making it hard for them to transfer information from a 2D source to the 3D world (Barr, 2010). Taylor et al. find that 3-year-old children have a harder time learning a verb from an educational touchscreen apps as compared with an in-person live demonstration. For young children, in-person opportunities continue to be important for learning (Taylor et al.).

Recent views have suggested that with an ever-changing digital landscape the meanings associated with screen-based information are in a state of flux (e.g., Sommer et al., 2023; Strouse and Samson, 2021). For example, whether via fictional child-oriented media characters or online personalities featured on social media platforms, children are increasingly provided with opportunities to develop parasocial relationships, one-sided bonds in which a sense of connection or emotional attachment is fostered, even though there is no actual personal interaction (Richert et al., 2011). Given the explosion in user-generated content, more needs to be known about the ways young children's relationships of this nature might shape their decision-making. In this context, Williams-Gant et al. find that parasocial relationships with familiar characters are less likely to influence a 4–5 year old's decision-making as compared with features more relevant to the object themselves.

Context–*Family use*

How parents use digital media has been an area of emerging research that suggests that parent use has associations not only with children's digital media habits but also with early childhood outcomes, given parents' key relational role in children's lives (Corkin et al., 2021; Holmgren et al., 2024; McDaniel and Radesky, 2018).

For instance, Tulviste and Tulviste find that greater parental and child duration of video game play has adverse associations with children's language skills. This may be related to the immersive and engaging nature of video gaming, which may make it more challenging to have back-and-forth reciprocal conversations (Tulviste and Tulviste). Similarly, Mason et al. find that greater disruptions in maternal attention occurred in a digital media condition as compared with the control condition; however, maternal attention overall was a more important predictor of interaction quality than the mere presence of digital media. Conversely, Kucker and Schneider find that social interactions with young children offset the detrimental effects of digital media use on children's vocabulary. However, Wildt find that parents may be commenting more frequently on the technology itself, to structure the interaction, or provide instructions, so the quality of language may not be as rich during digital media use as it is in the absence of digital media.

McDaniel et al. find that objectively-measured smartphone use during their time with their infant is linked with depressed mood, but not when parents perceived themselves to be more responsive to their infant, suggesting parent judgments and perceptions of their parenting may be one potential area for intervention.

Lastly, Reich et al. answer an important question about differences between maternal and paternal perceptions and boundaries around digital media, finding that fathers tend to report longer time limits with digital media compared with mothers. For both parents, stronger beliefs in the benefits of media during infancy predicts greater digital media use during the toddler years (Reich et al.).

Context–Measurement precision

Another important area of emerging work includes how caregivers might be relying on screen media for child soothing, which has been found to have adverse effects on social-emotional development longitudinally (Radesky et al., 2023) but often findings are based on a single item response. Suh et al. create a reliable, valid rating scale to describe the use of digital media for soothing among infants, toddlers, and children, which is key to precisely characterizing this phenomenon in future work.

Conclusion

In summary, these articles highlight how the collective science of digital media and early childhood is moving toward a more holistic and inclusive understanding of the nuanced ways that families are using digital media. This Research Topic of publications highlights how digital content can shape children's for better or worse, limitations to young children's learning from digital devices, and how device ownership might modify exposures to online content. Importantly, it brings into view how parents and caregivers are using digital media, with potential implications on young children's development.

Ultimately, this body of work may contribute to the development of tailored interventions around digital media use for young children, and to create anticipatory guidance and counseling for families and children that fits with the realities of how they are using digital media. With more novel and precise ways of measuring the complexity of family media ecology, there is strong possibility of both developing effective digital media interventions and accurately measuring its outcomes for families.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Measuring parents' regulatory media use for themselves and their children

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Introduction: Parents often use media to manage their own or their child's emotions and behaviors, which is called "regulatory media use." While the use of media to alleviate negative emotions and behaviors may be helpful in the short-term, there may be negative consequences in the long-term (e.g., for children's development of self-regulatory skills). Research remains limited, often relying on a single, binary question asking whether a parent ever uses media to calm their child. To enable future research on the effects of regulatory media use, this paper described initial scale development efforts for measuring parents' regulatory media use for themselves (parent scale) and their children (child scale).

Methods: These scales were tested in an aggregate sample of parents with children 1–10 years old, and with each of three subsamples representing parents of children in infancy (15-25 months old), early childhood (2–5 years old), and middle childhood (5–10 years old).

Results: Overall, the results provide initial support for the scales as a reliable tool for measuring regulatory media use. Both scales for parents and children had a stable three-factor structure that held within each of the three subsamples. Further, both scales had predictive validity, each predicting parenting stress and child screen time.

Discussion: Building upon earlier studies that often focused on single items to measure regulatory purposes, the initial scales appear to capture a multifaceted range of regulatory uses of media. The comprehensive measurement of regulatory media use enabled by these scales can inform more effective and tailored media guidelines and interventions, and the potential applications and implications for future research are discussed.

KEYWORDS

regulatory media use, instrumental media use, self-regulation, parenting stress, screen time

Introduction

Over the past few decades, the development of more accessible and portable screen media devices has led to an increase in their use by parents and young children households (Rideout and Robb, 2020). With their widespread adoption, the use of portable screen devices has generally been addressed in combination with all other screens by health profession guidelines such as the American Academy of Pediatrics (AAP) and World Health Organization (WHO). Both organizations recommend a limit of 1 h of screen media use between ages 2 through 4 (World Health Organization, 2019) or 5 years (AAP Council on Communications and Media, 2016). Despite these guidelines, studies show that children between 2 and 5 years old use media for an average of 2½ h per day, much of it in the form of handheld devices (Rideout and Robb, 2020). To understand the drives of screen media use in young children, research is needed that examines motivations for mobile and traditional screen use through daily routines.

Parents of young children often use media to fulfill not only their own psychological needs but also a wide range of parenting-related needs (Beyens and Eggermont, 2014), potentially leading to longer daily media use for both parents and children. Here we adopt "*regulatory media use*" to describe parents' use of screen media (e.g., television programs, streaming videos, and mobile phone apps) to regulate their own or their child's emotional state, attention, or behavior, such as using media to mentally check out, escape from stress, or calm a fussy infant. Emotional and behavioral self-regulation (vs. dysregulation) is an important clinical concept that is used to describe how parents and children manage emotional states and problem-solve in the moment, rather than using a maladaptive coping approach (e.g., tantrum, aggression, and avoidance; Blair, 2010; Montroy et al., 2016). Therefore, more research is needed that examines to what degree regulatory needs drive the use of media and mobile devices play in families.

While offering temporary relief from negative emotional responses and behaviors, regulatory media use may not be beneficial in the long run, as it does not address the underlying causes of emotional or behavioral dysregulation (e.g., Radesky et al., 2016b, 2023; Gordon-Hacker and Gueron-Sela, 2020). Moreover, frequent regulatory media use may displace interactive activities that are crucial for the development of self-regulatory skills, especially for young children (e.g., Domoff et al., 2020; Coyne et al., 2021). Notably, opportunities for regulatory media use have been more prevalent with the ubiquity of mobile devices, such as smartphones and tablets (Radesky et al., 2016a; Kildare and Middlemiss, 2017; Floegel et al., 2021). Despite its prevalence, research on regulatory media use is limited, often constrained by coarse measures, such as a binary question asking whether a parent ever uses media to calm their child. This paper seeks to establish a broader conceptualization of regulatory media use that captures a range of media behaviors for both parents and children. Furthermore, we seek to test the degree to which a range of media motivations might correlate with the use of media to calm a child (i.e., the primary form of regulatory media use that has been studied previously; Radesky et al., 2016b, 2023; Coyne et al., 2021; Brauchli et al., 2024). To this end, this paper describes initial efforts in scale development for measuring regulatory media use for parents and children in three subsamples of parents with children collectively spanning ages 1–10 years. First, we review the extant literature on regulatory media use for parents and children.

Regulatory media use for parents

Scholars have advocated for examining parents' media use through a family system lens, highlighting the importance of understanding how parental media use is related to -being of families and individual members (Coyne et al., 2017; Barr et al., 2020, 2024). Research has consistently found that parental media use may be linked with child behavioral problems through less responsive parent-child interactions (Kirkorian et al., 2009; McDaniel and Radesky, 2018). As such, parental media use has emerged as a promising target for interventions, being a modifiable aspect of parenting behavior aimed at enhancing parenting practices, and further, improving child development outcomes.

Parents of young children often turn to screen media as a means of managing their own emotional responses. Studies have indicated that when parents use media to avoid or escape from their own emotional responses, such parental media use may have negative effects on parenting practices (Torres et al., 2021; Zhang et al., 2022). Specifically, parents who engage with media use as an escape from their immediate parental responsibilities with preschool-aged children reported higher levels of parenting stress and guilt compared to those who leverage media to seek out social support or parenting information (Torres et al., 2021). This suggests that while media use can offer a convenient and immediate way for parents to unwind, the potential long-term impact depends on the underlying reasons and contexts of use.

Yet, not all parental media use has negative effects on parent-child interactions. Parents engage with media for various beneficial reasons, such as staying connected with the world outside their home or keeping in touch with loved ones during the challenging early days of parenting (Radesky et al., 2016a; Wolfers, 2021; Coyne et al., 2022; Linder et al., 2022). Moreover, qualitative research has demonstrated that parents with children younger than 7 years old often utilize media to seek out information and social support when dealing with stress (Wolfers, 2021). Such findings suggest that parental media use can even enhance parent-child interactions and overall family wellbeing, highlighting the complexities of parental media use.

Regulatory media use for children

Parents also use media to regulate their young children's emotional responses and behaviors in several ways. Media can serve as a calming tool, allowing parents to manage their child's emotional responses (Zimmerman et al., 2007; De Decker et al., 2012; Bentley et al., 2016; Radesky et al., 2016b; Nikken, 2019). For instance, it can be used as a distractor during new or stressful situations, such as a doctor's appointment. Such media use not only helps to regulate the child's emotional responses and behavior but also provides the parents with temporary relief or time for themselves (Nabi and Krcmar, 2016). Additionally, child media use can control child behavior by keeping them entertained in public places, such as at restaurants (Radesky et al., 2014; Floegel et al., 2021). As such, parents use media for their young children with regulatory purposes across a variety of settings and contexts.

Several cross-sectional studies have found a link between using media to regulate child emotions and the child's development, including worse self-regulation (Radesky et al., 2016b) and problematic media use (Coyne et al., 2021). A study with preschoolers revealed that using media to calm children was associated with their weaker executive functioning (Danet et al., 2022). However, studies have not clarified whether or how regulatory media use for children is causally related to their socio-emotional development. It could be equally possible that weak child self-regulation leads to more regulatory media use for managing children's emotional responses and behavior, and that regulatory media use causes lower self-regulation by displacing opportunities for children to practice self-regulatory skills. To address this issue, Radesky et al. (2023) explored the bidirectional, longitudinal associations between mobile device use and development in preschoolers. They found that higher emotional reactivity and lower executive functioning in preschoolers predicted a greater likelihood of using mobile devices to calm them at baseline. However, only emotional reactivity was associated bidirectionally and longitudinally with device use for calming at 3- and 6-month follow-ups. These associations were found to be stronger in boys and children with higher levels of surgency defined as higher impulsivity, activity level and reward seeking. Such findings suggest that there may be concurrent and longitudinal relationships between regulatory media use and child socio-emotional development.

Lack of comprehensive measures of regulatory media use

Mixed findings around regulatory media use may be due to differences in how it is measured and interpreted. Prior research has primarily investigated parental media use in a qualitative way, either through interviews about parents' motivations for media use (Torres et al., 2021; Wolfers, 2021) or by observing moment-to-moment parental media use in public (Radesky et al., 2014; Linder et al., 2022), exploring various reasons for parental media use in daily parenting. These qualitative studies have provided rich data to develop quantitative scales to test hypotheses and the generalizability of findings, such as associations between regulatory media use and parent-child dynamics and child development in large representative studies. Based on these qualitative findings, researchers have adopted a nuanced approach by conceptualizing regulatory media use as a set of distinct activities based on specific purposes or aspects of use, rather than treating it as a single, overarching construct (Zhang et al., 2022). Some researchers have sought to expand on prior work by testing more comprehensive measures of the context of parent and child media use (Lunkenheimer et al., 2023). This work involved examining how parents manage, perceive, and regulate both their own and their children's screen media use. These findings highlight the importance of developing a comprehensive scale to measure and differentiate the various aspects of parental media use.

Similarly, previous studies on child regulatory use have relied on relatively simple measures that capture limited variability between and within families. To date, child regulatory media use has been assessed with a single question alongside other media-related reasons (e.g., Cingel and Krcmar, 2013; Nabi and Krcmar, 2016; Nikken, 2019). A few studies focused on child regulatory media use also used a single situation to assess media use for regulatory purposes (e.g., Radesky et al., 2016b, 2023; Coyne et al., 2021; Danet et al., 2022). However, using a simple checkbox or single question could mask variability in regulatory use of media between participants and obscure the association between regulatory media use and child outcomes including behavioral/emotional development. Moreover, there may be various ways or contexts in which parents use media to regulate their child's emotional responses and behavior that have different implications for child development (e.g., occupying children during a daily routine vs. using media to soothe a distressed child). For example, reasons for using media with children may differ across different types of media such that videos are commonly used to keep children occupied, whereas books are used for educational purposes and less frequently for occupying (Kucker et al., 2024). Thus, it is crucial to consider child regulatory media use as potentially multifaceted. Recently, some researchers have attempted to measure child regulatory media use across multiple situations (e.g., Coyne et al., 2021), but psychometric value and usefulness of these measures for assessing child regulatory media use have yet to be examined.

Current study

In the current study, we developed and tested two scales, one for parent regulatory use and one for child regulatory use to characterize different aspects of regulatory media use for parents and children. In the current paper, we evaluated these scales in an aggregate sample of 791 parents drawn from three subsamples of parents with children of different ages: Subsample 1: 15–25 months ($n = 251$); Subsample 2: 2–5 years ($n = 227$); Subsample 3: 5–10 years ($n = 313$). We first identified the internal consistency and factor structure of each scale (parent, child) via exploratory factor analysis using the aggregate sample. Then, we conducted confirmatory factor analysis within each subsample to test if the same factor structure exists in each child age group. Finally, we examined associations between the regulatory media use scales, parenting stress and child screen time, as a means of assessing predictive validity.

Materials and methods

Participants and recruitment

The aggregate sample for this study included 791 parents of children 1–10 years old drawn from three larger studies. We describe the subsamples and recruitment methods for each subsample next.

Subsample 1

Subsample 1 data were collected from parents of toddlers who were 15–32 months old between February 2022 and March 2023, as a part of a larger study on children's language development and media use. The study received Institutional Review Board approval. Participants were recruited either through CloudResearch ($n = 219$) or in-person from a lab-based study ($n = 33$). Inclusion criteria for parents were (1) being 18 years or older, (2) being the primary caregiver of a child aged 15–32 months, (3) their child being primarily exposed to English, and (4) their child having no major diagnosed developmental delay. For the CloudResearch sample, the HIT (Human Intelligence Task, i.e., specific study posting) was visible only to those workers with an approval rate of 95% or higher and had at least 100 HITS approved. Eligible participants were those who had indicated on their platform profile they had a child who was 1 or 2 years old at the time of the

TABLE 1 Summary of demographics for each subsample and the aggregated sample.

	Subsample 1	Subsample 2	Subsample 3	Aggregated sample
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Child age (years)*	1.99 (0.36)	3.9 (1.1)	7.3 (1.6)	4.7 (2.6)
Parent age (years)*	32.3(5.5)	35.5 (7.8)	38.3 (5.6)	35.6 (6.8)
Household income group (1–12)*	7.8 (3.0)	7.2 (3.3)	8.4 (3.3)	7.9 (3.3)
	n **(%)**	***n*** **(%)**	***n*** **(%)**	***n*** **(%)**
Parent race*				
White	201 (85.5)	124 (64.2)	248 (81.6)	573 (74.6)
Black or African-American	27 (11.5)	54 (28.0)	24 (7.9)	105 (13.3)
Asian or Pacific Islander	7 (3.0)	15 (7.8)	18 (5.9)	40 (5.1)
Not listed/Mixed race	13 (5.2)	23 (10.1)	14 (4.6)	50 (6.3)
Parent ethnicity*				
Hispanic/Latino	21 (8.4)	65 (28.6)	26 (8.3)	112 (14.2)
Non-Hispanic/Latino	227 (90.0)	158 (69.6)	278 (88.8)	662 (83.7)
Parent education*				
<4 year college	96 (38.6)	116 (51.5)	92 (30.1)	304 (38.9)
4 year college	85 (34.1)	90 (39.6)	80 (26.1)	255 (32.6)
More than 4 year college	68 (27.3)	21 (9.3)	134 (43.8)	223 (28.5)

Household income group was treated as a continuous variable a 12-point scale with points 1–10 representing increments of $10,000 (e.g., 1 = $0-$9,999, 10 = $90,000-$99,999) and two additional categories, 11 = $100,000-$149,999, 12 = $150,000 or greater). Asterisks indicate statistically significant differences across subsamples using linear regression for continuous variables (child age, parent age, and household income) and chi-square tests for categorical variables (parent race, parent ethnicity, and parent education).

survey. Only those with an IP address within the United States were eligible. Each worker was paid $5 for completing the survey. Extensive data cleaning was used to ensure data quality prior to analysis as per recommendations (Chmielewski and Kucker, 2020). This included a short pre-screener to ensure eligibility, consistent responding to check questions across the questionnaires, and logical responses to open-ended questions. A total of 72 additional participants were dropped prior to analysis for not completing the full set of questionnaires or for failing one or more of these screening checks. The in-person sample completed the same set of questionnaires after the family participated in an in-lab word learning experiment. Each participant was recruited through either an internal database of interested families or social media posts for the region (Stillwater, OK). These participants were compensated $20 combined for the in-lab component plus the questionnaires. Only one additional participant was dropped for not completing the full survey.

In the final analytic sample of 251 parents for Subsample 1, parents were 32.3 years old (*SD* = 5.5) on average. Of these, 27.6% of the parents had a household income above $100,000, 85.5% were White, 61.4% completed at least a bachelor's degree, and 8.4% were Hispanic or Latino. The average age of the target child was 2.00 years old (*SD* = 0.4). Because child age was recorded in years only in Study 3, child age was converted to years in whole numbers for Subsample 1 for subsequent analysis. For example, children 15–23.99 months old were represented as 1-year-olds in regression models that included age. See Table 1 for additional demographic information.

Subsample 2

Subsample 2 involved parents of young children, with data collection via an online survey from May to July 2023. The study received Institutional Review Board approval. Participants were recruited through Prolific. Inclusion criteria for parents were: (1) being 18 years or older, (2) residing with the child for at least 5 days a week, (3) proficiency in English to provide informed consent and complete the survey, and (4) having at least one child born between 2017 and 2019. Out of 243 survey completions, 15 participants were dropped for not meeting quality control criteria (at least 85% correct on seven attention check questions).

The final analytic sample for Subsample 2 included 227 parents, averaging 35.5 years old (*SD* = 7.8). Of these, 25.4% reported a household income above $100,000, 64.2% were White, 51.5% completed at least a bachelor's degree, and 27.6% were Hispanic or Latino. The average age of the target child was 3.9 years (*SD* = 1.13). Because child age was recorded in years only in Study 3, child age was converted to years in whole numbers for Subsample 2 for subsequent analysis. For example, children 25–35.99 months old were represented as 2-year-olds in regression models that included age. See Table 1 for additional demographic information.

Subsample 3

Subsample 3 data were collected from parents of school-age children via an online survey between February and March 2021,

 10.3389/fdpys.2024.1377998

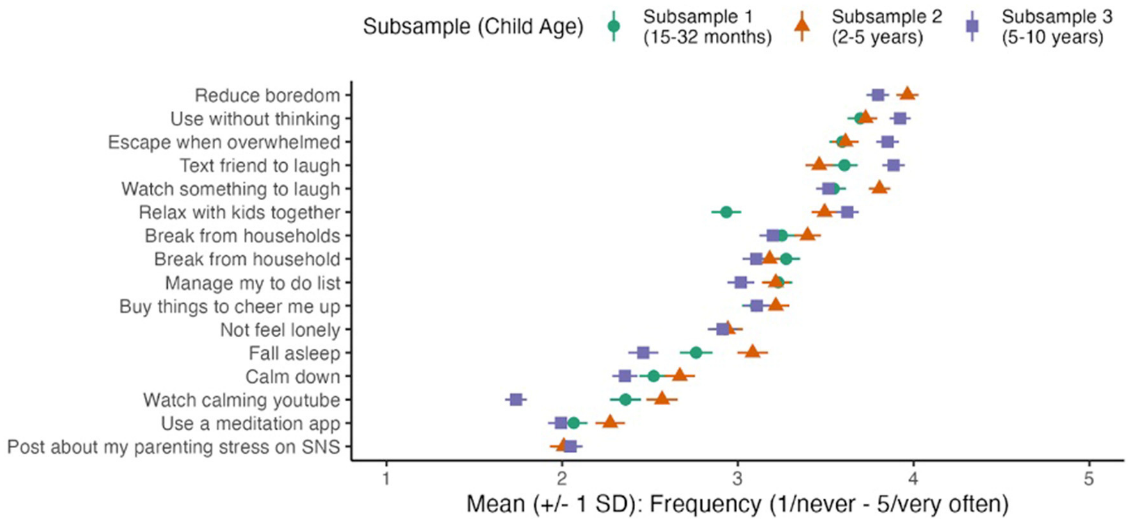

FIGURE 1
Mean and standard deviation for each item in the parent regulatory media use scale. Items were sorted in order of grand mean across the three subsamples.

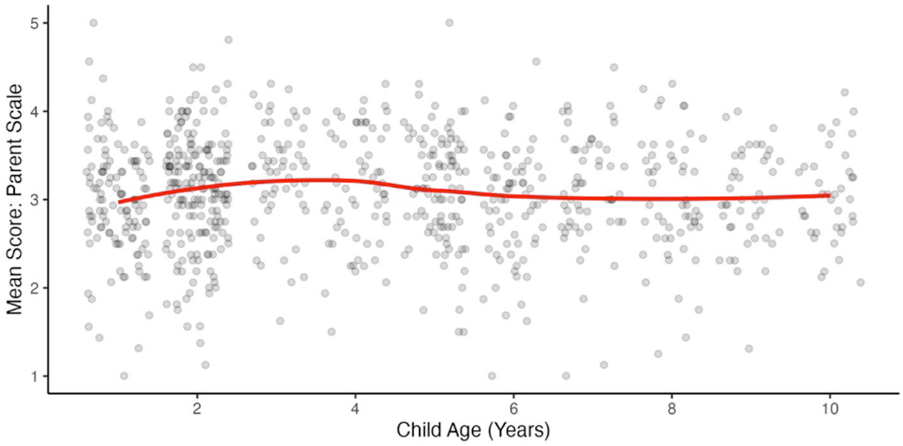

FIGURE 2
Overall score on the parent regulatory media use scale as a function of child age. Each dot represents an individual parent. The line represents the locally estimated sum of squares with a 95% confidence interval band.

as a part of a larger study on family experiences during the COVID-19 pandemic. The study received Institutional Review Board approval. Recruitment methods included postings on a university research participant registry; ads on social media; and flyers distributed by clinicians, parent-teacher organizations, and non-profit organizations. Inclusion criteria for parents were: (1) being 18 years or older, (2) being a parent or legal guardian, (3) having a child aged 5.00–10.99 years, (4) living with the child for most of the week, (5) having English proficiency, and (6) residing in Michigan. Of 413 interested parents, 313 were eligible and provided online informed consent. Ultimately, eight participants were dropped because they completed <½ of the survey.

The final analytic sample for Subsample 3 consisted of 313 parents, with an average age of 35.6 years ($SD = 6.8$). Of these, 41.1% had a household income above $100,000, 81.6% were White, 69.9% completed at least a bachelor's degree, and 8.3% were Hispanic or Latino. The average age of the target child was 7.3 years ($SD = 1.6$). See Table 1 for additional demographic information.

Measures

Regulatory media use scales

The regulatory media use scales for parents and children scales were designed to assess the motives behind parents' use of media to regulate their own or their child's emotional responses and behaviors. Items were developed based on themes and parent experiences identified through qualitative research with parents of young children (Radesky et al., 2016a; Torres et al., 2021). The parent scale comprised 16 items, including "To take a break and relax when my kids are showing difficult behavior and getting on my nerves," "To reduce feelings of boredom," and "To watch a calming YouTube video such as ASMR (Autonomous Sensory Meridian Response)." The child scale consisted of 12 items, including "When your child is upset (crying, yelling, showing big emotional responses) and needs to calm down," "To keep your child occupied as needed (not at a scheduled time of day), when you need to get a few things done or need some time to yourself," and "To help them fall asleep at night." Parents were asked to indicate the frequency with which they used media for each reason on a five-point Likert scale from 1 (never) to 5 (very often). A higher overall score in each scale represents a higher frequency of media use to regulate parents' own or their child's emotions and behaviors. The complete scales tested in this study can be found in Supplementary Tables 1, 2.

Parenting stress scale

Parenting stress was measured by the Parenting Stress Scale. The PSS is an 18-item self-report questionnaire that represents positive and negative themes of parenthood. Items include, "I am happy in my role as a parent," "Caring for my child(ren) sometimes takes more time and energy than I have to give," and "The major source of stress in my life is my child(ren)." Items are rated on 5-point Likert scales with response options ranging from 1 (strongly disagree) to 5 (strongly agree). The original investigation found good reliability ($\alpha = 0.83$). A higher score represents a higher level of self-reported parenting stress.

Child screen time

Child screen time was measured differently in Subsamples 1, 2, and 3. In Subsamples 1 and 2, parents reported the amount of their child's media use on both a typical weekday and a typical weekend as a numeric value using a slider scale that ranged from 0 to 8 h in 15-min increments. Parents used these slider scales for each of several activities, including TV/video viewing and digital app/game play. We computed the average daily time spent on TV/video and digital apps/games by averaging across both media activities and weighting by the number of days for weekdays (5 days/week) and weekends (2 days/week).

In Subsample 3, parents were asked to report their child's typical daily media usage, including TV, streaming video, live TV, and social media, on a scale ranging from 0 (none) to 8 (5 or more hours). The responses were averaged across media types to produce an overall score for each participant. To align with the continuous measure used in Subsamples 1 and 2, we used the midpoint of each time range in Subsample 3 (e.g., "16–30 min" became 23 min, "1–2 h" became 1.5 h). Therefore, child screen time was recalculated for minutes per week for all three subsamples, with a higher number indicating a greater amount of child screen time.

TABLE 2 Regression model of child age predicting the overall score on the parent regulatory media use scale (16 items).

	β (*SE*)
Child age	0.31 (0.15)
Child age (quadratic)	−0.28 (0.15)
Parent age	−0.14 (0.04)***
Parent race: Black or African American	0.38 (0.10)***
Parent race: Asian or Pacific Islanders	0.01 (0.16)
Parent race: Not listed or Mixed race	−0.05 (0.15)
Parent ethnicity: Hispanic/Latino	0.17 (0.11)
Intercept	−0.08
F-value	4.57***
R^2	0.03

Standardized betas are reported. Base group of the race category is White.
***$p < 0.001$.

Statistical analyses

First, we computed Cronbach's alpha to assess the internal consistency across all items and the overall homogeneity (Tavakol and Dennick, 2011) for the parent scale and the child scale. A higher alpha score indicates greater homogeneity, suggesting that the scale items more consistently measure the same underlying concept.

Next, we examined the overall parent and child scale scores as a function of child age. Given media use is sometimes found to vary non-linearly across age (Anand and Krosnick, 2005), we included both linear and quadratic terms for child age. We also included demographic characteristics as covariates if they (1) differed significantly by subsample as a proxy for child age (Table 1 and Supplementary Table 3), and (2) were significantly correlated with the dependent variable (Supplementary Tables 4, 5).

Third, we conducted an exploratory factor analysis (EFA) to identify the underlying factor structure of each scale, employing data from the aggregated sample across the three subsamples. We used the principal axis factoring approach with direct oblimin (oblique) rotation. In line with previous research finding that the popular Kaiser criterion (i.e., eigenvalue > 1.0) alone is insufficient (Velicer and Jackson, 1990), we also examined the scree plot to determine the optimal number of factors (see Supplementary Figures 1, 2). We followed recommendations by Howard (2016) to exclude items with low factor loadings (below 0.40 on the primary factor) or with cross-loading (loadings above 0.30 on other factors or a difference of <0.20 between the primary factor and other factors).

Subsequently, we conducted confirmatory factor analysis (CFA) using data drawn from each of the three subsamples. Thus, CFA was used to test whether the factor structure of the aggregated sample that was identified through EFA remained consistent in each child age group. We employed multiple fit indices alongside Chi-Square statistics to evaluate the model, as Chi-Square statistics can be influenced by sample size (Hu and Bentler, 1999). The additional fit indices considered were the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI),

TABLE 3 Summary of exploratory factor analysis for the parent regulatory media use scale (aggregated sample).

Item	Factor loadings		
	Factor 1	Factor 2	Factor 3
Escape (Factor 1)			
To take a break and relax when my kids are showing difficult behavior and getting on my nerves	**0.84**	−0.03	−0.07
To calm down in the moment, so that I don't yell at my kids or overreact to them	**0.73**	−0.02	0.19
Entertain (Factor 2)			
Without even thinking about it, I grab my phone when I'm bored or upset	0.10	**0.63**	−0.12
To reduce feelings of boredom	−0.08	**0.62**	−0.01
Calm (Factor 3)			
To use a meditation app (such as Calm or Headspace)	−0.01	−0.04	**0.72**
To watch a calming YouTube video such as ASMR	0.05	−0.05	**0.69**
Other Items (did not load on a factor)			
To watch something that will make me laugh	−0.06	0.43	0.27
When others in my household are stressing me out, I take a break and get on my phone	0.50	0.37	0.03
To not feel as lonely during the day	0.20	0.37	0.18
To help me fall asleep (for example, listening to music or watching videos)	0.10	0.15	0.34
To text or contact a friend who can help me out or make me laugh	−0.03	0.37	0.18
To manage my "to do list," which reduces my stress	0.04	0.12	0.34
To mentally "check out" or escape when the day has been overwhelming	0.40	0.37	−0.12
To post something about my current parenting stresses on social media	0.13	0.09	0.37
To buy things online, which generally cheers me up	0.01	0.31	0.33
To relax with my kids by watching a show together	−0.04	0.23	0.30

Significant factor loadings over 0.40 with a numerical difference between the primary factor and any alternative factors <0.20 appear in bold. N = 768, after dropping 23 with missing values on one or more indicators.

and the Tucker-Lewis Index (TLI). Acceptable and good fit were indicated by CFI and TLI values >0.90 and 0.95, respectively, combined with RMSEA values <0.08 (Hu and Bentler, 1999).

Lastly, we assessed predictive validity by testing associations between each factor in both parent and child scales and other relevant variables. First, we calculated each factor score by averaging the items included in the factors identified in the exploratory factor analysis. Then, for the parent scale, we examined associations with parenting stress. For the child scale, we explored associations with parenting stress as well as child screen time. A similar process was used to identify demographic covariate, but with the overall score of each scale (i.e., 16 items for the parent scale, 12 items for the child scale). In addition, we calculated correlations between factors within each scale (parent and child scale) and across the two scales.

Results

Parent regulatory media use scale

The mean score for the parent scale across all 16 items and subsamples was 3.08 ($SD = 0.63$) out of 5, roughly equivalent to "Sometimes." The original scale with all 16 items demonstrated satisfactory internal consistency overall ($\alpha = 0.82$) and within each subsample (Subsample 1: $\alpha = 0.82$; Subsample 2: $\alpha = 0.83$; Subsample 3: $\alpha = 0.81$). However, there was substantial variability among the 16 items and across the three subsamples, as illustrated in Figure 1.

Associations with demographic characteristics

We examined whether child age predicted the overall score of the 16 items on the parent scale. The overall score of the 16 items on the parent scale is plotted as a function of child age in Figure 2. The regression model included parent race, parent ethnicity and parent age as covariates because they differed across the subsamples (Table 1) and significantly predicted the dependent variable (see Supplementary Tables 4, 5). Results from the regression model can be found in Table 2. Parents' overall regulatory media use score (16 items) did not vary as a function of child age. However, there was a significant effect of race such that Black/African American parents reported using media for regulatory purposes more frequently than White parents ($\beta = 0.38$, $p < 0.001$). In addition, the overall score of the 16 items on the parent scale decreased with parent age ($\beta = -0.14$, $p < 0.001$).

Exploratory factor analysis

A three-factor structure emerged from EFA for the parent scale with high factor loadings within each factor and minimal cross-loading (Table 3). This model explained 36% of the variance among the items in the parent scale. Factor 1, "Escape" ($\alpha = 0.77$), represents media use to take a break or calm down to manage parenting stress. Factor 2, "Entertain" ($\alpha = 0.55$) represents media use to reduce parents' boredom. Factor 3, "Calm" ($\alpha = 0.69$), characterizes media use for relaxation and calming purposes, such as watching calming YouTube videos. Descriptive statistics, including the mean, standard deviation, and reliability for each factor in each subsample, are presented in Table 4. Two items (i.e., "to watch something that will make me laugh," "to text or contact a friend who can help me out or make me laugh") were on the borderline of our established criteria for inclusion in Factor 2. A *post-hoc* analysis tested whether including these two items in the factor would improve its reliability (see Supplementary Table 6). However, it did not markedly increase the reliability with these additional items ($\alpha = 56$), so we kept the original selection criteria, including only the two items in Factor 2.

Confirmatory factor analysis

We conducted CFA to assess the extent to which the 3-factor structure in the parent scale was an acceptable fit for data within each of the three subsamples. The model resulting from the EFA demonstrated acceptable fit for preschool-age (Subsample 2) and school-age children (Subsample 3) but did not quite meet our criteria for acceptability for the infant subsample (Subsample 1) on all 3 indicators. See Table 5.

Predictive validity: predicting parenting stress

We first computed a Pearson correlation between the overall score of the 16 items on the parent scale and parenting stress to measure the relation between these two variables. The overall score of the 16 items on the parent scale was correlated with parenting stress ($r = 0.24$, $p < 0.001$). Next, we fit a multiple regression model to predict parenting stress from the three factors identified through EFA. We did not include any demographic covariates in the model, as none of the demographic variables were significant predictors of parenting stress (see Supplementary Table 7). Table 6 presents the results of the multiple regression analysis. The overall model was significant [$F_{(3,764)} = 26.72$, $p < 0.001$], explaining 9% of the variance in parenting stress. Of the three factors in the parent scale, only one factor, using media to escape from family stress, was a significant predictor of increased parenting stress (Escape: $\beta = 0.30$, $p < 0.001$). This was not true for parent-reported use of media to entertain themselves or to use calming media (Entertain: $\beta = -0.05$, $p = 0.187$; Calm: $\beta = 0.02$, $p = 0.641$).

Child regulatory media use scale

The mean score for the child scale across all 12 items and subsamples was 2.20 ($SD = 0.71$), roughly equivalent to "Rarely." Similar to the findings in the parent scale, internal consistency for all 12 items in the child scale was satisfactory ($\alpha = 0.87$). This

TABLE 4 Descriptive statistics of factors in the parent regulatory media use scale.

	Subsample 1 (15–32 months)		Subsample 2 (2–5 years)		Subsample 3 (5–10 years)		Aggregated sample	
	M (SD)	Cronbach's alpha	*M (SD)*	Cronbach's alpha	*M (SD)*	Cronbach's alpha	*M (SD)*	Cronbach's alpha
Escape (Factor 1)	2.90 (1.14)	0.78	2.93 (1.15)	0.79	2.73 (1.16)	0.74	2.84 (1.16)	0.77
Entertain (Factor 2)	3.75 (0.92)	0.62	3.85 (0.80)	0.49	3.86 (0.88)	0.55	3.82 (0.87)	0.55
Calm (Factor 3)	2.21 (1.18)	0.76	2.42 (1.15)	0.70	1.87 (0.99)	0.60	2.12 (1.12)	0.69

TABLE 5 Model fit measures for confirmatory factor analysis of the regulatory media use scales.

Scale	Subsample	χ^2	*df*	CFI	TLI	RMSEA (90% CI)
Parent scale	Subsample 1	315.03	15	0.948	0.871	0.111 (0.073–0.153)
	Subsample 2	228.52	15	0.967	0.918	0.078 (0.027–0.129)
	Subsample 3	285.41	15	0.967	0.918	0.080 (0.035–0.128)
Child scale	Subsample 1	86.30	51	0.964	0.954	0.053 (0.034–0.071)
	Subsample 2	97.33	51	0.951	0.936	0.069 (0.048–0.090)
	Subsample 3	136.18	51	0.906	0.878	0.075 (0.060–0.089)

χ^2, χ^2 after Satorra-Bentler correction; df, degrees of freedom; CFI, Comparative Fit Index; TLI, TuckerLewis Index; RMSEA, Root Mean Square Error of Approximation; CI, Confidence Interval.

TABLE 6 Regression model of the factors in the parent regulatory media use scale predicting parenting stress.

	β *(SE)*
Escape	0.30 (0.04)***
Entertain	−0.05 (0.03)
Calm	0.02 (0.03)
Intercept	0.03 (0.03)
F-value	26.72***
R^2	0.09

Standardized betas are reported.
***p < 0.001.

consistency was also found within each subsample (Subsample 1: $\alpha = 0.87$; Subsample 2: $\alpha = 0.89$; Subsample 3: $\alpha = 0.79$). Again, however, there was substantial variability across the 12 items and the three subsamples, as shown in Figure 3.

Associations with demographic characteristics

Mirroring the analysis of the parent scale, we tested the degree to which child age predicted the overall score of the 12 items in the child scale. The overall score of the 12 items in the child scale is plotted as a function of child age in Figure 4. In this case, the regression model included parent age, parent race, parent ethnicity, parent education, and household income, each of which differed across the subsamples (Table 7) and significantly predicted the dependent variable (see Supplementary Tables 4, 5). The overall model was significant, $F_{(10,735)} = 15.49$, $p < 0.001$ and explained 16% of the variance. Model results revealed significant linear and quadratic effects of child age: (linear: β = 0.56, $p <$ 0.001; quadratic: β = −0.71, $p <$ 001). The negative quadratic term reflects the inverted-U pattern evident in Figure 4 showing that child regulatory behaviors were more frequently reported between 2 and 5 years than for either younger or older groups. In addition, there was a significant effect of parent race and parent education on the overall score of the 12 items on the child scale. Black/African American parents reported using media for regulatory purposes for their children more frequently than did White parents (Black/African American: β = 0.84, $p < 0.001$). In addition, the overall score of the 12 items on the child scale were lower for parents with an advanced degree than those with a 4-year degree (β = −0.22, $p = 0.01$).

Exploratory factor analysis

Similar to the analysis with the parent scale, we conducted EFA to identify if there are any distinct factors within the child scale. As a result, a three-factor structure emerged, accounting for 52% of the variance among the items (Table 8). Factor 1, "Regulate" ($\alpha = 0.85$), represents the use of media to regulate a child's emotional responses and behavior. Factor 2, "Occupy" ($\alpha = 0.76$), represents the use of media to occupy a child so the parent can take a break or get things done. Factor 3, "Sleep" ($\alpha = 0.83$), represents the use of media to help a child fall or stay asleep. All items were retained. Descriptive statistics, including the mean, standard deviation, and reliability for each factor in each subsample, are presented in Table 9.

Confirmatory factor analysis

The model from the EFA demonstrated acceptable fit on at least two of the three indicators within each of the three subsamples. See Table 5. These findings suggest that the three-factor structure in the scale is robust across different child age groups.

Predictive validity: predicting parenting stress and child screen time

We first computed a Pearson correlation between overall score of the 12 items on the child scale and parenting stress, which indicated these variables were significantly correlated ($r = 0.21$, $p <$ 0.001). Next, we fit a multiple regression model to predict parenting stress from the three factors identified through EFA. As with the parenting scale, no demographic covariates were included in this model predicting parenting stress. See Table 10 for the results of the multiple regression. The overall model was significant, $F_{(3,769)} =$ 10.98, $p < 0.001$, and explained 4% of the variance. Parent-reported media use to regulate a child's emotional responses and behaviors and to occupy a child significantly predicted greater parenting stress (Regulate: β = 0.12, $p = 0.007$; Occupy: β = 0.10, $p =$ 0.007). In other words, parents who report having their children use media as a way to regulate their children's emotional responses and behaviors and to occupy them reported greater parenting stress. This was not true for the factor capturing parent-reported use of media to help children sleep (β = 0.02, $p = 0.647$).

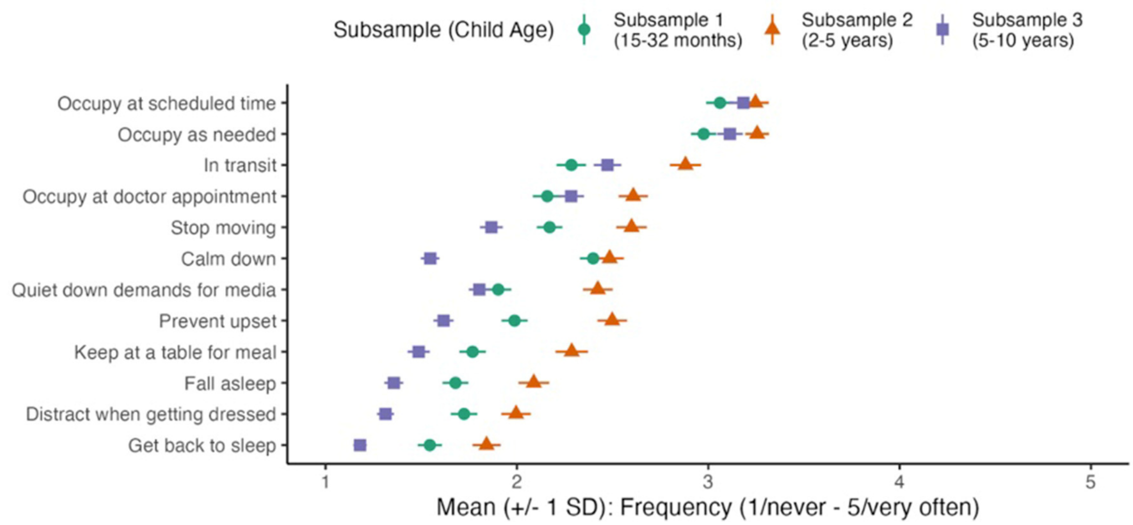

FIGURE 3
Mean and standard deviation for each item in the child regulatory media use scale. Items were sorted in order of grand mean across the three subsamples.

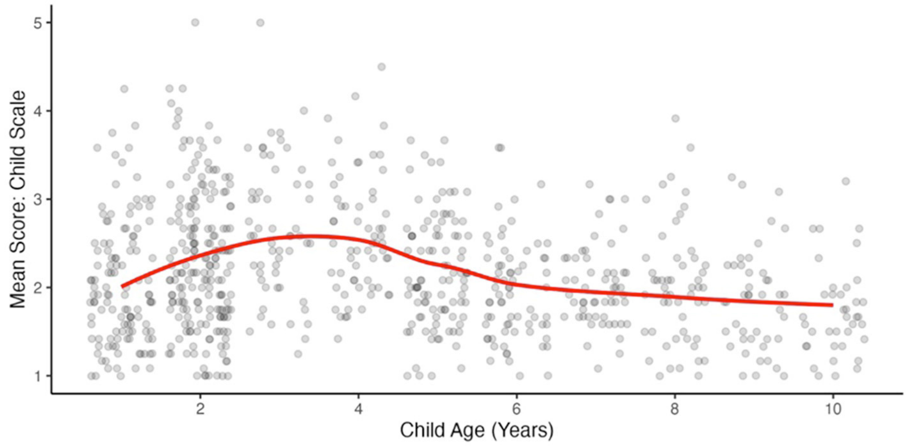

FIGURE 4
Overall score on the child regulatory media use scale as a function of child age. Each dot represents an individual parent. The line represents the locally estimated sum of squares with a 95% confidence interval band.

Next, we computed predictive validity using child screen time as a dependent variable. The overall score of the 12 items on the child scale score was significantly correlated with child screen time ($r = 0.14$, $p < 0.001$). As with parenting stress, we fit a multiple regression model with the three factors identified through EFA. We also included child age, parent age, and parent race as covariates because they were unevenly distributed across the three subsamples and predicted child screen time (see Supplementary Table 7). See Table 10 for the results of the multiple regression. The overall model was significant, $F_{(8,729)} = 7.94$, $p < 0.001$, and explained 7% of the variance. Results showed that parent-reported media use to regulate a child's emotional responses and behaviors significantly predicted greater child screen time ($\beta = 0.10$, $p = 0.032$). This was not true for the factors capturing parent-reported use of media to occupy their children or to help their children sleep (Occupy: $\beta = 0.03$, $p = 0.385$; Sleep: $\beta = 0.08$, $p = 0.073$). Additionally, child screen time increased as a function of child age ($\beta = 0.23$, $p = < 0.001$).

Associations between factors in the parent regulatory media use scale and child regulatory media use scale

Correlations among the factors in the parent and child scales are presented in Table 11. Notably, most of the factors within each scale were significantly correlated (parent: $r = 0.24$ to 0.31; child: $r = 0.13$ to 0.56). The only exception was the correlation between

TABLE 7 Regression model of child age predicting the child regulatory media use scale.

	β *(SE)*
Child age	0.56 (0.16)***
Child age (quadratic)	−0.71 (0.15)***
Parent age	−0.02 (0.04)
Household income	−0.04 (0.04)
Parent race: Black or African American	0.84 (0.10)***
Parent race: Asian or Pacific Islanders	0.26 (0.15)
Parent race: Not listed or Mixed race	0.26 (0.13)
Parent ethnicity: Hispanic/Latino	0.18 (0.10)
Parent education: <4 year college	0.02 (0.08)
Parent education: advanced (>4 year college)	−0.22 (0.09)*
Intercept	−0.13 (0.06)*
F-value	15.49***
R^2	0.16

Standardized betas are reported. Base group of the race category is White. Base group of the parent education category is 4 year college.
***p < 0.001; *p < 0.05.

the factors in the parent scale for reducing boredom and using calming media [$r_{(765)} = 0.02$, $p = 0.67$]. In addition, most of the correlations between the parent and child factors were significant. Specifically, the more parents used media to escape from their own family stress, the more they allowed their child to use media to regulate their child's emotional responses and behaviors, occupy their child, and help their child sleep [Regulate: $r_{(765)} = 0.41$, $p < 0.001$; Occupy: $r_{(765)} = 0.27$, $p < 0.001$, Sleep: $r_{(765)} = 0.22$, $p < 0.001$]. The frequency with which parents use media to reduce their own boredom was also correlated with the frequency with which they allowed their children to use media to regulate their children's emotional responses and behaviors and occupy their children [Regulate: $r_{(765)} = 0.12$, $p < 0.001$; Occupy: $r_{(765)} = 0.22$, $p < 0.001$]. In addition, the more parents used calming media for themselves, the more they allowed their child to use media to regulate their child's emotional responses and behaviors, occupy their child, and help their child sleep [Regulate: $r_{(765)} = 0.40$, $p < 0.001$; Occupy: $r_{(765)} = 0.09$, $p = 0.02$, Sleep: $r_{(765)} = 0.35$, $p < 0.001$].

Discussion

In this study, we aimed to evaluate psychometric properties of two newly developed scales designed to measure the multifaceted aspects of regulatory media use for parents and children. We focused on three subsamples representing parents of infants (15–32 months old), preschool-age children (2–5 years old), and school-age children (5–10 years old). Through exploratory factor analysis on the aggregated sample, we identified factors within each scale, which were subsequently confirmed in each age-specific subsample. Of particular interest were factors representing media use to regulate parents' and children's emotional responses and behaviors. These factors showed acceptable internal consistency and were related to parenting stress (parent and child scales) and child screen time (child scale). Additionally, we found significant correlations between the factors within each scale (parent and child) and across the scales.

Measuring regulatory media use for parents

The scale developed to measure parents' regulatory media use demonstrated reliable psychometric properties, as indicated by its overall reliability of $\alpha = 0.82$ for the full set of 16 items. This high reliability indicates a robust internal consistency within the scale, highlighting its effectiveness in assessing how parents use media for regulatory purposes in their everyday life. However, there was substantial variability among the individual items in the scale, as well as across the three subsamples. Such variability indicates that the extent to which parents use media for regulatory purposes may vary by specific situational contexts, varying ages of their children, or other demographic differences that vary across subsamples. These nuances led to further exploration of the scale's associations with demographics, as well as potential distinct factors within the scale.

We examined whether demographics significantly predict parents' overall regulatory media use. Child age did not emerge as a significant predictor. This finding suggests that the developmental stage of children may not greatly impact how parents use media themselves for their own regulatory purposes. Instead, our analysis revealed that both parent race and parent age were significant predictors of parents' regulatory media use. Specifically, Black/African American parents reported using media more frequently for their own regulatory purposes compared to White parents. However, it is worth noting that our subsequent analyses did not find a significant association between race and overall parenting stress. This could indicate that media serves as a more commonly used resource for Black/African American parents compared to White parents, not necessarily driven by underlying group differences in wellbeing. Nevertheless, it is necessary to delve deeper into the underlying reasons for these differences in the future research. Such an exploration can include determining whether these differences are associated with attitudinal variations, higher need for emotion regulation support due to systemic discrimination, or differences in media content and design features (e.g., use of targeted, engagement-prolonging digital design), to name a few. Additionally, our results showed a decrease in the overall score on the parent scale with increasing parent age. This suggests that younger parents are more likely to use media as a regulatory tool for themselves, possibly due to greater familiarity with or reliance on digital technologies. Overall, these findings highlight the complex ways in which parents use media for regulatory purposes. The associations with demographic factors such as parent race and age highlight the nuanced nature of media use in parenting, necessitating a more detailed exploration of these dynamics in future studies.

The EFA of the parent scale identified a three-factor structure: using media to escape from family stress, to entertain themselves,

TABLE 8 Summary of exploratory factor analysis for the child regulatory media use scale (aggregated sample).

Item	Factor loadings		
	Factor 1	Factor 2	Factor 3
Regulate (Factor 1)			
To prevent your child from getting overwhelmed or upset in a difficult or new situation	**0.73**	−0.02	0.06
To keep them at the table or help them eat at mealtime	**0.72**	−0.05	−0.07
To distract them while you get them dressed or ready for school	**0.71**	−0.06	0.00
To quiet down your child's demands for their favorite apps, video games, or shows	**0.66**	0.02	0.02
To stop your child from moving around too much when they are being too active or hyper	**0.65**	0.12	−0.01
When your child is upset (crying, yelling, showing big emotions) and needs to calm down	**0.65**	0.03	0.09
To keep your child occupied at doctor's appointments	**0.54**	0.06	−0.01
When in transit (riding in your car or on public transit) with your child	**0.43**	0.08	0.05
Occupy (Factor 2)			
To keep your child occupied as-needed (not at a scheduled time of day), when you need to get a few things done or need some time to yourself	−0.02	**1.00**	0.01
To keep your child occupied at a scheduled time of day, while you get things done (such as making dinner)	0.12	**0.57**	0.05
Sleep (Factor 3)			
To help them fall asleep at night	−0.06	0.00	**0.91**
To help them fall back to sleep when they've woken up in the middle of the night	0.16	0.00	**0.72**

Significant factor loadings over 0.40 with a numerical difference between the primary factor and any alternative factors < 0.20 appear in bold. N = 773, after dropping 18 with missing values on one or more indicators.

and to calm themselves. The first factor highlights the role of media use as a respite from the pressures and challenges of family life. This aligns with previous findings that suggest media can serve as a temporary escape providing parents with a chance to recover and take some rest (Radesky et al., 2016a; Torres et al., 2021; Zhang et al., 2022; Lunkenheimer et al., 2023). The second factor for the current study indicates that media is also used as a tool for entertainment, motivated by intentional or habitual pleasure-seeking or boredom reduction. The third factor captures the deliberate choice of media content that provides soothing or relaxation. This represents a strategic use of media to manage one's emotional state, particularly in seeking tranquility or reducing anxiety.

The results of the CFA in this study largely supported the EFA findings on the parent scale, particularly in terms of its structural consistency across three distinct age groups of children. However, the findings were not as robust in the infant subsample. This discrepancy may be due to the unique challenges faced by parents of infants, such as greater variability in their work schedules and access to and use of out-of-home childcare (Corkin et al., 2018). Despite these differences, the consistent factor structure within each age group suggests that the ways in which parents use media to regulate themselves (i.e., to escape family stress, reduce boredom, and utilize calming media) are common experiences among parents of young children, regardless of the specific age of their children. This pattern indicates that parents' regulatory use of media is an integral part of their daily lives (Livingstone, 2007), possibly serving as coping mechanisms for themselves. That is, the frequent reliance on media for regulatory purposes may reflect the persistent stressors or challenges parents encounter during the early years of their child's life. Despite relatively low consistency in the factor structures with the infant subsample, there was still high internal consistency among the original set of 16 items in the infant sample. This finding may suggest that while the overall scale is useful, it may reflect a more general tendency toward regulatory media use in this group rather than a constellation of distinct motivations. Future research should aim to replicate these findings and refine the scale, with a particular focus on items that capture meaningful variation among parents of young children.

Additionally, the overall parent scale score predicted parenting stress, particularly through one of its factors focusing on media use as an escape from family stress. This finding provides predictive validity, indicating parents who report more parenting stress overall are indeed more likely to report using media to self-regulate, and in particular to escape from family stress. Additional analyses found that parents with younger children reported frequent media use for themselves to escape from household stress. Moreover, this finding aligns with recent research showing that parent stress is positively associated with parental media use to regulate their own emotions and to ease the burden of caregiving (Lunkenheimer et al., 2023). This group of parents often use media as a means to momentarily distance themselves from the immediate demands

TABLE 9 Descriptive statistics of factors in the child regulatory media use scale.

	Subsample 1 (15–32 months)		Subsample 2 (2–5 years)		Subsample 3 (5–10 years)		Aggregated sample	
	M (SD)	Cronbach's alpha	*M (SD)*	Cronbach's alpha	*M (SD)*	Cronbach's alpha	*M (SD)*	Cronbach's alpha
Regulate (Factor 1)	2.04 (0.79)	0.87	2.47 (0.85)	0.86	1.80 (0.62)	0.77	2.01 (0.82)	0.85
Occupy (Factor 2)	3.02 (0.96)	0.72	3.25 (0.86)	0.66	3.15 (1.12)	0.82	3.14 (1.01)	0.76
Sleep (Factor 3)	1.61 (0.94)	0.80	1.94 (1.09)	0.87	1.27 (0.65)	0.71	1.58 (0.94)	0.83

TABLE 10 Regression model of the factors in the child regulatory media use scale predicting parenting stress and child screen time.

	Model 1	Model 2
	Parenting stress	Child screen time
	β *(SE)*	β *(SE)*
Regulate	0.12 (0.04)**	0.10 (0.15)*
Occupy	0.10 (0.04)**	0.03 (0.04)
Sleep	0.02 (0.04)	0.08 (0.07)
Child age		0.23 (0.04)***
Parent age		0.02 (0.04)
Parent race: Black or African American		0.14 (0.11)
Parent race: Asian or Pacific Islander		−0.08 (0.17)
Parent race: Not listed or Mixed race		0.10 (0.15)
Intercept	0.02 (0.03)	−0.02 (0.04)
F-value	10.98***	7.94***
R^2	0.04	0.07

Standardized betas are reported. The base group of the race category is White.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

TABLE 11 Bivariate correlations between factors in the parent regulatory media use scale and child regulatory media use scale.

	Parent scale			Child scale		
	1	2	3	4	5	6
Parent scale						
1. Escape						
2. Entertain	0.31***					
3. Calm	0.24***	0.02				
Child scale						
4. Regulate	0.41***	0.12***	0.40***			
5. Occupy	0.27***	0.22***	0.09*	0.40***		
6. Sleep	0.22***	−0.02	0.35***	0.56***	0.13***	

***$p < 0.001$; *$p < 0.05$.

and stress of managing a household with young children (Torres et al., 2021). Therefore, the parent scale (and particularly its escape factor) effectively captures the extent to which parents, especially those with younger children, use media and the reasons for their media use.

Measuring regulatory media use for children

The scale developed to assess regulatory media use for children also demonstrated reliable psychometric properties, as indicated by its overall reliability of $\alpha = 0.87$ across 12 items. Similar to the parent scale, there was substantial variability both across the items and across the three age groups. This variability suggests potential patterns in how parents utilize media to regulate their children, particularly in specific contexts and across different child age ranges. These nuances led to an additional investigation into its correlations with demographic variables and the possibility of unique factors within the scale.

In our analysis examining demographic predictors of the overall score of child regulatory media use, we found that child age was a significant predictor. There were both linear and quadratic associations between child age and the overall score on the child scale. This finding suggests that parents' use of media as a regulatory tool does not uniformly increase or decrease with a child's age. Rather, this type of media use increases during infancy and toddlerhood and reaches its peak during early childhood, an age range where behavior management can be the most challenging. This pattern can be linked with developmental changes in negative emotionality and self-regulation. Young children's negative emotionality begins to develop during their first 2 years of life (Rothbart and Bates, 2006; Lipscomb et al., 2011; Brauchli et al., 2024), and it peaks around early childhood. High levels of negative emotionality in childhood are linked to various behavioral problems, including internalizing (Ghassabian et al., 2014; Rodrigues et al., 2022) and externalizing behavior problems (Lipscomb et al., 2012; White et al., 2013; Perry et al., 2018). While it is an important developmental task for young children to master their emotional and behavior responses, young children often depend on external support to acquire those skills (Kopp, 1989; Coyne et al., 2021). A recent longitudinal study showed that there was a bidirectional relationship between 1 and 3-year-old children's screen time and their negative affect (Brauchli et al., 2024), suggesting that parents were using media to regulate their young children's negative emotions. Subsequently, there tends to be a decrease in the frequency and intensity of negative emotionality and externalizing behavior from preschool to late elementary school (Murphy et al., 1999; Sallquist et al., 2009), likely due to development of language skills (Skibbe et al., 2011, 2019; Vallotton and Ayoub, 2011), impulse inhibition (Fujita, 2011; Hofmann et al., 2012), and other contributors to self-regulation facilitated by prefrontal cortex development (Gillespie et al., 2018; Jadhav and Boutrel, 2019). Within early childhood, different aspects of self-regulation develop at varying times and rates; typically, emotional regulation develops before behavioral self-regulation (Howse et al., 2003). As self-regulation develops during early childhood, parents may find themselves using media less frequently to manage their children's emotional responses and behaviors than before.

Additionally, parent race and parent education were also significant predictors of the overall child scale score. This finding implies that structural factors may play an important role in shaping parental attitudes and practices regarding media use with children. These attitudes and practices may include many different aspects, from how appropriate and effective parents perceive media to be for their children (Rideout and Robb, 2020), to their access to various media devices, their familiarity with different types of media content, and their access to other parenting resources that may influence parental stress and burnout, such as affordable childcare (e.g., Kroshus et al., 2023). Prior studies have demonstrated that the lack of parent resources, including money, time, and energy, find it difficult to limit their children's media use (Evans et al., 2011; Minges et al., 2015; Nikken and Opree, 2018). Therefore, it is likely that parents who lack other means to provide alternative activities due to financial or other life pressure may be more likely to use media to regulate their children's emotions and behaviors. Overall, these findings highlight the complexity of structural factors associated with how parents use media with their children. This complexity underscores the need for future research to extend its focus beyond simply representative samples. Therefore, it is essential to examine diverse populations, acknowledging the varied socioeconomic, cultural, and individual contexts that shape family media use. Such an approach will ensure that findings are more universally applicable as well as be sensitive to the needs of different family dynamics.

The EFA identified a three-factor structure within this scale: using media to regulate children, to occupy children, and to help children sleep. The first factor reflects the strategic use of media to manage a child's emotional state or behavior. This strategic use captures how parents employ media as a tool to manage their child's emotional responses and behaviors, and is consistent with previous literature (Bentley et al., 2016; Radesky et al., 2016b). In addition, this factor may be associated with young children's socio-emotional development. Existing literature has found that the concurrent and longitudinal associations between using media to calm down young children and their socio-emotional development, including socio-emotional difficulties (Radesky et al., 2016a), as well as executive functioning and emotional reactivity (Radesky et al., 2023). In our scale development study, we did not examine the potential associations between this "Regulate" factor and children's socio-emotional development because appropriate measures of the latter were not available in each cohort. Future work should explore these associations and their implications for child development.

The second factor demonstrates media use for keeping the child occupied when parents need to be physically absent or are busy with other tasks. This type of media use has been described as a "babysitter" in previous studies (De Decker et al., 2012; Knowles et al., 2015; Bentley et al., 2016; Nikken, 2019). Within the context of parent-child dynamics, this type of media use fulfills the parents' practical needs and goals at specific times of day, while the first factor, to regulate a child's emotional responses and behaviors, is more related to the child's in-the-moment needs (Nikken, 2019).

The third factor captures media use in establishing or supporting a child's sleep routines. While previous research has found that media use either before or in the middle of the night to help children fall back to sleep when they wake up may be associated with lower quality sleep (Garrison et al., 2011; Hisler et al., 2020), this factor demonstrates that parents do use media to some extent to regulate their children's sleep. Future research should examine whether such regulatory media use is associated with sleep onset, quality, and duration. Together, these three factors in the child scale highlights the multifaceted role that media plays in the lives of young children.

The CFA in our study found an acceptable fit of the three-factor structure within each age group on at least one metric of model fit. This consistency suggests that the child scale effectively captures different aspects of regulatory media use for children with a wide range of ages. The child scale is consistent with prior research but advances the field that has predominantly relied on single item measurement. The development of a more sensitive and reliable child scale in the present study will improve measurement of child regulatory media and allow researchers to better predict child outcomes.

We further tested the predictive validity by examining associations between identified factors in the child scale and both parenting stress and child screen time. First, parents who reported higher parenting stress reported more frequent media use to regulate their child's emotional responses and behaviors, as well as to occupy them. This finding aligns with the previous research (Elias and Sulkin, 2019), which shows that parents often use media to fulfill their own needs. It suggests that parents experiencing parenting-related stress might rely more heavily on media as a regulatory tool for their children, possibly due to heightened reactivity to child behavior or a lack of alternative resources or coping strategies (Shin et al., 2021). Additionally, greater parent-reported child media use to regulate a child's emotional responses and behaviors was the only factor that predicted an increase in overall child screen time. Parents, particularly of young children, are gatekeepers of their child's media use, initiating and terminating it. Hence, parents who frequently use media to regulate their child are more likely to allow extended child screen time, such as watching TV/video or playing apps/games. In contrast to the intentional use of media to occupy children, this may be due to the on-demand nature of media use as a tool for emotion regulation, to which children may become habituated and keep expecting when they feel distressed. The findings may also suggest that using media for children at predictable times of the day might be a strategy for limiting overall child screen time, whereas using media to regulate children's emotional responses or behaviors could potentially lead to increased screen time. The overarching implication of these findings is that significant associations exist between parenting stress, child screen time, and the two factors (regulate and occupy), indicating that the child scale effectively captures the dynamics of parents using media for regulating their child's emotional responses and behaviors and for occupying them.

Associations between regulatory media use for parents and children

There were significant correlations between parent and child factors. The high level of internal consistency across all items in each scale (parent: 16 items, child: 12 items), combined with significant correlations between factors, suggest that there are consistent patterns in how parents use the response scale. Significant correlations between factors in the parent and child scales could indicate consistent patterns in each family's regulatory media use for all members in the household. That is, this consistency might demonstrate shared attitudes or role modeling of behaviors related to media use within the family context, highlighting how parents' media habits may be closely linked to those of their children. However, it may also simply reflect common method variance given both scales were completed by the same person within a single online survey.

Despite high correlations among the parent and child factors, EFA/CFA and predictive validity results for the two scales suggest there is some heterogeneity in the reasons a given parent uses media for themselves or their child that differentially predict factors such as parenting stress and child screen time. Overall, the parent and child scales provide novel insights into the varied regulatory roles of media in families with young children. It highlights the importance of understanding the reasons behind parent and children's media use and their potential associations with their development and daily routines.

Limitations and future directions

The current work represents an initial step in developing a valid, reliable measure that captures a range of regulatory uses of media for parents and children across a wide age range. Our results illustrate the possible utility of such a measure among parents of infants, young children, and school-age children. The results also capture more variability than past work regarding the frequency and nature of regulatory media use. These contributions notwithstanding, future work should seek to overcome some limitations in the current study. First, the reliance on parent-reported data for all measures, while practical, may introduce biases or inaccuracies in reporting. Future work should incorporate objective measures to complement and validate the self-reported data. For example, predictivity validity could be established using direct observations of parents' and children's media use.

Another limitation is that we did not collect data on parent and child gender. It is possible that fathers and mothers different in the extent to which they use media to regulate their child's emotional responses and behaviors. In addition, child gender may be associated with parental regulatory media use for their children, based on gender differences in self-regulation (Weinberg et al., 1999; Veijalainen et al., 2021) and emotion socialization (Root and Rubin, 2010; Chen et al., 2020). Future work should examine whether the extent to which parents use media for regulatory purposes with and around their young children differ by parent or child gender.

Other limitations arise from the limited scope and generalizability of this research. For example, the three studies included in the current paper were limited in the types of measures available for predictive validity. For example, future research could include measures other than parenting stress, such as other measures of parent wellbeing as well as child behavior and family dynamics. Such research would help to test the degree to which parent-reported reasons for using media with and around their children has value above and beyond global estimates of children's amount of media use. Moreover, future work should seek to establish the generalizability of the measure, such as testing reliability and validity within subpopulations in the US and cross-culturally.

A final set of limitations reflect the complexity of media use within the family system. While our scales capture variability in the frequency and nature of regulatory uses of media, they do not capture other perceived functions of media use, such as helping families bond through shared media use or educating parents and children through the use of educational/informative media (but see Koch et al., under review). There is some evidence to suggest regulatory use of media may be especially problematic, particularly for infants and young children (Radesky et al., 2016a, 2023; Coyne et al., 2021). Meanwhile, using media to get parenting support and advice may be more beneficial (Torres et al., 2021). A more comprehensive picture of the motivations driving parents' media use with and around young children will help to contextualize such media use and inform guidance aimed at encouraging healthy media practices. Similarly, we were not able to examine the types of media content and design features used, particularly for children. The potential impact of media use on children depends in part on the types of content and design (Radesky et al., 2014; Radesky and Hiniker, 2022). Thus, it will be important for future research to examine the degree to which different media motivations (including regulatory media use) result in use of different media content and design features.

Although not a limitation *per se*, another future direction involves refining and establishing generalizability of the scales. For example, only six out of a full set of 16 items were included in the three identified factors of the parent scale. It implies that several items within the parent scale captured behaviors or attitudes that did not align with other items in the scale. For the child scale, all the items in the child scale were included in the three identified factors of the child scale. Moving forward, our ongoing and future work will seek to refine these scales to maximize reliability and validity while minimizing participant burden. This process involves making adjustments or removing some items in the scales as necessary to better capture and focus on regulatory media use for parents and children.

Conclusions

Building upon earlier studies that often focused on single items to measure regulatory purposes (Nikken, 2019; Coyne et al., 2021; Radesky et al., 2023), the scales we tested in this paper are designed to capture more variability in regulatory uses of media with and around children. These initial scales appear to capture a multifaceted range of regulatory uses of media. This approach facilitates more detailed representations of how media is used in various situations to regulate emotional responses and behaviors, both for parents and children. From a practical standpoint, more comprehensive measurement of regulatory media use may inform more effective media guidelines and interventions tailored to specific regulatory needs and situations.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Wisconsin-Madison, Georgetown University, Southern Methodist University, and University of Michigan Medical School. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

BS: Formal analysis, Writing—original draft, Writing—review & editing. HK: Funding acquisition, Supervision, Writing—review & editing. RB: Funding acquisition, Writing—review & editing. SK: Funding acquisition, Writing—review & editing. CT: Conceptualization, Writing—review & editing. JR: Conceptualization, Funding acquisition, Writing—review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fdpys.2024.1377998/full#supplementary-material

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YouTube for young children: what are infants and toddlers watching on the most popular video-sharing app?

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Background: Infants and toddlers engage with digital media about 1–3 h per day with a growing proportion of time spent on YouTube.

Aim: Examined content of YouTube videos viewed by children 0–35.9 months of age and predictors of YouTube content characteristics.

Methods: We completed a secondary analysis of data from the 2020 Common Sense "YouTube and Kids" study. Parents were surveyed about demographics and YouTube viewing history. We developed a novel coding scheme to characterize educational quality and comprehension-aiding approaches (i.e., labels, pacing) in 426 videos watched by 47 children. Videos were previously coded for violence and consumerism. Bivariate analyses compared video-level predictors of higher quality educational content. Multivariable analyses examined child and family predictors of YouTube video content, adjusted for FDR.

Results: Only 19% of videos were age-appropriate, 27% were slow paced, 27% included physical violence, and 48% included consumerism. The game genre was associated with faster pace, more physical violence, more scariness, and more consumerism vs. all other videos. The informational genre was associated with more learning goals, slower pace, and less physical violence vs. all other videos. Child age 0–11.9 months vs. 24–35.9 months was associated with more age-inappropriate and violent content.

Conclusion: Physical violence and consumerism were prevalent among YouTube videos viewed by this sample, with infants being exposed to more age-inappropriate and violent content compared with toddlers. Caregivers may wish to select videos in the informational genre which tended to include more high-quality indicators and avoid gaming videos and monitor young infant video content.

KEYWORDS

YouTube, infants, digital media, parents, content analysis

Introduction

YouTube currently represents the largest share of young children's screen viewing, with young children 0–8 years of age spending over an hour per day on this video-sharing platform (Rideout and Robb, 2020). Over 80% of parents with a child less than 12 years of age report that their child watches YouTube (Smith et al., 2018). Among infants and toddlers, media use averages 40 min to 3 h per day (Zimmerman et al., 2007; Kabali et al., 2015; Rideout, 2017). Videos and apps directed to this age group are abundant (Radesky et al., 2020; Meyer et al., 2021); yet, prolonged or non-educational media use in the infant and toddler years is strongly linked with developmental delays (Madigan et al., 2020; Wiltshire et al., 2021). Accordingly, the National Institutes of Health Strategic Plan has emphasized early childhood screen media use as a research priority (2021–2025). However, there is a paucity of research examining content for this specific age group in the most-used streaming video app, YouTube.

Indeed, a growing proportion of screen media time is spent on YouTube, with 17% of children under two accessing online videos as of 2020 (Levine et al., 2019; Rideout and Robb, 2020). Prior research on infant/toddler media use has focused on television (TV) and DVDs, which have been heavily marketed to them in prior decades, but YouTube has received less study. YouTube differs from traditional TV or DVDs in many key ways, including the presence of user-generated videos, marketing content, and algorithms that may drive children's viewing patterns (Alruwaily et al., 2020; Radesky et al., 2020). These characteristics may make it harder for families to find high-quality, educational videos on this platform. Furthermore, the algorithm itself has lacked transparency (Covington et al., 2016). It may be possible that when families view videos with more educational characteristics, the algorithm may present more videos with similar characteristics (Covington et al., 2016). Given that content quality is an important driver of young children's developmental outcomes (Madigan et al., 2020), more needs to be known about what infants and toddlers specifically are viewing on YouTube.

Young children often demonstrate less learning after viewing a video as compared with a face-to-face demonstration. This difference in how infants are able to learn from screens as compared with a face-to-face demonstration is termed the "video deficit effect" (Zack et al., 2009). For infants and toddlers, design of digital media is particularly important to overcome the cognitive constraints (video deficit effects) when learning information from tablets or TV (Barr, 2010). Previous content analyses of infant DVDs and TV programs have therefore examined comprehension-aiding approaches within videos to help overcome this video deficit effect, with a theoretical grounding in the development of young children's visual attention (Vaala et al., 2010). Such comprehension-aiding strategies can help guide young children toward important aspects of the content (Vaala et al., 2010). Examples of these strategies include: using child-directed speech, leveraging joint attention with pointing or verbalizations, using labels, and repetition. Additionally, slow-paced design may allow more opportunity for young children to process the content delivered in videos, while fast-paced design may have implications for children's hyperactive behavior (Zimmerman and Christakis, 2007; Lillard and Peterson, 2011). Similarly, speech that is slower and includes motherese, defined as a speech pattern with sing-song prosody that emphasizes vowels, may allow for language to be better-understood (Golinkoff et al., 2015). In prior work examining content analyses of TVs and DVDs marketed toward families with infants and toddlers, joint attention occurred about 15% of the time, visual depiction using labels occurred about 22% of the time, and child-directed speech occurred about 9% of the time (Goodrich et al., 2009; Vaala et al., 2010). These types of comprehension-aiding approaches have not been examined on YouTube for infants and toddlers, yet this information could provide context on the educational quality of YouTube videos.

Another way in which YouTube differs from child-directed TV or DVDs includes the higher prevalence of violence and advertisements which are embedded within YouTube videos (Radesky et al., 2020). Indeed, 61% of parents reported that their child encountered content that was unsuitable for children on YouTube (Smith et al., 2018; Radesky et al., 2020). However, no studies have examined markers or characteristics of YouTube videos with higher quality to help guide parents toward video content that is more supportive of young children's learning. For example, if higher-quality videos have greater view counts or belong to different video genres, parents could use these indicators to guide their young child's viewing behavior on this platform.

Lastly, prior work has suggested that family and child characteristics might shape their media viewing habits for TV (Thompson et al., 2013; Radesky et al., 2022). Specifically, certain types of TV content such as Baby Einstein DVDs have been previously marketed toward low-income families as being educational without substantive evidence base to support those claims (DeLoache et al., 2010). Indeed, many families have indicated they select and choose to utilize digital media with young children because of their desire to provide them with educational opportunities (Radesky et al., 2016a,b). Similar to TV marketing practices, the YouTube algorithm may suggest specific types of content tailored to or marketed toward certain family and child characteristics. Prior work has found that lower family socioeconomic status was associated with longer YouTube duration and greater likelihood of using YouTube main as compared with YouTube Kids (Radesky et al., 2022). As YouTube's algorithm lacks transparency, more needs to be known about how family and child characteristics relate to the content they are offered. For instance, it has been proposed that young children may be more likely to view YouTube when sharing a device with an older sibling (Radesky et al., 2022). In one low-income sample, device ownership was prevalent among children 0–4 years of age, with about 44% having their own mobile device or tablet (Kabali et al., 2015). However, it is unknown what the implications of early childhood device ownership might be, and how to counsel families. Therefore, more needs to be known about contextual factors such as family structure and device ownership and how these relate to children's encounters with inappropriate content on YouTube.

Given that non-educational use of media in infancy and toddlerhood is associated with language delays, social-emotional delays (McArthur et al., 2022), and sleep problems (Janssen et al., 2020), we focused our content analysis on young children from 0–35.9 months of age. We aimed to:

1) Examine the content, educational quality, and comprehension-aiding approaches for videos that infants and toddlers have watched on YouTube. We hypothesize that overall educational quality and comprehension-aiding approaches are low in YouTube videos.
2) Test video-level characteristics (view count, genre) that predict educational quality of YouTube videos. We hypothesize that there are view counts are lower for YouTube videos with more educational characteristics and that certain genres such as

TABLE 1 Coding scheme description and Cohen's Kappa reliability.

	Description	Reliability
Age-appropriate	Developmentally-appropriate content for young child (0–2.99y) and specifically developed for infants and toddlers. Routine nursery rhymes, songs with positive messaging, Sesame Street, or Dora the Explorer are all examples of age-appropriate content	1.00
Labels	Label (in sentence with elaboration) matches a visual depiction, the name/title of an object is stated and matched with a visual depiction. (Audible and visual)	0.79–1.00
Joint attention	Presence of orienting approaches such as pointing to promote attention	0.74–1.00
Learning goal	Content is goal-oriented with learning. These include: someone teaching how to draw, reading a children's story to the audience, social-emotional learning such as sharing, teaching kindness/empathy, numbers and letters, and shapes learning. These might be more explicit with teaching	1.00
Fast pace	Fast cuts with multiple camera changes or new concepts introduced, generally faster than once every 20 s	0.64–0.78
Motherese	Speaks in a manner that places emphasis on the consonants (slower, emphatic speech) in a way that caregivers might speak to infants/young children	0.78–0.90
Child-directed speech	Narrator or character speaks directly to the child or asks a question directly to the child, in a way that is developmentally-appropriate	0.65–0.78
Violence (previously coded)	Presence of physical violence with weapons, gore, or personal injury	0.78–0.93
Scary content (previously coded)	Frightening themes such as horror, spookiness, or jump-scare games	0.82–1.00
Consumerism (previously coded)	Branded content, unboxing videos, calls to purchase items	0.69–0.92

Reliability range as there were multiple coders.

music and informational genres will predict higher educational quality of YouTube videos.

3) Assess associations between family- and child-level characteristics and educational quality of YouTube videos viewed by infants and toddlers. We hypothesize that less parent education, younger parent age, and child owning device predict lower educational quality of YouTube videos.

Methods

Study sample

We analyzed a subsample of data collected from the 2020 Common Sense Census (Radesky et al., 2020), which included a nationally representative sample of children 0–8 years of age. Of the 1,140 children in the Census study, 191 watched the main YouTube platform (i.e., not YouTube Kids) at least once per week and submitted their viewing history for analysis. Parents provided electronic informed consent to participate and the University of Michigan IRB found the study to be exempt from review. Caregivers submitted the most recent ten YouTube video URL links viewed by their child by copying and pasting from the history section of YouTube. For the current study, we examined a sub-sample of 47 infants and toddlers 0–35.9 months of age. Of the 470 videos they viewed, 20 were duplicates, 21 were no longer available, and 3 were not coded due to being in a foreign language, leaving 426 videos that were coded using our current coding scheme on educational quality. Of note, there is variability in the total number of videos for video content variables, depending on when they were coded and which YouTube videos were available on the YouTube platform at the time. For instance, the previously-coded videos such as genre included a different total number of videos given that some videos became unavailable when the infant and toddler coding schemes were developed.

Coding scheme development

We developed a coding scheme based upon prior work examining educational content and quality of infant and toddler TVs and DVDs (Goodrich et al., 2009; Vaala et al., 2010) however, we allowed for iterative additions of novel codes that were pertinent to YouTube content. Codes were refined in weekly meetings and review of videos. Over 20% of videos were double coded against a gold-standard coding scheme and differences were resolved between coders systematically through discussion. Coder's inter-rater reliability was calculated using weighted Kappa with goal >0.70 and discrepancies in coding were resolved by consensus.

As described in Table 1, codes comprised: age-appropriate content (how developmentally-appropriate the content was for a child of this age group); labels (label of a word matches a visual depiction); joint attention (character on YouTube directs infant attention by pointing, gesturing, or by verbal means such as saying 'look at that'); learning goal (content is goal-oriented with learning, examples including: explicit teaching such as social-emotional learning with sharing, reading a children's story, content with numbers and letters/shapes); fast pace (fast cuts with multiple camera changes every 20 s or new flashing images), motherese (speech that places emphasis on consonants with slower, emphatic speech in a way that caregivers might speak to infants/young children), and child-directed speech (YouTube character directly addresses a child and asks a question).

These codes have been identified in prior work around infant and toddler DVDs and TV as being components relevant to visual comprehension-aiding and learning (Goodrich et al., 2009; Vaala et al., 2010). Reliability for fast pace was slightly less than 0.70, possibly due to within-video variability of pace, though we defined this as video cuts once every 20 s. Content of advertisements was not coded.

Previously coded content and video characteristics

YouTube videos had previously been coded for negative content according to a reliable coding scheme based on Common Sense Media criteria. These included violence (presence of physical violence with weapons, gore, or personal injury), scary content (frightening themes such as horror, spookiness, or jump-scares), and consumerism (branded content, unboxing videos and calls to purchase items). Additionally, videos were previously classified by genre. These genres included: story-based, music-based, DIY (do-it-yourself), informational, reality, games/challenges, toys, compilations (videos showing clips of highlights or surprising moments from various places), and information such as news or science. Data regarding video duration and view count were abstracted from the YouTube interface at the time of initial coding (June 2020). Additional information about the coding schemes and classification of genres can be found in the primary Common Sense Media “YouTube and Kids” report (Radesky et al., 2020).

Child and family characteristics

Caregivers reported demographic information and data which included: child gender, child age, parent gender, caregiver age, caregiver education, household income. Caregiver race/ethnicity was categorized as White non-Hispanic, Black non-Hispanic, Hispanic, and multiracial. Number of children in the household was dichotomized into presence of siblings vs. only child. In the primary YouTube Common Sense Media study, child age was reported as a categorical variable: 0–11.9 months, 12–23.9 months, 24–35.9 months.

Analysis

Univariate analyses

Univariate analyses quantified the demographic information of our sample and frequency of different content codes across all 426 unique videos.

Video-level, bivariate analyses

To identify video characteristics that were associated with infant-toddler content codes, we examined bivariate associations between (1) view count and (2) video genre with the presence of each content code (labels, joint attention, learning goal, fast pace, motherese, child-directed speech, violence, scary content, and consumerism). Because of the multiple categories of genre, we chose to conduct pair-wise *t*-tests to compare each individual genre with all the other genres combined. We included Mann–Whitney U tests to compare high-quality indicators with YouTube views.

Child-level, multivariable analyses

For each child, we created a proportion score for each of the content codes, indicating the proportion of videos they watched that included those characteristics. For instance, each child watched approximately 10 videos and if 2 of the videos were coded as age-appropriate, we created a proportion score of 0.2 for age-appropriate videos. The proportion score therefore accounted for occasional missing videos among some children though the vast majority of children had complete data. We created multivariable models examining associations between demographic characteristics (child age, gender, caregiver age, caregiver education, caregiver income, caregiver age, child device ownership, and siblings were included as independent variables in each model) and proportion of videos that each child watched containing different content codes (labels, joint attention, learning goal, fast pace, motherese, child-directed speech, violence, scary content, and consumerism). We created separate models with each of the proportion scores as the outcome variable. For all analyses, we adjusted for multiple comparisons with a False Discovery Rate of 0.05. All analyses were completed using SAS 9.4.

Results

As shown in Table 2, 32% of children were 0–11.9 months old, 30% were 12–23.9 months old, 38% were 24–35.9 months old, 53% were male and 26% had their own tablet device. Of the caregivers, 60% were fathers. Caregivers were on average 34 years old. Regarding racial/ethnic diversity, 72% of caregivers identified as white, non-Hispanic, 13% Black, non-Hispanic, and 13% white, Hispanic. In terms of education, most caregivers had a bachelor’s degree or higher (68%).

As shown in Table 2, common video genres viewed by infants and young children included: music (31%), reality (25%), games (21%), story (17%), and toys (10%). Most videos were not age-appropriate (81%), though many contained labels (40%), some contained joint attention features (18%), few included a developmentally-appropriate learning goal (6%), and most were fast-paced (73%). About a quarter of videos contained physical violence (27%), and about half of the videos contained consumerism (48%).

View count was higher for videos with high-quality indicators such as: labels (19.3 million vs. 4.2 million, $p < 0.0001$), joint attention (17.0 million vs. 6.2 million views, $p < 0.0001$), motherese (18.4 million vs. 7.2 million views, $p < 0.004$). However, view counts were higher for fast-paced videos (13.6 million vs. 1.5 million views, $p < 0.0001$). These data are shown in Appendix A.

Additional bivariate analyses are presented in Tables 3A,B. In general, the music genre was associated with less physical violence, scariness, and consumerism as compared with all other videos. The DIY genre was associated with more presence of labels, slower pace, and less physical violence as compared with all other videos. The game genre was associated with less presence of labels, less joint attention, fewer learning goals, faster pace, more physical violence, more scariness, and more consumerism as compared with all other videos. The informational genre was associated with more learning goals, more child-directed speech, slower pace, and less physical violence as compared with all other videos. The toy genre was associated with more consumerism as compared with all other videos.

TABLE 2 Child demographic characteristics and video characteristics.

Demographic information	n = 47 (% or SD)
Child age	
0–11.9 months	15 (32%)
12–23.9 months	14 (30%)
24–35.9 months	18 (38%)
Child gender	
Male	25 (53%)
Female	22 (47%)
Parent age (years)	34.0 (SD = 4.8)
Parent gender	
Male	28 (60%)
Female	19 (40%)
Parent education	
High school or less	7 (15%)
Some college	8 (17%)
Bachelor's degree or higher	32 (68%)
Parent race/ethnicity	
White, non-Hispanic	34 (72%)
Black, non-Hispanic	6 (13%)
Hispanic	6 (13%)
Two or more races, non-Hispanic	1 (2%)
Child has their own device	12 (26%)
Video characteristics	
Genre (videos may fall into multiple genres), n = 441	
Story	77 (17%)
Music	135 (31%)
DIY	31 (7%)
Reality	109 (25%)
Games	91 (21%)
Satisfying	6 (1%)
Compilation	15 (3%)
Informational	32 (7%)
Toys	46 (10%)
Age-appropriate, n = 426	81 (19%)
Labels, n = 426	171 (40%)
Joint attention, n = 426	77 (18%)
Learning goal, n = 426	25 (6%)
Slow pacing, n = 426	116 (27%)
Motherese, n = 426	40 (9%)
Child-directed speech, n = 426	34 (8%)
Physical violence, n = 414	111 (27%)
Scary content, n = 411	61 (15%)
Consumerism, n = 410	196 (48%)

Multivariable analyses including covariates of child age, child gender, caregiver age, caregiver education, child owning their device, caregiver income, and siblings in the home are shown in Tables 4A,B. Child younger age (0–11.9 months vs. 24–35.9 months) was associated with viewing less age-appropriate content ($\beta = -33.6$, 95% CI [−56.0, −11.3], $p = 0.005$) and with viewing more violent content ($\beta = 27.1$, 95% CI [6.4, 47.9], $p = 0.01$).

Discussion

As of 2020, YouTube has represented the greatest share of young children's digital content viewing time and has distinct affordances from previous network TV and DVD content viewed by infants and toddlers, such as user-generated content and recommendation algorithms. Well-planned and developmentally-appropriate videos can promote social-emotional, language, and academic skills in young children (Fisch et al., 1999; Barr et al., 2010; Rasmussen et al., 2016). However, we found these types of videos to be uncommon in our sample of videos watched by infants and toddlers, with less than 6% of all videos containing learning goals. Rather, infants and toddlers encountered frequent violence and commercialism in this sample of videos. Though comprehension-aiding approaches such as child-directed speech and joint attention were common, they were used to direct infants and toddlers toward low-quality content.

Though educational quality overall in this sample of YouTube videos was low, more highly-viewed videos contained more comprehension-aiding approaches, were generally more age-appropriate, and contained less violent, scary, or consumerist content. Caregivers may be selecting videos that are generally more high-quality, or the YouTube algorithm has made these videos slightly more popular. The vast majority of these popular videos were nursery rhyme compilations. However, it also should be noted that videos containing violent or scary content included average view counts which were still quite high (in the millions). In the primary Common Sense Media "YouTube and Kids" study, most caregivers indicated that they co-viewed (i.e., watched videos with their children together) sometimes or frequently (Radesky et al., 2020). This prior work suggests that caregivers may try to select videos they perceive to be more educational and popular or possibly the YouTube algorithm may be creating a feedback loop once parents engage in educational content. On the other hand, in the same Common Sense Media "YouTube and Kids" study, about 10% of caregivers indicated they were surprised by some of the videos their child had watched, aligning with one naturalistic study finding that co-viewing occurs infrequently at home (Domoff et al., 2018). For families who may not be able to co-view with their children, avoiding genres such as video gaming may prevent unintended exposures to physical violence, scary content, and consumerism.

The formal features of YouTube videos, such as their fast pace, may have an impact on how infants and toddlers process their content visually and cognitively. Visual attention during infancy—alerting and orienting to stimuli are shaped by neurobiology and interactions with the environment (Colombo, 2001). Video pacing may drive some of these alerting responses. In particular, fast paced videos can be more challenging for young children to learn from because it is harder for young children to know what to focus on and orient to. Prior work has proposed that such fast cuts may be more stimulating for young children, and entrain young children to expect more intense visual input (Christakis, 2009). In one previous study of 4 years olds, fast pacing in an experimental design was associated with less optimal orientation to the video (Cooper et al., 2009). In another study, when

TABLE 3 Bivariate associations between video categories and video characteristics.

(A)	Presence of labels	Joint attention	Learning goal	Fast pace	Motherese
Age-appropriate (81)	68% (55)	35% (28)	21% (17)	61% (49)	21% (17)
Not age-appropriate (345)	34% (116)	14% (49)	2% (8)	76% (260)	7% (23)
	$p < 0.0001$	**$p < 0.0001$**	**$p < 0.0001$**	**$p = 0.006$**	**$p < 0.0001$**
Story (72)	39% (28)	21% (15)	8% (6)	85% (61)	11% (8)
All other genres (354)	40% (143)	18% (62)	5% (19)	70% (248)	9% (32)
	$p = 0.81$	$p = 0.50$	$p = 0.33$	**$p = 0.012$**	$p = 0.58$
Music (128)	42% (54)	14% (18)	7% (9)	70% (90)	8% (10)
All other genres (298)	39% (117)	20% (59)	5% (16)	74% (219)	10% (30)
	$p = 0.57$	$p = 0.16$	$p = 0.50$	$p = 0.47$	$p = 0.46$
DIY (31)	74% (23)	19% (6)	0% (0)	32% (10)	13% (4)
All other genres (395)	38% (148)	18% (71)	6% (25)	76% (299)	9% (36)
	$p < 0.0001$	$p = 0.85$	$p = 0.15$	**$p < 0.0001$**	$p = 0.49$
Reality (109)	50% (54)	37% (40)	6% (7)	82% (89)	14% (15)
All other genres (317)	37% (117)	12% (37)	6% (18)	70% (220)	8% (25)
	$p = 0.02$	**$p < 0.0001$**	$p = 0.78$	$p = 0.015$	$p = 0.07$
Games (89)	26% (23)	7% (6)	0% (0)	89% (79)	2% (2)
All other genres (337)	44% (148)	21% (71)	7% (25)	69% (230)	11% (38)
	$p = 0.002$	**$p = 0.002$**	**$p = 0.008$**	**$p = 0.0001$**	**$p = 0.009$**
Compilation (15)	13% (2)	7% (1)	7% (1)	80% (12)	0% (0)
All other genres (411)	41% (169)	19% (76)	6% (24)	72% (297)	10% (40)
	$p = 0.031$	$p = 0.24$	$p = 0.89$	$p = 0.52$	$p = 0.20$
Informational (30)	37% (11)	13% (4)	23% (7)	33% (10)	20% (6)
All other genres (395)	40% (160)	18% (73)	5% (18)	76% (299)	9% (34)
	$p = 0.69$	$p = 0.48$	**$p < 0.0001$**	**$p < 0.0001$**	$p = 0.04$
Toys (46)	65% (30)	44% (20)	7% (3)	80% (37)	15% (7)
All other genres (380)	37% (141)	15% (57)	6% (22)	72% (272)	9% (33)
	$p = 0.00024$	**$p < 0.0001$**	$p = 0.84$	$p = 0.21$	$p = 0.15$

(B)	Child-directed speech	Physical violence	Scariness	Consumerism
Age-appropriate (81)	19% (15)	4% (3)	1% (1)	16% (12)
Not age-appropriate (345)	6% (19)	33% (106)	13% (41)	57% (182)
	p = 0.0001	**p < 0.0001**	**p = 0.001**	**p < 0.0001**
Story (72)	7% (5)	45% (34)	22% (16)	28% (20)
Other genre (354)	8% (29)	23% (77)	8% (27)	52% (176)
	$p = 0.72$	**p < 0.0001**	**p = 0.002**	**p = 0.0001**
Music (128)	6% (7)	8% (9)	1% (1)	11% (13)
Other genre (298)	9% (27)	34% (102)	14% (42)	62% (183)
	$p = 0.21$	**p < 0.0001**	**p = 0.0002**	**p < 0.0001**
DIY (31)	19% (6)	3% (1)	3% (1)	53% (16)
Other genre (395)	7% (28)	29% (110)	11% (42)	47% (180)
	$p = 0.02$	**p = 0.003**	$p = 0.19$	$p = 0.53$
Reality (109)	11% (12)	20% (21)	12% (13)	66% (71)
Other genre (317)	7% (22)	29% (90)	10% (30)	41% (125)
	$p = 0.18$	$p = 0.051$	$p = 0.76$	**p < 0.0001**
Games (89)	0% (0)	64% (58)	19% (17)	89% (80)
Other genre (337)	10% (34)	16% (53)	8% (26)	36% (116)
	p = 0.002	**p < 0.0001**	**p = 0.0005**	**p < 0.0001**
Compilation (15)	0% (0)	43% (6)	15% (2)	15% (2)
Other genre (411)	8% (34)	26% (105)	10% (41)	49% (194)
	$p = 0.25$	$p = 0.17$	$p = 0.69$	$p = 0.02$
Informational (30)	23% (7)	0% (0)	7% (2)	67% (20)
Other genre (396)	7% (27)	29% (111)	11% (41)	46% (176)
	p = 0.001	**p = 0.0006**	$p = 0.35$	$p = 0.03$
Toys (46)	20% (9)	7% (3)	2% (1)	76% (35)
Other genre (380)	7% (25)	28% (108)	11% (42)	42% (161)
	p = 0.002	**p = 0.001**	$p = 0.04$	**p < 0.0001**

With FDR correction to account for a false discovery rate of 0.05. Significant results are bolded.

TABLE 4 Multivariable associations between child and parent demographic factors and video characteristics.

(A)	Dependent video characteristics β (SE)				
Independent predictors	Age-appropriate	Labels	Joint attention	Learning goal	Fast pace
Child age					
0–11.9 mo	−33.6 (11.2), $p = 0.005$	−14.5 (11.7), $p = 0.22$	−13.1 (8.9), $p = 0.15$	−8.7 (5.9), $p = 0.15$	11.7 (11.9), $p = 0.31$
12–23.9 mo	−16.4 (11.0), $p = 0.14$	1.0 (11.5), $p = 0.93$	−14.5 (8.8), $p = 0.11$	−5.8 (5.8), $p = 0.33$	8.0 (11.2), $p = 0.48$
24–35.9 mo (ref)	–	–	–	–	–
Child gender					
Female	−0.8 (9.1), $p = 0.93$	9.0 (9.6), $p = 0.35$	0.003 (7.3), $p = 0.99$	−0.6 (4.8), $p = 0.90$	5.4 (9.3), $p = 0.57$
Male (ref)	–	–	–	–	–
Parent age	−0.4 (1.0), $p = 0.67$	1.8 (1.0), $p = 0.09$	1.3 (0.8), $p = 0.11$	−0.3 (0.5), $p = 0.62$	1.5 (1.0), $p = 0.13$
Parent edu					
HS/some college	−22.7 (11.6), $p = 0.048$	−18.1 (11.8), $p = 0.13$	−3.8 (9.0), $p = 0.67$	−0.07 (5.9), $p = 0.99$	15.1 (11.4), $p = 0.19$
College (ref)	–	–	–	–	–
Child own device					
No	10.2 (11.0), $p = 0.36$	6.2 (11.6), $p = 0.60$	14.6 (8.9), $p = 0.11$	0.4 (5.9), $p = 0.95$	−15.9 (11.3), $p = 0.17$
Yes (ref)	–	–	–	–	–
Income	−1.5 (1.3), $p = 0.26$	−1.4 (1.4), $p = 0.31$	−0.7 (1.1), $p = 0.51$	0.4 (0.7), $p = 0.60$	2.0 (1.4), $p = 0.15$
Siblings in home	−3.4 (10.1), $p = 0.73$	3.9 (10.6), $p = 0.71$	0.7 (8.1), $p = 0.94$	−6.9 (5.4), $p = 0.21$	14.3 (10.3), $p = 0.17$
Only child (ref)	–	–	–	–	–

(B)	Dependent video characteristics β (SE)				
Independent predictors	Motherese	Child-directed speech	Violence	Scary content	Consumerism
Child age					
0–11.9 mo	−9.0 (6.7), $p = 0.19$	−5.9 (6.2), $p = 0.35$	27.1 (10.4), $p = 0.01$	−0.3 (5.7), $p = 0.96$	16.5 (13.1), $p = 0.21$
12–23.9 mo	−7.7 (6.5), $p = 0.25$	−5.6 (6.1), $p = 0.36$	20.3 (10.2), $p = 0.05$	0.1 (5.7), $p = 0.99$	17.5 (12.9), $p = 0.18$
24–35.9 mo (ref)	–	–	–	–	
Child gender					
Female	−2.9 (5.4), $p = 0.60$	6.1 (5.1), $p = 0.24$	7.7 (8.5), $p = 0.37$	3.1 (4.7), $p = 0.51$	−1.1 (10.7), $p = 0.92$
Male (ref)	–	–	-	–	–
Parent age	0.7 (0.6), $p = 0.23$	−0.1 (0.5), $p = 0.91$	−1.6 (0.9), $p = 0.09$	0.1 (0.5), $p = 0.85$	0.8 (1.1), $p = 0.50$
Parent edu					
HS/some college	−5.7 (6.7), $p = 0.40$	0.6 (6.2), $p = 0.91$	11.7 (10.4), $p = 0.27$	0.1 (5.8), $p = 0.98$	20.1 (13.1), $p = 0.13$
College (ref)	–		–	–	–
Child own device					
No	−2.1 (6.6), $p = 0.76$	5.1 (6.1), $p = 0.41$	−21.5 (10.3), $p = 0.04$	−4.9 (5.8), $p = 0.40$	−3.3 (13.0), $p = 0.80$
Yes (ref)	–	–	–	–	–
Income	−0.4 (−0.8), $p = 0.58$	−0.3 (0.7), $p = 0.70$	1.5 (1.2), $p = 0.23$	0.7 (0.7), $p = 0.32$	−0.4 (1.6), $p = 0.82$
Siblings in home	0.6 (6.0), $p = 0.92$	−2.1 (5.6), $p = 0.72$	−7.3 (9.4), $p = 0.44$	−1.1 (5.3), $p = 0.83$	−0.7 (11.8), $p = 0.95$
Only child (ref)	–	–	–	–	–

All covariates below (independent predictors) have been included in the models. With FDR correction to account for a false discovery rate of 0.05. Significant results are bolded.

4 years old children immediately viewed a fast-paced cartoon vs. a slow-paced educational cartoon, they exhibited weaker executive functioning in a lab-based task (Lillard and Peterson, 2011). Lastly, another study of 4 years olds found fast pacing and realism might both impact inattention (Kostyrka-Allchorne et al., 2019).

Additionally, because young children's visual attention is still developing, prior work has focused on comprehension-aiding approaches embedded in videos which direct infants and toddlers to the content (Meltzoff, 1988; Cooper et al., 2009; Goodrich et al., 2009), and which are designed to make it easier to learn language (i.e., motherese). These comprehension-aiding approaches were used fairly frequently with rates similar to or with greater frequency than those found in infant TV/DVDs (Vaala et al., 2010). However, these comprehension-aiding approaches often directed children to attend to violent and consumerist content rather than educational content.

Our study found that the youngest infants (0–11.9 months as compared with 24–35.9 months) were more frequently exposed to age-inappropriate and violent content, which is consistent with one prior study examining the content of infant TV exposures (Barr et al., 2010). It is possible that caregivers inadvertently included video links of a sibling's YouTube viewing history, which is a limitation of this study. However, our multivariable modeling controlled for the presence of siblings in the home, and this did not alter our findings. Prior work has found that infants typically attend to TV content about 5% of the time (Anderson and Pempek, 2005), therefore caregivers may perceive that the content is less important during infancy. However, in one low-income sample, caregivers self-reported fewer verbalizations directed toward infants when infants were viewing adult-oriented content as compared with educational content (Mendelsohn et al., 2008). Toddlers and preschoolers may view less of this violent or age-inappropriate content as they may have stronger preferences about what they view. Caregivers may be more inclined to select videos that are more age-appropriate as they perceive their child has more ability to learn from the content (Kirkorian, 2018). It is also possible that the YouTube algorithm may be personalizing digital content based upon a child's viewing history, creating a feedback loop. More needs to be known about how the YouTube algorithm may be directing caregivers toward certain video options and how caregivers of the youngest infants (0–12 months of age) select YouTube content.

Physical violence was present in 27% of these videos and it was the youngest infants in our sample (0–11.9 months) who were viewing more of these videos. The developmental implications of violent content for very young infants is unclear, as infants younger than 18 months of age have difficulty transferring information from a screen to the real world, though infants as young as 14 months can imitate from TV screens (Meltzoff, 1988; Barr et al., 2007; Zack et al., 2009; Barr, 2010). It is possible that for such infants younger than 14 months of age, violent content may appear as more fast-paced cuts. In prior work, greater exposure to violent TV and non-violent entertainment TV at 1–3 years of age was associated with greater symptoms of inattention and hyperactivity five years later, as compared with educational content (Zimmerman and Christakis, 2007). However, the same associations were not true when children were exposed to this content at age 4–5 years (Zimmerman and Christakis, 2007). One prior randomized control trial has found reductions in externalizing symptoms for preschool boys when violent TV content was replaced with age-appropriate content (Christakis et al., 2013). These studies suggest a period of heightened susceptibility to violent content around 1–3 years of age. Violent and fast-paced content may shape children's attention even for the youngest children who may not fully understand what is occurring on the screen.

Consumerist content was prevalent in this sample of YouTube videos. Young children less than 8 years of age still have difficulty recognizing traditional advertising (Kunkel et al., 2004; Alruwaily et al., 2020). In previous work examining advertising content on YouTube, advertising was often embedded into the video itself and also leveraged parasocial relationships where the main YouTube character delivered the commercial content, termed host-selling (Alruwaily et al., 2020). Given these qualities, it may be challenging for young children to recognize videos on YouTube being advertisements. Though infants and preverbal toddlers have desires and preferences, they cannot yet negotiate with their caregivers at the store for certain products (Valkenburg and Cantor, 2002). For preverbal children, advertisements may have a stronger impact on their caregivers or siblings. Two to three-year olds may be more susceptible to the influences of advertising due to their stronger preferences and expressive language abilities (Valkenburg and Cantor, 2002). Prior work has found that when caregivers denied children's requests for products, children who were more heavy viewers of advertisements argued about the purchase twice as frequently compared with lighter viewers of advertisements (Calvert, 2008). Future work should examine the immediate effects of advertising content on infant, toddler, and parenting behaviors.

This study is not without limitations. Our sample size was small and these data were collected during the COVID-19 pandemic which may have shaped the types and quantity of videos viewed by young children. We only coded 10 videos viewed per participant, but our prior work (Radesky et al., 2020) suggests that children generally view the same video genres over time, so this is likely an adequate sampling approach. Additionally, previous work examining infant DVDs and TV programs have coded fewer videos and have not linked content with infant and family characteristics (Goodrich et al., 2009; Vaala et al., 2010). Prior work has found that digital media exposure was higher during pandemic times and caregivers may have had less supervision over their children's viewing habits during this period of time (Dore et al., 2021; Eales et al., 2021). Therefore, our results may not be generalizable outside of the pandemic time frame. Future work may consider including a larger sample of infants and toddlers and examining the context of how infants and toddlers view YouTube. Additionally, it would be important to examine associations between YouTube content viewed by infants and toddlers and longitudinal associations with developmental outcomes.

To our knowledge, this is the first study to examine YouTube content among young infants and toddlers and characterize associations between video characteristics and family characteristics. We found that videos with low educational quality, fast pacing, violent, and consumerist content were highly prevalent on YouTube for toddlers and infants. Caregivers may wish to pre-select videos for their young children including genres such as music or informational content and avoiding content such as gaming or compilation videos. Lastly, even for young infants, selecting YouTube videos that are age-appropriate and educational remains important, given associations between non-educational media use and developmental delays. YouTube may consider age-appropriate grouping of videos for specific age groups and elevating content that is more age-appropriate in their algorithm.

Data availability statement

This study involved a secondary analysis of a subsample of data collected from the 2020 Common Sense Census (Radesky et al., 2020). Further questions should be directed to TM, chungti@med.umich.edu.

Ethics statement

The studies involving humans were approved by University of Michigan, IRB exempt status. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

DH: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. TB: Conceptualization, Writing – original draft, Writing – review & editing. JS: Writing – review & editing, Formal analysis, Methodology. MR: Methodology, Writing – review & editing, Conceptualization, Data curation, Investigation, Project administration, Supervision. JR: Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing, Formal analysis, Funding acquisition, Writing – original draft. TM: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing, Investigation.

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Conflict of interest

JR is a paid consultant and on the board of directors for Melissa & Doug Toys LLC and receives research funding from Common Sense Media. MR was employed at Common Sense Media during the production of this research and is currently employed by Google. TM is a paid consultant for PBS Kids.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Appendix A

TABLE A1 Video view characteristics and association with view counts.

Videos characteristics	View count in millions of views median (IQR)	*p*-value for Mann–Whitney U test
Labels not present Labels present	4.2 (0.9–18.9) 19.3 (3.0–76.6)	**<0.0001**
Joint attention absent Joint attention present	6.2 (1.0–26.7) 17.0 (3.8–76.6)	**<0.0001**
Learning goal absent Learning goal present	19.3 (7.9–133.7) 7.3 (1.3–30.9)	**0.006**
Slow-paced content Fast-paced content	1.5 (0.1–9.7) 13.6 (2.6–47.4)	**<0.0001**
Motherese absent Motherese present	7.2 (1.1–30.8) 18.4 (4.3–103.7)	**0.004**
Child-directed speech absent Child-directed speech present	7.4 (1.2–29.1) 34.2 (3.0–111.2)	**0.01**
Physical violence not present Physical violence present	8.7 (1.3–46.5) 4.5 (1.1–15.7)	0.05
Scary content absent Some scary content More prevalent scary content	8.5 (1.4–39.3) 2.2 (0.5–14.0) 4.3 (1.1–4.3)	**0.007**
Consumerism absent Consumerism present	14.3 (1.8–57.9) 3.6 (0.9–15.6)	**<0.0001**

With FDR correction to account for a false discovery rate of 0.05. Significant results are bolded.

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Social interactions offset the detrimental effects of digital media use on children's vocabulary

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Young children's rapid vocabulary growth during the first few years is supported by input during social interactions with caregivers and, increasingly, from digital media. However, the amount of exposure to both sources can vary substantially across socioeconomic classes, and little is known about how social interactions and digital media use together predict vocabulary in the first few years of life. The current study takes a first step toward examining whether increased social interactions with other individuals may buffer the potentially detrimental effects of digital media use on language among a socioeconomically diverse sample. 305 caregivers of children between 17 and 30-months completed questionnaires about their family demographics, their child's technology use, and the child's daily routines and social interactions. Findings suggest children who experience fewer human interactions and greater technology exposure have smaller vocabularies than their peers who socialize more and use less technology, and this disparity becomes greater as children get older. Moreover, the number of social interactions moderates the link between SES, digital media, and vocabulary such that the negative impact of digital media on vocabulary for children from low SES households can be offset with increased social interactions. Together, this suggests that increasing the amount of human interactions may serve as a protective factor for vocabulary outcomes in a world where digital media use is prominent.

KEYWORDS

digital media, social interactions, vocabulary, socioeconomic status, language development

1 Introduction

During the first years of life, young children's vocabulary expands rapidly, from 50 words at 18-months to over 500 by 30-months (Fenson et al., 1994). This rapid growth is fueled, in part, by relevant language input from, and interactions with, social partners (Hoff, 2006; Rowe, 2008). Such interactions are beneficial for multiple reasons – not only do they provide linguistic input, but they also give children opportunities for dyadic conversations and exposure to pragmatic elements supporting language growth. Problematically though, distractions and interruptions in children's environments associated with the use of digital media can reduce both the quantity and quality of language input (Reed et al., 2017) and subsequent vocabulary growth (Madigan et al., 2020). It is especially important that we characterize such distractions and interruptions in the early language environments of children from lower socioeconomic status (SES) households, as they are shown to experience less vocabulary growth compared to their higher SES peers (Hart and Risley, 1995; Golinkoff et al., 2019). Notably, early evidence suggests that disruptions from digital media may be more pronounced for children from low SES households, having downstream negative effects on their language development (Dynia et al., 2021). However, prior work has suggested that interacting with multiple communicative partners can improve communication skills (Lev-Ari and Sebanz, 2020), suggesting that social interactions could offset the negative association between digital media use and vocabulary. In the current study, we examine whether increased social interactions broadly (including those outside the home) may buffer the potentially detrimental vocabulary effects of digital media use among a socioeconomically diverse sample.

1.1 The rise of digital media

By the time children are 2 years old, they experience nearly 2 h of screen time per day (Kucker et al., 2024); an amount that rises as children age. More media use by young children is associated with a smaller vocabulary size (Madigan et al., 2020). This is particularly true when children engage in solo, passive video viewing without a caregiver or social partner (Lytle et al., 2018). The general consensus is that while there are beneficial uses of digital media (e.g., educational, social connection, joint engagement Linebarger and Vaala, 2010; Lytle et al., 2018), the omnipresence of digital media in young children's lives has the potential to hinder language development. One primary reason for this is that heightened media exposure can diminish and replace the rich social interactions known to foster language growth. For example, higher rates of digital media use predict fewer child-directed utterances (Pempek et al., 2014; Lederer et al., 2022), fewer conversational turns between children and caregivers (Cycyk and De Anda, 2021; Sundqvist et al., 2021), and less vocalization by the child (Ferjan Ramírez et al., 2021).

Digital media use is also significantly more prevalent in lower SES households (Rideout and Robb, 2020; Dore and Dynia, 2021). In particular, TV consumption is higher among lower SES, Black families (Yang-Huang et al., 2017; Stoll, 2023) who report significantly higher use of background TV, especially for infants (Lapierre et al., 2012). These differences in how families use background TV may have unique downstream impacts on language input (Skoe et al., 2013) wherein increased exposure to background TV can either promote or hinder children's ability to learn new words, impacting vocabulary growth. In fact, research has shown that higher rates of digital media exposure in lower SES households is associated with lower expressive language skills (Dynia et al., 2021). Together, digital media use appears to diminish opportunities for face-to-face social interactions and opportunities for children to use their growing language skills, and this may be particularly troublesome for lower SES families.

1.2 The importance of social interactions

Social interactions are arguably one of the most important mechanisms supporting children's language growth. Interactions with both adults and children bring opportunities for hearing language input, practicing talking themselves, and engaging in language-relevant pragmatic behaviors, all of which support language growth (Hoff, 2006). For instance, more social contacts at the start of preschool predict increases in verbal and non-verbal language skills by the end of the year (Hofmann and Müller, 2021), and the more preschoolers interact with their peers, the more likely they are to talk to both their peers and teachers, in turn predicting vocabulary growth (Perry et al., 2018). Social interactions in the home are also critical (e.g. Ramírez-Esparza et al., 2014), as numerous studies have shown that the quantity and quality of language input from caregivers promotes language development (Hart and Risley, 1995; Rowe, 2012; Romeo et al., 2018) and too much background noise or chaos might diminish language (Lecheile et al., 2020). As children get older, their social interactions become increasingly mature and important for continued language growth (Ramírez-Esparza et al., 2017).

However, the quantity and quality of these social interactions varies widely. Classic studies of children from lower SES households have argued that children hear less child-directed speech (Schwab and Lew-Williams, 2016) and less language input from caregivers (Rowe, 2012). However, other work with low SES households has indicated language input often comes from a variety of other communicative partners in these households (Shneidman and Goldin-Meadow, 2012; Shneidman et al., 2013; Sperry et al., 2019; referred to often as overheard speech). When other speakers beyond the primary caregiver are accounted for, differences in input are often diminished (Sperry et al., 2019; Dailey and Bergelson, 2022). This means that broader opportunities for social interactions beyond just the primary caregiver are likely critical, especially for diverse samples and it is important to consider the role of other individuals in children's environments, beyond primary caregivers and home-based interactions. Doing so can help us develop a more holistic understanding of the relationship between daily social interactions and language development (Poudel et al., 2024). It also means that the facilitatory role of multiple communicative partners in promoting children's language development is especially relevant for children who come from diverse socioeconomic households.

1.3 Current study

Taken together, both the amount of time a child spends engaging with digital media, and their opportunities for social interactions broadly, impact their developing vocabulary knowledge. Indeed, children exposed to more media hear less child-directed speech (Christakis et al., 2009; Anderson and Hanson, 2017), and higher rates of media use in the home (primarily by caregivers) result in less dyadic turn-taking and conversations with children (Sundqvist et al., 2021). Reductions in language input associated with higher rates of digital media use have negative downstream effects on vocabulary size. However, patterns of digital media use and social interactions vary as children get older and across SES groups, with children from lower SES household being exposed to more media, having more communicative partners, yet still being at risk for language delays. Given interactions with multiple social partners can reduce digital media use and increase language input, the amount of social partners a child has may offset the link between media use and vocabulary. However, a direct test of the relationship between children's own media use, overall number of social interactions, and vocabulary, especially in a diverse sample, has not been assessed. Because of this, the pathways by which media use alters language development remain unknown.

2 Materials and methods

2.1 Participants

Caregivers of children 17–30-months-old were recruited to participate online through Cloud Research between February 2022 and April 2023. All completed surveys were screened for inattentive/illegitimate responses and data were cleaned according to guidelines for online data collection (Chmielewski and Kucker, 2020). Specifically, responses that had inconsistency in reporting their child's birthday, irregular free response answers, repeated submission of the surveys, or were ineligible due to being outside the age range or not being exposed to English were not included in the final sample ($n = 103$). The final sample included 305 caregivers ($n_{female} = 209$) of 17–30-month-old children ($n_{female} = 135$) from a wide variety of socioeconomic backgrounds (M_{income} \$75,000, Range: <\$10,000 to >\$200,000; $M_{education}$ 2-year college degree, Range: 8th grade – Doctoral degree), but were largely White (Caregiver: 81%; Child: 75%) and non-Hispanic (Caregiver: 92.5%; Child: 89%) (see Supplementary Table S1 for full demographic information).

Using the pwr.f2.test function from the pwr package (Cohen, 1988) of R (R Core Team, 2020), we calculated the sample size necessary to execute multiple regression analyses with 4 predictor variables. The Cohen.ES function verified that a value of 0.15 represented the ability to detect medium effect sizes (Cohen, 1988). Using these medium effect sizes, with a significance level at 0.05, and power at 90%, we calculated the sample size necessary to execute our analysis at 103. We also used the ssMediation.VSMc function from the powerMediation package (Vittinghoff et al., 2009) of R to compute the sample size needed to reliably conduct a mediation analysis. Using the same power and effect size stated above, with the regression coefficient for the mediator set at 0.04, we calculated the sample size necessary to execute our analysis was 118. Therefore, we have sufficient power to conduct all subsequent analyses.

2.2 Materials and procedure

Caregivers completed questionnaires about family demographics (parent education, income, employment status, ethnicity, race), and their child's digital media use. Because prior work has found that the majority of children's digital media time at this age is spent with videos/TV and most children have some level of regular TV time (Kucker et al., 2024), the average minutes/day spent watching videos/TV/movies from the Media Assessment Questionnaire (MAQ; Barr et al., 2020) was used as the metric for digital media use. Children's expressive vocabulary was measured with the MacArthur-Bates Communicative Development Inventory: Words and Sentences (MCDI; Fenson et al., 1994). Children's total amount of social interactions was assessed through a self-report asking "On average, how many people does your child interact with on a daily basis?"[1]. The study was approved by the Oklahoma State University and Southern Methodist University Internal Review Boards and all participants gave informed consent.

2.3 Analysis

The goal of the current analysis is to pinpoint how digital media and social interactions influence children's vocabulary learning. Given each of these variables differ across development and vary on the basis of SES, we further probed how age and SES differentially impact the relationship between digital media, social interactions and vocabulary. First, we include bivariate correlations between all variables of interest. We next evaluated how the association between digital media and social interactions varies across ages by utilizing a multiple regression model with a three-way interaction between these terms and vocabulary as the outcome variable. In this model, age is used as a possible moderator by which the impact of media and social interactions change as children get older, while controlling for SES. Given SES-based differences in both vocabulary and digital media use are highly reported, we next used a serial mediation model to identify whether digital media use is the process by which vocabulary differences exist across SES. Lastly, to identify whether the number of social interactions children engage in can offset SES-based differences in vocabulary and digital media use, we ran conditional processes (i.e., moderated-mediation), by including social interactions as a moderator in the above mediation model.

3 Results

3.1 Bivariate correlations

Children's average vocabulary size (based on the MCDI) was 175.90 words ($SD = 173.57$, Range: 0–664), their average daily digital media use was 122.39 min/day ($SD = 103.18$, Range: 0–480), and they engage with an average of 5.54 people/day ($SD = 4.27$, Range: 1–30). As children got older, they also increased their number of social interactions [$r(297) = 0.12$, $p = 0.04$]. Consistent with prior work, Pearson's correlations revealed greater digital

1 Though just a single item was used to measure social interaction here, this particular question demonstrated strong internal validity with unpublished variables from this same data set. For instance, the average number of social interactions incrementally rises along with the number of people involved in a child's childcare situation - children's whose primary source of childcare is a parent, nanny, or other close relative interact with an average of 4.6 people/day, whereas those who report childcare that is primarily in a larger group setting (>5 children) average 13.1 people/day.

TABLE 1 Pearson's R Correlations between demographic and behavioral variables.

	1	2	3	4	5	6	8	9
(1) Age in days	1							
(2) Vocabulary	0.47***	1						
(3) Maternal education	0.04	0.13*	1					
(4) Paternal education	0.12	0.12*	0.59***	1				
(5) Average parent education	0.08	0.14*	0.89***	0.9***	1			
(6) Income	0.05	0.13*	0.47***	0.4***	0.49***	1		
(8) Social interaction	0.12*	0.06	0.07	0.04	0.06	0.15*	1	
(9) Digital media use	0.06	−0.13*	−0.21***	−0.16**	−0.21***	−0.17**	−0.21***	1

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

media use (TV/video time) was associated with less vocabulary knowledge [$r(305) = -0.13$, $p = 0.03$]. More digital media use was also associated with lower rates of social interaction, $r(297) = -0.21$, $p < 0.001$, coming from a household with lower rates of parental education, $r(305) = 0.14$, $p = 0.01$, and less income [$r(303) = 0.13$, $p = 0.02$]. Given average parental education and income held similar relationships with other variables of interest, and are often combined in studies of SES, all subsequent analyses utilized a composite measure of SES, wherein the rank order of average parental education and income were averaged together. All results are included in Table 1.

3.2 At what age do social interactions offset the relationship between digital media use and vocabulary?

A multiple regression model examined the interaction between age, amount of social interaction, and amount of digital media use on vocabulary, when controlling for SES (composite score). A three-way interaction between age, amount of social interaction, and amount of digital media use emerged ($b = 36.88$, $t = 2.12$, $p = 0.04$; Figure 1). To probe this three-way interaction term, we used the sim_slopes function in R (Cohen et al., 2003; Bauer and Curran, 2005). For children 19 months old and younger, there is no association between amount of social interaction, amount of digital media use, and vocabulary. For children older than 19 months old, when the number of people children interacted with was below 1.28, digital media had a negative effect on vocabulary outcome (see Supplementary Table S2 for simple slopes statistics). Among this age group, interacting with <9.81 people resulted in a negative relationship between digital media use and vocabulary, although this relationship was only marginally significant among children older than 27.94 months. These findings suggest that higher amounts of digital media use are associated with smaller vocabulary size when older children engage in fewer social interactions. This relationship is true regardless of SES. There was also a main effect of age ($b = 90.03$, $t = 9.51$, $p < 0.001$) and amount of digital media use ($b = -21.77$, $t = -2.11$, $p = 0.04$), with older children and children with lower rates of digital media use having larger vocabularies.

3.3 The mediating role of digital media on the relationship between SES and vocabulary

We utilized mediation to identify if differences in total vocabulary knowledge related to SES could be explained by digital media use. We used the PROCESS macro (Hayes, 2022) to specify this serial mediator model with ordinary least squares path analysis (see Figure 2). To ensure age did not provide an alternative explanation for the effects of SES on the outcomes, we controlled for this variable in the serial mediation analysis. Indirect effects for the specific pathways were computed using bias-corrected bootstrapping with 5,000 samples to construct 95% confidence intervals. Intervals not containing zero indicate that the indirect effect is statistically significant. Completely standardized indirect effects were computed (labeled "abcs" in Figure 2) to obtain measures of effect size (Preacher and Hayes, 2008); values of |0.01|, |0.09|, and |0.25| are considered small, medium, and large effects, respectively. The SES-to-Digital Media Use-to-Total Vocabulary pathway emerged as significant (abcs: B = 0.03, boot S.E. = 0.01, boot 95% CI [0.01, 0.05]).

3.4 Can social interactions offset the relationship between SES, digital media use, and total vocabulary?

Given the well-established relationship between SES and vocabulary knowledge, as well as the mediating role of digital media between these variables, we next sought to determine whether social interactions can offset this relationship. Conditional processes, also known as moderated mediation, were implemented to identify if SES-to-Digital Media Use-to-Total Vocabulary pathway was moderated by social interactions. We used the PROCESS macro (Hayes, 2022) to specify this moderated mediation model (using model 14; see Figure 3). To ensure that age did not provide an alternative explanation for the effects of social interaction on the outcome, we controlled for this variable in the analysis. Once again, bias-corrected bootstrapping with 5,000 samples was implemented to construct 95% confidence intervals for the indirect effects.

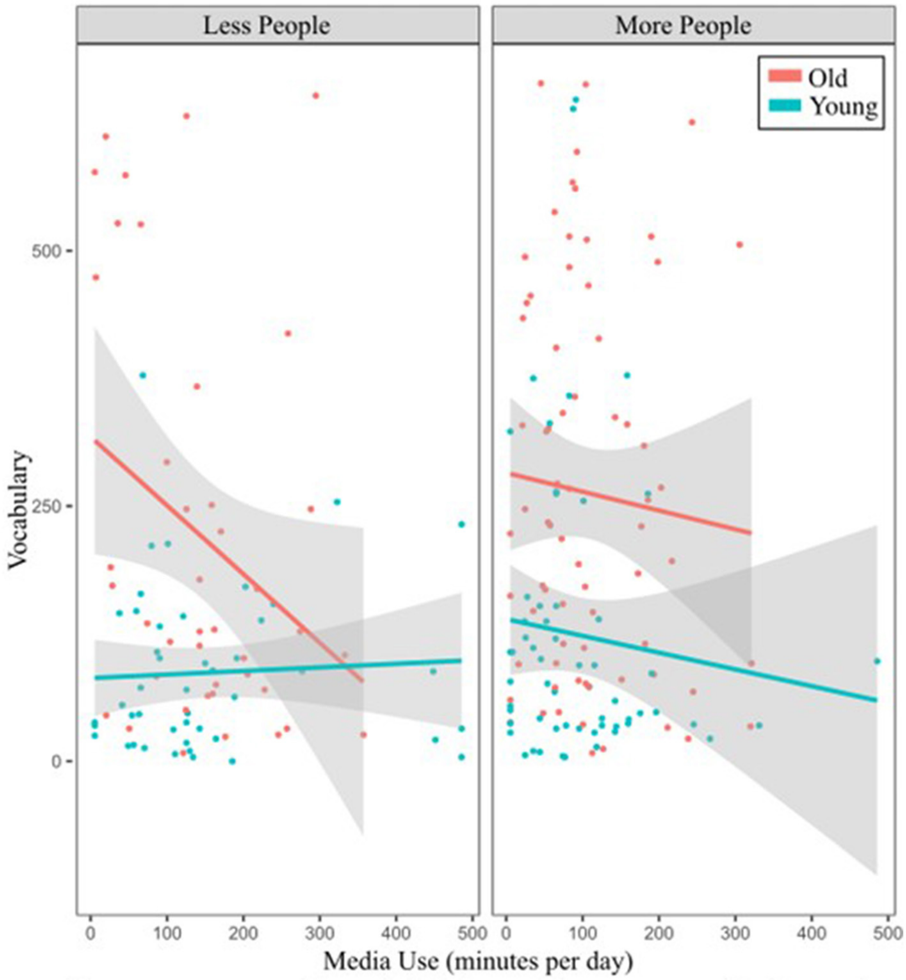

FIGURE 1
Influence of digital media use, age, and social interaction on vocabulary size. Older children (red line) and younger children (blue line) were dichotomized as older or younger than 23.48 months. Interacting with less (left plot) or more (right plot) people was dichotomized as interacting with more or less than 5.54 people.

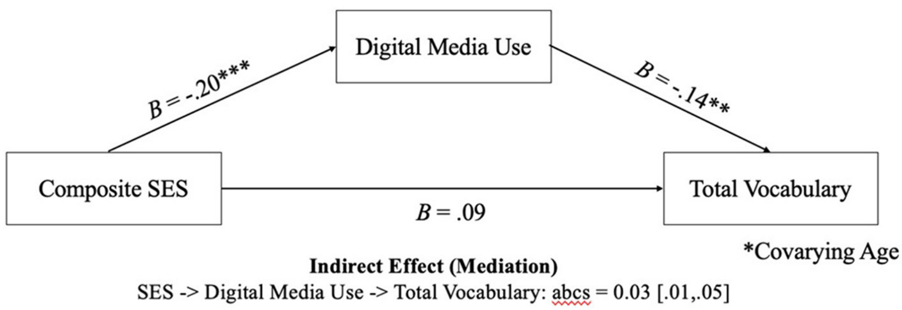

FIGURE 2
The association between SES and vocabulary was fully mediated by digital media use, when controlling for age. abcs = completely standardized indirect effect. The 95% confidence intervals for the indirect effects are contained in brackets after the point estimates and were constructed using bias-corrected bootstrapping with 5000 samples. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

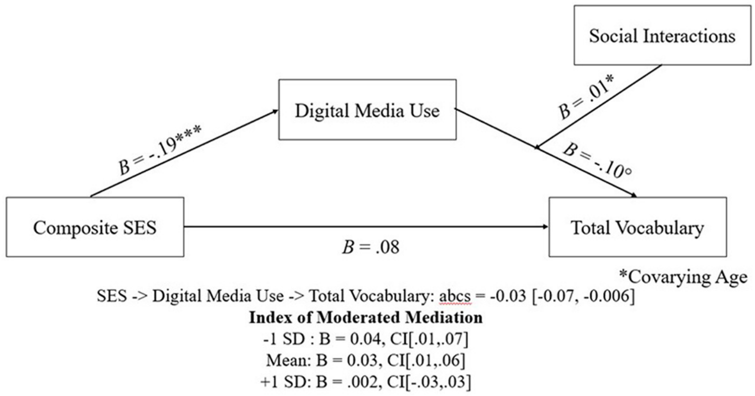

FIGURE 3
The SES to Digital Media Use to Total Vocabulary pathways varies significantly depending on the number of people a child interacts with on a regular basis. The 95% confidence intervals for the indirect effects were constructed using bias-corrected bootstrapping with 5000 samples. abcs = completely standardized indirect effect. The 95% confidence intervals for the indirect effects are contained in brackets after the point estimates and were constructed using bias-corrected bootstrapping with 5000 samples. Under the Index of Moderated Mediation, the reported mean and SDs represent the number of social interactions that significantly moderated the mediation model. °$p < 0.10$, *$p < 0.05$, ***$p < 0.001$.

Intervals not containing zero indicate that the indirect effect is regarded as statistically significant.

The SES-to-Digital Media Use-to-Total Vocabulary pathways significantly varied across SES (Index = −0.03, boot S.E. = 0.02, 95% CI [−0.07, −0.006]). The bootstrapped confidence intervals of the conditional effects indicated that individuals from lower SES households have higher amounts of digital media use, however, this only negatively impacts vocabulary if the child interacts with <5 people on a regular basis (1 SD: B = 0.04, boot S.E. = 0.02, boot 95% CI [0.01,0.08]; Mean: B = 0.03, boot S.E. = 0.01, boot 95% CI [0.01,0.06]). For children who interact with more than five people, the observed negative effects of digital media use on vocabulary are not present (+1 SD: B = 0.003, boot S.E. = 0.02, boot 95% CI [−0.03, 0.03]).

4 Discussion

One rising concern related to digital media use is it indirectly impacts children's language development by removing other linguistically rich experiences such as social interactions with others. Prior work has found that more digital media use correlates with less language input and fewer conversational turns from caregivers (e.g., Sundqvist et al., 2021), however, no work has gone beyond the home environment to tap broad opportunities for social interactions in a child's daily life. Moreover, no work has done so in conjunction with digital media use across a diverse set of families. Here, we take a first step toward such a goal and ask if media use (and specifically time spent watching videos) correlates with the overall amount of daily social interactions an individual has and how these social interactions influence children's vocabulary knowledge. We find, consistent with other recent work, that children at this age are watching videos/TV an average of 2 h/day; a rate that has increasing risen over the past few years (Rideout and Robb, 2020; Bergmann et al., 2022). Most importantly though, 17–30-month-old children here who experience less social interaction and greater digital media use have smaller vocabularies, and this disparity widens as children develop. Moreover, children from low SES households are likely to experience greater digital media use, putting them at risk for poorer vocabulary outcomes. Importantly though, our findings suggest higher amounts of social interaction may benefit vocabulary for all children, but especially those from lower socioeconomic backgrounds.

These results also contribute to our understanding of pathways and possible mechanisms for vocabulary growth in children from a range of SES backgrounds. As has been shown in past research, children from lower SES household were more likely to have smaller expressive vocabularies than their higher SES peers. We expand on this line of work by demonstrating that a critical mediator of this relationship is digital media use, a variable which is often overlooked in studies of the vocabulary gap. This finding has important implications for caregivers and policymakers, as digital media use is a relatively malleable risk factor. In fact, several existing policies suggest caregivers should limit digital media use by children; however, despite revised recommendations by the American Academy of Pediatrics (AAP), rates of children's digital media use continue to rise. Specifically, research has shown that from as early as 8 months of age, children have regular daily exposure to screens, which only increases with age (Bergmann et al., 2022). Digital media rates rise so much so that overall screen use among teens and tweens has increased by 17 percent from 2019 to 2021 — growing more rapidly than in the 4 years prior (Rideout and Robb, 2020). Given the increasing prevalence of digital media in children's lives the current study suggests that increasing the number of social interactions children engage in may serve as an alternative point of intervention to offset the detrimental effects of digital media on vocabulary. This is especially true for children from lower SES backgrounds. Numerous studies have cited the importance of social interactions in children's language development (Weisleder and Fernald, 2013; Tamis-LeMonda et al., 2014; Romeo et al., 2018). However, only a few studies have highlighted the importance of considering "other" social partners, beyond primary caregivers, in capturing the language input provided to children (Sperry et al., 2019). The current findings demonstrate that by interacting with more social partners, low SES children are more likely to experience gains in vocabulary that would otherwise be negatively influence by digital media use.

The current work highlights the moderating effect broader social interactions may have on digital media's impact on language development. Children who engaged in higher rates of digital media use were less likely to interact with more people and had smaller vocabularies, replicating past findings that digital media use decreases opportunities that are critical for language development (Christakis et al., 2009; Anderson and Hanson, 2017; Sundqvist et al., 2021). Here, only the overall amount of social interactions was measured via a single item on a parent report survey, which could include everything from playing with siblings, to talking with grandparents, to interacting with a classroom of preschoolers. Despite the variability in source of the social interactions, the effect of simply being around more people seems to offset the negative impacts of digital media use on vocabulary. This is consistent with prior work showing that interactions with both caregivers (Ramírez-Esparza et al., 2014) and peers (Perry et al., 2018) can boost language, primarily because it leads to more opportunities for using and learning new words. Future work ought to further test these mechanistic explanations with extended recording of both media use and social interactions outside the home. Differentiating social interaction inside and outside the home may also prove to be a fruitful endeavor as various lines of work suggest that household routines and chaos could factor into children's language (e.g., Lecheile et al., 2020). Moreover, the current study does not incorporate social interactions *during* digital media use which may be even more beneficial for language – prior work finds digital media use that is interactive, social, and used with a social partner is more facilitative to language learning (Linebarger and Vaala, 2010; Lytle et al., 2018). It is also possible that the types of words and quality of word learning experienced in social interactions differs from those in digital interactions – another avenue for future work.

Taken together, these results suggest that the growing prevalence of digital media in young children's daily lives may have negative impacts on vocabulary, but critically, social interactions alter that impact in a positive way, possibly by providing opportunities for hearing and using language (Sundqvist et al., 2021). By increasing attention to the overall daily social interactions of young children we may be able to offer ways to mitigate media's negative effect on children's early vocabulary growth, across all socioeconomic backgrounds.

Data availability statement

The original contributions presented in the study are publicly available. This data can be found here: https://osf.io/mv2ua/?view_only=2793f7f362824eafb81d0d5d43ea9608.

Ethics statement

The studies involving humans were approved by the Oklahoma State University IRB and the Southern Methodist University IRB. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SK: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Writing – original draft, Writing – review & editing. JS: Conceptualization, Formal Analysis, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fdpys.2024.1401736/full#supplementary-material

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Concurrent and longitudinal associations between touchscreen use and executive functions at preschool-age

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Introduction: The prevalence of touchscreen devices has recently risen amongst young children. Some evidence suggests that increased touchscreen use may be negatively related to preschool-age children's executive functions (EFs). However, it has been argued that actively interacting with touchscreen devices (e.g., via creative apps for drawing) could better support EF development compared to passive use (e.g., watching videos). There is a pressing need to understand whether the type of use can explain potential associations between touchscreen use and EF.

Methods: By following up longitudinally on an infant sample, now aged 42-months ($N = 101$), the current study investigates the relative contributions of passive and active touchscreen use, measured concurrently at 42-months and longitudinally from 10-to-42-months, on parent-reported EFs.

Results: A multivariate multiple regression found no significant negative associations between touchscreen use and preschool EF. There was a significant positive association between active touchscreen use at 42-months and the BRIEF-P Flexibility Index.

Discussion: The lack of significant negative associations found is consistent with an earlier study's findings in the same sample at infancy, suggesting that the moderate levels of early touchscreen use in this sample are not significantly associated with poorer EF, at least up to preschool-age.

KEYWORDS

touchscreen, executive functions, preschool cognitive development, media exposure, active screen use, passive screen use

Introduction

Executive functions (EFs) are core cognitive skills needed to control our attention and purposeful behaviors to work toward goals in everyday life (Blair, 2016). EF skills include inhibitory control (IC; deliberately supressing dominant yet inappropriate responses), working memory (WM; actively maintaining important information in mind), and cognitive flexibility (CF; considering simultaneous representations of an object or event and/or flexibly alternating between tasks). EF skills develop rapidly during early childhood and play an important role in social and academic school readiness (Blair et al., 2005; Hendry et al., 2016). EFs rely on the development of the prefrontal cortex (Best and Miller, 2010; Fiske and Holmboe, 2019), which is thought to be particularly susceptible to individual differences in children's early environments (Hodel, 2018). Several environmental factors, including maternal mood (Power et al., 2021), socioeconomic status (Lawson et al., 2018), as well as traditional screen media (e.g., television; Kostyrka-Allchorne et al., 2017a) have been linked to developmental differences in EF. In recent years there has been an increase in the use of touchscreen devices (e.g., tablet devices and smartphones) amongst young children (Bedford et al., 2016; Bergmann et al., 2022; Hendry et al., 2022). The increased portability of touchscreen devices may make them more easily accessible to young children, potentially increasing the opportunity to impact early EF development (Jusiene et al., 2020; Eric, 2021; Taherian Kalati and Kim, 2022). However, the relatively recent increase in popularity of touchscreen devices amongst young children means that research addressing associations between touchscreen media and early EF development is still limited. The aim of this study was to test the association between duration and type of touchscreen use and EF skills in preschool-age children.

Given the relatively limited research investigating the impact of touchscreen use on early EF skills, it is important to consider the impact of traditional screen media (i.e., television, TV) on young children's cognitive development. Christakis et al. (2004) found that TV exposure before 3-years was associated with parent-reported attentional problems at 7-years. Similarly, Miller et al. (2007) found that TV viewing was associated with more inattentive/hyperactive behaviors amongst preschoolers, which could have a negative impact on early EF skills considering that maturing attentional control forms the basis of preschool EF development (Garon et al., 2008). Experimental studies investigating the effect of immediate viewing of fantastical screen content, which potentially violates children's knowledge/expectations of reality, have also shown links to reduced EF proficiency post-television viewing (in comparison to EFs measured pre-television viewing; Rhodes et al., 2020). It may be that such content is difficult for children to incorporate into their pre-existing mental representations, depleting their limited attentional resources needed for successful EF performance (Lee and Lang, 2015; Rhodes et al., 2020). With touchscreen usage becoming increasingly prevalent amongst young children (Kostyrka-Allchorne et al., 2017b), it is important to determine whether touchscreen devices may exacerbate the negative effects of screen media previously found between TV viewing and early EF skills.

Although several studies have found negative associations between touchscreen use and early EF development, the majority of these have employed unitary measures of EF, or combinations of several EF measures to explore general executive functioning (Barr et al., 2010; Lillard and Peterson, 2011; Nathanson et al., 2014; Antrilli and Wang, 2018), despite the different core EF components being identifiable during the preschool period (Garon et al., 2008). IC, WM and CF each have separate developmental trajectories and show differential associations with more complex forms of EF (Friedman et al., 2011; Hendry et al., 2016; Devine et al., 2019; e.g., looking ahead to the attainment of a goal and planning one's actions accordingly). Investigating different EF skills separately is particularly important considering that across existing research, conclusions regarding the effect of touchscreen use on individual EFs have varied. A longitudinal study by Portugal et al. (2023) found no differences in impulse/self-control between low touchscreen users and high touchscreen users ($\geq$15 min/day) at 42-months, but did find that high users showed reduced performance on lab-based WM and CF tasks. However, these effects became non-significant after controlling for background TV, suggesting the effect found may not be specific to touchscreen devices, but instead related to a child's broader media environment (Portugal et al., 2023). By contrast, McNeill et al. (2019) found a negative association between preschoolers' touchscreen use (>30 min/day) and IC measured 12-months later (indexed by a Go/No-Go task), but found no links with WM or CF. Similarly, McHarg et al. (2020) found that parent-report of regular screen media use (including touchscreens) at 4-months predicted poorer performance on a self-regulation task at 14-months, but was unrelated to WM or CF. Lawrence et al. (2020) found similar effects later in childhood, as 32-to-47-month-olds who used touchscreen devices more regularly, and at an earlier age, displayed lower self-regulation as measured by experimental tasks.

One potential factor which could be contributing to these different patterns across studies is the way in which children are using touchscreen devices. Screen use can involve more *"passive"* viewing of screen content that requires little interaction/input from the child (e.g., TV-viewing), or *"active"* use which necessitates interactive and cognitive engagement with a screen-media device (e.g., creative apps for drawing, educational games, etc.; Corkin et al., 2021). Some experts in the field have argued that the increased interactivity of active touchscreen use could better support early cognitive development (Christakis, 2014; Kirkorian, 2018; Corkin et al., 2021). During active touchscreen use, because young children can easily navigate touchscreen devices using swiping and tapping motions with their fingers, they are able to touch and manipulate images and characters on the screen in addition to seeing and hearing them (Li et al., 2018). This multimodal stimulation may make the content more realistic and easier to process for some children (Benski and Fisher, 2013). Therefore, the increased interactivity promoted in active touchscreen use may reduce any negative effects on EFs in comparison to passive video-watching (Subrahmanyam and Greenfield, 2008).

There is some preliminary evidence to support active touchscreen use being more developmentally appropriate for early EF development. Huber et al. (2018) found that children were more likely to perform better on a WM task and a delay of gratification task after playing an educational app than after viewing a fantastical cartoon. Similarly, Li et al. (2018) found that simply watching fantastical video content from a game on an iPad had a negative effect on IC, whilst active interaction with the same game had no effect on IC. In contrast, Helm and McDermott (2022) found that active touchscreen use via playing a cooking game on a tablet, in comparison to having no touchscreen usage and instead completing a similar cooking task with toys, had an immediate negative impact on IC performance. However, the active touchscreen game played still involved some passive video-watching which may have negatively impacted subsequent IC performance. Further investigation is needed to better understand the relative contributions of active and passive touchscreen use on different EF skills. This could help to determine whether there should be different screen media guidelines for young children depending on how touchscreen devices are used.

Age is another important factor to consider when investigating the impact of touchscreen media on early EF skills. Although a study by Lui et al. (2021) found no negative associations between touchscreen use and a composite EF measure at 10-months, Hendry et al. (2022) found a negative association between screen use (including touchscreens) and the same composite EF measure amongst a slightly older sample of young children up to 36-months. Bedford et al. (2016) found that average daily duration touchscreen usage time increased with age from 6-to-36-months. Therefore, it is plausible that touchscreen use needs to build up over the first few years of life to have a detrimental effect on EFs at preschool-age. It is also worth considering that touchscreen usage during toddlerhood and the preschool years may be fundamentally different to usage during infancy. While children start to attend to screen content from infancy, sustained attention increases until mid-childhood (Anderson et al., 1986), suggesting that the opportunity for screen-time to impact development may increase with age as children can attend to screen content for much longer durations of time. Therefore, the possible negative effects of early touchscreen usage may appear later in development during the preschool-years rather than in infancy.

By following up on Lui et al.'s (2021) infant sample, now aged 42-months, the current study aims to investigate how concurrent (42-month) and longitudinal (10-to-42-month average) touchscreen use (predictor) is associated with the development of different EF skills (IC, WM and CF, outcome variables) in early childhood. The current study tested (1) whether we replicate negative effects of touchscreen use on EFs found by previous research now that the sample is preschool-age, potentially due to the accumulation of usage over time (McNeill et al., 2019; Lawrence et al., 2020; McHarg et al., 2020; Hendry et al., 2022; Portugal et al., 2023); and (2) whether the effects were driven by passive or active touchscreen use.

Materials and methods

Participants

Participants were 101 42-month-olds (48 boys) from the longitudinal Oxford Early Executive Functions (OEEF) study at the Oxford University BabyLab (see the sample demographics in Table 1). The OEEF study received ethical approval from the University of Oxford (Ref. No. R57972). Parents provided informed consent prior to data collection, which took place from April 2019 to November 2022. The longitudinal design allowed information about the children's touchscreen media usage to be collected at six timepoints across the first 3.5-years of their lives. Specifically, touchscreen media usage was reported when the sample was 10-, 16-, 24-, 30-, 36-, and 42-months-old. EF was also measured at these six timepoints, but the current study only focused on EF skills measured at 42-months. Participants were recruited from the local hospital, the Oxford University BabyLab volunteer database, and social media, and had to meet at least one of the following criteria to be included in the analysis: (a) born at 36 weeks' gestation or later or (b) weighing at least 5.5 lbs (2.5 kg) at birth. Three participants were excluded from the final sample of 101 children due to potentially serious health issues (e.g., brain abnormalities, oxygen deprivation at birth). Families received Amazon vouchers, stickers and small toys for participating in the OEEF study.

TABLE 1 Sample's demographic characteristics.

Characteristic	*N*	Mean	*SD*	Min	Max
Child's age (in months)*	101	42.06	0.45	41.09	43.78
Mother's years of education**	100	18.20	3.24	8	30
	N	%			
Child's Sex					
Male	48	47.52			
Female	53	52.48			
Child's Ethnicity					
White British	73	72.28			
White and Mexican	1	0.99			
White and Black Caribbean	1	0.99			
White and Black African	1	0.99			
White and Asian	4	3.96			
White and Arabic	1	0.99			
Other White	15	14.85			
Other Mixed	1	0.99			
Asian	1	0.99			
Prefer not to say	1	0.99			
Unanswered	2	1.98			

*Age at which the sample's preschool EFs were measured.
**1 missing response.

TABLE 2 Frequency of TUQ responses at each timepoint.

Timepoint	*N*	Mean Age*	Age SD	Min Age	Max Age
10-months	100	10.07	0.28	9.67	11.45
16-months	97	16.22	0.37	15.63	18.29
24-months	85	24.38	0.37	23.75	25.79
30-months	82	30.48	0.60	29.80	32.63
36-months	86	36.45	0.56	35.39	37.99
42-months	94	42.07	0.41	41.12	43.29

*Mean age (in months) of the child when the TUQ was completed at each timepoint.

Materials

Touchscreen use questionnaire (TUQ)

The OEEF team created the 12-item TUQ to measure early touchscreen use via parent-report (the full TUQ can be found in the Supplementary material; Lui et al., 2021). The TUQ was completed by parents (usually the mothers of participants, $N = 89$) online via Qualtrics. At 42-months, 94 parents in the final sample completed the TUQ. The number of participants who completed the TUQ at the previous five timepoints can be seen in Table 2.

Administering the TUQ across these different timepoints allowed both concurrent touchscreen use at 42-months, and average touchscreen use from 10-to-42-months to be measured. To be included in the final sample of 101 participants used for the analyses, all participants needed to provide TUQ data on at least

3/6 of the timepoints, with at least one of these being at 10-,16-, or 24-months, and at least one being at 30-, 36-, or 42-months (only two participants did not meet this criteria).

As part of the TUQ, at each timepoint the duration of participants' passive and active touchscreen use were individually measured by a single item rated on an ordinal scale. Parents reported their child's passive touchscreen use via the following item: "In the past week, roughly how long in total did your child spend looking at (but not touching) a touchscreen device? (Not including visits to the BabyLab)." Parents then reported their child's active touchscreen use via this item: "In the past week, roughly how long in total did your child spend interacting with (tapping or swiping) a touchscreen device? (Not including visits to the BabyLab)." Parents separately rated these passive and active touchscreen duration items on a 7-point Likert scale ($1 = <5$ min, $2 = 5–20$ min, $3 = 20–60$ min, $4 = 1–2$ h, $5 = 2–4$ h, $6 = 4–6$ h, $7 = 7$ or more hours). The score of passive touchscreen duration (from the "looking at" item) and the score of active touchscreen duration (from the "interacting with" item) at each timepoint were used in the analyses.

Participants' average passive and active touchscreen use across the six timepoints were calculated separately. Scores of passive touchscreen duration from 10-to-42-months were averaged to calculate an average passive touchscreen use score across the first 3.5-years of life. Likewise, scores of active touchscreen duration from 10-to-42-months were averaged to calculate an average active touchscreen use score across the first 3.5-years of life. These average passive touchscreen use and average active touchscreen use scores had good internal consistency across timepoints (Cronbach's $\alpha = 0.85$; Cronbach's $\alpha = 0.84$, respectively).

The behavior rating inventory of executive function, preschool version (BRIEF-P)

The BRIEF-P is a parent-reported measure of preschool EFs which has been extensively validated amongst different subgroups of children (Gioia et al., 2000; Bausela Herreras, 2019; e.g., across different cultures and clinical samples). Parents rated how frequently their child had problems with different behaviors during the past 6 months on a 3-point scale (Never, Sometimes, Often). It consists of 63 items in five non-overlapping scales which form three overlapping summary indexes: the Inhibitory Self-Control Index (ISCI), the Flexibility Index (FI), and the Emergent Metacognition Index (EMI). The ISCI is composed of the Inhibit scale (item example: "The child is fidgety, restless or squirmy") and Emotional Control scale (item example: "The child overreacts to small problems"). The FI is also composed of the Emotional Control scale, as well as the Shift scale (item example: "The child has trouble changing activities"). The EMI is composed of the Working Memory scale (item example: "The child has trouble with activities or tasks that have more than one step) and Plan/Organize scale (item example: "The child does not complete tasks after given directions"). The ISCI, FI and EMI indexes were used as measures of the three EF domains (IC, CF, and WM) within the sample. At 42-months, 101 parents completed the BRIEF-P. Because a higher BRIEF-P score means lower EF skills, for ease of interpretation scores were reversed (by subtracting from 100) so that higher BRIEF-P scores represented stronger EF skills. All of the summary indexes had very good internal consistency (ISCI Cronbach's $\alpha = 0.91$, FI Cronbach's $\alpha = 0.87$, EMI Cronbach's $\alpha = 0.90$).

Sociodemographic questionnaire

The OEEF team created a questionnaire to collect demographic information from the sample. Parents reported their child's age and sex, who their primary caregiver was, and information about their household (number of rooms, total family annual income, number of adults in the household). Mothers and fathers separately reported their marital status, number of years in education, and occupation. From this questionnaire, child's sex and mother's years in education were used in the current study's analyses. Child's sex was controlled for because there is behavioral evidence of sex differences in early EFs (Wiebe et al., 2008). Mother's years in education (a common proxy for socioeconomic status (SES)) was controlled for because previous research has found that children from lower socioeconomic contexts are more negatively affected by screen use, and children from higher socioeconomic contexts also tend to have stronger EF skills (Bernier et al., 2010; Denham et al., 2015; Ribner et al., 2017). Only 67 participants provided information about their father's years in education, therefore mother's years in education was used as a proxy of SES.

Procedure

As part of the longitudinal OEEF study, data was collected from the sample at 10-, 16-, 24-, 30-, 36-, and 42-months. Participants visited the Oxford University BabyLab at 10-, 16-, and 42-months. During these visits, participants completed an EF task battery and parents completed the TUQ, as well as the BRIEF-P at the 42-month timepoint. Within 2 weeks prior to their 42-month visit, parents also completed the sociodemographic questionnaire. This questionnaire was also completed 2 weeks prior to their 10-month visit, therefore if any participants did not complete the questionnaire at 42-months, the sociodemographic information provided at 10-months was included instead.

At the 24-month timepoint, due to the COVID-19 pandemic, very few participants were able to visit the Oxford University BabyLab after the UK government's lockdown restrictions were implemented in March 2020. Therefore, the majority of participants completed the TUQ remotely at the 24-month timepoint, and all participants completed the TUQ remotely at the 30- and 36-month timepoints.

Statistical analysis

IBM SPSS Statistics Version 29.0.2 was used for statistical analysis. The Kolmogorov-Smirnov test, histograms, and normal Q-Q plots showed that all variables violated the assumption of normality, apart from the BRIEF-P EMI index (see Supplementary material). Therefore, Spearman's Rank correlation coefficient, which is robust against skewed data, assessed bivariate associations between touchscreen use (both passive/active and average/concurrent use) and EF skills (as measured by the BRIEF-P's Inhibitory Self-Control, Flexibility, and Emergent Metacognition indexes; Bishara and Hittner, 2012). The Benjamini-Hochberg procedure was used to correct the alpha level of 0.05 for the false discovery rate (12 family-wise comparisons, see Supplementary material).

TABLE 3 Descriptive statistics of passive and active touchscreen use at each timepoint.

	10-months	16-months	24-months	30-months	36-months	42-months	Average (10–42 months)
Passive touchscreen use*							
Mean	1.86	2.39	3.07	3.36	3.21	3.37	2.84
SD	1.14	1.45	1.58	1.96	1.76	1.83	1.23
Active touchscreen use**							
Mean	1.26	1.84	2.33	2.66	2.28	2.79	2.22
SD	0.69	1.25	1.59	1.79	1.77	1.58	1.06

This table only includes participants who met the criteria of completing the TUQ on at least 3/6 of the timepoints, with at least one of these being at 10-,16-, or 24-months, and at least one being at 30-, 36-, or 42-months (N = 101).
*Passive touchscreen use = the duration a child spent looking at (but not touching) a touchscreen device in the past week (rated on a 7-point Likert scale from "<5 min" to "7 or more hours").
**Active touchscreen use = the duration a child spent interacting with (tapping or swiping) a touchscreen device in the past week (rated on a 7-point Likert scale from "<5 min" to "7 or more hours").
ISCI, Inhibitory Self-Control Index; FI, Flexibility Index; EMI, Emergent Metacognition Index.

TABLE 4 Descriptive statistics of the reversed BRIEF-P indexes.

EF Index	*N*	Mean	*SD*	Min	Max
Inhibitory self-control	101	48.56	9.14	13	64
Flexibility	101	48.38	8.95	13	65
Emergent metacognition	101	47.93	10.56	24	66

To assess the effects of touchscreen use beyond sociodemographic variables, a multivariate multiple regression was performed to integrate the different variables into one model whilst also adjusting the significance test for the multiple dependent variables. Maternal education (a common proxy for socioeconomic status) and child's sex were entered into the model as independent variables known to influence early EF development (see the "Sociodemographic Questionnaire" section in the Methodology).

Before conducting the multivariate multiple regression, further preliminary analyses (i.e., Cook's distance, tolerance and variation inflation factor (VIF) statistics, plots of standardized and predicted residuals) were run to check for violations of normality, linearity, multicollinearity, and homoscedasticity (see the Supplementary material). As some of the independent variables were formed from some of the same TUQ items (i.e., the average touchscreen use scales were partly made up of the 42-month touchscreen use scales), Spearman's correlations were run between all the independent variables to check for the assumption of no multicollinearity (see Supplementary material; Hinkle et al., 2003). None of the variables had a correlation coefficient higher than 0.8, and all other assumptions were met, so the multivariate multiple regression was performed.

Results

Descriptive statistics

Descriptive statistics for the sample's passive and active touchscreen use at each of the six timepoints from 10-to-42-months of age can be seen in Table 3, showing that usage gradually increased amongst the sample over the first 3.5-years of life. Descriptive statistics for the BRIEF-P indexes at 42-months can be seen in Table 4.

Correlations between touchscreen use and executive functions

There was a significant positive correlation between 42-month active touchscreen use and scores on the BRIEF-P Flexibility Index ($r_s = 0.27, p = 0.01$), but this did not survive correction for multiple comparisons (Benjamini-Hochberg adjusted $p = 0.08$). No other significant correlations were found between touchscreen use and executive functions as measured by the BRIEF-P. See Table 5 for the full correlation table.

Additional analyses

Although touchscreen usage has typically been measured in previous research by a single rating of the duration spent on touchscreen devices in a specific time period (Cheung et al., 2017; McHarg et al., 2020; Corkin et al., 2021; Bergmann et al., 2022; Portugal et al., 2023; e.g., in a week), in addition to weekly duration of touchscreen use, the current sample's *frequency* of touchscreen use was also measured. Parents separately rated how frequently their child completed different actions on a touchscreen (e.g., how often their child would 'do drawings or scribbles' on a touchscreen device). Each action was then classified as either passive or active, allowing passive and active touchscreen use to be further differentiated from one another beyond just duration of touchscreen use. The change in frequency of touchscreen use from 10-to-42-months was very similar to the change in duration of touchscreen use (gradually increasing over time; see the Supplementary material). A correlational analysis between frequency of touchscreen use and the EF skills (as measured by the BRIEF-P) was also run to see if this differed from the correlational analysis with duration of touchscreen use presented above. No significant correlations were found between frequency of touchscreen use and EF skills (see Table 6 for the full correlation

TABLE 5 Correlations between touchscreen use and EF skills as measured by the BRIEF-P.

Variables	42-month Passive Touchscreen Use	42-month Active Touchscreen Use	Average Passive Touchscreen Use	Average Active Touchscreen Use
ISCI scores	0.04	0.13	0.06	0.08
FI scores	−0.08	0.27*	−0.07	0.14
EMI scores	0.10	0.04	0.14	0.07

*p < 0.05, two-tailed.
ISCI, Inhibitory Self-Control Index; FI, Flexibility Index; EMI, Emergent Metacognition Index.

TABLE 6 Correlations between touchscreen use frequency and the BRIEF-P indexes.

Variables	Frequency of 42-month Passive Use	Frequency of 42-month Active Use	Frequency of Average Passive Use	Frequency of Average Active Use
ISCI scores	−0.11	0.03	−0.14	0.03
FI scores	−0.06	0.07	−0.13	0.10
EMI scores	−0.09	−0.004	−0.04	−0.03

*p < 0.05, two-tailed.
ISCI, Inhibitory Self-Control Index; FI, Flexibility Index; EMI, Emergent Metacognition Index.

table). The Supplementary material includes further discussion of this additional correlational analysis.

Multivariate multiple regression

The results of the multivariate multiple regression investigating the associations between different types of touchscreen use and each EF skill are reported in Table 7. When child's sex and years of maternal education were accounted for, no significant negative associations between passive or active touchscreen use and parent-reported preschool EFs were found, whether this was concurrent use at 42-months or average use from 10-to-42-months. However, a positive association was found between concurrent active touchscreen use at 42-months and Flexibility Index scores, such that higher active touchscreen use was associated with better Flexibility Index scores ($p = 0.03$, Wilks' Lambda $= 0.081$, partial $\eta^2 = 0.05$). The 42-month active touchscreen use model as a whole did not significantly explain EF variation (in all three EF outcome measures), $F_{(3,91)} = 2.681$, $p = 0.052$; partial $\eta^2 = 0.08$. None of the other predictors significantly explained variation in any of the EF outcome measures.

Discussion

In a follow-up of the Lui et al. (2021) infant sample, the current study aimed to test the association between touchscreen use and executive function skills at preschool-age. After controlling for demographic variables (child sex and maternal education), no negative associations were found between touchscreen use and preschool EFs. This is consistent with Lui et al.'s (2021) earlier findings in the same sample, suggesting that the moderate levels of early touchscreen use observed in this sample are not significantly associated with poorer EF skills. One positive association was found between active touchscreen use at 42-months and the BRIEF-P Flexibility Index. This positive association is at least partially consistent with Lui et al.'s (2021) finding of a positive association between overall touchscreen use (combining active and passive touchscreen use) and a parent-reported composite EF score in the same sample at 10-months. However, it is important to note that Lui et al. (2021) combined duration and frequency of touchscreen usage into a single measure of touchscreen use, whereas the current study only found an association between *duration* of active touchscreen use and cognitive flexibility (see Supplementary material for the full correlational analysis between *frequency* of touchscreen use and EFs at 42-months). While touchscreen use is most commonly measured and defined in terms of duration, there is a need for future research to consider how duration vs. frequency of use may differentially impact early EF development.

The current study's findings are broadly consistent with previous reports of active touchscreen usage being less detrimental to EF abilities than passive usage (Huber et al., 2018; Li et al., 2018; Hu et al., 2020; Bustamante et al., 2023). If replicated in other samples, what could explain the positive association between active touchscreen use and CF found in the present study? It has been hypothesized that CF may be exercised and practiced by switching between engaging with a screen-based activity and other activities (e.g., interacting with a parent), or quickly switching between different screen-based activities. This task-switching at a young age may enhance the ability to adapt and switch successfully from one task to another by minimizing task-switching costs (Alzahabi and Becker, 2013). Some research has shown that practicing one's ability to switch between actions, objectives and rules when interacting with screen media (i.e., engaging in more than one media or non-media activity simultaneously) can train and improve CF in other contexts (Alzahabi and Becker, 2013; Murphy and Shin, 2022).

However, the lack of direct EF assessment is a limitation of the current study, and the positive association found between active touchscreen use and CF needs to be replicated using experimental measures of CF in addition to parental report. Portugal et al.

TABLE 7 Multivariate multiple regression for the variables predicting each EF domain.

Predictors	B	SE	*p* value	95% CI
Inhibitory Self-Control Index				
Child sex	−1.48	1.96	0.45	(−5.37, 2.41)
Maternal education	−0.32	0.32	0.32	(−0.96,0.31)
42-month passive touchscreen use	−0.19	0.86	0.82	(−1.90, 1.51)
42-month active touchscreen use	0.85	0.94	0.37	(−1.01, 2.71)
Average passive touchscreen use	0.58	1.29	0.65	(−1.97, 3.15)
Average active touchscreen use	−0.44	1.59	0.79	(−3.60, 2.73)
Flexibility Index				
Child sex	−1.42	1.83	0.44	(−5.05, 2.20)
Maternal education	−0.53	0.30	0.08	(−1.13,0.06)
42-month passive touchscreen use	0.04	0.80	0.96	(−1.55, 1.63)
42-month active touchscreen use	1.99	0.87	0.03*	(0.25, 3.72)
Average passive touchscreen use	−0.71	1.21	0.56	(−3.10, 1.69)
Average active touchscreen use	−1.10	1.48	0.46	(−4.04, 1.85)
Emergent Metacognition Index				
Child sex	0.21	2.27	0.93	(−4.31, 4.72)
Maternal education	0.15	0.37	0.68	(−0.59.89)
42-month passive touchscreen use	−0.23	1.00	0.82	(−2.21, 1.74)
42-month active touchscreen use	−0.26	1.09	0.81	(−2.42, 1.90)
Average passive touchscreen use	0.73	1.50	0.63	(−2.25, 3.71)
Average active touchscreen use	0.71	1.85	0.70	(−2.96, 4.38)

*$p < 0.05$, two-tailed.

(2023) actually found that 42-month-old children with high levels of touchscreen use had poorer performance on a composite experimental measure of CF and WM. It may be the case that parental reports vs. experimental tasks assess different aspects of EF (Toplak et al., 2013). Although experimental measures of EF were also used in the OEEF study, the current paper focused on parent-reported EF because parental report tends to measure more ecologically valid aspects of EF (such as pursuing everyday goals), whereas EF tasks relate to accuracy of test performance and processing efficiency (Toplak et al., 2013). It remains an important aim for future research to tease apart the association between touchscreen use and experimental tasks vs. parent-reported EF.

In addition to the Shift scale, the BRIEF-P Flexibility Index is made up of the Emotional Control scale. Although previous research has found increased overall touchscreen use (combining passive and active touchscreen use) to be associated with lower self-regulation (Lawrence et al., 2020), the positive association found in the present study could suggest that moderate amounts of active touchscreen use may not show the same negative associations. In line with this, no associations were found between touchscreen usage and the BRIEF-P Inhibitory Self-Control Index (which consists of the Emotional control scale and Inhibit scale). Additionally, no associations were found between touchscreen usage and the Emergent. Metacognition Index (which consists of the Working Memory scale and Plan/Organize scale). WM and IC seem to influence and support each other over the preschool period, with performance on WM and inhibition tasks correlating with one another (Senn et al., 2004). It has been hypothesized that CF improves particularly rapidly during the preschool period, and that CF abilities are theoretically built on WM and IC which may have already undergone rapid development earlier in life (Scionti and Marzocchi, 2021). Therefore, CF may be more sensitive to external influences of EF development, such as touchscreen usage, during the preschool period in comparison to IC and WM.

It is also important to consider how touchscreen use is related to a young child's broader media environment, which often involves a mixture of TV, tablets, smartphones, and video game consoles. The negative association found by Portugal et al. (2023) between touchscreen use and CF/WM was no longer significant once background TV was controlled for. Although a recent study by Brauchli et al. (2024) found that general screen time (including both TV and touchscreen use) did not influence 12-to-36-month-olds' effortful control (a construct related to EF), many other contextual and content-related screen media factors in a child's environment were not considered. For example, the impact of background TV likely depends on many factors, including the number of TVs in a home and how many hours a child spends at home. Unfortunately, no data about the OEEF sample's broader media environment beyond touchscreen devices was collected. Additionally, passive and active touchscreen use being measured only by a single item each is a clear limitation of the current study by potentially oversimplifying children's diverse use of screen media. Therefore, the use of more nuanced and objective measures of children's duration, content, and usage-type of various media platforms could produce a more comprehensive picture of children's media environment in future studies. This will allow for a better understanding of how different ways in which screen media are used can influence the early development of not only EFs, but also other cognitive domains (such as language). For example, Neumann and Neumann (2014) found that touchscreen usage was positively associated with emergent literacy skills in preschoolers, but that this association was dependent on many important factors beyond just tablet use time, such as quality of content.

Strengths and limitations

To date, no study has separately investigated the longitudinal and concurrent effects of passive and active touchscreen use on EF in such a large sample of preschoolers. By collecting data on a wide range of active touchscreen usages, future research can more specifically pinpoint where any positive impacts of active touchscreen use may lie.

The longitudinal design of the current study allowed us to consider children's touchscreen use across the first 3.5-years of life, as well as concurrent covariation. Children's capabilities and developmental needs undergo significant changes during the preschool period, and children may be more vulnerable to the effects of environmental influences such as screen media usage at different ages (Zelazo and Carlson, 2012; Horowitz-Kraus et al., 2023). This is why the preschool period is arguably the optimal time to investigate whether screen media influences essential EF and EF-related skills (e.g., academic and socio-emotional skills; Conway and Stifter, 2012). Importantly, however, measuring touchscreen use *across* the first 3.5-years of life guards against temporary fluctuations at one specific age. We did not find any associations between average passive or active touchscreen use from 10-to-42-months and preschool EFs. Although not corroborating the potential beneficial effect of active usage on cognitive flexibility, this result supports the conclusion of Lui et al. (2021) that there is no obvious negative impact of touchscreen use on EFs (at least within a relatively high-SES sample), extending this finding up to 42-months of age.

Several limitations of the current study should be considered. Firstly, we cannot determine the causal direction of the association found between 42-month active touchscreen use and the BRIEF-P Flexibility Index. It may be that children who already have stronger flexibility skills could be more motivated to actively engage with touchscreen devices. Their stronger flexibility skills could enable them to more successfully process information presented both on and off screens, as well as enable them to apply any flexibility-related skills taught to them via touchscreens in other contexts which do not involve screens. This highlights the importance of future research considering a range of other pre-existing differences related to EF which could drive differences in touchscreen usage, or mediate the relationship between touchscreen use and EFs.

In relation to considering other covariates, although maternal years in education was controlled for as a proxy for SE background, the sample was broadly from a high-SE context with moderate-to-low touchscreen use levels. This lack of variation in touchscreen use levels meant that longitudinal touchscreen trajectories could not be estimated to allow for trajectory-based comparisons. Previous research has found that children from lower SE contexts are typically exposed to longer durations of screen-based media (Barr et al., 2010; Kostyrka-Allchorne et al., 2017a). Hence, the current study's sample characteristics may have resulted in the (mainly) null results, and the potential negative impacts of excessive touchscreen use cannot be ruled out. Studying children with excessive screen media use is particularly important as this group has been found to be at an elevated risk for emotional and behavioral problems and low self-regulation skills (Lawrence et al., 2020; Gueron-Sela et al., 2023). Future research should test the potential cumulative impact of touchscreen use using growth curve and growth mixture modeling in a larger cohort of children with more varied levels of touchscreen use than the current sample. This would allow for trajectory- and class-based comparisons to better understand the impact of excessive touchscreen use on early cognitive development.

Conclusion

Using data from the OEEF study (a large longitudinal study investigating early EF development), the present study investigated the potential associations between touchscreen use and the development of preschool EFs. The relative contributions of concurrent and longitudinal passive and active touchscreen use on preschool EF development were tested. Contrary to some previous findings, touchscreen use was not negatively associated with EFs, and active touchscreen use at 42-months was positively associated with parent-reported scores on the BRIEF-P Flexibility Index. Distinguishing between the effects of different types of touchscreen use on EF development, and how these relate to a child's broader media environment, will be key for policymakers and early years practitioners to create more nuanced, evidence-based guidelines.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Oxford Central University Research Ethics Committee (reference number: R57972/RE012). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

AM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. AF: Funding acquisition, Investigation, Project administration, Supervision, Writing – review & editing. BB: Formal analysis, Writing – review & editing. RB: Conceptualization, Methodology, Supervision, Writing – review & editing. AH: Investigation, Methodology, Writing – review & editing. KH: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Daily smartphone use predicts parent depressive symptoms, but parents' perceptions of responsiveness to their child moderate this effect

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Introduction: Smartphone use during caregiving has become increasingly common, especially around infants and very young children, and this use around young children has been linked with lower quality and quantity of parent-child interaction, with potential implications for child behavior, and parent-child attachment. To understand drivers and consequences of parent phone use, we were interested in the daily associations between parent phone use and depressed mood, as well as the potential for parent perceptions of their responsiveness toward their infant to alter the association between parent phone use and mood.

Methods: In the present study, we explored associations between day-to-day changes in parent smartphone use (objectively-measured via passive sensing) around their infant, depressed mood, and parent perceptions of their responsiveness to their infants among a sample of 264 parents across 8 days. We utilized multilevel modeling to examine these within-person daily associations.

Results: Objectively-measured parent smartphone use during time around their infant was significantly associated with depressed mood on a daily basis. Interestingly, this was not true on days when parents perceived themselves to be more responsive to their infant.

Discussion: These results suggest that parent judgements and perceptions of their parenting behavior may impact the potential link between parent phone use and parent mood. This is the first study utilizing intensive daily data to examine how parent perceptions may alter the felt effects of phone use on their parenting. Future work examining potential impacts of smartphone use on parenting should consider the effects of both actual use and perceptions about that use.

KEYWORDS
smartphone use, parenting, parent responsiveness, caregiving, depression, technoference, phubbing, phone tracking

Introduction

Smartphone use during caregiving has become increasingly common, especially around infants and very young children (Knitter and Zemp, 2020; Braune-Krickau et al., 2021). According to the Pew Research Center, more than half of parents (56%) felt they spend too much time on their smartphone, while about 68% reported being distracted by their phone when spending time with their children (Auxier et al., 2020). Research suggests that about 42%—72% of parents report that technology sometimes interferes with parenting activities, such as mealtime, playtime, bedtimes, and so forth (Radesky et al., 2018; Newsham et al., 2020), and phone tracking studies show that parents spend on average 27% of their time around their infant on their smartphone (McDaniel et al., 2023). Phone use specifically during the infant feeding context is also prominent, with most mothers reporting engaging in this use (Ventura et al., 2020; Coyne et al., 2022).

Parent smartphone use around young children has been linked with lower quality and quantity of parent-child interaction, with potential implications for child behavior and parent-child attachment (see McDaniel, 2019 for a review). Among adolescents, heavier parent social media use has been linked with worse teen mental health (Coyne et al., 2023) and many children and adolescents report wanting their parents to reduce media use during family times (Steiner-Adair and Barker, 2014). Therefore, helping parents develop balanced relationships with digital media from infancy through adolescence has been a goal of organizations such as the American Academy of Pediatrics (Hill et al., 2016).

In the present study, we explore associations between day-to-day changes in parent smartphone use, depressed mood, and parent perceptions of their responsiveness to their infants. Drivers of parent phone use around young children include connecting with others, fulfilling parenting needs, getting a break from caregiving duties, and relieving stress (Radesky et al., 2016; Kushlev and Dunn, 2019; McDaniel, 2019; Torres et al., 2021; Wolfers, 2021). In qualitative work, parents describe using smartphones as a mood regulation strategy that allows them to both escape distressing interactions with children and access entertaining content. Yet, at the same time, these parents report that smartphones can be a source of stress from information overload, receiving unwanted social contact, seeing upsetting content on social media, and more (e.g., Radesky et al., 2016; Torres et al., 2021; Wolfers and Schneider, 2021). Therefore, day-to-day changes in mood deserve further exploration as both a driver of, and effect from, parent smartphone use.

We chose to focus our study on infancy, a time period in which parents experience higher rates of depression symptoms, which is known to impact responsiveness to infants and young children (Bernard et al., 2018) and could potentially be exacerbated by heavier phone use. Several studies have documented that smartphone use can create disruptions or distractions during caregiving (Myruski et al., 2018; McDaniel, 2019; Dragan et al., 2021) and infant feeding (e.g., Nomkin and Gordon, 2021), in part due to lower parent responsiveness to child social cues when they are looking at their phone (Vanden Abeele et al., 2020; Braune-Krickau et al., 2021). Responsiveness is particularly important in infancy where the foundations for parent-child attachment begin (Ainsworth et al., 1974; Raval et al., 2001; Boldt et al., 2020). Parental responsiveness has been measured directly in laboratory and naturalistic settings, in which parent-child interactions are observed (Radesky et al., 2014, 2015; Hiniker et al., 2015; Abels et al., 2018; Kushlev and Dunn, 2019; Vanden Abeele et al., 2020). However, in this study, to facilitate intensive daily collection of parent behaviors throughout their everyday life, we measured *perceptions* of parental responsiveness rather than an objective measure. Though perceptions and behavior may not always match, we were interested in whether perceptions (i.e., parents' feelings/cognitions about their parenting) may influence the daily association between parent phone use and their mood. This builds upon prior work showing links between parent perceptions of responsivity and their phone use (Braune-Krickau et al., 2021; Mikić and Klein, 2022). Further examination of the links between parent mood, smartphone use, and perceptions of parenting responsiveness is needed to yield insights into potential intervention points to support parents in more balanced media use.

Smartphone use and parent mood

In general, research has indicated that intense and frequent phone usage patterns can be associated with worse mental health, higher depression symptoms, and lower wellbeing (Elhai et al., 2017; Rozgonjuk et al., 2018; Braune-Krickau et al., 2021; Kong et al., 2021). In parents specifically, higher global ratings of depression symptoms have been positively associated with more phone use around children as well as parent-reported preoccupation with phone use and trouble staying away from smartphones during time with children (Newsham et al., 2020; McDaniel, 2021). Potential drivers for this association include using a phone as a coping mechanism (Fei et al., 2023; Hood et al., 2023; Swit et al., 2023; Wolfers et al., 2023a,b) or to seek an escape from negative emotions (Roberts et al., 2022). On the other hand, as noted above, the act of smartphone use may also contribute to heightened negative emotions (Radesky et al., 2016; McDaniel, 2019) due to exposure to negative news, social comparison, or lack of sleep. For example, passive social media use and mindless scrolling have been linked to negative mood and depression symptoms in adults (Hoffner and Lee, 2015; Scott et al., 2017). Indeed, smartphone use can also lead to negative social comparisons, feelings of wasted time, and fear of missing out (e.g., Sagioglou and Greitemeyer, 2014; Coyne et al., 2017), with subsequent links with dissatisfaction with parenting, negative mood, and worse self-perceptions (Amaro et al., 2019; Burnell et al., 2019; Wang et al., 2020; Kirkpatrick and Lee, 2022). Additionally, phone use in certain contexts, such as around parents' bedtime, can lead to worse sleep and increased negative mood (Exelmans and Van Den Bulck, 2016; Lastella et al., 2020; McDaniel et al., 2022b). In other words, smartphone use and mood are bidirectionally linked (e.g., Jun, 2016; Cui et al., 2021; Zhang et al., 2023), with distinct mechanisms driving different directions of associations.

Given the immediacy of these drivers and effects of phone use, we propose that there likely are day-to-day associations between depression symptoms and parent smartphone use. However, prior studies have often examined this topic using global self-reported mood, comparing parents with higher vs. lower smartphone or social media use. Conducting within-parent comparisons of day-to-day changes in mood and smartphone use both helps reduce between-person confounding and may elucidate mechanisms within the context of families' everyday lives.

Smartphone use and parent responsive behavior

Infancy is a critical period for the formation of attachment relationships between parents and infants as well as for the development of various emotion regulation processes (Eisenberg et al., 1998; Boldt et al., 2020; Berona et al., 2023). The caregiving environment, which parents create for their child via their activities and interactions, often plays an important role in this development (Wu and Feng, 2020; Dragan et al., 2021; Bornstein and Tamis-LeMonda, 2022). A vast body of literature focuses on parent-infant interactions and has shown that responsiveness, sensitivity, and interactional synchrony are critical for the child's cognitive, social, and emotional development (Harrist and Waugh, 2002; McFarland et al., 2019), as well as the bond formed between parent and infant (Ainsworth et al., 1974; Boldt et al., 2020). Infants often rely on their parents to assist them with the co-regulation of their emotions, especially during early infancy (Aureli et al., 2018; Buhler-Wassmann and Hibel, 2021). As infants cue for and receive responses from their parents, they begin to set up their internal representations of what the parent-child relationship (and perhaps future relationships) should look like; if parents are generally responsive to their cues and needs in a sensitive manner (i.e., responding warmly, in a timely manner, and contingent to child needs), infants will form a secure attachment relationship with their parent (Ainsworth et al., 1974; Crandell et al., 1997; Raval et al., 2001; Mesman, 2021).

Several studies have examined how parents respond to their child when using their phone and have found that parents are less likely to respond or pay attention to their child during phone use (Abels et al., 2018; Kushlev and Dunn, 2019; Vanden Abeele et al., 2020). For example, Hiniker et al. (2015) found that 56% of caregivers at a playground were distracted by their phone and therefore less responsive to their child (i.e., did not acknowledge their child's bid for attention and remained on their smartphone). Another naturalistic observation study of 53 parent-child dyads further supported these findings as parents on their smartphones were found to respond significantly less to their child in a waiting room and playground environment (Vanden Abeele et al., 2020). Similarly, observational data from Radesky et al. (2014) at fast-food restaurants found that parents whose attention was highly absorbed in their phone took longer to respond to child bids for attention. Lastly, greater smartphone use was related to less encouragement from caregivers to children (Radesky et al., 2015). Various experimental studies also highlight how higher levels of phone use could precipitate less parent responsiveness. For example, a study that assessed parental digital media use during infant feeding found that caregivers were less sensitive when using a tablet as compared to listening to classical music (Ventura et al., 2019), and Porter et al. (2024) found that parent eye contact and vocalizations with their toddler decreased during parent phone use.

As a response to parent smartphone use, infants and very young children tend to react with increased negative affect and fussiness as shown in experiments and naturalistic observations (Elias et al., 2021; Rozenblatt-Perkal et al., 2022). For example, in a naturalistic study on playgrounds and restaurants, it was found that when parents demonstrated low levels of emotional support due to device use, their children reacted with externalizing symptoms such as frustration and disappointment (Elias et al., 2021). Other negative outcomes extend to infants as reported in Rozenblatt-Perkal et al. (2022) experimental study which examined phone use in parent-infant interactions. Findings suggest that infants exposed to parent phone use experienced negative affect and increased heart rate as compared to lower symptoms of reactivity among infants who engaged in undisrupted play (Rozenblatt-Perkal et al., 2022). Furthermore, Porter et al. (2024) also found an increase in infant heart rate, vagal withdrawal, and a decrease in infant positive affect during parent phone use.

Experimental and observational work has also suggested that parent smartphone use contributes to difficulty with soothing and repairing their connection with their infant. For example, an increase in infant negative affect during parent smartphone use was found in Myruski's Still Face experimental study, and parents who had heavier smartphone usage habits had more difficulty with the co-regulatory "reunion" phase of the experiment (Myruski et al., 2018). Another still-face experiment found that parental smartphone use was associated with greater infant-self comforting behavior (Stockdale et al., 2020). Thus, we see that parent responsiveness often decreases during parent phone use *and* infants and children notice and may react to this use and distraction. Although effects on attachment have yet to be thoroughly tested, these changes may lead to lower quality parent-infant bonds and attachment relationships over time, at least if phone distraction occurs frequently (e.g., McDaniel, 2019). Therefore, phone use may be a modifiable factor in shaping parent-infant interactions during the perinatal or infancy period.

Parent perceived responsiveness, smartphone use, and daily mood

Links between smartphone use (both during caregiving in general and during infant feeding) and daily mood are not likely to be the same on all days or for all parents. Indeed, theoretical models of media effects (Valkenburg and Peter, 2013) and recent research in adolescents (Beyens et al., 2020) suggest that subsets of individuals are more likely to experience changes in mood with their media use. Parents with higher parenting self-efficacy (e.g., who perceive they are more effective in their parenting) on a given day or those who are generally more responsive to their infants might not experience as much distress from fluctuations in their smartphone use. On the other hand, parents may feel more dissatisfaction on days when they perceive they pay more attention to their smartphones than their infants. Smartphones, by their nature, demand attention, which can lead parents to sometimes feel a sense of detachment from their immediate surroundings (Reed et al., 2017; McDaniel, 2019; Lemish et al., 2020). Consequently, parents may perceive themselves to be more distracted, less emotionally available to their children, less attuned to their child's needs, and not meeting their own expectations for quality of parenting (Kildare and Middlemiss, 2017; McDaniel and Radesky, 2018; McDaniel, 2019; Vanden Abeele et al., 2020; Braune-Krickau et al., 2021). Indeed, many parents express feeling guilty

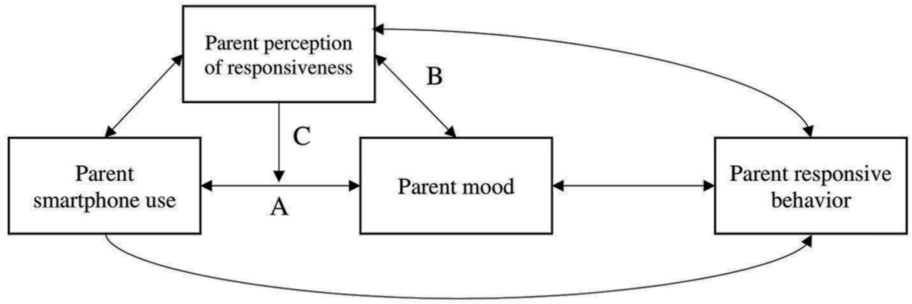

FIGURE 1
Conceptual model of the complex connections between parent smartphone use, perceptions of responsiveness, mood, and actual parent behavior. In the current study, we focus on paths A and B, as well as the moderation of path A by perceptions of responsiveness (path C).

about their phone use around their child (Wolfers et al., 2023a), which for many translates into a desire to change aspects of their phone use (McDaniel et al., 2023).

Conversely, when parents perceive they have been highly responsive to their infants (i.e. responding to crying, facial expressions, etc.), positive mood often follows and contributes to a strong emotional attachment between the child and caregiver (Malatesta et al., 1989; World Health Organization, 2004). This positive emotional state may reinforce the perception of responsive caregiving, creating a cycle wherein perceived responsiveness is linked with positive mood. On the other hand, when parents perceive themselves as less responsive, negative mood may emerge (Eisenberg et al., 1991; Shipman and Zeman, 2001).

Thus, we propose the following conceptual model (see Figure 1), which illustrates the many possibilities of how parent smartphone use, perceptions of responsiveness, mood, and actual parent behavior can be connected. In the current study, we focus on daily within-parent associations between smartphone use and parent mood (path A) and daily within-parent perceptions of responsiveness and parent mood (path B). In addition to these daily within-person associations, we also seek to examine how parental self-reported perception of responsiveness to their infant moderates associations between daily fluctuations in depression symptoms and smartphone use (path C).

Current study

In this study, we utilized parent self-reports and passively tracked smartphone use across 8 days to examine daily associations between depressed mood, objectively-measured smartphone use around their infant, and perceptions of parents' responsiveness to their infant. We explored both phone use around infant in general (i.e., times when physically near infant or playing with infant) and phone use during infant feedings. Thus, we asked the following:

- RQ1: Is parent smartphone use around their infant associated with daily depressed mood?
- RQ2: Is parent perception of responsiveness to their infant associated with daily depressed mood?
- RQ3: Do parents' perceptions of their responsiveness moderate the association between smartphone use and depressed mood on a day-to-day basis?

Based on our conceptual model and prior literature, we hypothesized that:

- H1: Greater smartphone use would be associated with greater depressed mood on a day-to-day basis.
- H2: Parent perceptions of lower responsiveness to their infant would be associated with greater depressed mood on a day-to-day basis.

Methods

Participants and procedures

We analyzed data from 264 individual parents (76% mothers; 79% Non-Hispanic Caucasian; M_{age} = 30.82 years, *SD* = 4.82; *Median income* = \$70,000, *M* = \$79,942, *SD* = \$47,540) of infants (M_{age}= 6.65 months, *SD* = 3.51, *Range* = 1–13 months) from an NIH-funded study (*Healthy Digital Habits in Parents of Infants*; R21NR019402), who consented, completed an online baseline survey, and then participated in 8 days of phone use measurement (via an app installed on their smartphone; *Chronicle* for Android users, *RescueTime* for iPhone users) and nightly surveys. The apps collected continuous phone use data, and using MATLAB and Python scripts we converted this use into amount of phone use in 15-min intervals across the entire 8 days. Each night, in addition to completing measures of depressed mood, responsiveness, and stressful child behavior, parents also completed a time diary (rating various activities in 15-min intervals across their day—such as time around child, child feedings, sleep, and so forth). Our MATLAB and Python scripts were also utilized to merge the phone use and time diary data together and to create the phone use around child variable (described in the Measures). Phone use measurement and daily survey completion rates were typically high. Specifically, in our modeling, 95% had 5 or more days of phone use around child data (*Mean days* = 7.38, *SD* =

1.35, *Total days* = 1,949). Participants were recruited through a Midwestern healthcare system and via announcements on social media and in public spaces. Greater details about recruitment, the sample, procedures, and phone use variable creation are found in McDaniel et al. (2023).

Measures

Phone use around infant

Using the merged phone use/time diary data, we calculated the amount of time each day the parent was on their phone during times around their infant (including physically near or playing with infant, but not including infant feeding time, when the infant slept, or when the parent marked that someone else had used their phone). We then created a proportion variable by dividing the phone around infant time by the total time around infant, and days when the parent had spent no time with their infant were coded as missing. This gave us the proportion of child time spent on their phone around their infant during general (not feeding) times for each day.

Phone use during infant feeding

We created this variable in the same way as the phone use around infant variable, except we focused only on the infant feeding times. This gave us the proportion of feeding time spent on their phone each day.

Depressed mood

We adapted the CES-D Short Form (CES-D-SF; Levine, 2013) to measure the frequency of six depressive symptoms each day (e.g., "I felt depressed," "I felt everything I did was an effort"); we did not include the seventh item ("My sleep was restless") from the CES-D-SF on our daily surveys, as we desired a measure of depressed mood during the day, not from the previous night. Others have also adapted and successfully utilized the CES-D in daily survey research to measure daily depressed mood (Steers et al., 2014). In our study, parents rated each item on how often they had felt that way today on a 5-point scale ranging from 0 (*None of the time*) to 4 (*All or almost all the time*). Multi-level factor analysis indicated that one factor at both the within- and between-levels fit the data well, $\chi^2(16) = 53.98$, $p < 0.001$, RMSEA = 0.03, CFI = 0.98, TLI = 0.96, SRMR within = 0.02, SRMR between = 0.02. Within- and between-person reliability also suggested that the depressed mood scale adequately assessed the construct at both levels (WP reliability = 0.75, BP reliability = 0.98). Items were averaged to produce an overall depressed mood score for each day.

Perceptions of delayed responsiveness

We measured delayed responsiveness each day with a single item from the Maternal Infant Responsiveness Instrument (MIRI; Amankwaa et al., 2007) and adapted to the daily context ("Today, I feel I sometimes responded slowly to my baby"). Parents rated their perceptions on a 5-point scale from 1 (*Strongly disagree*) to 5 (*Strongly agree*). Thus, higher scores represented greater perceived delayed responsiveness.

Daily control variables

As parenting stress and sleep issues can influence parent mood (e.g., Meltzer and Mindell, 2007; Fang et al., 2022), we also measured stressful infant behavior and parent sleep hours. Parents rated their infant's behavior each day on a single item ("Today, how much did you experience your infant's behavior as stressful?") on a 10-point scale, from 1 (*Not at all*) to 10 (*Very much so*). Each day, parents also reported how many hours they slept the previous night (similar to the Pittsburgh Sleep Quality Index, PSQI; Buysse et al., 1989). As the amount of time parents were with their infant each day varied from parent-to-parent and across days within parents, we also measured how many hours parents reported being with their infant each day (from their time diary ratings).

Data analysis

We first examined descriptives and bivariate correlations at the between-person level (see Table 1). Then, to examine our hypotheses and research question we ran two multilevel models (MLM) in SAS Proc Mixed predicting daily depressed mood (one model including phone use around child in general as a predictor and another model including phone use during feedings as a predictor). MLM was used as there was nesting in the data (i.e., participants completed multiple days). We first ran an the intercept-only model to examine the amount of variance accounted for by the intercept (ICC = 0.645), which indicated that about 35.5% of the variance in daily depressed mood is likely due to within-person differences. Then, we entered our predictors and controls (as seen in Table 2). All daily variables were split into their between-person (differences across parents) and within-person (differences from day-to-day within parents) portions before being entered into the models (Bolger et al., 2013). Although we were most interested in the daily, within-person processes, this also allowed us to compare the within-person processes with the between-person differences. Moderation of the potential impact of daily phone use on daily parent mood by parent perceptions of responsiveness was examined by entering the interaction term at both the between-person and within-person levels (i.e., see *BP phone X BP responsiveness* and *WP phone X WP responsiveness* in Table 2). Significant interactions were then explored by plotting the predicted values of depressed mood at different values of the variables (specifically, the average and one standard deviation above and below[1]). The simple slopes at different levels of moderator variable were then calculated.

1 At the between-person level, the values represent the sample average and sample standard deviations across all days of data. At the within-person level, the values represent the participant's average (and technically also the sample average due to the coding of each participant's average level as 0 in the within-person variable) and the standard deviation across the sample in within-person fluctuations across all days.

Results

Descriptives and bivariate correlations

On average, parents rated themselves as experiencing a low degree of depression symptoms most days (Table 1), although as we examined response frequencies we found that parents rated at least one depressive symptom as occurring on 75% of all days collected. Parents spent on average one-quarter of their time around their child and during feedings on their smartphone (Table 1). Depending on the parent, this average ranged from 2 to 75%. Also, 50% of all days collected showed one-quarter or more of their child time on their phone. On average, parents did not report that their responses to their infant were slow, although parents expressed somewhat of a delay on 62% of days. Yet, these averages mask the daily variability. Indeed, intraclass correlation coefficients suggest that about 36% of the variance in depression was due to within-person variability (i.e., variance that cannot be accounted for by between-person differences), while the within-person daily variability was even greater for phone use around infant (56%), phone use during feeding (65%), and delayed responsiveness (65%).

Between-person bivariate correlations (see Table 1; i.e., correlations among the variables, when variables were averaged across all days within each parent) revealed that those parents with greater phone use around their infant, on average, also tended to show greater average depressed mood, although this was not true of those who showed greater average phone use during infant feeding times. Those with greater depressed mood on average also tended to perceive their responsiveness as slower and infant behavior as more stressful on average. As would be expected, they also reported fewer average sleep hours.

RQ1/H1: greater smartphone use and greater depressed mood

Our MLM results (Table 2) revealed that depressed mood and phone use around infant were associated at the within-person level. In support of our hypothesis, this suggests that on days when parents used their phone more than usual around their infant (not during feeding) they also experienced more depressed mood ($b = 0.20$, $p = 0.03$). However, contrary to our hypothesis, this main effect was not observed for phone use during infant feeding times ($b = 0.11$, $p = 0.17$). Between-person results suggested similar results, namely that those who engaged in greater phone use around their infant compared to those who engage in less use showed greater depressed mood on average ($b = 0.94$, $p < 0.01$), although this was not the case for those who engaged in greater phone use during feeding ($b = 0.34$, $p = 0.21$).

RQ2/H2: perceptions of lower responsiveness and greater depressed mood

MLM results (Table 2) revealed within-person daily associations between perceptions of delayed responsiveness and depressed mood. In support of our hypothesis, on days when parents perceived themselves as being slower to respond to their infant, they also showed greater depressed mood (Model 1 and 2 $bs = 0.03$, $ps = 0.01$). Interestingly, no significant between-person association was found (Model 1 $b = 0.01$, $p = 0.86$; Model 2 $b = 0.04$, $p = 0.46$), suggesting that parents who generally perceived themselves to be less responsive to their infant did not have higher depression symptoms compared to parents who generally perceived themselves to be more responsive.

RQ3: moderation by perceptions of responsiveness of effect of smartphone use on depressed mood

Our MLM results (Table 2) revealed significant moderation by parents' perceptions of their responsiveness at the within-person level for phone use around infant ($b = 0.33$, $p < 0.01$) and

TABLE 1 Between-person descriptives and correlations among daily study variables.

	Depressed mood	Phone use around child	Phone use during feeding	Delayed responsive-ness	Stressful child behavior	Parent sleep hours	Time with child (hours)
Depressed mood	–	0.16**	0.07	0.11‡	0.26***	−0.20**	0.03
Phone use around child		–	0.77***	0.04	−0.04	−0.13*	0.11
Phone use during feeding			–	−0.03	−0.06	−0.19**	0.16**
Delayed responsiveness				–	0.42***	−0.08	0.00
Stressful child behavior					–	−0.13*	0.07
Parent sleep hours						–	0.03
Time with child (hours)							–
Mean	0.68	0.27	0.27	2.07	2.58	6.77	6.91
SD	(0.64)	(0.12)	(0.14)	(0.74)	(1.17)	(1.08)	(2.27)

N = 264.
‡p = 0.06.
*p < 0.05.
**p < 0.01.
***p < 0.001.

TABLE 2 Unstandardized estimates for the multilevel models of daily phone use around their infant and perceived delayed responsiveness to infant and associations with depressed mood.

Fixed effects	Model 1: Phone use around child as predictor of daily depressed mood		Model 2: Phone use during feeding as predictor of daily depressed mood	
	b	*SE*	*b*	*SE*
Intercept	0.76***	(0.045)	0.74***	(0.043)
Day	−0.02***	(0.005)	−0.02***	(0.005)
Gender	−0.09	(0.09)	−0.12	(0.09)
Between-person (BP) portion of daily variables				
BP sleep hours	−0.09**	(0.03)	−0.11***	(0.03)
BP child behavior	0.12***	(0.03)	0.12***	(0.03)
BP child hours	0.00	(0.02)	0.00	(0.02)
BP phone use around infant	0.94**	(0.30)	0.34	(0.27)
BP delayed responsiveness	0.01	(0.05)	0.04	(0.05)
BP phone X BP responsiveness	−1.29***	(0.37)	−0.87*	(0.35)
Within-person (WP) portion of daily variables				
WP sleep hours	−0.04***	(0.01)	−0.03***	(0.01)
WP child behavior	0.03***	(0.01)	0.03***	(0.01)
WP child hours	−0.01**	(0.00)	−0.01*	(0.01)
WP phone use around infant	0.20*	(0.09)	0.11	(0.08)
WP delayed responsiveness	0.03*	(0.01)	0.03*	(0.01)
WP phone X WP responsiveness	0.33**	(0.11)	0.25**	(0.09)

Gender is coded 0 = female and 1 = male. Day is centered on day 1. Daily variables were split into between-person and within-person portions and both portions were included in each model. Model 1 N = 264, Model 2 N = 260.
***p < 0.001.
**p < 0.01.
*p < 0.05.

phone use during feeding ($b = 0.25$, $p < 0.01$). Between-person moderation effects or perceived responsiveness were also observed for phone use around infant ($b = -1.29$, $p < 0.001$) and phone use during feeding ($b = -0.87$, $p = 0.01$). Figures 2 and 3 display the plots of the predicted values of depression at different values of the variables (e.g., +1SD, −1SD), and Table 3 shows the simple slopes at these chosen values. In probing these interactions, at the within-person level, parents perceived themselves as greater than or equal to 0.82 points less responsive than their usual (+1SD) on 14% of days, and parents perceived themselves as greater than or equal to 0.82 points more responsive than their usual (−1SD) on 14% of days. At the between-person level, 19% of parents perceived themselves as greater than or equal to 0.74 points less responsive than the sample average (+1SD), and 18% of parents perceived themselves as greater than or equal to 0.74 points more responsive than the sample average (−1SD).

At the within-person level (see Figure 2), on days when parents perceived themselves as at their typical level of responsiveness or lower, phone use around infant showed a significant positive association with depression symptoms—but there was no significant association on days when parents perceived themselves as more responsive than their typical amount. Similarly, on days when parents perceived themselves as less responsive than usual, more phone use during feeding was significantly associated with higher depression symptoms.

Moderation results appeared different at the between-person level (see Figure 3). Average phone use around infant showed significant associations with average depression symptoms only among parents with average and higher general levels of perceived responsiveness. Similarly, average phone use during feeding showed significant associations with average depression symptoms only among parents with higher general levels of perceived responsiveness. In other words, among parents who perceived themselves as having lower general levels of responsiveness, there were no associations between average levels of phone use and average levels of depression symptoms.

Discussion

In this study of parents of infants, we used intensive longitudinal data collection to examine day-to-day fluctuations in parental smartphone use, depression symptoms, and their perceptions of their responsiveness to their infant. We found significant within-person daily associations. Specifically, on days when parents used their phone more around their infant, they also showed greater depression symptoms. Additionally, on days when parents perceived themselves as being less responsive to their infant, they also showed greater depression symptoms. We

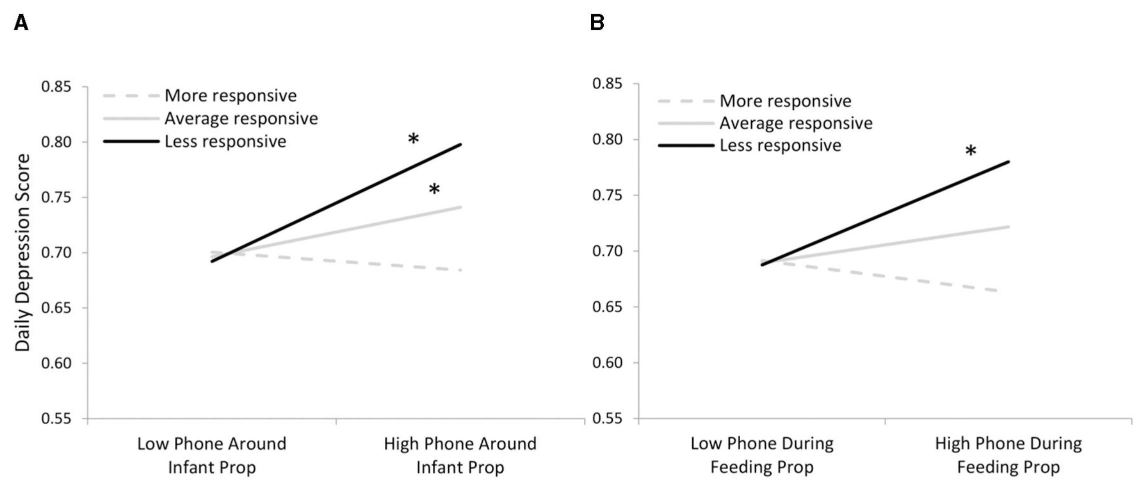

FIGURE 2
Predicted values of daily depressed mood by within-person levels of phone use around child and day-to-day perceptions of delayed responsiveness. **(A)** shows phone use around child (not including feedings) and **(B)** shows phone use during feeding. Levels are presented at 1 SD above, average, and 1 SD below the participant's level of the daily variables. Significant slopes are marked with a *.

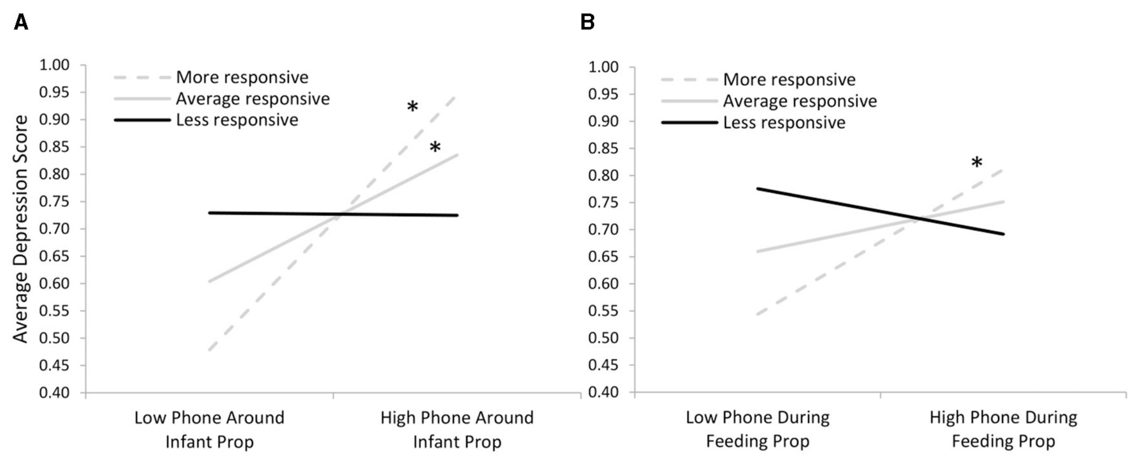

FIGURE 3
Predicted values of average depressed mood by between-person levels of average phone use around child and average perceptions of delayed responsiveness. **(A)** shows phone use around child (not including feedings) and **(B)** shows phone use during feeding. Levels are presented at 1 SD above, average, and 1 SD below all parents' average values. Significant slopes are marked with a *.

also found significant moderation of the daily association between phone use and depression by perceptions of responsiveness.

These findings support our hypothesis (H1) that parents would feel more depressed on days when they engaged in greater smartphone use around their infant, which is a novel contribution to the literature, as prior work has typically examined these processes utilizing cross-sectional, between-person data (e.g., McDaniel, 2019 for a review). Regardless of overall typical levels of phone use, depression, and other between-person factors, we show that a parent's own mood state is connected on a daily basis with their smartphone use. This process is likely bidirectional, as we know that parents often turn to phone use as a coping or self-regulation strategy (Radesky et al., 2016; Torres et al., 2021; Wolfers et al., 2023a,b). At the same time, heavier phone use during child time on a given day might impact mood and/or lead to feelings of distraction, wasted time, or other self-perceptions (via negative social comparisons, disappointment in not meeting one's expectations for phone use during parenting, etc.; Sagioglou and Greitemeyer, 2014; Radesky et al., 2016; Coyne et al., 2017; Kirkpatrick and Lee, 2022; Mikić and Klein, 2022). Moreover, we controlled for daily sleep quality and stressful infant behavior in our multi-level models, so the links between mood and smartphone use we demonstrated exist independent of sleep-displacement or parenting stress. Future work should examine these stress-to-phone use processes with intensive data.

We also found support for our hypothesis (H2); on days when parents felt more depression symptoms, they also perceived themselves as being less responsive to their infants. These daily fluctuations in mood and infant responsiveness could be bidirectional, in that depressed mood might lead to flatter

TABLE 3 Unstandardized effects of phone use on daily depressed mood at different levels of perceived delayed responsiveness.

Fixed effects	Model 1: Phone use around child as predictor of daily depressed mood		Model 2: Phone use during feeding as predictor of daily depressed mood	
	b	*SE*	*b*	*SE*
Between-person (BP) phone use effect				
At +1 SD BP delayed responsiveness	−0.09	(0.38)	−0.49	(0.47)
At average BP delayed responsiveness	0.94**	(0.30)	0.34	(0.27)
At −1 SD BP delayed responsiveness	1.82**	(0.70)	0.93*	(0.46)
Within-person (WP) phone use effect				
At +1 SD WP delayed responsiveness	0.41**	(0.15)	0.28*	(0.12)
At average WP delayed responsiveness	0.20*	(0.09)	0.11	(0.08)
At −1 SD WP delayed responsiveness	−0.004	(0.12)	−0.02	(0.10)

**$p < 0.01$.
*$p < 0.05$.

affect or psychomotor slowing that influences responsiveness to infants. Alternatively, because parents may experience reciprocal interactions with infants as mutually satisfying, a more responsive day might help lift a parent's mood. Thus, at a within-person level we were able to detect effects for fluctuations in daily mood. Yet, our between-person results were not consistent with prior research comparing parents with and without clinical depression (e.g., Campbell et al., 1995; Paris et al., 2009). Our sample of parents tended to have lower daily depression symptoms on average—suggesting that researchers may need to study parents with more clinically significant postpartum depression or major depressive disorder diagnoses to detect and better understand between-person differences.

Most interestingly, we found interactions between parent perceptions of responsiveness, smartphone use, and depression symptoms that may yield insights into mechanisms underlying these associations. On a within-person level, it was only on days when parents felt they had been about average or less responsive to their infants that smartphone use around the infant and depression symptoms were linked. This could potentially be explained by greater parental guilt experienced on these days. Previous cross-sectional and interview studies have found that parents express using their phones when feeling down or stressed but also feel guilty regarding smartphone use around their child (Radesky et al., 2016; McDaniel et al., 2022a; Wolfers et al., 2023a). It is also possible that positive, responsive interactions with their infant buffer parental mood, in that they feel more effective or emotionally regulated, so that smartphone use has less of a negative effect on mood. We did not examine the types of apps that parents used around their child, but this is an important area for future research. For example, using the camera and messaging features might allow a parent to take photos or videos while playing with their child and share their positive experience with others. Whereas using apps with possibly more negative emotional content (e.g., news, social media) may not support parents feeling effective in their parenting and time.

Finally, it is also interesting that associations with mood, although still present, were weaker for phone use during infant feeding time as compared to phone use during other general infant times. Some prior work has suggested that the potential impacts of phone use during infant feeding times may not be as negative and sometimes could lead to positive outcomes for parents (e.g., Coyne et al., 2022). It may also be that parents interpret and evaluate their phone use during feeding differently, perhaps viewing it less negatively than phone use during other times around their infant. This should be tested by future work.

Surprisingly, when examining between-parent differences, moderated effects were reversed as compared to the within-person effects. In parents whose average self-reported responsiveness was high, higher average smartphone use during child time and feeding was linked to higher average depression symptoms. Yet, in parents who generally reported lower perceived responsiveness, phone use was not linked to average mood. This contrary moderation effect might be explained by different self-expectations between parents who generally rate themselves as highly responsive as compared to those who generally rate themselves as being less responsive. For example, highly responsive parents might experience more guilt with higher phone use, as they might expect themselves to be highly attuned to child behavior and are frustrated when parent-child interactions are interrupted by smartphone use. Indeed, recent research has found that smartphone interruptions may be perceived as intrusive or disruptive to parents during times with their infants, contributing to daily stress (Munzer et al., 2024). Infancy is also a time when parents establish their identity and self-efficacy as a new parent, so higher smartphone use may be stressful if it conflicts with their own expectations for their parenting behavior (Kildare and Middlemiss, 2017; McDaniel, 2019). It is also possible that parents who report lower perceived responsiveness use their smartphones differently (e.g., different content) than parents who see themselves as more responsive; either way, our findings suggest that differences between parents in their typical levels of smartphone use and mood symptoms are not homogenous among all parents.

Our results have clinical implications, particularly for professionals who support parents of infants through public health nursing, home visiting programs, or early parenting or relational health interventions. Clinicians can help new parents reflect on fluctuations of their daily mood that correspond to either interactions with their infant or their technology use. This process might include looking at the parents' phone usage readout together (i.e., Screen Time or Digital Wellbeing tools) and facilitating a discussion of which app usage contributes most to feelings of stress, negative social comparison, distraction from infant interactions, or poor sleep. Because patterns of phone usage vary considerably between parents (McDaniel et al., 2024b), a one-size-fits-all approach will be less effective. Instead, clinicians can use shared-decision making and motivational interviewing to help the parent come up with feasible behavioral changes regarding technology use that align with their parenting values. In addition, the American Academy of Pediatrics (Hill et al., 2016), recommends that parents complete a Family Media Plan that includes boundaries (e.g., no-tech times or places) around not only their children's technology use, but their own. Pediatric clinicians could also assuage the guilt parents may feel about their technology use, which can be a counterproductive mindset (Moreno and Radesky, 2023; McDaniel et al., 2024a); and instead focus on pragmatic strategies for helping their daily interactions with their infants feel more positive and responsive (e.g., McDaniel, 2020).

Limitations of this study include its predominantly white non-Hispanic sample, although our cohort reflects the racial/ethnic diversity of the midwestern state in which data were collected. We also relied upon a single item to measure daily parent perceived responsiveness. Single item measures are common within intensive daily data designs due to participant burden. However, results should be replicated in future work utilizing a more extensive measure of perceptions of responsiveness; for example, slowness of response may not fully or always be the best indication of responsiveness. Our focus was not to assess actual responsive behavior, but future work could likely benefit from assessing both behavior and perceptions—and intensive longitudinal observational measures (e.g., wearable audiorecorders such as LENA) may be of worth for measuring parent responsiveness. Finally, depression was the sole parent mental health variable we tested in this analysis. It is possible that other mental health disorders common in the perinatal period (e.g., anxiety) could be comorbid with depression and/or driving the associations with smartphone use (Hashemi et al., 2022; Santander-Hernández et al., 2022). Additionally, depression and other mental health disorders may have different associations with general smartphone use than they do with clinical overuse (i.e., smartphone addiction), and this possibility should be explored in future studies.

Despite these limitations, one strength of the current study is our intensive daily data design which allowed for the examination of within-person associations. In other words, we were able to get closer to life as it is really lived (Bolger et al., 2003) and to better match our conceptualizations of mechanisms of change and fluctuation in parent phone use and mood with real-life data (Collins, 2006). Additionally, we had objective measures of parent smartphone use (passively sensed via an app installed on parents' smartphones); thus, we have more trust in our estimates of phone use and phone use effects—instead of relying on parent reports of phone use which are often inaccurate (e.g., Yuan et al., 2019). Although the current data allowed for an examination of daily associations, it is not known whether smartphone use predicts mood or mood predicts smartphone use on a momentary basis—indeed, prior work has shown that both pathways are viable and it is often a bidirectional process (e.g., Jun, 2016; Cui et al., 2021; Zhang et al., 2023). Future work likely would need to examine mood states at an even more detailed, momentary level to fully assess the directionality of these pathways.

Overall, the current study expands upon the previous literature by examining within-person, daily processes amongst parent smartphone use, depressed mood, and perceptions of responsiveness to infants. Objectively-measured parent smartphone use during time around their infant is significantly linked with depressed mood on a daily basis. Interestingly, this is not true on days when parents perceive themselves to be more responsive to their infant, suggesting that parent judgements and perceptions of their parenting behavior may impact the potential effects of parent phone use on parent mood. This is the first study utilizing intensive daily data to examine how parent perceptions may alter the effects and potential meaning of parent phone use for parenting, and it appears promising that future work should expand on considering the links and interactions between actual phone use and perceptions when discussing the potential impacts of smartphone use.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Parkview Health Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The Ethics Committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because the research presented no more than minimal risk of harm to subjects and involved no procedures for which written consent is normally required outside of the research context. Participants consented to the study via an online consent form where they typed their study ID number and selected that they consent to participate.

Author contributions

BM: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. SU: Writing – original draft, Writing – review & editing. JP: Conceptualization, Funding acquisition, Writing – review & editing. VC: Software, Validation, Writing – review & editing. MD: Conceptualization, Funding acquisition, Writing – review & editing. JR: Conceptualization, Funding acquisition, Investigation, Resources, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Four hours with dad, but 10 minutes with mom: variations in young children's media use and limits based on parent gender and child temperament

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Introduction: Research on children's media use has disproportionately focused on maternal reports of use. As such, we know little about how mothers' and fathers' reports of children's media use align, how such reports might be related to parental beliefs about the benefits of media for children, or the potential differential impact of child characteristics, such as temperament and gender.

Method: Using a sample of 210 low-to-moderate income, racially and ethnically diverse families, we asked new mothers and fathers about their child's media use and limits at 9, 18 and 24 months of age.

Results: On average, reports of co-use of media, children's use of media alone, exposure to background television, diversity of daily media use, and use of media for behavior management did not significantly differ between mothers and fathers and were moderately correlated, $r(df) = 0.2–0.7$. However, comparisons within dyads found that parents did not often agree on their child's media use. Couples also tended to report different limitations on use, with fathers reporting much larger time limits. For both mothers and fathers, stronger beliefs in the benefits of media when children were infants were predictive of more reported media use at 24 months. Infant negative emotionality was predictive of the use of media for behavior management for both mothers and fathers, and for other types of media use for fathers.

Conclusion: Parents of the same child reported media use over the first two years differently, which may indicate informant effects in media research or actual differences in young children's media use with each parent. Given the risks of media use in early childhood to displace important developmental processes, understanding young children's media use within the family system is important.

KEYWORDS

media, digital technology, parenting, early childhood, temperament, infancy, fathers, toddler

1 Introduction

Increasingly, pediatric organizations around the world recommend that infants and toddlers abstain from any media use, perhaps with the exception of video chat (Chassiakos et al., 2016; World Health Organization, 2019; Australian Department of Health, 2021). However, extant research finds that children engage with media at a young age, often before 18 months (Tang et al., 2018; Levine et al., 2019). This is not surprising given the range of devices children have access to in their homes (e.g., tablets, phones, computers, video games), and research—even before increases due to the COVID-19 pandemic—found that children under 2 years of age use media devices on average for 1–2 hours a day (Elias and Sulkin, 2019). Currently, the bulk of studies on young children's media use rely on maternal, rather than paternal, reports with little consideration of whether media use and limits for the same child differ by parent. Further, little work has considered how children's media limits and use might evolve from infancy through toddlerhood, or what might contribute to stability or changes in use, such as parents' beliefs about the benefits of media and child characteristics like gender or temperament. Thus, we explore longitudinally, mother-reported and father-reported media habits of children from 9 to 24 months of age and how such use is related to children's gender, difficult temperament, and parents' beliefs about the benefits of media.

1.1 Young children's media use

With the ubiquitous presence of digital devices in homes (Huber et al., 2018; Statista, 2023), very young children are exposed to media on a regular basis (AAP Council on Communications and Media et al., 2016; Elias and Sulkin, 2019; Brushe et al., 2023), most often through television programs (on televisions or streamed through mobile devices; Huber et al., 2018; Ofcom, 2023). This television/TV-like use includes child-focused programming as well as background television and adult-focused programming. Though less common, research also finds infants and toddlers use tablets and apps regularly as well (Paudel et al., 2017; Pew Research Center, 2020; Radesky et al., 2020; Brushe et al., 2023).

Studies have identified a variety of reasons why parents opt for their young children to engage with media. Reasons include beliefs in the benefits of media as an educational tool or necessary skill for the future (Elias and Sulkin, 2019; Ochoa and Reich, 2020; Griffith, 2023), wanting to support cultural practices (like songs in another language; Ochoa and Reich, 2020), and desires to distract, occupy, or emotionally calm children (Beyens and Eggermont, 2014; Coyne et al., 2017; Elias and Sulkin, 2017, 2019; Nikken, 2019). Interviews with parents about their young children's media use find an assortment of reasons for use within the same household, including education, distraction, entertainment, and family time (Brito et al., 2017; Elias and Sulkin, 2019; Ochoa and Reich, 2020; Tang et al., 2021; Thompson et al., 2023). Thus, young children's media use could be for children's learning, general family functioning, or the mental health of one or both parents.

Other than some notable exceptions, the vast majority of research to date on children's media use and parents' reasons for enabling that use is based on samples of predominantly, if not exclusively, mothers. Thus, little is known about if or how young children's media use might differ with mothers and fathers. Though alignment in parenting rules is an important aspect of coparenting (McHale et al., 2002), little work has compared the media allowances and limits between parents of the same child to see how they align. Nor has research considered that mothers and fathers may estimate children's media use differently. If parents' reports are similar, then media research could utilize either parent. If not, then greater consideration is needed as to potential informant effects based on parent gender or recognition that perhaps media practices may vary between mother-child and father-child dyads.

Cross-sectional studies find mothers' and fathers' screen use to be linked to children's screen time (Tang et al., 2018; Lee et al., 2022), with fathers' use of screens to control behavior being associated with children's greater screen time on the weekends (Tang et al., 2018). Parents' rules and restrictions around media use are related to children's later media use and problems with media use in the future (Collier et al., 2016; Mares et al., 2018; Shawcroft et al., 2023). However, little research has explored how the limits that mothers' and fathers' set for their very young children's media use might align or differ. A survey of parents of children between 2 and 17 years of age found that when parents had differing levels of media restriction, there was more conflict around media use and displays of problematic behaviors by children (Mares et al., 2018). However, these data were cross-sectional and both caregivers were not surveyed; instead, respondents (mainly mothers) were asked to report on their partners' practices.

Coparenting research stresses the importance of parental alignment of rules and support of each other as parents (McHale et al., 2002; McHale and Lindahl, 2011; Campbell, 2023). Studies in domains other than media find that disagreements among parents in rules to be linked to child opposition and lower satisfaction with parenting (Hill and Holmbeck, 1987) and discrepancies among parents, especially coparenting conflict and undermining are tied to parenting stress, lower self-efficacy, and depression (Campbell, 2023). Conversely, couples' support of one another is linked to more involved parenting of toddlers and more cooperative parenting practices (Murphy et al., 2017). However, research is lacking on the alignment of couples' rules for their children's media use, which may be especially important when professional pediatric recommendations internationally for the ages in our sample (9–24 months) are abstinence or very minimal use (e.g., AAP Council on Communications and Media et al., 2016; Australian Department of Health, 2021).

Most research on young children's media use and parental rules about their use relies on samples of predominantly white, middle-class families, limiting our understanding of the media use and limits for ethnically, racially, and economically diverse young children. Given that research with older children finds that those from households with low incomes have more daily use of media than children from homes with more financial resources, and that Black and Latine youth consume more media than their white peers (Nagata et al., 2022; Hedderson et al., 2023), more research examining diverse samples with younger ages is needed to better understand the range of media use in early childhood.

1.2 Child influences on media use

Emerging research suggests that child characteristics might influence children's media use. Age is the most robust contributor to children's media use, with older children tending to use more media than younger ones (Rideout and Robb, 2020; Rideout et al., 2022). However, little research has considered how mothers' and fathers' rules and allowed uses change for their young children over time. Gender, on the other hand, has inconsistently been related to screen time, with some finding males to use media more in early childhood than females (Przybylski and Weinstein, 2017) and others finding gender unrelated to media use in other samples (Veldman et al., 2023). Children's behaviors and dispositions appear to be related to media use in early childhood. For instance, mothers' ratings of infant crying and fussiness (Thompson et al., 2013) and high physical activity levels (Nabi and Krcmar, 2016) are associated with TV viewing. Greater behavioral dysregulation in infants and toddlers is also linked to increased digital device use (Levine et al., 2019) including parents' greater likelihood to use mobile devices to calm less well-regulated children down (Radesky et al., 2016, 2020). Such findings suggest that media use in early childhood may be associated with temperamental characteristics, with more difficult behaviors (e.g., fussiness, high activity levels, negative emotionality) being tied to more media use, especially to calm and distract the child (Coyne et al., 2021). Thus, in order to better understand how mothers and fathers of the same child allow use and set limits over time, it is important to consider if children's age, gender, and temperament are similarly or differentially tied to those choices.

1.3 Parents' positive beliefs about media

Research consistently finds parental beliefs about media to be associated with children's media use, with beliefs about its benefits being linked to greater use (Elias and Sulkin, 2019; Ochoa and Reich, 2020; Griffith, 2023). For instance, a national survey of parents with children between 8 and 18 years of age found that positive beliefs about media were associated with greater media use (Lauricella and Cingel, 2020). Similarly, a daily diary study over a 1-week period found associations between parents' beneficial views of media and higher levels of television viewing for their 3–5-year-old children (Njoroge et al., 2013). Though beliefs are robustly associated with use, most studies are cross-sectional or very short time frames and involve preschool-age or older children, raising questions about how parental beliefs relate to media use from infancy to toddlerhood. This is especially important when media use at these young ages is contrary to most pediatric recommendations.

1.4 Study aims

Given that most research on very young children's media use has focused on mothers' choices, often within white, affluent families, little is known about parenting choices over time, from infancy through age two, or reported uses by fathers or racially, ethnically, and economically diverse families. In considering parents' media limits and permitted use for their young children, a considerable gap remains around the similarities or differences in couples' reports of their young children's media use cross-sectionally and over time and how their beliefs about media and their children's own characteristics influence those choices. Therefore, we assess new mothers' and new fathers' media limits and practices with their children from infancy to toddlerhood, consider how their reports align from 9 to 24 months, and how their beliefs about media and their child's age, gender and temperament might be related to reported use.

2 Method

Data are drawn from the Baby Books 2 study, a NICHD-funded parenting intervention in which educational information about typical child development was provided through bilingual English/Spanish baby books, given when children were 9, 12, 15, 18, and 24 months of age. Participants were recruited through community outreach (e.g., WIC locations, pediatric offices, Head Start centers, nurse home visiting programs) in Orange County, CA and the Washington DC area, when their first child was 6–9 months of age. At baseline, all heterosexual couples were cohabiting, able to read English or Spanish at a first-grade level or higher, and had a family income of no more than $70,000. Data were collected through home visits and phone calls when children were 9, 12, 15, 18, 21, and 24 months, with books provided at all but one (21 months) of these waves. Data from the 9, 12, 18, and 24 month waves are used for this paper. Participants were randomly assigned to 1 of 4 groups following baseline data collection. Three groups received educational intervention books designed for mothers (mom book group), books designed for fathers (dad book group), or both book types (both-book group) and one group served as a control, receiving commercially produced books (see Reich and Díaz, 2020 for more details). Information about temperament was collected via phone call when children were 12 months old. Due to social distancing policies during the COVID-19 pandemic, some of the later home visits were changed to video-chat and phone calls. All materials and procedures were reviewed and approved by two university Institutional Review Boards.

2.1 Participants

Two hundred ten families participated in the Baby Books 2 intervention (420 parents and 210 children). These parents were predominantly Latine (67.6%), followed by Black (13%), White (7%), Asian (5%), and multiethnic or other (7%). About half of the couples were married (though another 43% reported living

TABLE 1 Participant characteristics.

	All parents N (%)	Mothers N (%)	Fathers N (%)
Education			
Less than high school	73 (17.3%)	22 (10.5%)	51 (24.3%)
High school diploma or equivalent	96 (22.9%)	43 (20.5%)	53 (25.2%)
Some college	121 (28.8%)	65 (31%)	56 (26.7%)
2- or 4-year college degree	44 (10.5%)	25 (11.9%)	19 (9%)
Some graduate school or higher	86 (20.5%)	55 (26.2%)	31 (14.8%)
Race/ethnicity			
Hispanic/Latine	284 (67.6%)	142 (67.6%)	142 (67.6%)
Black, non-hispanic	54 (12.9%)	27 (12.9%)	27 (12.9%)
White	31 (7.4%)	14 (6.7%)	17 (8.1%)
Other	51 (12.1%)	27 (12.9%)	24 (11.4%)
Nativity			
Born in the U.S.	195 (46.4%)	103 (49%)	92 (43.8%)
Born outside the U.S.	225 (53.5%)	107 (51%)	118 (56.2%)
Marital Status			
Married or living as married	353 (84%)	174 (82.9%)	179 (85.2%)
Other	67 (16%)	36 (17.1%)	31 (14.8%)
Income			
<$11,000	28 (6.7%)	18 (8.6%)	10 (5%)
$11,000–45,000	191 (45.5%)	101 (48%)	90 (42.8%)
More than $45,000	154 (36.6%)	64 (30.5%)	90 (42.8%)
Missing income	47 (11.2%)	27 (12.9%)	20 (9.4%)
Working	486 (68%)	95 (45%)	190 (90%)
Attending school	60 (14%)	36 (17%)	24 (11.5%)
Language			
English only	63 (15%)	26 (12.4%)	37 (17.6%)
Spanish only	53 (12.6%)	30 (14.3%)	23 (11%)
Bilingual	277 (66%)	142 (67.6%)	135 (64.3%)
Multilingual	27 (6.4%)	12 (5.7%)	15 (7.1%)
	Mean (SD)	**Mean (SD)**	**Mean (SD)**
Parental age	28.3 (6.35) Range 18–53 years	27.15 (5.69) Range 18–43 years	29.51 (6.76) Range 18–53 years

as married) and slightly over half (53.5%) were born outside of the United States. Most parents were bilingual (66%), and all but 12.6% spoke English. At baseline (9 months), 45% of mothers and 99% of fathers were working and 17% of mothers and 11.5% of fathers were attending school. See Table 1 for details. Due to the COVID-19 pandemic, participation in data collection at 18 and 24 months was lower than earlier waves, with data from 420 parents at 9 months, 302 parents at 18 months, and 281 parents at 24 months.

2.2 Measures

2.2.1 Parenting of children's media use

Mothers and fathers were asked about their child's different types of media use 9, 18, and 24 months. These closed-ended questions about the frequency of exposure were rated on a 5-point Likert scale (0 = never or rarely, 1 = some days each week, 2 = most days each week, 3 = once a day, 4 = several times each day). Items included use alone (e.g., put the TV, DVD, or stream programs for your child to watch alone), with the parent (e.g., play on tablet, iPad and/or smartphone together), passive/background TV use (TV on even when no one is watching, TV/streaming during mealtimes, when trying to fall asleep), and use to manage behavior (rewards, punish, calm or distract; e.g., Give your child a tablet, iPad, and/or smartphone as a reward for being good). Children's frequency of media use alone (solo use), with the parent (co-use), to manage behavior, and passive TV use were all averaged, with 0 indicating never or rarely and 4 indicating use several times each day. Parents, at 9 and 24 months, were asked (yes/no) about eight types of media activities the child did on a daily basis and these were summed (e.g., watching/streaming TV or movie, watching YouTube videos, playing an app/game, playing on a mobile device, playing on a laptop or computer, video chatting, looking through digital pictures, and looking at/reading electronic books). At 9 and 24 months, parents were also asked two open-ended questions, "Do you set limits on how much time your child is using technology like TV, tablet, smartphone?" and "What kind of limits do you use?"

Using an inductive qualitative coding strategy, broad themes and patterns across the sample were identified before responses were thematically coded. Responses were aligned by child so that each dyad's (mother/father) limits could be compared. Answers that were of the same type (e.g., time limits, use to get things done), stated the same complete restriction ("doesn't use anything"/"don't give him anything") or were mildly different in limit (e.g., "rarely uses it at all"/"rarely watch TV 15–20 min tops") were scored as aligned. Time limits that were within double of the partner (e.g., "20–30 mins every day"/"no more than 1 hour") were coded as slightly misaligned. Disagreement in limits (misalignment) was code when one parent reported no limits and the other described limits, when one parent reported that the child had no media use and the other parent reported media use, and when time limits were discrepant by more than 50% (e.g., "she can only watch TV 20–30 minutes"/"no more than 2 hours a day"). Alignment patterns were collaboratively coded by the first and fifth authors.

Media use was not a primary aim of the BB2 project, which resulted in fewer media use questions being asked at the 18-month home visit compared to 9- and 24-month visits given other data collection priorities and time constraints.

2.2.2 Parents' beliefs about children's media use

Parents were asked, at 9 and 24 months, how much they agreed or disagreed (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree) with five statements about the benefits of children's use of media. These were: *TV, tablets and phones are useful for distracting children when they are being difficult. TV and games help young children learn to speak English or another language. Children are never too young for educational games on a tablet, iPad or smartphone. Smartphones and tablets make parenting easier. Children need to be skilled with computers and other devices to be successful in life.* A summary score of the beliefs was calculated in which higher values indicate greater agreement in the benefits of digital media use.

2.2.3 Temperament

Children's temperament was assessed with the EAS Temperament Scale, a parent report of how certain traits are or are not characteristic of a child (Buss, 1991; Mathiesen and Tambs, 1999; Buss and Plomin, 2013). For this analysis, we focus on the emotionality subscale which indicates more negative affect/difficult temperament. The five items query about intense negative emotional reactions (e.g., "child reacts intensely when upset," "child cries easily") and were summed with higher values indicating more negative emotionality. Because mothers' and fathers' alignment in temperamental ratings were only moderate (Intraclass correlation between couples was 0.43 with 95% confidence intervals of 0.3, 0.61), each parents' own rating of emotionality was used for analyses.

2.2.4 Background

At the baseline home visit, parents reported the background characteristics of themselves and their child. This included parental age, gender, country of origin, race and ethnicity, marital status, educational attainment, employment, and family income. Parents also reported on their child's age, gender, and race and ethnicity.

2.3 Analytic plan

In order to understand children's early media habits, how limits and media use align between mothers and fathers, and how they change over time, we first looked at frequencies of different types of media use when children were 9, 18, and 24 months of age and correlated how these frequencies of use (passive TV, solo use, co-use, behavior management, daily types of use). We also used t-tests to assess if mothers' and fathers' ratings significantly differed. To assess alignment in ratings between couples, intraclass correlations (ICCs) were calculated for each wave. Beliefs about media benefits and open-ended responses about limits were also compared. Next, to examine potential links between child characteristics and frequencies of media use by mothers and fathers, correlations between children's emotionality at 12 months and previously discussed types of media use were examined. Repeated measure ANOVA was used to assess potential changes in media use from infancy to toddlerhood. Finally, five separate regression analyses for mothers and fathers were estimated to examine potential links between parents' beliefs about media benefits at 9 months and frequency of media use (passive TV exposure, solo use, co-use, behavior management, daily use) at 24 months. In addition to controlling for parent sociodemographic characteristics (age, race, education, income), models included child gender, temperamental emotionality, and study group assignment as covariates. Data were analyzed with STATA 14.2 and R Studio version 4.3.1.

3 Results

3.1 Patterns of media use in infancy: 9 months

A large portion of the children in this study engaged with media regularly in infancy. At 9 months, 23% of parents reported that

TABLE 2 **Media use and beliefs as reported by mothers and fathers at 9, 18, and 24 months.**

	9 mo			18 mo			24 mo			9–24 mo
	Mother	Father	t-test (M vs. F), corr (M&F), ICC (couple), (95% CI)	Mother	Father	t-test (M vs. F), corr (M&F), ICC (couple), (95% CI)	Mother	Father	t-test (M vs. F), corr (M&F), ICC (couple), (95% CI)	Repeated ANOVA
	Mean (sd), range	Mean (sd), range		Mean (sd), range	Mean (sd), range		Mean (sd), range	Mean (sd), range		
Average solo-use[a] (across devices)	1.03 (0.7), 0.29–4.43	1.04 (0.76), 0.29–4.71	$t = -11$, $p = 0.92$, $r = 0.7$, *ICC couple* = 0.82*** (0.75, 0.87)	–	–		1.9 (0.81), 1–4.29	1.93 (0.78), 1–4.29	$t = -0.25$, $p = 0.8$, $r = 0.61$, *ICC couple* = 0.75** (0.65, 0.83)	All: F = 236.2***, Mom: F = 101***, Father: F = 47.6***
Average co-use[a] (across devices)	1.38 (0.89), 0.2–4	1.36 (0.91), 0.2–5	$t = 0.15$, $p = 0.88$, $r = 0.7$, *ICC couple* = 0.82** (0.75, 0.87)	–	–		2.2 (0.77), 1–4.6	2.31 (0.84), 1–5	$t = -1.1$, $p = 0.26$), $r = 0.59$, *ICC couple* = 0.73*** (0.61, 0.81)	All: F = 164.1***, Mom: F = 68.4***, Father: F = 100.5***
Average background TV[a]	2.2 (0.86), 1–4.8	2.25 (0.89), 1–5	$t = 0.57$, $p = 0.57$, $r = 0.37$, *ICC couple* = 0.54*** (0.4, 0.65)	–	–		2.31 (0.84), 1–4.6	2.30 (0.9), 1–4.6	$t = 0.09$, $p = 0.92$, $r = 0.59$, *ICC couple* = 0.74*** (0.63, 0.82)	All: F = 7.128**, Mom: F = 5.8**, Father: F = 1.65
Average behavior[a] management	1.09 (0.99), 0–5	1.11 (1.09), 0–5	$t = -0.17$, $p = 0.87$, $r = 0.22$, *ICC couple = 0.66**** (0.55, 0.74)	1.91 (1.08), 0–4	1.87 (0.94), 0–4	$t = 0.63$, $p = 0.72$, $r = 0.57$, *ICC couple* = 0.64*** (0.5, 0.74)	1.9 (1), 1–5	1.91 (0.93), 1–5	$t = -0.09$, $p = 0.93$, $r = 0.51$, *ICC couple* = 0.62* (0.46–0.73)	All: F = 142.7***, Mom: F = 72.5***, Father: F = 69.9***
Types of daily uses[b]	1.99 (1.5), 0–6	1.76 (1.37), 0–5	$t = -0.1.07$ $p = 0.29$, $r = 0.4$, *ICC couple* = 0.57** (0.44, 0.68)	–	–		3.13 (1.46), 0–6	3.25 (1.57), 0–6	$t = -0.67$, $p = 0.51$, $r = 0.42$, *ICC couple* = 0.58** (0.4, 0.7)	All: F = 223***, Mom: F = 102.1***, Father: F = 123.6***
Media beliefs[c]	2.24 (0.57), 0–2.8	2.5 (0.55), 0–3	$t = -4.74$, $p < 0.001$, $r = 0.3$, *ICC couple* = 0.43*** (0.2, 0.59)	–	–		2.39 (0.53) 1–3.8	2.58 (0.49), 1.4–3.6	$t = -2.98$, $p = 0.003$, $r = 0.32$, *ICC couple* = 0.45** (0.2, 0.62)	All: F = 20.68***, Mom: F = 19.1***, Father: F = 3.88

[a]Range for Solo-use, Co-use, Background TV, and Behavior Management: 0 = never or rarely, 1 = some days each week, 2 = most days each week, 3 = once a day, 4 = several times each day.
[b]Count of types of media used on average day.
[c]Range of mean beliefs response: 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

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their infant was not using media at all, with 10% explicitly stating that the child was too young (e.g., *"When she gets bigger"*). For the other 77%, television watching was the most common use of media for infants, with half of parents saying their 9-month-old watches TV daily and 82% of homes having the TV on some to all the time. For most children, this was the only type of daily media use. Table 2 indicates the frequency of each type of use across infants. As for types of limits new parents had for their infants' media use, these ranged from time-limited (e.g., "*when rocking him to sleep, 5 minutes max*") and purposeful (e.g., "*FaceTime with grandparents for 10 minutes*") to higher daily amounts (e.g., "*The limit is 4 hours*").

Of the parents who reported that their child did not use media yet, 84% shared that they had the television on at mealtimes, kept it on even when no one was watching, and engaged in co-use of media with their child, like looking at pictures together or video-chatting with relatives. Thus, only 18% of all parents consistently reported no media use by their 9-month-old across all media use variables (i.e., no solo use, co-use, use to manage behavior, passive TV, limitations with use descriptions, and no devices in a given day) and only 8% of couples both reported that their child was not using media across all these variables (17 children).

There were no significant differences in mean levels of media reported by mothers and fathers (range from *not all or rarely* to *several times a day*), though correlations ranged from 0.22 to 0.7 between all mother and father reports of types of media use (passive TV, solo use, co-use, use for behavior management, and types of daily use). See Table 2 for details. Again, only 17 couples agreed that their child was not using media yet. In comparing covariation across couples, intraclass correlations (ICCs) ranged from 0.54 to 0.83 and were significant.

In comparing parents' descriptions of limits for their 9-month-old's media use, 54% of couples aligned in their descriptions of limits (i.e., described same type of limit). Most of the agreements were among couples who reported no limits at all or no use of media at all, typically because they believed the child was too young for media ("*currently none, but future, yes*"). About a quarter of couples agreed that they had time limits, but only 14 couples reported the same time limit. Some of the discrepancies were minor (e.g., mother: "*less than 5 minutes*" vs. father: *"give it for a little time – plus or minus 10–15 minutes"*) and others were much larger (e.g., mother: *"only 30 minutes"* vs. father: *"2–3 hours a day"*). A subset of parents described limits based on specific needs such as putting child to sleep (e.g., *"for baby to sleep"*), distracting child *("only in car, to get in car seat"*), needing to do something *("puts on TV when need to cook"*), or to calm ("*she only gets phone when fussy*"). No parents mentioned quality of media content/programming as part of their limits. Time limits, for those that allowed use of media, ranged from 5 minutes to 4 hours per day. When couples disagreed on time limits, fathers tended to report much larger time limits than mothers (typically 2–6 times longer than mothers). Mothers and fathers mean beliefs about the benefits of media were significantly correlated at 9 months ($r = 0.57$, $p < 0.01$), with fathers having significantly more favorable beliefs about the benefits of media than mothers [$t_{(418)} = 4.757$, $p < 0.0001$ CI (−0.37, −0.15)]. ICC across couples was significant at 0.43 (CI = 0.2–0.59).

3.2 Patterns of media use at 18 months

Parents reported more media use by their child at 18 months than at 9 months, but due to constraints on data collection, not all types of media use were asked at this wave. Only 17 parents reported that their child was not using media of any kind, and only three couples agreed that their child had no use. Mothers and fathers reported non-significant differences in mean levels of media use for behavior management, with mothers' and fathers' responses correlated 0.57 and couples' ICC of 0.73 (CI = 0.6–0.8) (see Table 2).

3.3 Patterns of use at 24 months

Parents reported significantly more of every type of media use than previous waves (with the exception of fathers' report of background TV) (see Table 2). By 24 months, 38 parents reported that their child was not using media at all (which is slightly higher than the 18-month wave), and both parents agreed that their child was not using media in only six families. Television continued to be the most common source of media use, with 93.2% of parents reporting that their child watched TV and 84% reporting that the TV is typically on at mealtimes or when no one is watching. Parents reported significantly more types of media activities each day by their toddler, and increased use of devices for behavior management (see Table 2 for details). Time use limits ranged greatly from a few "*30-second videos on YouTube*" to "*3–4 hours a day*". Table 2 indicates the frequency of passive TV use, solo use, co-use, use for behavior management, and types of daily use.

Like the previous waves, correlations of mothers' and fathers' reporting on their children's media use were moderate, ranging from 0.42 to 0.61 and ICC across couples ranged from 0.58 to 0.75. Similar open-ended responses (e.g., Mother: "*only 30 minutes a day*" vs. father: "*30–60 a day*" or mother: "*only as a special treat*" vs. father: "*we try to limit it*") for media limits were found in 33% of couples. The other 2/3 of parents reported more pronounced misalignments in limits with some disagreeing about use at all (mother: "*only let her watch a movie a day*" vs. father: "*don't want her to use, too soon*"), and some having very different time limits (mother: "*no more than 10 minutes per day*" vs. father: "*Four hours total a day*"). In general, fathers' open-ended limits included much larger estimates of time use than mothers. Unlike limits listed at 9 months, parents of toddlers offered few limits beyond time (e.g., "*two hours max a day*"), duration of specific activities (e.g., "*2 hours to watch movie*"), or time of day (e.g., "*she can watch shows for 15 min before bed*", "*only when he is eating*"). A few parents mentioned using media to distract (e.g., "*lets him use only when busy*") or in response to good or bad behavior (e.g., "*If she behaves, she can watch more. If not, she can't watch it*"). No parents mentioned the quality of programming or activity as part of their limits, though a few mentioned "educational" TV or videos.

Mothers' media beliefs became more positive over time, with scores significantly increasing from 9 to 24 months, $M = 0.18$, $t_{(150)} = 4.37$, $p < 0.01$, 95% CI (0.10, 0.27), while fathers' mean media beliefs, though higher than mothers, remained stable from 9 to 24 months. Mothers' and fathers' media beliefs were significantly correlated $r = 0.55$, $p < 0.01$ and couples' ICC was 0.62 (CI = 0.46–0.73).

3.4 Parenting beliefs, age, child gender and temperament, and children's media use

In considering characteristics of the child that might be related to media use and how parents' beliefs about the benefits of media may change over time, correlations between mothers' and fathers' reports of their media beliefs at 9 months, frequency of media use at 24 months, and child emotionality at 12 months were examined. Since both mothers and fathers reported on their child's emotionality at 12 months, their subjective perception of temperament was used. Mothers' reports of their child's emotionality were only significantly correlated with their reports of children's media use for behavior management at 24 months of age, $r = 0.19$, $p < 0.05$. For fathers, reports of their child's negative emotionality were significantly correlated with passive TV use ($r = 0.20$, $p < 0.05$), solo media use ($r = 0.21$, $p < 0.05$), co-use of media ($r = 0.19$, $p < 0.05$), and media use for behavior management at 24 months of age ($r = 0.27$, $p < 0.05$).

Next, five regression models were run for each parent type to examine links between mothers' and fathers' beliefs about the benefits of media at 9 months and reports of their child's media use at 24 months. Each model included the child's emotionality at 12 months and child gender as covariates and controlled for parental age and education level. Initial model estimates also included mothers' and fathers' self-reported race/ethnicity, and income, but as none were a significant covariate in any model, they were removed for parsimony. Study condition was significant in only one model but included in all models to account for non-independence (see Tables 3, 4 for details).

Fathers' beliefs about the benefits of media at 9 months were significantly associated with higher average frequencies of media use at 24 months across all models (passive TV use, solo use, co-use, use for behavior management, and daily types of use), while mothers' beliefs about media at 9 months were associated with higher toddler media use in every model except total types of daily media use. Child emotionality was linked to higher media use in all models for fathers, except for types of daily media use. For mothers, children's negative emotionality was only associated with higher media use for behavior management. Child gender was a significant predictor of more types of daily media use and higher co-use for mothers, with use/co-use being higher with daughters. However, child gender was not a significant covariate in any of the father models. Fathers' age was consistently associated with less media use across models. Parental education was also related to less media use for some, but not all models. Finally, a larger portion of the total variance of children's media use was explained in the father models, ranging from 0.22 to 0.40, as compared to the mother models, ranging from 0.18 to 0.26.

4 Discussion

Children in this sample were regular media users from infancy to toddlerhood. Though the American Academy of Pediatrics and

TABLE 3 Regressions of associations between mothers' media beliefs at 9 months, child emotionality at 12 months, child gender, and child media use at 24 months.

	Avg. passive TV			Avg. daily use			Avg. solo use			Avg. co-use			Avg. behavior management		
	Est.	SE	t (CI)	Est.	SE	t (CI)	Est.	SE	t (CI)	Est.	SE	t (CI)	Est.	SE	t (CI)
Intercept	**1.96****	0.50	3.94 (0.97, 2.94)	**0.42****	0.11	3.75 (0.20, 0.65)	**1.78****	0.46	3.91 (0.88, 2.68)	**2.33****	0.45	5.16 (1.44, 3.22)	**1.73****	0.50	3.49 (0.75, 2.71)
Media beliefs[a]	**0.47****	0.11	4.19 (0.25, 0.70)	0.05	0.03	1.86 (−0.00, 0.10)	**0.39****	0.10	3.79 (0.18, 0.60)	**0.31****	0.10	2.99 (0.10, 0.51)	**0.33****	0.11	2.96 (0.11, 0.56)
Child emotionality[b]	0.02	0.02	1.02 (−0.02, 0.05)	0.00	0.00	0.54 (−0.01, 0.01)	0.03^{+}	0.02	1.94 (0.00, 0.06)	0.02	0.02	1.00 (−0.02, 0.05)	**0.04***	0.02	2.44 (0.01, 0.08)
Age	−0.02	0.01	−1.49 (−0.04, 0.01)	0.00	0.00	−0.99 (−0.01, 0.00)	−0.02	0.01	−1.70 (−0.04, 0.00)	**−0.03***	0.01	−2.27 (−0.05, 0.00)	**−0.03***	0.01	−2.28 (−0.05, −0.00)
Education	−0.08	0.05	−1.57 (−0.19, 0.02)	−0.02	0.01	−1.26 (−0.04, 0.01)	**−0.15****	0.05	−3.12 (−0.25, 0.06)	−0.07	0.05	−1.55 (−0.17, 0.02)	**−0.13***	0.05	−2.45 (−0.24, −0.03)
Child gender[c]	0.00	0.14	−0.02 (−0.27, 0.27)	0.05	0.03	1.68 (−0.01, 0.11)	0.19	0.13	1.48 (−0.06, 0.44)	**0.25***	0.13	2.03 (0.01, 0.50)	0.23	0.14	1.64 (−0.05, 0.50)
Study condition[d]	−0.11	0.15	−0.75 (−0.41, 0.19)	**−0.08***	0.03	−2.25 (−0.15, −0.01)	−0.19	0.14	−1.34 (−0.46, 0.09)	−0.20	0.14	−1.48 (−0.48, 0.07)	−0.12	0.15	−0.80 (−42, 0.18)
R^2	0.18			0.13			0.27			0.20			0.23		

$N = 147$. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{+}p = 0.05$.
[a]Media beliefs was measured at 9 months of age.
[b]Child emotionality is a temperament scale measured at 12 months of age.
[c]Gender 0 = son, 1 = daughter.
[d]Study Condition 0 = control, 1 = intervention. Significant relationships are bolded.

TABLE 4 Regressions of associations between fathers' media beliefs at 9 months, child emotionality at 12 months, child gender and child media use at 24 months.

	Avg. passive TV			Avg. daily use			Avg. solo use			Avg. co-use			Avg. behavior management		
	Est.	*SE*	*t* (CI)	*Est.*	*SE*	*t* (CI)	*Est.*	*SE*	*t* (CI)	*Est.*	*SE*	*t* (CI)	*Est.*	*SE*	*t* (CI)
Intercept	1.58**	0.48	3.27 (0.62, 2.52)	0.25*	0.12	2.11 (0.02, 0.49)	0.97*	0.43	2.28 (0.13, 1.82)	0.97*	0.47	2.08 (0.04, 1.89)	1.07*	0.45	2.37 (0.18, 1.96)
Media beliefs[a]	0.71**	0.11	6.28 (0.49, 0.94)	0.12**	0.03	4.40 (0.07, 0.18)	0.64**	0.10	6.31 (0.44, 0.87)	0.75**	0.11	6.82 (0.53, 0.97)	0.50**	0.11	4.74 (0.29, 0.71)
Child emotionality[b]	0.04*	0.02	2.43 (0.01, 0.08)	0.01	0.00	1.50 (−0.00, 0.02)	0.04*	0.02	2.51 (0.01, 0.07)	0.04*	0.02	2.20 (0.00, 0.07)	0.06**	0.02	3.32 (0.02, 0.09)
Age	−0.05**	0.01	−4.58 (−0.07, −0.03)	−0.01*	0.00	−2.30 (−0.01, −0.00)	−0.03**	0.01	−3.41 (−0.05, −0.01)	−0.03**	0.01	−3.26 (−0.05, −0.01)	−0.03**	0.01	−3.58 (−0.05, −0.01)
Education	−0.11*	0.05	−2.22 (−0.20, 0.01)	−0.02*	0.01	−2.12 (−0.05, −0.00)	−0.10*	0.04	−2.48 (−0.19, −0.02)	−0.05	0.05	−1.14 (−0.14, 0.04)	−0.09	0.04	−1.97 (−0.17, 0.00)
Child gender[c]	0.18	0.13	1.42 (−0.07, 0.44)	0.01	0.03	0.44 (−0.05, 0.08)	0.19	0.11	1.62 (−0.04, 0.41)	0.23	0.13	1.85 (−0.02, 0.48)	0.06	0.12	0.51 (−0.18, 0.30)
Study condition[d]	−0.06	0.15	−0.38 (−0.35, 0.24)	−0.07	0.04	−1.94 (−0.14, 0.00)	−0.01	0.13	−0.11 (−0.27, 0.24)	−0.19	0.14	−1.32 (−0.47, 0.09)	0.10	0.14	0.71 (−0.18, 0.37)
R^2	0.40			0.24			0.37			0.38			0.31		

$N = 125$. $^{*}p < 0.05$, $^{**}p < 0.01$.
[a]Media beliefs was measured at 9 months of age.
[b]Child emotionality is a temperament scale measured at 12 months of age.
[c]Gender 0 = son, 1 = daughter.
[d]Study Condition 0 = control, 1 = intervention. Significant relationships are bolded.

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other professional organizations recommend no media use other than video-chat at these ages, and only high-quality media use for no more than an hour in the toddler period (AAP Council on Communications and Media et al., 2016), most families were not following these recommendations. As others consistently find (e.g., Hish et al., 2021; Bellagamba et al., 2021), these children used television/TV-like streaming more than any other form of media. This included background television, as well as up to 4 hours a day of direct television watching (assuming mothers' and fathers' reports overlap and should not be summed). This could have significant impacts on children's language, socioemotional, cognitive, and physical development. Meta-analyses find that young children's media use, especially television viewing, is linked to lower language skills (Madigan et al., 2020). This finding could be due to displacement of opportunities to hear language and produce language in responsive interactions (Pempek and Kirkorian, 2020), as experimental studies confirm that both watching television and having television on in the background reduce language in the child's environment as well as their efforts to produce language (Kirkorian et al., 2009; Pempek et al., 2014). Some also propose that screens might create a digital bubble in which children engage in less private speech, which may affect language development and executive function (Bochicchio et al., 2022).

Further, decades of research have linked young children's television viewing with poor physical health outcomes, such as reduced gray/matter volume in the visual cortex, hypothalamus and sensorimotor areas of the brain (Takeuchi et al., 2013), weight gain (Jackson and Cunningham, 2017), poor nutritional intake, and reduced physical activity (Cox et al., 2012). Television viewing is associated with poor socioemotional and cognitive outcomes as well (Anderson and Pempek, 2005; Desmarais et al., 2021). Thus, our finding of regular TV exposure and use for almost all of the children in this study is important and potentially concerning.

The low-to-moderate incomes of our sample may play a role in the high use of media at these young ages, as studies have found family income to be negatively associated with media use (i.e., households with low incomes tend to watch more television than well-resourced homes; De Craemer et al., 2018; Chen and Adler, 2019; Ramírez et al., 2021). Our sample lacked high incomes to make such comparisons, though we did not find income to be linked to media uses with the low-to-moderate income ranges in our sample. Though studies find that children from ethnic and racial minority groups tend to use more media than their White, majority peers (Thompson et al., 2010; Goode et al., 2020), we did not observe differences based on race or ethnicity, though our sample was predominantly non-white.

Families in this study had multiple devices in their homes, but television was by far the most commonly used form of media for infants and toddlers. Mobile devices, such as tablets and smartphones were less commonly used, though parents did report use often and at higher rates from 9 to 24 months. In the open-ended discussions of limits, parents also mentioned these mobile devices, such as the child being given the phone when fussy. Though tablets and smartphones have more potential for interactivity, which can be beneficial to learning (Xu, 2023), they also have the potential to expose children to inappropriate advertising and persuasive design features that make discontinuing use challenging (Meyer et al., 2019; Radesky et al., 2022). Importantly, research has found that parents tend to have difficulty recalling their children's mobile device use, often underestimating (35.7%) or overestimating (34.8%) children's tablet and smartphone use in comparison to objective (logging) measures of use (Radesky et al., 2020).

4.1 Mother vs. father informants

The vast majority of research on children's use of media utilizes maternal reports of frequency, duration, and types of use (Paudel et al., 2017; Eirich et al., 2022). Our findings indicated few significant differences in mothers' and fathers' reporting of media use on average, with reports being moderately correlated. Parents of the same child rarely selected the same frequency of use as their partner, but in the aggregate, mothers' and fathers' total ratings were comparable. This suggests utility to either mother or father report for aggregated and larger sample studies but caution when looking at specific uses for specific children. In considering limits, which were mainly time limits, the majority of couples did not agree on the limitations around their child's use of media. In some cases, one parent reported no use while the other reported regular daily use. Even when both parents agreed that the child had limits on media use, they often had sizable discrepancies (e.g., 10 min vs. 4 hrs per day). Since actual use of media was not recorded, we do not know whether one parent was more valid in their reporting or if young children have different media use and limitations with each parent. This is an area that warrants further investigation, as a small body of research finds that children may have different media practices with each parent (Connell et al., 2015; Nikken and Schols, 2015), and children's media use with mothers may be associated with different child outcomes than media use with fathers (Tang et al., 2018).

Mothers and fathers did endorse significantly different beliefs about the benefits of media for children, with fathers' being more favorable. It is unclear as to why men held more positive beliefs than women in this sample. Studies over the past three decades have found that men tend to use internet technologies more than women (Morahan-Martin, 1998; Goswami and Dutta, 2015; Qazi et al., 2022), which may be related to more positive beliefs about their benefit. Research has found links between parental beliefs about media and children's media use (Njoroge et al., 2013; Domoff et al., 2017; Griffith, 2023). However, the majority of these studies focused on mothers' beliefs about media. Some notable exceptions include mothers and fathers (Cingel and Krcmar, 2013; Hinkley and McCann, 2018; Ochoa and Reich, 2020), but few studies have considered beliefs within couples or across time. Our findings demonstrate that positive beliefs about the benefits of media are related to both mothers' and fathers' decisions about their young child's media use. Given men's significantly more positive beliefs than women, future work should further explore the link between fathers' beliefs and their children's media use, especially over time.

4.2 Child contributions to media use

How parents perceived their child's negative emotionality was related to decisions about their child's media use. For both mothers and fathers, negative emotionality was linked to more parental reports of using media to reward, punish, calm, and distract children. A growing body of research is documenting how children's difficult temperament is linked to higher use of media, from toddlerhood onward (Nabi and Krcmar, 2016; Coyne et al., 2021; Shin et al., 2021). The use of media to help manage behavior might limit young children's opportunities to cultivate self-regulatory skills and executive functions. In a sample of 3–5-year-olds, Radesky et al. (2023) found that the use of media to calm children was predictive of lower executive functioning skills 3 and 6 months later (Radesky et al., 2023). Similarly, Coyne et al. (2021) found that use of devices for behavior regulation was tied to stronger emotion reactivity and problematic media use in 2–3-year-olds. As such, children with more difficult temperaments might be at risk for missing valuable opportunities for cultivating these important self-regulatory processes. Given the stronger relationship between father-reported media uses and child negative emotionality, it is possible that these risks might be greater with fathers than mothers.

Interestingly, children's negative emotionality was linked to fathers', but not mothers', reporting of more passive TV exposure, use of media alone, and co-use of media. Limited research has explored differences in mothers' and fathers' reports of their young children's media use, but extant work has noted interesting differences. For instance, a survey of parents of children 8 years and younger found that fathers were significantly more likely than mothers to spend time co-using videogames and computers with their child (Connell et al., 2015). An older experimental study of television viewing found that family TV watching resulted in less talking and positive interactions toward children for fathers, but not for mothers (Brody et al., 1980). Research indicates that children might have different media experiences with mothers and fathers and our findings suggest that temperament might be associated with these differences. Future work should consider the intersection of child characteristics with those of their parents, including parental beliefs, gender, and dispositions.

Also associated with differences in children's media use were parental age and education, with older and better educated parents reporting lower rates of media use for their young children. Research, in a variety of aspects of parenting, finds that more education and older age are linked to positive parenting practices and better child outcomes (e.g., Ragozin et al., 1982; Tearne, 2015; Yildirim et al., 2020). These findings suggest that media limits and access might be another parenting domain linked to these characteristics.

4.3 Limitations

This study, utilizing data from a longitudinal parenting intervention, was limited in its measurement of media use. First, only parental reports of media use were possible. Without more objective measures, there is no way to know the accuracy of their reports with young children's actual use or the quality of the programming or media used. Second, though the frequency of types of use was captured, total screen time was not. Thus, estimates of total time using media were not possible. Third, the 18-month home visit utilized a shorter media measure due to time constraints of direct assessments needed for the main aims of the grant, and as a result, information comparable to the 9- and 24-month average solo use, co-use, passive TV use, and types of daily use were not available. Fourth, some of the data were collected during the COVID-19 pandemic, which contributed to missing data and likely resulted in different media patterns for those interviewed before or during the social distancing policies in place. Fifth, data are not available as to how much time each parent spent with their child during waking hours. Most parents worked and we do not have data on whether they worked from home or during the day or night. Finally, all parents were new parents, low-to-moderate income and living in California or the Washington DC area. As such, findings may not generalize to other types of parents.

5 Conclusion

Extant research focusing on young children's media use is highly reliant on maternal reports, often lacking consideration of fathers' perspectives. By interviewing both mothers and fathers of the same child about their media use, we were able to compare media practices and limits within couples. Though average values in the aggregate were not significantly different, mothers and fathers rarely agreed on their young child's media use and often reported different frequency and limits for use. Such findings indicate the need for more research to understand whether mothers and fathers simply report different values or if children have different media experiences with each parent. Importantly, parents' beliefs that media is beneficial and how they view their child's emotional reactivity are significantly related to the types of media their young children use. Thus, interventions to reduce media use in early childhood may benefit from targeting parents' beliefs about media, as well as helping to cultivate skills for managing their children's negative emotions without screens.

Data availability statement

The datasets presented in this article are not readily available, as families did not consent to sharing their data at enrollment. Requests to access the datasets should be directed to SR, smreich@uci.edu.

Ethics statement

The studies involving humans were approved by University of California, Irvine IRB and University of Maryland IRB. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

SR: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. KM: Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. AK: Data curation, Formal analysis, Investigation, Writing – review & editing. DF: Data curation, Formal analysis, Investigation, Writing – review & editing. EM: Conceptualization, Data curation, Investigation, Writing – review & editing. NC: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The influence of entertainment and brand characters on children's object preferences and monetary judgments

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Companies often use images of popular characters from children's media on their products. The current study investigated how different types of popular characters (i.e., entertainment or brand) influence children's trust, preference for, and monetary judgments of objects. Additionally, we explored whether children's own parasocial relationships with such characters influence their preferences and judgments. Participants included 66 four- and five-year-olds ($M_{age} = 5.06$; $SD = 0.48$; 34 boys; 32 girls). First, children completed a selective trust task measuring their preference for information from a familiar or unfamiliar character. Then children asked which object (i.e., damaged with a familiar character image or undamaged without a familiar character image) they would want and which people would pay more money for. Results indicated regardless of character type (i.e., entertainment or brand), children did not trust (i.e., seek out new information or endorse specific testimony) the familiar marketing character more than an unfamiliar character. Children across all character conditions did not display a preference for either object, however they were more likely to rate the undamaged object as more valuable than the damaged object featuring the familiar character. Parasocial relationships for all types of characters were high and did not relate to children's preferences or judgments. These findings expand on previous research suggesting that although the presence of familiar media characters can influence children's preferences for individual objects, children can also weigh more relevant features of an object, such as potential flaws in the design, when making other decisions (e.g., value).

KEYWORDS

familiar characters, selective trust, object preference, monetary judgment, parasocial relationship

Introduction

In 2023, licensed toys (e.g., toys with specific logos, packaging design, graphic images) accounted for over 30% of the total toy market across 12 global markets (Circana, 2024). Of the licensing logos and images, many include popular familiar characters from children's media programs (e.g., Elmo from *Sesame Street*©). These characters are also used in other industries to market to children, such as the food and beverage industry which often feature familiar characters on food packaging, typically for foods of low nutritional value (Harris et al., 2010; Elliott, 2019). Some companies create their own distinct brand characters (e.g., Kellogg©'s Tony the Tiger) to feature on children's products. Although these characters are also familiar to young children (Batada and Borzekowski, 2008), they are used solely to promote a product, rather than to provide entertainment (Phillips, 1996). Research over the past few decades has found that featuring characters on products is an effective marketing strategy and children will be more likely to request or prefer a product if it features a character (Derbaix and Bree, 1997; Neeley and Schumann, 2004; Boyland and Halford, 2013; Hémar-Nicolas et al., 2021). However, it is unclear whether children judge products differently depending on the character type (e.g., entertainment or brand) or their relationship with the character that is used in the marketing strategy.

Previous research has found that popular entertainment characters influence children's judgments about various products. For example, when a popular entertainment character is displayed on food packaging, children judge that the food is more tasty than when judging the same food without the packaging (Roberto et al., 2010; Kotler et al., 2012; Letona et al., 2014). Similarly, when popular entertainment characters are displayed on books, preschoolers are more likely to want to read them (Jacoby and Edlefsen, 2020). This preference for objects depicting popular entertainment characters even extends to damaged objects (Danovitch and Mills, 2014, 2017). When presented with identical pairs of objects where one object is damaged and has a picture of a familiar popular entertainment character and the other object is in perfect condition but does not picture the familiar popular entertainment character, children as young as 4 years old prefer the damaged object depicting the familiar entertainment character more than the object without the character.

Earlier research conducted by John (1999) proposed a conceptual framework for understanding consumer socialization as a series of stages. Following Piaget (1970), he proposed that children aged 3 to 7 years old are in a pre-operational stage in which they are only able to focus on a single, perceptually salient attribute of an object (e.g., its color) when making decisions. However, more recent research by Vanderbilt and Andreason (2023) suggests that young children can weigh several characteristics of the same object and can assign differential importance to each characteristic depending on the task at hand. To assess this hypothesis, Vanderbilt and Andreason (2023) presented children with damaged objects with a character or undamaged objects without a familiar character (similar to Danovitch and Mills, 2014, 2017) and asked children which object they would want to take home, as well as which object they would prefer to use to complete a functional task (e.g., needing to moving objects across the room). The results indicated that 3- and 4-year-olds prefer to take home objects depicting a familiar popular entertainment character more than objects without the characters—even if those objects are damaged. However, when asked which object children would need to complete a functional task, children prioritized object functionality over the presence of a character. These findings suggest that although popular entertainment character have a strong influence on children's preferences, children are able to weigh other factors (e.g., functionality), depending on the type of judgment.

As consumers, individuals not only take into account their preference for an object or its functionality, but also its worth. The mechanisms through which young children make monetary value assessments of objects have clear implications for the persuasive marketing of products (Gelman and Echelbarger, 2019). Research suggests that children grasp the concept of value from a young age and can assign specific dollar amounts which reflect relative worth (Frazier and Gelman, 2009). Previous research invited 4- to 12-year-old children to provide monetary evaluations across a variety of objects (Gelman et al., 2015). Across all ages, children consistently assigned the highest monetary value to objects that they were told "belonged" to familiar entertainment characters (e.g., Ernie's rubber ducky), suggesting that children's monetary assessment of objects is strongly influenced by the association of an object with a familiar entertainment character. However, to our knowledge no research has explored how children would monetarily evaluate damaged objects which feature, rather than are associated with, familiar characters.

Although popular entertainment characters (e.g., Elmo) are often used in product advertising for children, companies also create brand characters for the sole purpose of advertising their products (e.g., Kellogg©'s Tony the Tiger). The featuring of brand and entertainment characters on products targeted at children has undergone considerable scrutiny. Young children are often regarded as cognitively immature (Schor, 2008), potentially lacking the ability to recognize marketing tactics, understand their persuasive purposes, and resist their allure (Hudders et al., 2017). In particular, the use of such strategies within the food industry has prompted ethical concerns. Almost half of UK food and drink products featuring familiar characters are high in fat, saturated fat, sugar and/or salt, with few companies employing such strategies on nutritious products (Action on Sugar, 2019). Such encouragement of the consumption of unhealthy products is associated with public health issues related to childhood obesity (Kraak and Story, 2015). Therefore, it is crucial to explore how the visual appeal of brand characters' images might influence children's product choices and evaluations.

The current study expands on previous research to examine whether children's monetary judgments for damaged objects featuring familiar characters are similar to their preferences for these items, and whether the type of familiar character (i.e., entertainment or brand characters) influences these judgments. We also examined if these judgments and preferences relate to children's trust and parasocial relationships. Several authors (e.g., Danovitch and Mills, 2017; Vanderbilt and Andreason, 2023) have theorized that children's preference for objects featuring familiar characters may be driven by emotion. More specifically, children may have parasocial relationships, or one-sided emotional attachments, with these characters (Schlesinger et al., 2016). Young children often treat familiar characters as realistic and trusted friends (Bond and Calvert, 2014). They are likely to form the strongest parasocial relationships with characters to which they have high exposure in the media (Richards and Calvert, 2017) and who behave in a way which suggests they can interact directly with the audience (e.g., looking directly at the viewer; Auter, 1992). No research has explored potential relations between the strength of children's parasocial relationship with the character and children's preference for damaged objects featuring those characters.

Methods

Participants

Sixty-six 4- and 5-year-olds ($M_{age} = 5.06$; $SD = 0.48$; 34 boys; 32 girls) participated. One caregiver did not provide the date of birth for their child at consent but informed the researcher that the child was 4 years old; therefore, exact age could not be calculated and this participant was not included in the average age reported. An additional 10 participants were excluded from the analysis because they were not familiar with the characters ($M_{age} = 4.93$; $SD = 0.35$). The minimum number of participants ($N = 66$) required was determined by an *a priori* power analysis using G*Power (Faul et al., 2007), employing an effect size of 0.40, at a significance level of 0.05.

Participants were recruited from various locations in the Boston MA area including the park, museums, and local schools. Additional demographic information (i.e., caregiver education level, family household income, and child's race and ethnicity) were optional for the caregiver to report. Thirty-six percent of caregivers did not provide their education level, 4.5% had less than a high school degree, 1.5% had some college, 6% had a Bachelor's degree, 26% had a Master's degree, and 26% had a Professional degree/Doctorate. Forty-eight percent of caregivers did not provide their household income, 1.5% ranged from \$25,000-\$49,999, 4.5% ranged from \$50,000-\$74,999, 3% ranged from \$75,000-\$99,999, 6% ranged from \$100,000-\$149,999, 11% ranged from \$150,000-\$199,999, 4.5% ranged from \$200,000-\$249,999, 4.5% ranged from \$250,000-\$300,000, and 17% ranged >\$300,000. Finally, thirty-nine percent of caregivers did not provide the race and ethnicity of their child, 36% of participants were identified by their caregivers as Caucasian-American, 11% Asian, 3% Middle Eastern, 2% Hispanic/Latino, and 9% were identified as belonging to two or more race and ethnicities.

An additional 16 children ($M_{age} = 4.79$; $SD = 0.44$; 12 boys; 4 girls) from the same community participated in a control condition for the object preference and monetary evaluation trials only. Three additional children were excluded because they failed to pass the monetary judgment training task ($n = 2$), or did not complete the task due to inattention ($n = 1$).

Materials

Three informant type conditions were created *a priori* (i.e., brand characters, entertainment characters with intended high parasocial relationship, or entertainment characters with intended low parasocial relationship) to examine potential differences in children's judgments based on character type. Initially, a web search was conducted to establish characters familiar to pre-school children, and which fit into the following three distinct categories: (1) "strong parasocial" characters featured in popular television shows, which children are likely to be regularly exposed to, and who break the fourth wall (i.e., engage with the audience) (2) "weak parasocial" characters featured in popular movies, which children are likely to be less regularly exposed to and which do not interact with the audience, and (3) "brand" characters featured in popular branding commercials. The search yielded a set of six characters for each category.

To explore children's familiarity with these characters, we presented them to eleven 3- to 5-year-olds, and invited them to identify either the name of the character or the show/movie/commercial they were from. Children were most familiar with Daniel Tiger (from *Daniel Tiger's Neighborhood*; 100%) and Elmo (from *Sesame Street*; 80%) for the "strong parasocial" category, Moana (from *Moana*; 90%) and Elsa (from *Frozen*; 70%) for the "weak parasocial" category, and Finn (from *Goldfish*; 100%) and Red (from *M&M*; 100%) for the "brand" category. These six characters were included in the study. Each character was presented in a neutral pose, and appeared to be looking at the viewer. Following Danovitch and Mills (2014), we modified the familiar character's image to create an unfamiliar equivalent for each of the six familiar characters. This perceptually-matched image was created by uploading the character's image to the website "Image Color Summarizer" (Krzywinski, 2006), where the color percentage breakdown of the original image was analyzed. This information was then used to create a new image of the same dimensions as the original.

Following the same object designs as used in Danovitch and Mills (2014, 2017), five pairs of identical objects were used in both the object preference task and monetary value task: a bucket, a binder, a mask, a bag of candy, and a bag of crackers. The first three objects were selected randomly but the other two were selected based on their relevance to the brand characters (i.e., a candy bag for *M&M*'s Red and a cracker bag for *Goldfish*'s Finn). Within each pair, one object was "damaged" (e.g., parts of the bucket were ripped off, the cover of the binder was torn and bent), and the other object was in perfect condition (see Figure 1). On the damaged object, a printed cut-out of each familiar character was displayed in a central location. On the undamaged objects, a printed cut-out of a perceptually-matched image (an image of the same size and color as the familiar character's image) was placed in a central location. Individual photos were taken of each of the damaged and undamaged objects. The order that the object pairs were presented was determined by a 5 × 5 Latin square design. For half of these orders, the damaged object was on the left side of the screen, and for the other, half the damaged object was on the right side of the screen.

Parasocial interaction measure

The Parasocial Interaction Measure was adapted from Richards and Calvert (2017), and included 17 questions delivered in a fixed order, measuring children's level of parasocial relationship with each familiar character (see Appendix).

Monetary evaluation introduction and training

The monetary evaluation training task was adapted from Gelman et al. (2015). The items in the monetary evaluation introduction consisted of pictures of money, a painting, a crumpled piece of paper, roller skates, dirty socks, pack of gum, a drum set, a toy boat, and a cup. The items used

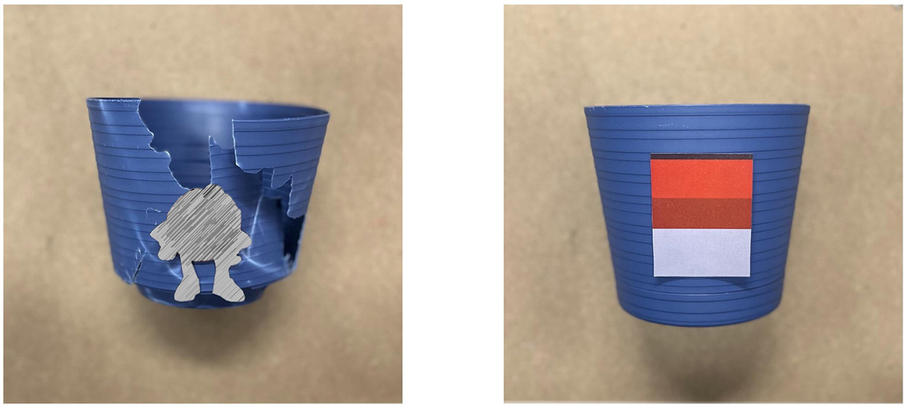

FIGURE 1
Example of a damaged and perfect object pair from the brand character condition as presented on screen in PowerPoint. Silhouette indicates the location of the character image that cannot be reprinted here due to copyright law.

in the training trials were a box of crayons, a single crayon, a fancy toy train, a plain toy train, a fancy pen, a plain pen, a whole cookie, a partially eaten one, clean shoes, and dirty shoes.

Procedure

Character selection

Children were randomized into one of three conditions: "Strong Parasocial", "Weak Parasocial", and "Brand." To begin, they were presented with the two characters relevant to their condition (e.g., Elsa and Moana for the "Weak Parasocial" condition) and invited to choose their favorite. To confirm their familiarity with their chosen favorite, children were asked two questions: "What is [character's] name?" and "What movie/show/commercial are they from?" This character was shown to them in the following tasks. If the child was unfamiliar with their initial favorite, the researcher asked about their familiarity with the other character presented. If the children displayed familiarity with the other character within the condition, that character was instead used in the following tasks. Children that were unfamiliar with both characters were excluded.

Unfamiliar character introduction

Next, children were shown the unfamiliar, but perceptually similar, character. The experimenter said, "Now I am going to show you a new character. Their name is Jesse. Jesse is from a brand new movie/show/commercial that no one has watched yet." To make sure children were unfamiliar with this character, children were asked, "Have you ever seen Jesse before?" Four child claimed to be familiar with Jesse, and were reminded that Jesse was a new character from a new movie/show/commercial no one had seen before.

Selective trust trials

Children then completed two selective trust tasks: ask and endorse (modified from Danovitch and Mills, 2014).

Ask trial

Children were shown the familiar and the unfamiliar character and asked, "Which character would you ask to find the answer to this question: What season is best for Flurping?". Children could respond by saying the name of the character or pointing to their choice on the screen.

Endorse trials

Across three trials, a speech bubble for each character appeared on the screen displaying conflicting statements (e.g., "Hoon flowers smell good/bad"). The experimenter read each statement aloud, and then invited the child to endorse one of the two statements. For example, the experimenter might say, "Red says Hoon flowers smell good and Jesse says Hoon flowers smell bad. What do you think? Do Hoon flowers smell good like Red says, or bad like Jesse says?" Children could respond by repeating the statement or pointing to the character whose statement they were endorsing. Eight different orders were created to control for the character-statement match, as well as the side of the screen on which each character was displayed.

Object preference trials

Next, children completed the object preference task (adapted from Danovitch and Mills, 2014). Children were presented with five pairs of identical objects (one damaged and one undamaged). For each pair, they were invited to consider the object they would choose if they were shown them in a store.

Parasocial relationship

Children then saw the familiar character on the screen and answered the Parasocial Relationship Measure. Children could respond to each question with "yes", "maybe", or "no". "Yes" responses were scored as 1, "maybe" responses were scored as 0.5, and "no" responses were scored as "0". Averages across the 17 questions were calculated for the Parasocial Relationship Measure.

Monetary evaluation introduction

To begin, children were reminded that money is used to purchase things and were shown two pairs of objects: (1) a painting and a crumbled ball of paper and (2) roller skates and dirty socks. The experimenter explained that people typically pay more for one of the items (i.e., painting and roller skates). Then, children were given examples of items and their cost (e.g., "People would pay $1 for a pack of gum and $100 for a drum set").

Monetary evaluation training trials

Next, children were trained on the two monetary evaluation tasks: *forced choice evaluations* (i.e., "Which object would people pay more money for?") and *open-ended evaluations* (i.e., "How much would people pay for this object?"). Children completed a total of five trials where one object was considered more valuable than the other. The object pairs used in the training trials were (1) a box of crayons and a single crayon, (2) a plain toy train and a fancy toy train, (3) a plain pen and a fancy pen, (4) a cookie with one bit missing and a whole cookie, and (5) dirty shoes and clean shoes. Following the same procedure as Gelman et al. (2015), feedback was provided after each trial. If the child correctly answered a test trial, they were told that they were right, people would pay more for the object they selected, and they were told why (e.g., "You're right! People would pay more for this box of crayons because there are more.") If the child did not correctly answer a test trial, they were told people would pay more money for the other object and why (e.g., "Actually, I think people would pay more for this this box of crayons because there are more").

Monetary evaluation test trials

Next, children were presented with the same five pairs of objects (one damaged and one undamaged) from the Object Preference Trials. For each pair, they were invited to indicate which object "people would pay more money for" (i.e., *forced choice evaluations*), as well as the amount people would pay for each item (i.e., *open-ended evaluations*).

Results

Character selection

In the Strong Parasocial condition, 14 children selected Daniel Tiger and eight selected Elmo as their favorite character. In the Weak Parasocial condition, four children selected Moana as their favorite, whereas 18 selected Elsa as their favorite character. In the Brand condition, five children selected Finn and 17 selected Red as their favorite character. One child originally selected Finn and one child originally selected Red as their favorite character but could not name the character or the commercial; because they could name the character and commercial of the other character, they continued the study with the character with which they were familiar. Removing these participants did not change the overall pattern of results, therefore they were included in the analyses. When introduced to Jesse, four children claimed to be familiar with Jesse, and one child refused to answer.

Parasocial relationship

Seven participants did not answer one of the 17 parasocial relationship questions. As such, proportional scores were calculated out of the total number of questions answered. To determine if our assigned conditions differed on their level of parasocial relationships, a one-way ANOVA with character type was conducted. There was a significant difference in the average parasocial relationship score between the three conditions, $F(2, 63) = 3.21$, $p = 0.047$. A *post hoc* Tukey's t-test indicated that children reported a parasocial relationship that was significantly stronger in the Strong Parasocial Condition ($M = 0.744$, $SD = 0.141$) than in the Weak Parasocial Condition ($M = 0.611$, $SD = 0.210$), $t(63) = 2.53$, $p = 0.036$, $d = 0.74$. There was no significant difference between Brand ($M = 0.672$, $SD = 0.164$) and Strong or Weak Conditions, $ps > 0.369$.

Selective trust trials

Ask trial

There was no difference in the distribution of responses between children in the three conditions, $\chi^2(2, N = 66) = 2.57$, $p = 0.277$. Collapsed across conditions, 36 of 66 total children indicated that they would ask the familiar character for the answer to a novel question, whereas 30 indicated they would ask the novel character, $\chi^2(1, N = 66) = 0.55$, $p = 0.460$.

Endorse trials

Two participants in the Brand condition were missing values for one of the endorse trials. Removing these participants did not change the overall pattern of results, therefore they were included in the following analysis. Children endorsed the familiar character's testimony 51% of the time in the Strong Parasocial condition, 55% of the time in the Weak Parasocial condition, and 55% of the time in the Brand condition.

To examine the effects of condition and parasocial relationship on children's endorsement of the familiar character's testimony, we developed a Generalized Mixed Model in Jamovi Version 2.3 (The Jamovi Project, 2022). Preliminary analyses revealed no significant main effects of Age (measured continuously) or Gender, and no significant interactions. Thus, Age and Gender were not included in our primary analyses. The fixed effect in the final model was Condition, and child's Parasocial Relationship score was included as a continuous predictor. The model also included a random effect for the Child. The generalized mixed effects model revealed no significant main effect of Condition or Parasocial Relationship score or interactions, $ps > 0.373$.

Additionally, to determine if all children (i.e., collapsed across condition) endorsed the familiar character's testimony at rates higher than the unfamiliar character's testimony, a χ^2 Goodness of Fit test was conducted across all the trials ($N = 196$). Children did not show any significant difference in their endorsement of the familiar character's testimony (56% of the trails) than the unfamiliar character's testimony (44% of the trails), $\chi^2(1, N = 196) = 2.94$, $p = 0.086$.

Exploratory analysis: the role of valence

To further understand the null result for the Endorse Trials, an exploratory analysis of children's endorsement by valence was conducted. Recall that the characters provided testimony that varied in valance (i.e., positive or negative; e.g., flowers smell good/bad). Previous selective trust research with familiar characters (e.g., Williams and Danovitch, 2019) suggests that children attend to the valence of the testimony when making an inference about the credibility of subjective statements. Trial responses were recoded as endorsing the positive or negative testimony, regardless of character type. To determine if all children (i.e., collapsed across condition) endorsed the positive testimony at rates higher than the negative character's testimony, a χ^2 Goodness of Fit test was conducted across all trials ($N = 196$). Children were more likely to endorse the positive testimony (80% of the trails) over the negative testimony (20% of the trails), $\chi^2(1, N = 196) = 71.0$, $p < 0.001$.

Object preference trials

Children chose the damaged object with the familiar character's image 51% of the time in the Strong Parasocial condition, 55% of the time in the Weak Parasocial condition, and 59% of the time in the Brand condition.

To examine the effect of Condition and Parasocial Relationship on children's preference for damaged objects with familiar character's image, we developed a Generalized Mixed Model in Jamovi Version 2.3 (The Jamovi Project, 2022). Preliminary analyses revealed no significant main effects of Age (measured continuously) or Gender, and no significant interactions. Thus, Age and Gender were not included in our primary analyses. The fixed effects in the model were Condition and child's Parasocial Relationship score was included as a continuous predictor. The model also included random effects for the child and type of object. The Generalized Mixed-effects Model revealed no significant main effect of Condition or Parasocial relationship score or interactions, $ps > 0.090$.

To explore children's overall object preference, we collapsed children's choices across conditions and ran a χ^2 Goodness of Fit test on all 330 trials. The results indicated that children were more likely to select the undamaged objects (57% of the trails) over the damaged object with the image of the character (43% of the trails), $\chi^2(1, N = 330) = 5.87$, $p = 0.015$.

Exploratory object preference with control condition

To examine the effects of the presence or absence of a character's image on children's preference for damaged objects, we developed an exploratory Generalized Mixed Model in Jamovi Version 2.3 (The Jamovi Project, 2022). The fixed effect in the model was Control Condition (i.e., control condition or experimental condition). The model also included random effects for the child and type of object. The generalized mixed effects model revealed a significant main effect of Control Condition, $B = -4.14$, $SE = 1.05$, 95% CI [0.002, 0.12], $p < 0.001$, such that children in the Control Condition were less likely to select the damaged object than children in one of the three experimental conditions.

Monetary evaluations training trials

Forced choice evaluations

When invited to select which of two choices people would pay more money for, all but one participant correctly identified the more valuable of two objects 60% of the time or more. One participant scored lower than 50% in this task. However, excluding this participant did not change the overall pattern of results, therefore, they were included in the subsequent analysis.

Monetary evaluations test trials

Forced choice evaluations

One participant in the Weak Parasocial condition did not complete this task and was excluded from the following analysis. Children indicated that the damaged object with an image of the familiar character was more costly 19% of the time in the Strong Parasocial condition, 24% of the time in the Weak Parasocial condition, and 24% of the time in the Brand condition.

To examine the effects of Condition and Parasocial Relationship on children's monetary value of damaged objects with images of familiar characters, we developed a Generalized Mixed Model in Jamovi Version 2.3 (The Jamovi Project, 2022). Preliminary analyses revealed no significant main effects of Age (measured continuously) or Gender, and no significant interactions. Thus, Age and Gender were not included in our primary analyses. The fixed effect in the model was Condition and child's Parasocial Relationship score was included as a continuous predictor. The model also included random effects for the child and type of object. The generalized mixed effects model revealed no significant main effect of condition or parasocial relationship score or interactions, $ps > 0.443$.

Additionally, to determine if all children (i.e., collapsed across condition) endorsed the familiar character's testimony at rates higher than the unfamiliar character's testimony, a χ^2 Goodness of Fit test was conducted across all trials ($N = 325$). Children were more likely to view the undamaged objects (77% of the trails) as more valuable than the damaged object with the image of the character (23% of the trails), $\chi^2(1, N = 325) = 94.2$, $p < 0.001$.

Exploratory monetary value with control condition

To examine the effects of the presence or absence of a character's image on children's preference for damaged objects, we developed an exploratory Generalized Mixed Model in Jamovi

Version 2.3 (The Jamovi Project, 2022). The fixed effect in the model was Control Condition (i.e., control condition or experimental condition). The model also included random effects for the child and type of object. The generalized mixed effects model revealed no significant main effect of Control condition, $p = 0.263$, such that children in the Control Condition did not value the undamaged object more or less than children not in the control condition.

Discussion

This research investigated how different types of marketing characters (i.e., entertainment or brand) influence children's trust in, preference for, and monetary judgments of objects. Additionally, we explored whether children's own parasocial relationships with such characters influence their judgments. Across all tasks, the type of character (i.e., brand or entertainment) did not influence children's judgments. One explanation for this finding could be that although children in the Strong Parasocial vs. Weak Parasocial conditions had different parasocial relationship scores, the parasocial scores of the Brand characters were not significantly different than either of the other two groups. Overall, children had high parasocial relationship scores suggesting that brand characters have comparable–and as strong of–levels of influence on children's judgment as do entertainment characters. This is surprising, given that children only encounter brand characters in advertisements and on products, which likely evoke less emotional engagement than observing entertainment characters in movies or TV shows (Dessart and Pitardi, 2019). These findings indicate that companies can build effective marketing strategies using brand characters as well as entertainment characters.

Contrary to previous findings (e.g., Danovitch and Mills, 2014), children across all conditions did not trust (i.e., seek out new information or endorse specific testimony) the familiar marketing character more than the unfamiliar, but perceptually similar, character. It is plausible that, although children indicated strong parasocial relationships with the familiar characters, they had no information about either of the characters' credibility prior to making judgments about from whom to learn, further highlighting the proposed separation between emotional trust and epistemic trust (Jaswal and Kondrad, 2016). Indeed, previous research exploring children's selective learning from characters allowed children to hear a statement during a familiarization phase prior to making judgments about brand characters (Danovitch and Mills, 2014). Using this paradigm, children were more likely to trust the familiar character's subjective statements when the character's previous statement history aligned with children's own beliefs (e.g., "Birthday parties are fun"). Taken together, the results from our study and the findings from Danovitch and Mills (2014) indicate that children do not blindly trust statements from familiar marketing characters and instead rely on previous information to make decisions about from whom to seek out and endorse information. Rather, these findings suggest that children consider both characteristics of the informant, and characteristics about the claim when making decisions about from whom to learn.

We further explored this possibility by including an exploratory analysis of children's endorsement based on statement valence. Specifically, because subjective statements can be either positively or negatively valenced, we explored whether the valence of the characters' statement influenced children's selective trust. Similar to previous selective trust literature involving familiar characters (e.g., Williams and Danovitch, 2019), children in our study were more likely to endorse positively valenced subjective testimony, regardless of the character's familiarity. As mentioned in Williams and Danovitch (2019), young children are prone to a positivity bias (Boseovski and Lee, 2008; Boseovski, 2010) when encountering subjective information and, in those instances, may prioritize what an informant says instead of who the informant is. Future research including subjective testimony should consider including equally valenced (e.g., two conflicting positive or two conflicting negative statements) to further examine the relative contributions of valence to children's selective trust decisions.

When asked which of two objects children would want, children across all character conditions displayed no preference for either the undamaged or damaged object featuring the familiar character. Nevertheless, when examining children's preference for the object in the three experimental conditions including a marketing character against a control condition with no image of a character, children in the control condition displayed an increased preference for the undamaged object than did children in the character conditions. This result replicated previous findings that the presence of characters influence children's product preferences (Roberto et al., 2010; Danovitch and Mills, 2014, 2017; Vanderbilt and Andreason, 2023).

As discussed in the introduction, although the children were familiar with the marketing character, it is unlikely that this character was their ultimate favorite, which, in turn, could have been the reason why no effects of parasocial relationship were found on children's judgments. Parasocial relationships are likely strongest for favorite characters, and thus could have had a greater influence on children's decision-making. Future research should consider including children's favorite entertainment and brand characters to explore how such preferences might modify children's willingness to accept damaged products. Moreover, previous research examining children's beliefs in the existence of novel fantastical beings suggests that increased exposure is related to more belief in their reality status (Woolley et al., 2004). Since brands create their own characters that are initially unfamiliar and market to children to build familiarity, future research should explore children's preferences for an object including a novel brand character over repeated exposure to that character.

Another goal of the current research was to examine children's monetary judgments of objects. Our results suggest that regardless of condition (i.e., all three experimental conditions and the control condition), children were more likely to rate the undamaged object as more valuable than the damaged object featuring the familiar character. These findings indicate that although popular entertainment character have a strong influence on children's object preferences, they do not impact children's monetary judgments. Contrary to Gelman et al. (2015), the characters in our study did not own/possess the objects and were simply present on the object. Future research should examine the role of ownership through providing explanations to the child about character ownership of the object to determine possible effects on monetary value.

Although we predicted familiarity and parasocial relationships with the familiar media characters would significantly influence children's trust, preference, and monetary value, this was not supported by our results. It is possible that other characteristics such as a history of accuracy (Corriveau et al., 2009), expertise (Sobel and Corriveau, 2010), or reality status (Richert and Smith, 2011) may be necessary in order for media characters to have more of an influence on young children's judgments. Future research should consider creating novel characters with these characteristics to further understand what features, or combination of features, are most influential to children's decision making.

A methodological limitation of the current study is that all participants were from a WEIRD population (i.e., western, educated, industrialized, rich, and democratic; Henrich et al., 2010). Given that SES relates to the amount of digital media children are exposed to Rideout and Robb (2020), it is possible that a more diverse sample may show a better understanding of the influence of popular characters on children's trust and judgments of products. Additionally, an individual's culture influences their consumer behaviors and values (e.g., Schwartz, 2007; Nayeem, 2012). It is possible children from non-WEIRD populations might have different consumer behaviors than more capitalist societies such as the United States. Future research should replicate the current study with more diverse populations.

With an increase over the past two decades in marketing directly to children (Buckingham, 2007), it is important for researchers to examine how children make product justgments. This research allows caregivers, policy makers, and marketing companies to better understand children's decisions as active consumers. As our findings suggest, even if children prefer a damaged object featuring a familiar character, they are sensitive to the damage when making other judgments, such as monetary values. These findings add to a growing body of literature addressing popular concerns on marking strategies used directly for children. Although character images on objects make an object more desirable to children, as young consumers, the images do not fully influence their preferences and have no effect on how they judge an object's value. Caregivers and policy makers should consider providing feedback to children when introducing new products. Asking the child to consider more than just the perceptual features (e.g., what can the object do or how much does the object cost?) may help children recognize a product's worth over their own individual preferences.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Boston University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

AW-G: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. IH: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. KC: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Publisher's note

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Appendix

Parasocial Interaction Measure			
Does [familiar character's name] get hungry?	Yes	Maybe	No
Does [familiar character's name] get sleepy?	Yes	Maybe	No
Is [familiar character's name] pretend?	Yes	Maybe	No
Does [familiar character's name] have feelings?	Yes	Maybe	No
Do you believe what [familiar character's name] tells you all the time?	Yes	Maybe	No
Does [familiar character's name] make you feel safe when you are scared?	Yes	Maybe	No
Is [familiar character's name] cute?	Yes	Maybe	No
Is what [familiar character's name] tells you true?	Yes	Maybe	No
Is [familiar character's name] real?	Yes	Maybe	No
Do you think [familiar character's name] can feel guilty? (like when you feel bad about having done something)	Yes	Maybe	No
Do you think [familiar character's name] can feel embarrassed? (like when you feel silly about having done something)	Yes	Maybe	No
Do you think [familiar character's name] can feel proud (like when you feel really good about something you have done well)	Yes	Maybe	No
Do you think [familiar character's name] can feel love?	Yes	Maybe	No
Do you think [familiar character's name] can figure out how to do things? (like when you don't know how to do something but you figure it out)	Yes	Maybe	No
Do you think [familiar character's name] can make choices? (like when you choose to do one thing over another thing)	Yes	Maybe	No
Do you think [familiar character's name] can remember things?	Yes	Maybe	No

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Weekend screen use of parents and children associates with child language skills

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Introduction: The study examined the relationship between screen time and types of screen activities engaged in by children, mothers, and fathers on weekends, and its association with mother-reported vocabulary and grammatical skills of children aged 2;5 to 4;0.

Methods: Mothers reported the language skills of 421 children (M *age* = 38.18 months; SD = 5.73) by the Estonian CDI-III, and the screen use of children, mothers, and fathers by the Screen Time Inventory. We applied Latent Class Analysis (LCA) to analyze the screen time of children, mothers, and fathers, aiming to identify common family screen use profiles.

Results: The results showed that higher total screen time of children was linked to poorer vocabulary and grammatical skills. None of the screen-based activities that children, mothers, and fathers engaged in, including co-viewing of screens and socializing time, were found to positively relate to language skills. Playing video games was negatively associated with children's language skills, regardless of whether it was the child, mother, or father gaming. LCA identified 3 distinct family screen use profiles (low, moderate, and high users) which differed by parental education, screen-based activities, and children's language skills.

Discussion: The findings underscore the significance of family-based interventions when addressing screen time within the context of child language development.

KEYWORDS

screen time, expressive vocabulary, grammatical skills, language development, CDI, screen-based activities, preschoolers, latent class analysis

1 Introduction

Advances in touchscreen technology and the ease of access to various electronic devices at home have significantly heightened screen exposure among young children. Despite the World Health Organization's (WHO, 2019) guideline that screen time for children aged 2–5 should not exceed 1 h per day, most 2–3-year-olds surpass this recommended limit (Madigan et al., 2020a).

There is a substantial body of research linking children's screen time to various aspects of cognitive development, learning, and wellbeing (Xie et al., 2018; McArthur et al., 2021; Zhang et al., 2022). The focal point of the current study is the relationship between screen exposure and language skills, a critical area given that early language development is the best predictor of later development, wellbeing, and academic success in children (Golinkoff et al., 2019). Nonetheless, findings on the association between screen time and language development are mixed. Numerous studies show that excessive screen time is associated with reduced language skills (Duch et al., 2013; Lin et al., 2015; Madigan et al., 2020b; Axelsson et al., 2022). For example, Sundqvist et al. (2023) found that higher child and parental exposure to electronic media was associated with smaller expressive vocabulary at age 2, and that children's screen time at age 2 negatively predicted children's vocabulary at age 5. In contrast, other studies have suggested a positive effect of greater screen time on vocabulary size (e.g., Jing et al., 2023). Other studies state that preschoolers' total screen time is unrelated to their expressive vocabulary (Alloway et al., 2014; Taylor et al., 2018; Zhang et al., 2022). These divergent findings reported in literature could stem from variations in the tools used to measure child screen time and language skills, differences in screen usage (solitary vs. co-viewing), screen content features (interactive or not; program; intended audience: child- vs. adult-directed), media type, child age, and differences in the availability of apps at particular ages of children (Xie et al., 2018; Axelsson et al., 2022).

In many cultures, children learn language largely through adult-child verbal interactions. They need opportunities for language-rich experiences and interactive talk—back-and-forth interactions with adults (Golinkoff et al., 2019; Rowe and Snow, 2020). Screen interactions can reduce or even substitute time otherwise dedicated to dyadic face-to-face verbal interaction with adults, which has been considered essential for child language acquisition and development (Anderson and Hanson, 2017). Studies have shown that background TV exposure significantly diminishes the quantity and quality of verbal interactions between mothers and children (Kirkorian et al., 2009; Lavigne et al., 2015). Despite the shift toward more interactive media forms like computers, tablets, and mobile touchscreen devices that complement TV viewing, most research findings on child language acquisition continue to focus on the effects of traditional media rather attending to new, more interactive media (Lauricella et al., 2015). Recent studies highlight that children learn new words more effectively from live interactions and real-life events than from video content alone (Roseberry et al., 2009) or from chat interactions such as via Skype (Roseberry et al., 2014). Radesky et al. (2015) found that parents' excessive use of mobile devices reduces their interactions with children. Parental technoreference—regular disruption of face-to-face interactions between parents and children due to the use of a screen device—has an impact on child mental health, family relationships, and children's cognitive development (Mackay et al., 2022). Although not yet experimentally validated, parental technoreference may have a great impact on child language development.

The WHO (2019) recommendations for children's screen use advocate for parental co-viewing and discussion with children about the content of what they see and do. There is some research evidence that children who co-view media with parents outperform those who use media independently (Madigan et al., 2020a; Griffith et al., 2021; Mustonen et al., 2022). Nonetheless, most studies on effects of screen use on children's language development focus on impacts of children's solitary device use rather than on co-viewing with a parent or both parents. Moreover, most prior studies have centered on English-speaking children and those of older ages (Neuman et al., 2017; Madigan et al., 2020a).

Our study aims to describe the screen use patterns of Estonian families' and the overall home digital environment, addressing their connection to the language skills of children aged 2;5–4;0. The reason for focusing specifically on this age period is that children are often first introduced to screens at ages 2 and 3 years (Nevski and Siibak, 2016). Moreover, the instrument used for assessing language skills of children is designed for children aged 2;5–4;0 years. This study examines media exposure and screen use across the entire family, recognizing that children's home environment is where long-term behavioral patterns, including healthy screen use, are initially formed (Lauricella et al., 2015; McArthur et al., 2021). It has been observed that parents with higher screen time tend to have children with similarly high screen time (Lauricella et al., 2015; Nevski and Siibak, 2016; Mustonen et al., 2022).

Acknowledging that research evidence suggests that not all screen time is equally impactful, the effect of screen use on language development may vary based on the content and purpose of specific screen activities. When examining the link between screen use and children's language skills, it is essential to consider the time dedicated to specific screen-involving activities. The literature lacks a systematic study on how various digital activities relate to children's language skills. An additional objective was to explore the duration of different screen-based activities, and whether it relates to children's vocabulary and grammatical scores.

Variability in children's screen time has been attributed to several factors, including gender and SES. Children from lower-income families tend to spend more time on screens compared to their peers from higher-income families (Cameron et al., 2015). In families with higher educational attainment, children's engagement with screens does not detract from developmentally more-appropriate activities such as reading (Vandewater et al., 2006; Taylor et al., 2018), and is not negatively related to children's language skills, possibly because parents with higher education may compensate for screen time by engaging in more conversation with their children and doing so in ways that support language development (Taylor et al., 2018). Regarding gender as a potential factor, girls are reported to spend more time with screen devices than boys (Taylor et al., 2018). Similarly, gender and SES are factors that also explain the wide variability in children's language development. Mothers with higher education have been found to speak in ways that better support children's language development: talking more with children, using a greater variety of words, and engaging children more in back-and-forth conversations (Pace et al., 2017; Rowe, 2018). Girls tend to be ahead of boys in language development, although the degree of precociousness is rather small (Fenson et al., 2007; Eriksson et al., 2012).

In summary, this study was guided by the following research questions:

RSQ1: How much time do Estonian children, along with their parents, spend on screen devices during a typical weekend day, including co-viewing screens with parents, and how does this screen time relate to children's language skills (expressive vocabulary and grammatical skills)?

RSQ2: When examining screen use patterns in Estonian families, can a small set of underlying subgroups be identified? Do these latent classes differ in terms of sociodemographic characteristics, screen time and types of activities engaged in by each family member, and children's language skills?

RSQ3: How does the time spent on different screen activities by the child, mother, and father relate to children's language skill outcomes?

2 Method

2.1 Participants

The sample included 421 children (38.2 ± 5.7 months of age and 52% were female). Mothers were 32.5 ± 5.1 and fathers 35.3 ± 6.2 yrs. of age. Parental education was categorized as at least a bachelor's degree (55.6% of mothers and 34.5% of fathers) or less than a bachelor's degree (25.5% of mothers and 45.6% of fathers), with 18.9% of mothers and 19.9% of fathers not reporting their educational level. The sample was reflective of the educational distribution among the Estonian population. According to the OECD adult education level indicator, 54.8% of 25- to 34-year-old Estonian women and 39.9% of 25- to 34-year-old men have acquired tertiary education (OECD, 2022).

2.2 Procedure

Data were collected using an online questionnaire from November 2018 to July 2019, i.e., before the onset of COVID-19. In Estonia, families are well-equipped with digital devices: 93.2% have an Internet connection (Statistics Estonia, 2023), 39.4% of Estonian children up to 3 years old use smartphones, and 25.5% use tablets daily (Nevski and Siibak, 2016). Families participating in the study were recruited through Facebook groups for parents with children aged 2;5–4 years, and through kindergartens from different regions in Estonia. The current study is part of a larger research project about the associations between children's language development and their language and digital environment at home. The current study uses data regarding the use of digital media devices by children, mothers, and fathers measured by the Screen Time Questionnaire, and children's language skills measured by the Estonian Communicative Development Inventory-III (ECDI-III, Tulviste and Schults, 2020). Although it was not specified which parent would be expected to complete the web-based questionnaires, it was mostly the mothers who provided the reports (except for two fathers). The criteria for inclusion in this study was that children are from families where the dominant language is Estonian, children have no serious health and language problems, and data regarding children's language skills and all family members' (i.e., children's, mothers', and fathers') screen use were available. In Estonia, 82.8% of children aged 0–5 live together with their mother and father (OECD Family Database, 2018). We have no information about whether the parents resided together permanently or had a different arrangement. At the end of the data collection, written feedback on the child's language results was sent to the parents.

2.2.1 The screen time inventory

The instrument was designed by us for a previous project and consisted of four parts. First, parents were asked to indicate all screen devices (e.g., television, smart phone, tablet, laptop, game console, other) the child, mother and father used during last 2 weeks. Second, in alignment with the diversity of screen media and exposure to various media already at a young age, we asked parents to estimate how many hours and minutes children, as well as their mothers and fathers spend with various screen devices (including traditional media such as TV as well as new media such as computers, laptops, tablets, cell phones, game consoles etc.) on a typical weekend day for various screen-based activities: entertainment, gaming, shopping, learning, and socializing. For example, parents were asked, "Please mark how many hours and minutes the child, mother and father used the screen devices for the playing video games on video, computers, or mobile devices on a typical weekend day". The parent wrote hours in one box and minutes in another about each activity for every family member. Third, we asked about co-viewing of the screens, "How much time (in hours and minutes) did your child use digital devices with a parent during a typical weekend day?" The fourth part of the inventory measured parents' attitudes toward children's screen use. Parents were asked to rate the usefulness or harmfulness of spending time with screens on 11 different aspects of child development (i.e., math skills, physical activity, behavior, creativity, reading skills, attention span, speaking, communication skills, knowledge acquisition, understanding others, and sleep) on a five-point scale, from very harmful (5) to very beneficial (1).

In the current study, the second and third parts of the inventory, i.e., the amount of time of different screen-based activities of each family member and co-viewing with parents, were analyzed. Total screen time for the mother and father was calculated by summing up the time spent on all individual screen activities. For children, time spent on entertainment, gaming, and socializing activities was collected and summed up to derive total screen time. Children's total screen time on a typical weekend day was categorized as meeting the recommended limits (low screen use, $\leq$1 h/day) vs. exceeding the recommended limit by spending either 1–2 h/day (moderate screen use) or more than 2 h/day (high screen use) with screens. Total screen time of mothers and fathers was broken down into three groups: low screen user ($\leq$2 h/day), moderate screen user (2–4 h/day), and high screen user (>4 h/day).

2.2.2 ECD-III

Children's language skills were assessed by the ECDI-III (Tulviste and Schults, 2020). This is an Estonian adaptation of the Swedish version of the CDI-III developed by Eriksson (2017), exhibiting sufficient internal consistency (Cronbach's $\alpha = 0.97$ for the Vocabulary section and $\alpha = 0.92$ for the Grammar section) and concurrent and predictive validity (Tulviste and Schults, 2020, 2023). The Vocabulary and Grammar sections were included in this study. In the Vocabulary section mothers marked the words their children produce using a 100-item vocabulary list that included food words ($n = 16$), body words ($n = 26$), mental words ($n = 30$), and emotion words ($n = 28$). In the Grammar section, parents reported on their child's Grammatical constructions and Sentence complexity. The Grammatical construction section consists of seven items, including the plural, comparisons, past tense, and conjunctions. The parents were asked to mark for each item if their child has never used a particular example of grammar (scored 0), has used it several times (scored 1), or uses it daily (scored 2). The Sentence complexity section includes 10 pairs of sentences that consist of a short sentence with simple grammar and a complex, more elaborated sentence. For each pair, the parents had to indicate whether their child currently uses the simpler one (scored 0), alternates between simple and complex sentences (scored 1), or currently uses the more complex one (scored 2). The maximum score for grammatical skills is 34.

The study was approved by the Research Ethics Committee of the University of Tartu, Estonia.

2.2.3 Statistical analysis

To estimate the screen time of Estonian children, mothers, and fathers on a typical weekend day, and to evaluate whether total screen time of each family member relates to children's language skills, descriptive and correlational analysis of each study variable was performed using IBM SPSS 29.0. One-way ANOVAs were used to compare means, and Pearson's chi-squared tests were used to compare proportions. Pearson correlational analyses were performed to address the links between screen use and language skills.

To explore the typologies of screen use in families, screen use patterns of individual family members (child, mother, and father) were subjected to Latent Class Analysis (LCA) on our sample ($n = 421$). LCA was conducted based on individual total screen time values for the child, mother, and father. Mothers provided the screen time estimates for all family members. LCA will generate probabilities for membership in all identified classes in the model, allowing to evaluate, for example, the membership of low screen time mothers or high screen time children in each identified class (Sinha et al., 2021). The optimal class solution was determined by comparing 2- through 5-class models based on key statistical indicators including Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC), entropy, as well as the class sizes and overall utility of the model in explaining qualitative differences between the classes (Raftery, 1995; Berlin et al., 2014). Finally, a 3-class model was selected to best describe the latent screen use typologies in families in Estonia.

3 Results

3.1 Data description

Findings suggest that 6.7% of children were non-users of digital devices. Most children (69.5%) were high users of screen devices, i.e., their screen time exceeded 1 h per day. Descriptive statistics for expressive vocabulary, grammar, total screen time and screen-based activities for the child, mother, and father in the whole sample, and for the three identified family class profiles are presented in Table 1. Children as well as their mothers and fathers were active screen users, although large individual differences were evident regarding all study variables (see Table 1). Children were mainly engaged with entertainment, whereas mothers and fathers were mainly engaged with entertainment and socializing.

3.2 Family screen use profiles

LCA identified three distinct family screen use profiles, which we named with the aim of reflecting the predominant screen use behavior or the three family members: (1) low screen use family (32.5%); (2) moderate screen use family (32.3%); (3) high screen use family (35.2%) (see Figure 1). The classes were named with the aim to reflect the predominant screen use patterns of the child, mother, and father within each class.

Table 1 presents descriptive statistics on study variables across the three detected classes. As seen in Table 1, there were significant differences among three profiles in parents' age and educational level, time of co-viewing screens with a parent, children's, mothers', and fathers' total screen time, as well as in times engaged with different screen-based activities, except the time fathers spent for learning, and children for learning and socializing. Children from the low screen use family class had significantly higher vocabulary scores than those from the high screen use profile, $F_{(2,411)} = 4.22$, $p = 0.015$, ηp2 = 0.020. They also reflected significantly higher grammatical scores than peers belonging to the moderate or high screen use profiles, $F_{(2,407)} = 4.48$, $p = 0.012$, ηp2 = 0.022.

3.3 Correlation among study variables

Correlational analysis showed that children's and fathers' screen use were not related to children's age in months, but there was a significant negative correlation between mothers' total screen use and children's age ($r = -0.107$, $p = 0.028$). Children's vocabulary scores were strongly related to their age ($r = 0.404$, $p < 0.001$), as well as their grammatical scores ($r = 0.237$, $p < 0.001$). Accordingly, we proceeded to control for the age of children when exploring associations between children's language skills and total screen time, as well as individual screen-based activities of the child, mother, and father. Table 2 presents the results of correlational analyses. As seen in Table 2, child total screen time was significantly related to mothers' and fathers' screen time and negatively associated with children's vocabulary and grammatical scores. Co-using screens with parents wasn't related to children's language skills.

A correlational analysis correcting the age of children found that vocabulary and grammatical scores of children were negatively associated with their total screen time and the time spent with entertainment and gaming. Children's vocabulary scores were negatively related to mothers' entertainment and mothers' and fathers' gaming, and children's grammatical scores were negatively related to mothers' gaming and fathers' total screentime and gaming (see Table 2).

4 Discussion

This study aimed to investigate the relationships between families' screen time use and mother-reported language skills in Estonian children aged 2;5–4;0 years. The first research question explored how much time Estonian children, mothers, and fathers spend on a typical weekend day with screens and whether the total screen time of each family member is related to children's

TABLE 1 Child and parent demographics, screen use, and children's language scores by the ECD-III, in the total sample and in different family profiles according to the 3-class model generated by Latent Class Analysis.

	Whole sample ($n = 421$)	Class 1: low screen use family ($n = 137$)	Class 2: moderate screen use family ($n = 136$)	Class 3: high screen use family ($n = 148$)	*P*-value
Demographics					
Child's age (months)	38.18 (5.73)[1]	39.39 (6.42)[b]	37.66 (5.81)[a]	37.53 (4.74)[a]	0.010
Child sex (% female)	48.0	48.2[a]	57.4[a]	49.3[a]	0.291
Mother's age (years)	32.55 (5.10)	33.32 (5.26)[a]	32.67 (4.91)[a]	31.72 (5.04)[b]	0.029
Mothers with higher education (%)	68.5	77.9[a]	74.1[a]	53.5[b]	<0.001
Father's age (years)	35.31 (6.23)	36.58 (6.82)	35.15 (5.92)	34.29 (5.75)	0.008
Fathers with higher education (%)	43.1	51.4[a]	48.3[a]	29.5[b]	0.002
ECDI-III					
Vocabulary score	56.68 (22.37)	61.07 (20.65)[a]	55.63 (24.80)[a,b]	53.57 (21.02)[b]	0.015
Grammatical score	18.54 (8.75)	20.26 (7.83)[a]	18.33 (9.38)[a,b]	17.17 (8.76)[b]	0.012
SCREEN TIME (h)					
Mother					
Screen use total	3.95 (3.07)	1.79 (1.48)[a]	2.97 (0.80)[b]	6.84 (3.26)[c]	<0.001
Entertainment	2.11 (1.72)	0.83 (0.77)[a]	1.70 (0.87)[b]	3.66 (1.77)[c]	<0.001
Gaming	0.15 (0.51)	0.05 (0.17)[a]	0.12 (0.37)[a]	0.28 (0.76)[b]	<0.001
Shopping	0.21 (0.44)	0.09 (0.21)[a]	0.18 (0.34)[a]	0.35 (0.62)[b]	<0.001
Learning	0.27 (0.82)	0.15 (0.52)[a]	0.08 (0.29)[a]	0.58 (1.21)[b]	<0.001
Socializing	1.23 (1.51)	0.71 (0.87)[a]	0.89 (0.63)[a]	2.01 (2.12)[b]	<0.001
Father					
Screen use total	4.25 (3.47)	1.77 (1.44)[a]	4.01 (3.02)[b]	6.76 (3.46)[c]	<0.001
Entertainment	2.43 (2.07)	1.02 (0.96)[a]	2.34 (1.84)[b]	3.82 (2.11)[c]	<0.001
Gaming	0.57 (1.21)	0.16 (0.46)[a]	0.53 (1.14)[b]	1.00 (1.58)[c]	<0.001
Shopping	0.07 (0.26)	0.03 (0.10)[a]	0.05 (0.17)[a]	0.14 (0.38)[b]	<0.001
Learning	0.17 (0.70)	0.08 (0.46)	0.30 (1.01)	0.14 (0.49)	0.027
Socializing	1.02 (1.52)	0.50 (0.79)[a]	0.80 (0.96)[a]	1.71 (2.11)[b]	<0.001
Child					
Screen use total	1.76 (1.70)	0.70 (0.62)[a]	1.57 (0.74)[b]	2.90 (2.24)[c]	<0.001
Entertainment	1.51 (1.28)	0.61 (0.57)[a]	1.45 (0.74)[b]	2.38 (1.53)[c]	<0.001
Gaming	0.16 (0.59)	0.06 (0.21)[a]	0.06 (0.20)[a]	0.33 (0.94)[b]	<0.001
Learning	0.07 (0.76)	0.02 (0.10)	0.03 (0.12)	0.16 (1.28)	0.206
Socializing	0.03 (0.18)	0.02 (0.08)	0.03 (0.11)	0.04 (0.27)	0.504
Co-viewing	1.05 (1.17)	0.55 (0.71)[a]	0.86 (0.71)[a]	1.66 (1.53)[b]	<0.001

[a,b,c]Within a row, means without a common superscript differ ($P = <0.05$).

[1]Numbers in each cell are: means, SDs in parentheses.

vocabulary and grammatical skills. According to our data, all family members were on average active screen users, with children spending 1.8 h, mothers 4 h, and fathers 4.3 h daily with screen devices. At the same time, there were wide individual differences in total screen time as well as in the time spent with different screen-based activities. Among 421 children, 128 (30.5%) did not exceed the recommended screentime limit of up to 1 h/day. During the investigated age period, there were no age-related differences in the time children spent with screens, matching the findings of a longitudinal study by Sundqvist et al. (2023), while the total screen time of mothers (but not fathers) decreased significantly as children's age increased. This may be partly because parents have been found to talk more when children become older and as children's language skills improve (Tulviste and Tamm, 2021;

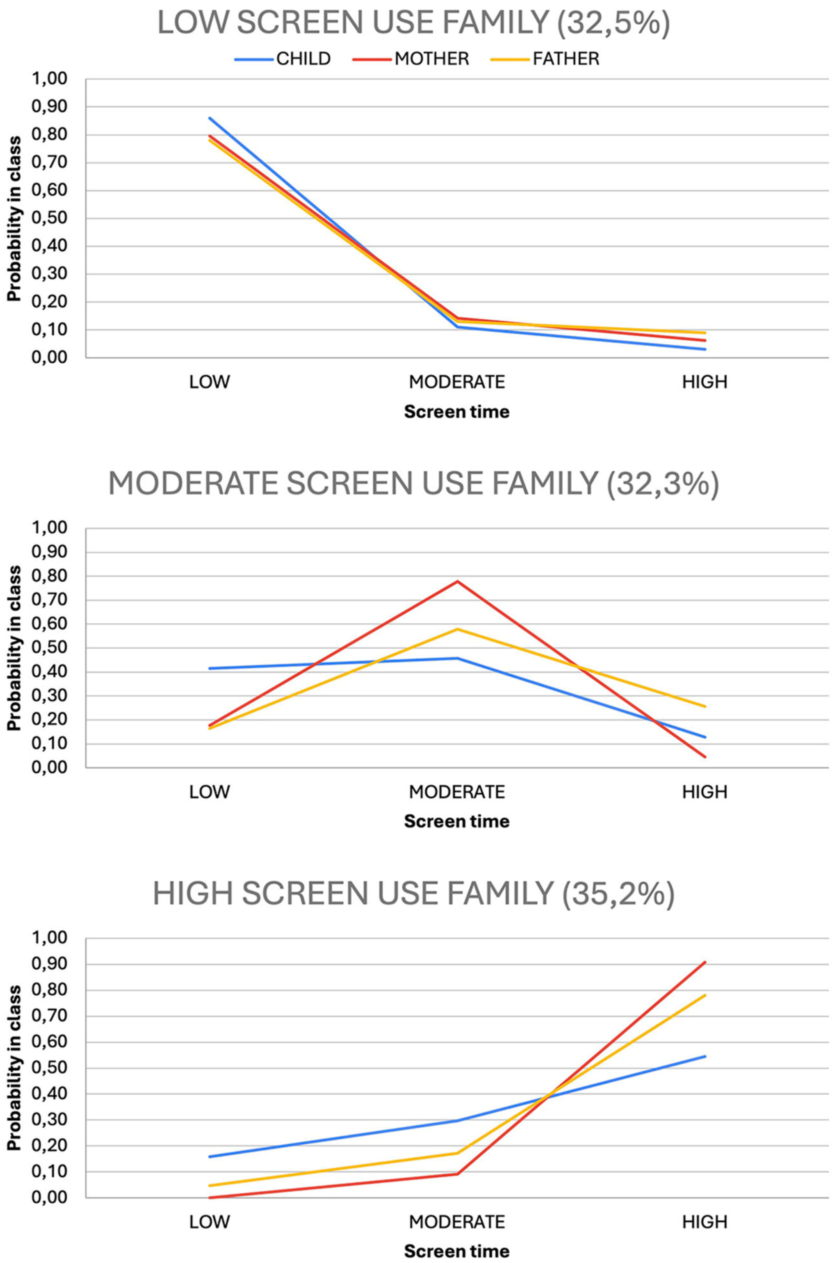

FIGURE 1
The 3-class model of Estonian families according to the screen use patterns of family members—the child, mother, and father—generated by Latent Class Analysis. The model identified 3 distinct classes (class size in parenthesis): (1) low screen use family (32.5%); (2) moderate screen use family (32.3%); (3) high screen use family (35.2%). For children, screen time was defined as low (≤1 h/day), moderate (1–2 h/day) or high (>2 h/day), and for the mother and father as low (≤2 h/day), moderate (2–4 h/day) or high (>4 h/day).

Dailey and Bergelson, 2023). It could also reflect that mothers of younger children can spend more time with screen devices because their children request less attention from them (e.g., sleep for longer periods) than when they become older.

The study found that when controlling for the age of children, those with higher total language scores used digital devices less than their peers with lower language skills. Thus, the results confirm previous research indicating a negative correlation between children's greater screen time and early language skills (Duch et al., 2013; Lin et al., 2015; Madigan et al., 2020a). In line with earlier studies (Lauricella et al., 2015; Mustonen et al., 2022), we also observed that the greater screen use of mothers and fathers is associated with increased screen time in children. The study contributes new insights by showing that fathers' (not mothers') longer screen time was negatively associated with grammatical skills of children. Accordingly, it is probable that more time on screens reduces opportunities for face-to-face verbal family interaction and other language-rich experiences essential for language development (Anderson and Hanson, 2017).

TABLE 2 Correlations between screen use by children and parents, and children's language skills, controlling for children's age in months.

	Child							
	Vocabulary	Grammar	Screen use total	Entertainment	Gaming	Learning	Socializing	Co-viewing
ECDI-III								
Vocabulary score	1.00	0.73*	−0.12*	−0.13*	−0.15*	0.07	0.00	−0.03
Grammar score	0.73*	1.00	−0.11*	−0.11*	−0.18*	0.06	0.00	−0.02
Mother screen use total	−0.06	−0.05	0.48*	0.48*	0.27*	0.07	0.05	0.41*
Entertainment	−0.11*	−0.05	0.51*	0.55*	0.17*	0.08	−0.01	0.36*
Gaming	−0.16*	−0.20*	0.40*	0.26*	0.58*	−0.01	0.06	0.11*
Shopping	0.07	0.08	0.03	−0.01	−0.01	0.10	0.03	0.29*
Learning	0.01	−0.01	0.16*	0.15*	0.13*	−0.01	0.07	0.22*
Socializing	0.03	0.00	0.19*	0.19*	0.09	0.03	0.03	0.20*
Father screen use total	−0.09	−0.11*	0.38*	0.39*	0.21*	0.02	0.10	0.34*
Entertainment	−0.07	−0.05	0.38*	0.43*	0.14*	0.03	0.05	0.29*
Gaming	−0.15*	−0.21*	0.24*	0.23*	0.23*	−0.03	0.02	0.16*
Shopping	0.00	0.00	0.21*	0.09	0.01	0.19*	0.47	0.19*
Learning	0.04	0.04	−0.04	−0.03	−0.04	−0.02	0.02	−0.02
Socializing	0.01	−0.02	0.12*	0.11*	0.11*	0.00	0.04	0.22*
Child screen use total	−0.12*	−0.11*	1.00	0.81*	0.56*	0.42*	0.10	0.43*
Entertainment	−0.13*	−0.11*	0.81*	1.00	0.28*	−0.05	−0.02	0.54*
Gaming	−0.15*	−0.18*	0.56*	0.28*	1.00	0.01	0.02	0.09
Learning	0.07	0.06	0.42*	−0.05	0.01	1.00	0.00	−0.03
Socializing	0.00	0.00	0.10	−0.02	0.02	0.00	1.00	0.10
Co-viewing	−0.03	−0.02	0.43*	0.54*	0.09	−0.03	0.10	1.00

*$p < 0.05$.

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Previous studies have emphasized that co-viewing media with parents is crucial for minimizing adverse effects of screen devices on child language development (Griffith et al., 2021; Mustonen et al., 2022). Our study did not find evidence that co-viewing of digital devices is related to better language skills in children. Research indicates that less verbal interaction occurs when the TV is turned on (Kirkorian et al., 2009; Lavigne et al., 2015), and more time is spent in silence when playing with electronic devices than when playing with toys (Griffith and Arnold, 2019). Moreover, Estonian mothers have been found to talk less and expect less verbalization from children than mothers of other cultural backgrounds (Tulviste et al., 2003). It might be that families engage in silent co-viewing of movies on TV or computer or that they co-play games without discussing and elaborating the content, which may result in limiting rich language learning opportunities for young children. Greater emphasis should be placed on informing parents that limiting use of digital devices or promoting verbal interaction with children when co-using digital devices may enhance children's language skills (Griffith et al., 2021).

The study did not identify any positive associations between screen use and language skills in this age group, even when children co-viewed screens with parents or engaged in socializing via digital devices. It has been shown that verbal interactions with children through digital tools become more common as children grow older, beyond our study's participant age range (Rudi et al., 2015). Since family screen time is a modifiable behavior, recommendations to reduce screen time for all family members may lead to improved language skills in children, provided that verbal interactions within the family increase.

Significant variability in screen time among family members prompted our second research question: are there distinct common profiles reflecting family's screen use? Using latent class analysis on total screen time for the child, mother, and father, three distinct family classes were identified: low screen user child with low screen user parents (the low screen use family), moderate screen user child with a moderate screen user mother and moderate to high screen user father (moderate screen use family), and finally a high screen user child with high screen user parents (high screen use family). This suggests that within each class, family members share similar average screen times. Comparing the three profiles revealed that families of high screen users had fewer mothers and fathers with a high education level compared to other two profiles. This aligns with previous findings that low-SES families tend to use screens more than higher-SES families (Taylor et al., 2018). Significant differences were also noted among the three classes in time spent on all different online activities, except for children's learning and socializing and fathers' learning. Children in the low-users' classes had higher reported vocabulary and grammatical scores compared to children from high-users' classes.

The third research question concerned different screen-based activities of children, mothers and fathers, and the association of each screen activity with children's language skills. We found that children were primarily engaged in entertainment, while their mothers and fathers practiced entertainment and socializing. Children who allocated more time for entertainment also had mothers with greater entertainment time use, and those who spent more time with gaming had both parents who engage in longer gaming sessions. The study demonstrates that for children, entertainment and playing video and computer games were negatively associated with their reported vocabulary and grammatical skills. It is important to point out that the negative impact of gaming could be partly attributed to a relative lack of developmentally appropriate computer games for this age group of Estonian children. Games in the English language with limited interactivity or visual-only content likely do not offer rich opportunities for learning oral language and communication skills, unlike personalized back-and-forth social interactions in the native Estonian language (Tatar and Gerde, 2023).

A limitation of the study is its cross-sectional design. Results raise questions about whether the family profiles remain stable when children grow older. Only a longitudinal study design can address this question and clarify the direction of causality between screen use and language skills. Another limitation is that the data were collected before the COVID-19 pandemic. It is possible that pandemic restrictions have altered families' screen use habits as well as children's language skills. The third limitation is that all data, including the child's and the fathers' screen use data, are reported by the mother. Furthermore, only families where children live with both of their parents participated.

Most prior research on the associations between children's screen time and language skills has focused solely on children's total screen time without explicitly considering the screen time of other family members or the specific screen activities in which children and parents engage. The strength of our study is that it examined weekend screen use across the entire family and identified family screen use profiles as a possible factor influencing child language skills. Another strength is our detailed examination of screen time activities for both children and parents, revealing the specific uses of screens. As a result, we found that more gaming time is a negative predictor of children's language skills, regardless of the participant (child, mother, or father) engaged in gaming. The study underscores the negative association between screen time and language development, suggesting that at the age of 2;5–4;0, children's language skills do not benefit from spending weekend days in front of screens. The greatest risk for language skills occurs when children themselves, their mothers, and fathers play video/computer games on screen devices. The results contribute to our understanding of the sources of individual differences in early language development, while also offering practical insights for educational and clinical interventions aimed at reducing screen time to enhance children's health and developmental outcomes. Family profiles aim in identifying children most in need of intervention due to their own and their parents' excessive screen use. Specifically, recognizing the three classes within the typology of family screen use over weekends (low vs. moderate vs. high users) highlights the necessity of family-based interventions for families with heavy screen use to support children's language development by limiting their screen time. The results reinforce the importance of whole-family interventions when seeking to reduce children's excessive digital devices usage, since family members screen use profiles tend to match. Furthermore, the study results suggest that considering families' screen time profiles and which types of screen activities they engage in, is crucial for evaluating the child's language development environment at home.

5 Conclusion

Our study suggests that the time children dedicate to digital devices is associated with lower scores on mother reported language skills. The findings demonstrate that children's screen use patterns compare to those of their parents. Furthermore, activities with screens at weekends should be accounted for when mapping the child language development environment at home, since children who themselves and whose mothers and fathers spend weekends playing video/computer games may face a greater risk of slower language development.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Research Ethics Committee of the University of Tartu, Estonia. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

TT: Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Funding acquisition, Project administration, Resources, Supervision. JT: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Can 3-year-old children learn verbs using an educational touchscreen app?

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Introduction: Research demonstrates that children can learn nouns using touchscreen apps, however there has been less attention to whether apps can also promote verb learning. In addition, only a few studies have investigated the role of adult-child co-use for facilitating language learning from touchscreen apps.

Method: In the present study, 3-year-old children were taught three novel verbs in a live condition or with an app. Children in the app condition either used the app in a child-led interaction or an adult-led interaction. Children's verb learning was assessed using a three-choice pointing task.

Results and discussion: Only children in the live condition showed evidence of verb learning and performed above chance, and there were no differences in performance by children in the app conditions. Children therefore did not show evidence of verb learning from our experimental app. Further research therefore needs to investigate different strategies for adult-child co-use and the role of different app features for supporting children's verb learning from apps.

KEYWORDS

children, touchscreen apps, educational technology, word learning, verb learning, language

1 Introduction

Children's language development is an essential early skill related to children's socio-emotional development (Clegg et al., 2015) and academic success (Fiorentino and Howe, 2004). Children's language development is strongly linked to the language they hear in their everyday environments both in terms of the quantity and the quality of the language experienced (Hart and Risly, 1995; Hoff and Naigles, 2002; Huttenlocher et al., 2010; Rowe, 2012; Weisleder and Fernald, 2013). For today's child, language development is both supported and hindered by digital technologies in their environment (Madigan et al., 2020; Kolak et al., 2023; Taylor et al., 2018). In this study, we investigate the conditions under which use of digital technology may provide an additional support to children's language development, in particular, in their acquisition of new vocabulary. Specifically, we test how verb learning may be supported by children using an app that they direct themselves vs. using an app in co-use with an adult, and comparing learning from those situations with children learning the same words in a live interaction with an adult.

While educational digital technologies provide an opportunity to hear language that could support children's language development (Kolak et al., 2023), studies also demonstrate that parent media use may disrupt language development. Specifically, parent language is negatively impacted by the presence of background television (Christakis et al., 2009; Kirkorian et al., 2009; Pempek et al., 2014), and mobile device use during parent-child interactions can disrupt word learning altogether (Reed et al., 2017). More recently a naturalistic study conducted in children's homes found a negative association between background television and parent-child interactions playing with a toy together and a positive association with infants' individual activities (Uzundag et al., 2024).

In a meta-analysis, Madigan et al. (2020) found that while children's overall screen use—defined as time spent watching television, playing video games, using touchscreen devices or computers—was negatively related to their language scores, educational content and adult-child co-use was positively related to children's language scores. More recently, Jing et al. (2023) found a small positive correlation between children's digital media exposure and their vocabulary scores in experimental studies with educational media designed to support children's vocabulary learning. Thus, children's educational digital technology use has the potential to enrich a child's language development when used alongside other forms of interaction known to support language development (Taylor et al., 2018).

Children's touchscreen apps may be particularly well suited to supporting children's language development due to their interactive and contingent nature facilitating learning in a similar way to a social partner (see Kirkorian, 2018 for review). Apps with a learning goal targeting early skill development can also engage a child's attention and promote active learning and problem solving, provide specific feedback relating to a child's performance, scaffold the content to align with a child's performance on a given task (e.g., making a task more or less difficult) and expose children to a wide range of vocabulary (see Hirsh-Pasek et al., 2015; Kolak et al., 2021, 2023 for similar arguments). Research shows that apps with a learning goal include more utterances including single and multi-word utterances, words with an earlier age of acquisition, and contain lower frequency words similar to books compared to apps without a learning goal (see Kolak et al., 2023; Taylor et al., 2022). Apps therefore have the potential to provide an enriched form of language input for young children.

Indeed, studies demonstrate that pre-school age children can learn new words from touchscreen apps (e.g., Ackermann et al., 2020; Arnold et al., 2021; Chiong and Shuler, 2010; Dore et al., 2019; Kirkorian et al., 2016; Russo-Johnson et al., 2017; Walter-Laager et al., 2017). Dore et al. (2019) found that 4-year-olds could learn uncommon words (4 concrete nouns, 4 verbs, and 2 abstract nouns) from an experimental app when tested immediately after using the app for just 10–12 min or after using the app once a week for 4 weeks in the classroom. Using the Khan Academy Kids app available in the app marketplace, Arnold et al. (2021) found that over a 10-week period 4- and 5-year-old children using the app for around 13 min per day showed subsequent gains in literacy skills.

However, research to date has primarily focussed either on broad gains in language skills (e.g., Arnold et al., 2021; Chiong and Shuler, 2010) or on children's ability to learn specific nouns from an app (e.g., Kirkorian et al., 2016; Russo-Johnson et al., 2017; Walter-Laager et al., 2017, with the exception of Dore et al., 2019). Word learning encompasses more than just acquisition of nouns, it is also important to consider other major classes of word type including children's ability to learn verbs, adjectives and adverbs. Although Dore et al. (2019) included exposure to 6 nouns and 4 verbs in their study, they did not distinguish between children's ability to learn the nouns and verbs from the touchscreen app. This is a particularly important question given that children learning the English language typically acquire nouns before verbs (Waxman et al., 2013; but note that this is not the case in other languages e.g., Tse et al., 2005). There are several reasons for this greater apparent difficulty in acquiring verbs. Verbs have less reliable contexts with other words in utterances than do nouns (Gleitman, 1990; Monaghan et al., 2015), meaning that distributional information for verbs is weaker than for nouns in English. In addition, verbs are conceptually less coherent than nouns, in that verb referents are dynamic and transient, whereas noun referents tend to be more stable within the child's environment (Childers and Tomasello, 2002; Gentner, 1982; Gillette et al., 1999), potentially requiring greater contextual information to support learning of verbs than nouns (e.g., Arunachalam and Waxman, 2011). Touchscreen apps may be advantageous for verb learning because they can display dynamic actions and provide a useful environment where transience and ambiguity in verb reference can potentially be controlled. Thus, understanding how apps can promote verb learning is important for determining the full range of language support available from different kinds of exposure.

Another form of digital exposure is learning through interaction with an interlocutor through technology-mediated communication, such as video chats. Roseberry et al. (2009) found that 2.5-year-old children could learn verbs from a video only when the video was accompanied by a live adult imitating the actions, while 3-year-old children showed some evidence that they could learn verbs from video alone. In a follow up study, Roseberry et al. (2014) explored the role of social contingency in supporting 2.5-year-old children's verb learning from screens. Two and half-year-old children were shown novel actions labeled either during a live interaction, a socially contingent onscreen interaction (via Skype) or via a yoked video of the socially contingent onscreen interaction. The children learnt the novel verbs in the socially contingent conditions only and showed no evidence of learning if they saw the yoked video (Roseberry et al., 2014). Roseberry et al. (2014) suggest that social contingency is important when learning from digital media to establish trust between the child and teacher, given that the researcher is able to respond accurately to the child's responses and cues. In a similar way, touchscreen apps may offer a form of contingency in response to children's touch, though digital contingency lacks the same social component present in Roseberry et al. (2009, 2014)'s research. The contingency offered by touchscreen apps and their interactive nature may therefore be a help in supporting children's verb learning.

Along with the paucity of research on children's verb learning from touchscreen apps and other digital media, there have been few studies exploring the role of adult-child co-use on children's word learning from apps. American Academy of Pediatrics (2016) recommend parent-child co-use during children's media use whereby parents interact with their children about the digital content. Consistent with this recommendation, a recent meta-analysis with 17 eligible studies found a small but significant positive effect of co-viewing on children's learning across several learning domains (Taylor et al., 2024). Approximately half of the studies included in the meta-analysis included the experimenter as the adult-co-user, and the person co-using the digital media with children did not moderate the significant positive effect of co-viewing (Taylor et al., 2024). However, the majority of studies used video or television for the digital content (Taylor et al., 2024). Adult-child co-use can support children's learning through increasing children's attention to the digital content (Samudra et al., 2020). In their study, Samudra et al. (2020) found that 3- to 4-year-old children's comprehension of a video was associated with adult-child co-use, attention to the video and their language skills.

Adult-child co-use may be particularly beneficial for children's word learning given the social nature of children's language learning. For example, Strouse et al. (2018) found that 2.5-year-old children learnt more words from a socially contingent facetime video chat in a parent co-use condition compared to when the parent was engaged in another activity during the word learning task. In that study, parents were instructed to interact with the adult onscreen to set an example for their child rather than specifically directing the child's interaction with the onscreen actor. However, some research suggests that parents are less likely to engage with their children during children's app use compared to toy play, perhaps explained by apps requiring continuous attention and the fact that children spent the majority of their app use with the tablet on their lap (Hiniker et al., 2018). Indeed, Connell et al. (2015) found that approximately 64% of parents of 0–8-year-olds co-use touchscreen devices with their children "some of the time" or "all or most of the time." A systematic review by Ewin et al. (2021) found that parents engage in many forms of support during mobile device co-use such as interacting only when asked for help, supporting understanding and engagement with the content, and providing physical and technical support.

Understanding what constitutes effective parent-child co-use techniques to facilitate learning is also important since caregivers engage in various forms of co-use behaviors (Ewin et al., 2021). Neumann (2018) found that parents most frequently use cognitive scaffolding (e.g., helping children solve problems) to support 2–4-year-olds on a touchscreen rather than technical scaffolding (e.g., telling children how to use the app). In contrast, Griffith and Arnold (2019) found that parents talked more about the app (e.g., app features or how to interact with the app) compared to the apps' literacy and math content when using an app with their 4-year-olds. In relation to children's learning outcomes, Sheehan et al. (2019) found that parents' task relevant talk during a coding app was positively related to 4-year-old children's learning, while parents' questions were negatively related to children's learning. Importantly, these observational studies cannot reveal what aspects of adult-child co-use facilitate children's learning.

A couple of studies have started to investigate the role of parent-child app co-use on children's learning outcomes. In one study exploring whether co-use can improve children's ability to learn coding skills from an app (Griffith et al., 2022), 4- and 5-year-old children either played a coding app independently, with their parent, or played a coloring app with their parent. Overall, children who played the coding app showed an improvement in their coding skills compared to pre-test, with the greatest improvement in coding skills found for children who played the app with their parent rather than independently (Griffith et al., 2022). Similarly, Walter-Laager et al. (2017) found that 2-year-old children played with a touchscreen app for longer when using the app together with an adult compared to using the app independently. In addition, children who used the touchscreen app with an adult showed the greatest improvement in their knowledge of 12 nouns presented on the touchscreen app compared to children who used the app without an adult (Walter-Laager et al., 2017). Consistent with findings for parent-child co-use during video viewing (e.g., Strouse et al., 2018), parent-child co-use during app use is beneficial for children's learning (Griffith et al., 2022; Walter-Laager et al., 2017). Nevertheless, to date, no study has directly manipulated co-use for children's touchscreen apps to explore the impact on verb learning, where the dynamics of the referent and contextual information tend to be very different to those for noun learning.

In the current study we asked whether children can learn verbs from touchscreen apps under child-led or adult-led co-use conditions, and in a live condition. Three-year olds were shown three novel verbs either on an app where the child led the app interaction or where the experimenter led the app interaction, or in a live interaction with the experimenter. Each novel verb was presented four times; twice in isolation and twice in intransitive sentences, and children were given the opportunity to watch a video clip in which the action was demonstrated. Verb learning was tested on the touchscreen tablet using a three-choice pointing task using the same images from the app conditions. Given that Naigles et al. (2005) showed that by 2 years of age, children can transfer novel verbs learnt in a live interaction to videos, we hypothesized that children in the live condition would perform above chance on the verb learning test. We therefore hypothesized that any difference in test performance between the live and app conditions would result from differences in learning. Children under the age of 3 years can only learn a novel verb from a video if it is supplemented with live interaction (Roseberry et al., 2014, 2009). Thus, we hypothesized that children in the child-led app condition would not show evidence of learning, while children in the adult-led app condition would show evidence of learning. Note that the age we selected is at the cusp of beginning to be able to learn verbs with and without social scaffolding (Roseberry et al., 2009) and so potentially able to highlight distinctions between learning from apps vs. live interactions.

2 Method

2.1 Participants

A total of 29 36–48-month-old monolingual English language participants (m = 41.90 months, SD = 3.79) were included in data analysis. An additional 10 children were tested but excluded due to experimenter error (n = 5; 2 live condition, 2 adult-led condition, 1 child-led condition), child's refusal to complete the pointing task (n = 1, live condition), child's limited interaction with the app in the child-led condition (n = 1), bilingual (n = 1 child-led condition), and incomplete demographic information (n = 2 child-led condition). Ethical approval for the study was obtained from the University Research Ethics Committee at Lancaster University.

2.2 Stimuli

Four wooden objects were used for the live demonstrations (see Figure 1). Action verbs were selected from Childers and Tomasello (2002) and included *dacking* (spinning the object on a flat surface), *gorping* (putting the object on one's head), and *meeking* (holding the object up to the eye like a telescope).

An app was created using an ABC format common to first words apps aimed at children. The app showed the letters D, G and M followed by four different images of children performing the action "dacking" after the letter D, "gorping" after the letter G and "meeking" after the letter M. In addition, three short videos were included which showed a child performing each action (5–7 seconds in duration). When a picture was pressed, an abc "button" on the top right of the screen could be pressed so that an audio recording of the action label was played and the action word was written on the screen. The audio labels were played in the following order "D dacking," "the boy is dacking," "the girl is dacking," "D dacking," and followed the same sentence structure for each action word. In addition, a video icon in the top left of the screen could be pressed to play a video. The app was displayed on a Google Nexus 7 with a 7-inch screen.

2.3 Procedure

Children were tested at nurseries and in the lab. Prior to participating in the study, informed consent was obtained for nursery testing by sending parents an information sheet about the study along with the consent form and questionnaire or for lab testing by giving parents the paperwork upon their arrival to the lab. Children were randomly assigned to one of 3 conditions, an adult-led app condition ($n = 12$; mean age = 42.67, SD = 3.98), a child-led app condition ($n = 7$; mean age = 43.14, SD = 3.98), and a live condition ($n = 10$; mean age = 40.10, SD = 3.03). A one-way ANOVA confirmed that there were no significant differences in age between the three conditions [$F_{(2,26)} = 1.854$, $p = 0.177$].

All children engaged in a warm up interaction with the experimenter until a smile was elicited from the child. Following the warm up, the word learning session started (see Figure 2). All sessions were video recorded.

2.3.1 Word learning session

Children in both the live and app conditions heard the novel action labels repeated four times in total.

For children in the adult-led app condition, the experimenter said "Do you want to see a fun app?" The experimenter then started the app and proceeded to click through the images in a systematic way. The experimenter let children see the home screen before clicking on the first picture of the action "dacking" and pressing the abc button to play the action label, the experimenter then swiped left to bring up the next picture followed by the abc button. For the third picture, the experimenter pressed the abc button and then the video button. Once the video had finished playing, the experimenter then swiped left again to show the final picture and pressed the abc button to play the action label. Once all of the "dacking" pictures had been shown, the experimenter clicked back onto the home screen and then started the same process for "gorping" and "meeking." Exposure to the app in this systematic way lasted approximately 2 ½ min.

For children in the child-led app condition, the experimenter said "I'm going to show you what these buttons do and then you can have a play with it. You can click on this (one picture thumbnail), you can click on this (ABC-reveals word on the screen), you can click on this (video), and you can click on this (Babylab logo-home button). Now you can have a play." The child was then given the app to play with, and there was no interaction with the adult in terms of the app's content, similar to the distinction between the co-use and alone use of apps in Griffith et al. (2022). If the child seemed discouraged to engage with the app, the experimenter would try to encourage them by stating the app was very fun and they would only have a play with it for a few minutes. Exposure to the app in this condition lasted approximately 5–6 min.

For children in the live condition, the experimenter said "I have some fun things to show you." The experimenter then brought out the first object and presented the "dacking" action while saying the action label, followed by demonstrating the action on the second object while saying "I'm dacking," the third object while saying "I'm dacking" and then demonstrating action on the fourth object saying "dacking." The same process followed for the "gorping" and "meeking" actions using the same objects in the same order and the same sentence structure for the action labels in the same order. After each action demonstration the object was placed out of sight so that only one object was visible at a time. The live demonstrations lasted approximately 2 min.

2.3.2 Word learning test

Children participated in a three-choice pointing task (method adapted from Twomey et al., 2014) for the word learning test. For the pointing task, images were presented on the touchscreen tablet and the test images were taken from the verb learning app. The pictures were therefore familiar to children in the app conditions but novel to children in the live condition. Children were given three warm up practice trials in which the experimenter asked the child to point to one of three pictures depicting familiar actions in succession (sleeping, drinking, sliding) and provided feedback on children's responses (e.g., "That's right," "Well done!"). The practice trials were followed by six test trials in which the experimenter asked the child to point to pictures of each of the novel actions labeled in the word learning session twice. The experimenter did not provide feedback during the test trials. The order in which the novel object labels were asked for and the quadrant for each image were counterbalanced across conditions using a Latin square design.

2.4 Scoring

Approximately 20% ($n = 6$) of the video recordings were double coded by an independent observer. Inter-observer reliability analysis was 94% (kappa = 0.883). For the pointing task, children were given a score of 0 (wrong) or 1 (correct) for each of the six

FIGURE 1
Live demonstration objects.

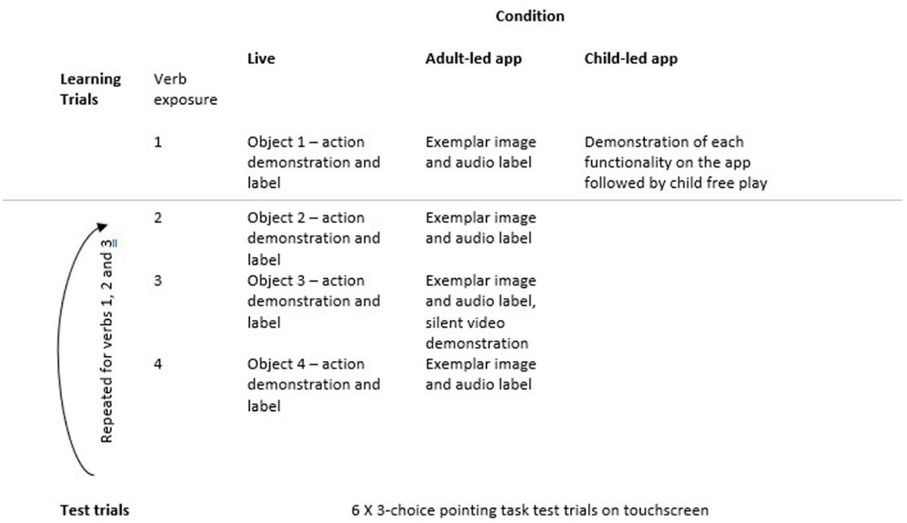

FIGURE 2
Diagram of the experimental design.

pointing trials. A mean score was then calculated across the six trials to give children a pointing task score. Preliminary analysis revealed no significant effect of gender or test word order on word learning scores, and the data was therefore collapsed across gender and word order.

3 Results

The learning accuracy for all three groups is shown in Table 1. We conducted one sample *t*-tests to determine whether performance was better than chance (0.33) for each condition, also shown in Table 1. The live condition resulted in significant learning, but the app conditions did not show learning better than chance.

TABLE 1 Accuracy for the three conditions, comparisons against chance level.

Condition	Mean	SD	n	t	*p*	*d*
Live	0.58	0.27	10	2.91	0.017	0.92
Adult-led app	0.33	0.22	12	0.05	0.960	0.01
Child-led app	0.43	0.25	7	1.04	0.341	0.39

In order to compare performance across the conditions, we next conducted generalized linear mixed effects (GLME) model analyses on accuracy of children's responses during the test phase. In the model we used Helmert coding to determine whether there was a difference in learning from live interaction compared to either type of app (learning material format), where the live condition was coded as 1, and each app condition was coded as −0.5. A significant positive effect would indicate that the live condition was advantageous for learning compared to the apps. We also used Helmert coding to determine whether there was a difference between the two types of app (app interaction condition: child-led or adult-led), with the child-led app coded as 1, and the adult-led app coded as −1 (and the live condition coded as 0 so that it did not contribute to this factor). A significant positive effect would indicate that the child-led app resulted in better learning than the adult-led app. We included participant as a random effect, but also including which word was being tested as a random effect resulted in a singular fit, so this was omitted. The model failed to converge when learning material format or app interaction

TABLE 2 Final GLME model of learning accuracy from live compared to app interactions.

	Estimate	SE	z	p
Intercept	−0.398	0.214	−1.862	0.063
Learning material format	0.774	0.345	2.244	0.025

174 observations, 29 participants. R syntax: glmer (Accuracy ∼ ApporLive + (1|ParticipantID), data = data, family = binomial).

condition were included as random slopes, so only a random intercept was included.

We first constructed a null model which contained only random effects, then we added in the fixed effects one at a time, using log-likelihood comparisons to determine whether each fixed effect contributed significantly to model fit (Barr, 2013).

Adding learning material format as a fixed effect significantly improved model fit, $\chi^2_{(1)} = 4.49$, $p = 0.026$. Adding app interaction condition (adult-led, child-led) did not significantly improve model fit, $\chi^2_{(1)} = 0.74$, $p = 0.389$, and so this was not included in the final model. The final model is shown in Table 2.

The results show, that children learned significantly better from live interactions than either app condition, and that there was no significant difference between the effectiveness of the two app interaction conditions used in this study. Further, the results confirmed that learning was not effective for either app condition in this study with participants in those conditions not performing above chance.

3.1 *Post hoc* power analyses

For the effect of whether the condition was live or the app, the effect size was 0.77. *Post hoc* power analyses (using powerSim and mixedpower Monte Carlo simulations, Kumle et al., 2021) yielded estimated power = 0.65, 95% CI = (0.62, 0.68). Simulations with different sample sizes indicated that, in a future study, 45 participants would be needed for power = 0.80, and more than 60 participants would be needed for power to exceed 0.90. However, we also calculated a Bayes Factor to determine whether there was evidence for the experimental hypothesis of a difference between live and use of the app compared to the null hypothesis (that there would be no difference). There was moderate evidence for there being a difference between conditions, $BF_{HN}(0, 0.40) = 5.26$ (Lee and Wagenmakers, 2014), indicating that the sample was sufficient to produce evidence for the distinction.

For the effect of whether the app was adult-led or child-led, the effect size was small at 0.22. *Post hoc* power analysis indicated power = 0.16, 95% CI = (0.13, 0.18) for detecting this effect as significant. Simulations indicated that a study would require 325 participants in order to reach power >0.80. Thus, because co-use has a small effect on learning, we would require a large number of participants to find a significant difference in learning in a future study. Bayes Factor calculations reflected that there was no evidence for either the experimental hypothesis of there being a difference between conditions, nor of evidence for there being no difference, $BF_{HN}(0, 0.35) = 1.14$.

4 Discussion

In the present study, 3-year-old children successfully learnt novel verbs as demonstrated by above chance performance in pointing at static pictures of the verbs in the live condition but not in the app conditions. This finding is particularly striking because children in the live condition had to transfer the verb learnt in a live context to a previously unseen static 2D image of the verb on the touchscreen tablet (see also Naigles et al., 2005 for verb learning transfer ability). For children in the app conditions, the static images used during the test session were also used in the learning phase and should have been more familiar to those children. Thus, despite the potentially easier transfer from training to test, children showed no evidence of learning novel verbs from our experimental app, in contrast to the literature demonstrating that children can learn novel nouns from apps effectively (e.g., Kirkorian et al., 2016; Russo-Johnson et al., 2017). The current study thus demonstrates that there was sufficient referential information present in the situation for children to acquire the verbs (e.g., repetitions of the novel action and verb), but that the mode of delivery of this information had consequences for whether the verb was learned.

Our use of two conditions to deliver the app content to children enabled us to test various conditions under which verbs could be learned by children. Children in both the adult-led and child-led app conditions did not perform above chance in the learning test. For children in the child-led app condition, this finding contrasts with previous research demonstrating that children can learn new words (primarily nouns) from touchscreens when using touchscreen apps independently (e.g., Dore et al., 2019; Kirkorian et al., 2016; Russo-Johnson et al., 2017; Walter-Laager et al., 2017). However, our finding is consistent with studies on children's verb learning from video in which children required additional live social interaction to support their learning (Roseberry et al., 2014, 2009) which was not present to the same degree in our adult-led app condition which focused on systematically showing children the app content rather than providing interactions about the app content. Thus, we had hypothesized that children in the adult-led app condition would show evidence of verb learning but our findings do not support this hypothesis. This may have been because of the relatively fixed way in which co-use was determined in our study. In the co-use condition, the adult showed the child the functionality of the app, and operated the app. In Griffith et al. (2022) for instance, the child operated the app with the adult alongside. The agency of the use, and the contingency of responses by the adult, therefore may have influenced the differences in learning in our study compared to Griffith et al. (2022), though in their case the app was around developing programming rather than language skills.

Importantly, there are a number of different strategies that can be employed for adult-child co-use when children use touchscreen apps together (see Griffith and Arnold, 2019; Neumann, 2018; Sheehan et al., 2019). In our study, an unfamiliar adult showed the child each of the app features in a systematic way and the child did not interact with the app during the word learning session, similar to our live condition in which the child was not allowed to interact with the toys during the word learning session. Prior work has shown that this strategy can support 2.5- and 3-year-olds when learning to imitate specific actions to make a puzzle on a touchscreen (Zimmermann et al., 2017). However, this strategy might not be helpful for supporting children's verb learning from touchscreens. Furthermore, in their observational study, Griffith and Arnold (2019) found that caregivers held the tablet 38% of the time and interacted with the touchscreen 20% of the time. A purely adult-led method of parent-child co-use is therefore uncommon during naturalistic interactions with touchscreens and may have disrupted children's learning. Moreover, parent-child co-use interactions during media use in studies are typically not scripted and may be beneficial in supporting children's learning, though no moderator effect of the adult co-using digital media with children has been found (Taylor et al., 2024).

Verb learning from our app may have been impoverished due to the timing of the verb label or the number of exemplars provided by the app. Children in the app conditions saw a dynamic video of each action only once without a verbal label, and verbal labels were provided alongside a static picture of the action before and after the dynamic video. In contrast, children in the live condition saw four dynamic demonstrations of the action with the verb labeled during the action demonstration. Given that motion information is inherent in verbs, motion information may be necessary when learning novel verbs (Kersten and Smith, 2002). In addition, children in the app conditions saw static images of four novel actors and novel objects for each verb (16 novel objects and actors in total for the three novel verbs). In contrast, children in the live condition saw the same actor across all verb demonstrations and the same four novel objects for each action (one novel actor and four novel objects in total for the three novel verbs). Prior work has shown that multiple exemplars during learning can hinder children's ability to extend verbs to a novel actor (Maguire et al., 2008) and children attend to object information when learning novel verbs with novel objects (Kersten and Smith, 2002). Therefore, the app conditions may have provided children with too many exemplars of the verb action, or children need motion information to learn verbs.

Equally, it is also possible that verb learning from our touchscreen app was hindered by the quality of our app. Studies investigating word learning from touchscreen apps differ significantly in terms of app design from apps designed for experimental purposes (Dore et al., 2019; Kirkorian et al., 2016; Russo-Johnson et al., 2017) to commercially available apps (Walter-Laager et al., 2017). Dore et al. (2019) based their app design on the four pillars framework (Hirsh-Pasek et al., 2015) and therefore the app was designed to support learning based on cognitive theory and the science of learning. In contrast, experimental apps typically have simple designs, for example, requiring children to touch the screen to play a video of an adult opening a box and labeling the object inside (Kirkorian et al., 2016) or a narrator labeling a single object on the screen followed by the ability for children to tap or drag the object to move it across the river (Russo-Johnson et al., 2017). Our experimental app was based on a commercially available app, and evaluating our experimental app using Kolak et al. (2021)'s app evaluation questionnaire which is based on theories of children's cognitive development and learning from digital media, suggests that our app would score just 6/20 in terms of educational potential. Indicating that the commercially available app on which our app was based is also unlikely to support children's learning is consistent with prior studies investigating the educational potential of commercially available children's touchscreen apps in the app marketplace (Kolak et al., 2021; Meyer et al., 2021; Taylor et al., 2022).

Children's touchscreen apps have the potential to enrich a child's language input and support their language development (see Kolak et al., 2023; Taylor et al., 2022). Although research to date has started to explore what makes an app educational for young children and how to support children's noun learning from apps, understanding how touchscreen apps could support other forms of word learning (e.g., verbs, adjectives, and adverbs) or areas of language development (e.g., syntax) remains under researched. While our study starts to address a gap in the literature by investigating children's verb learning from touchscreen apps, our study is limited in three ways. First, the sample size is small, and although it was sufficient to detect a difference between the live and app conditions, if there are (much) smaller differences between child- and adult-led conditions then these were not possible to observe in the current study. Second, the study is limited by its inability to tease apart whether the effects we observed were specific to verb compared to noun learning, or whether the observed difference between live compared to app use conditions were due to the particular constraints of the app that we had designed. Future work could directly compare verb and noun learning from a well-designed educational app. Doing so will help us understand whether adult-child co-use and specific app features are necessary to support verb learning from children's apps. Third, the study was restricted to learning intransitive verbs. Though this is in line with many previous studies of verb learning (e.g., Childers and Tomasello, 2002; Monaghan et al., 2015; Srinivasan et al., 2017), extending the research to address how both transitive and intransitive verbs are acquired is an important aim for future research (Childers et al., 2023).

5 Conclusion

In conclusion, we investigated the conditions under which children might be able to learn novel verbs from technology, comparing how 3-year-old children learn from live interaction varied from using an app with an adult vs. using an app alone. We found that the children in our study did not show evidence of verb learning from a touchscreen app regardless of whether the child or the adult led the app interaction, although they did show learning of the same verbs from a live interaction. Nevertheless, we encourage future work to consider how touchscreen apps could support children's language development beyond noun word learning and consider the role of different app features for supporting verb learning. Furthermore, research should start to systematically explore optimal strategies for adult-child co-use when using touchscreen apps to support children's language development.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/cdn4m/?view_only=69358efc47f44751845a6d7f70cde33b.

Ethics statement

The studies involving humans were approved by the University Research Ethics Committee at Lancaster University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

GT: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. GW: Methodology, Writing – review & editing. PM: Formal analysis, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The role of behavior-related comments in parent–child interactions with the digital audio learning system Tiptoi®

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Introduction: Whereas previous research has extensively explored shared reading of both print and digital storybooks, it has paid little attention to hybrid storybook reading. This study aims to address two gaps in the existing literature: First, we investigate the use of a hybrid reading medium, specifically Tiptoi®, in the Digital Home Literacy Environment (DHLE) of young children. Second, we examine parental comments during shared storybook reading, focusing particularly on the purpose of behavior-related comments.

Methods: We conducted a study involving 40 preschoolers and first graders (aged 4–7 years). Using a survey, we examined the use of Tiptoi® as a hybrid reading medium in children's DHLE. Additionally, we analyzed parent-child interactions during shared reading sessions with Tiptoi® through semi-naturalistic observation.

Results: Results indicate that children aged 4-7 use Tiptoi® regularly and mostly independently. For parent-child interactions, we found that behavior-related comments typically served to provide instructions, to structure the interaction, and to address the technology itself.

Discussion: Overall, this study provides valuable insights into the use of Tiptoi® in children's DHLE, and it highlights the importance of parental behavior-related comments in enhancing the practice of reading with hybrid storybooks.

KEYWORDS

Tiptoi®, digital storybook, literacy, parent–child interaction, behavior-related talk

1 Content- and behavior-related talk in shared storybook reading

1.1 Printed traditional storybooks

The home serves as the primary environment for children's initial learning and developmental experiences. Within this context, the Home Literacy Environment (HLE) emerges as a multifaceted construct encompassing a spectrum of literacy-related interactions, resources, and attitudes available within the household (Niklas et al., 2021). Extensive research indicates that the HLE, such as parental attitudes and the quality of verbal parent–child interactions, significantly predicts children's language (Wirth et al., 2020) and reading development (Hamilton et al., 2016). Building upon the crucial role of HLE in children's development, considerable attention has been devoted to investigating the impact of shared storybook reading (Heller and Rohlfing, 2017) on children's language skills (Flack et al., 2018). In a recent study with 9–18-month-olds, Clemens and Kegel (2020) demonstrated that common activities (e.g., toy play or mealtime) are not as effective in enhancing language development, because they elicit a significantly lower level of language use and interaction between parent and child compared to shared book reading. Through storybook reading, adults provide a greater lexical diversity compared to conversations for young children, whereby children gain access to new words that they would not experience in a typical conversation (Montag et al., 2015) or during toy play (Heller and Rohlfing, 2017; Hoff-Ginsberg, 1991). Moreover, parental language contains more syntactically complex utterances during storybook reading than in natural parent–infant interactions (Ece Demir-Lira et al., 2019). Finally, book-reading interactions include a higher number of conversational turns, and a higher parent word count compared to other activities (Gilkerson et al., 2017).

Importantly, research underscores that shared storybook reading is an interactive activity in which parents not only read aloud but also engage their child in discussions about a book's content. With this reading technique, called dialogical reading (Olszewski and Hood, 2023; Whitehurst et al., 1988), adults encourage children to take an active part in the reading situation by talking about the content or asking questions. Shared dialogic reading facilitates language development and might be especially beneficial for the development of the expressive language in young preschoolers (Mol et al., 2008). Adults begin with simple questions until children are familiar with a story. Then they introduce more challenging, open-ended prompts such as asking children to predict what will happen next or to relate something in the story to their own lives (Zevenbergen and Whitehurst, 2003). In addition, adults provide feedback on children's talk and model complex responses to questions. The goal is to promote linguistically rich conversations that encourage children to express themselves. These dialogic strategies, such as questioning, labeling, providing contingent responses, and offering affirmations (Fletcher and Reese, 2005), scaffold an interaction or conversation about the book between the adult and child and contribute significantly to children's language development.

Research on dialogic or *content-related* reading indicates that caregivers' verbal input changes across children's preschool years (Goodsitt et al., 1988). For younger children, caregivers primarily use storybook reading as an activity for vocabulary teaching, focusing on what questions, attention direction, and picture labeling (Ninio and Bruner, 1978). Initially, caregivers emphasize labeling and word teaching, but as children grow older, the focus shifts to more complex utterances about the story content (Goodsitt et al., 1988). For instance, Heller and Rohlfing (2017) found that young children were first prompted to respond to what questions with pointing gestures; but later, they were encouraged to answer open-ended questions about the story, such as "What is happening here?" This shift in content-related dialogue suggests that caregivers adjust their cognitive and linguistic demands to align with their children's developmental levels (Goodsitt et al., 1988). Therefore, it is not solely the act of reading but also the extratextual discourse surrounding the book content that enhances language skills in children (Fletcher and Reese, 2005; Reese and Cox, 1999).

Whereas content-related reading practices have been researched extensively, there is much less literature on behavior-related reading practices. Through *behavior-related* reading practices, caregivers play a crucial role in teaching young children the conventions of reading. These early interactions help infants learn the basics of literacy such as holding books upright, not chewing them, and turning pages in the correct sequence (DeLoache and DeMendoza, 1987). For example, mothers often share the task of turning pages with their two-year-olds to involve them in the reading process and give them the opportunity to practice this rule (Goodsitt et al., 1988). Such behavior-related talk is also described as *orientation*, highlighting that these actions aim to maintain the child's attention and guide their behavior (DeLoache and DeMendoza, 1987). Together, these two reading practices—content- and behavior-related reading—create a well-rounded experience that supports children's overall learning and development.

1.2 Digital storybooks: e-books

Similarly to children's HLE, their DHLE (Digital Home Literacy Environment) can be characterized by several key dimensions such as children's access, frequency of digital media usage, and parents' quality of support (Bonanati et al., 2022; Lehrl et al., 2021). Although it is widely agreed that children benefit from engaging in rich verbal and affective interactions during traditional storybook reading, recent studies comparing parent–infant interactions with analog (print) vs. digital storybooks have yielded mixed results (Hassinger-Das et al., 2019). Some studies have found no significant differences between the two book formats (e.g., De Jong and Bus, 2003; Lauricella et al., 2014). For instance, no differences were found in children's visual attention (Richter and Courage, 2017) nor in the quality of parent–infant interactions (Strouse et al., 2023) when comparing paper and digital books. Other studies show an advantage for digital storybooks in parent–infant interactions (e.g., Etta and Kirkorian, 2019; Strouse and Ganea, 2017). For example, Strouse and Ganea (2017) found that e-books elicited more pointing gestures, more book-related utterances, and longer visual attention in children compared to printed books. Another study revealed that children learned more words from an e-book with built-in narration compared to a condition in which parents read the book (O'Toole and Kannass, 2018). In contrast, other research indicates significant differences in children's information recall (Dore et al., 2018), child utterances and story comprehension (Miosga, 2020), parents' scaffolding strategies (Miosga, 2020), dialogic reading (Parish-Morris et al., 2013), and behavior and content-related talk (e.g., Miosga, 2020; Munzer et al., 2019; Parish-Morris et al., 2013).

The latter studies highlighted that printed books encourage more content-oriented talk compared to digital books, whereas digital books elicit more behavior- and technology-related talk (Parish-Morris et al., 2013; Ozturk and Hill, 2020). Further studies indicate that parents talk more about the book content (Munzer et al., 2019), ask more story-related questions (Krcmar and Cingel, 2014), and use more distancing prompts (Parish-Morris et al., 2013) when reading printed books compared to digital books with their children. Conversely, parents talk more about the book format and the environment (Krcmar and Cingel, 2014), use more technology-related comments such as "Swipe with your finger" or "Don't touch that button" (examples from Munzer et al., 2019), ask their children fewer questions, and stop less often to discuss the story when reading digital books (Wainwright et al., 2020). According to recent studies, behavior-related talk in parent–child reading interactions is considered less important compared to content-related talk, because meaningful engagement time is taken up by instructional comments (Hassinger-Das et al., 2019). This parallels the argumentation of the "displacement hypothesis" (Neuman, 1988). This line of research adds that while traditional books facilitate rich dialogic interactions linking story content to children's experiences, digital books lead to more discussions about the child's behavior, potentially hindering beneficial dialogic interaction (Parish-Morris et al., 2013). This leads to the conclusion that children comprehend significantly more in the traditional book condition than in the electronic book condition (Krcmar and Cingel, 2014) due to the lower proportions of behavior-related utterances (Parish-Morris et al., 2013).

1.3 Hybrid storybooks: the digital audio learning system Tiptoi®

Hybrid reading media, which include digital audio systems (Tiptoi®, BOOKii, TING, LeapReader) or digital reading companions (Luka, Reading Sidekick with Alexa), represent a special reading format. They merge the traditional printed book with digital components, and are distinct from screen media such as e-books that engage users through visual and acoustic means on a screen. Instead, hybrids blend a printed book with digital elements specifically for audio enhancement. The Tiptoi® digital audio learning system features a digital pen equipped with sophisticated technology to allow interaction with the printed book. The reading experience can be enriched with additional explanations or interactive activities by tapping on icons such as "Explore," "Learn," "Storytelling," "Music," and "Game." By then placing the digital pen on different parts of the book—images or text—audio files are activated and played through an integrated speaker in the pen. These audio files range from sounds and words to complete sentences. This multifaceted engagement provides children with various ways to interact with the book according to their interests and preferences. Recent versions of Tiptoi® also support the recording of custom audio files directly onto the pen, enabling multilingual families to add content in their heritage languages (Rohlfing et al., 2024). Rechlitz et al. (2016) highlighted user-friendliness as a standout feature of the Tiptoi® system along with the ease of downloading audio files to set up the pen. The capacity for children to use the pen independently stands out as particularly beneficial. Given the pen's explanatory functions within the book, it enables young readers, who might not yet have independent reading skills or who can manage only limited text, to use the device autonomously (Choi et al., 2020). According to reports from 61% of parents, children always use the digital pens by themselves, with only 15.6% indicating that use was primarily or exclusively with parental involvement. This independent usability is attributed to the design of digital reading and learning pens, which are intended for solo use by children (Pfost et al., 2018; Rechlitz et al., 2016; Schmitt et al., 2022), suggesting their value as supplements to traditional reading activities at home or in educational settings. However, it is essential to acknowledge certain limitations of the Tiptoi® system. One major constraint is that digital pens are only compatible with their corresponding books; for instance, Tiptoi® pens cannot be used with TING books. Additionally, while e-book readers often offer options on how to receive the book content—whether statically, through voice-over only, or with all features activated—Tiptoi® books are ideally used with the digital pen to fully utilize their features. Without the pen, it is not possible to access the full book content such as character speeches, additional explanations, or information necessary for playing embedded games.

In recent years, an increasing preference for hybrid reading media has been observed among German families. Research by Stiftung Lesen, a national German nonprofit organization dedicated to promoting reading competence, revealed that in 2014, only 8% of German households owned a digital learning system (Maas et al., 2014). At that time, smartphones and tablet PCs were more prevalent in the surveyed families. In contrast, a later survey by Pfost et al. (2018) indicated that ownership of digital learning systems in homes had increased to 65.7%, although only 21.6% had ever used an e-book. Whereas the digital learning system has gained popularity as a reading tool for children in Germany, how widely it is used in other countries remains unclear. For example, the Tag reading system, LeapReader, introduced to children in Scotland as part of a study, illustrates the novelty of such technology in this region (Stephen et al., 2013). In addition to the limited international research on the usage and familiarity of digital audio systems in other countries, there is also a lack of studies examining parent–child reading interactions with these devices.

Stephen et al. (2013) provided access to various technologies, including the LeapReader, to a small sample of predominantly high-income families. They observed that some parents adopted a more "teacher-like" approach when their children interacted with the Tag compared to other technologies such as gaming consoles. Specifically, they introduced the Tag to their children, guided them toward interactive symbols on the page, and showed them how to access the story elements (Stephen et al., 2013). A similar study by Schmitt et al. (2022) focused on the LeapReader, aiming to describe how parents and their young children used the LeapReader over several months. This study also reported that parents demonstrated teaching behaviors, instructing their children on how to listen attentively to the text rather than randomly tapping hotspots. Even if parental comments were not coded explicitly, these two studies suggest that parents use behavior-related talk when using digital audio systems such as the LeapReader with their children. This also indicates that behavioral comments serve an important purpose, such as teaching children how to interact with the technology.

In summary, in addition to traditional storybooks, children have access to a wide range of digital reading devices that allow them to engage with books even if they have limited or no literacy skills. Recent evidence suggests that a quarter of children aged two to five use digital devices daily (miniKIM, 2023). This underscores the importance of the extensive research that has been devoted to exploring both digital and print book formats. The primary goal of prior studies has typically been to compare the effects of different book formats on parent–child interactions, assessing how the same book content—whether presented in print, as a static e-book with no interactive features, or as an interactive e-book with additional features such as sound effects and animation—can influence the dynamics of parent–child verbal and nonverbal exchanges (e.g., Munzer et al., 2019). Thus, parents' extratextual talk in shared storybook interactions, especially behavioral and content-related talk, plays a central role in studies that compare different forms of storybook. It is worth noting that in our literature review, we found studies that focus primarily on young infants up to preschool-aged children. Studies exploring parent–child reading interactions with school aged children are still lacking in this field. This might be explained by noting that especially the period before school entry is considered crucial for later language and literacy development. Therefore, research and interventions focus on this critical period when parent–child interactions are thought to be particularly influential. Another reason might be that shared storybook reading with school-aged children is less common in family routines. Whereas most children between the ages of three and five are read to at home, a significant number of parents discontinue this practice once their child enters school (Stiftung Lesen, 2022), even though most first graders are not able to read independently.

Our review of existing studies reveals that parents' frequency of behavior and content-related talk differs when comparing digital and print book formats. Moreover, in the context of traditional storybook reading, parental behavioral talk is generally described as a key practice for teaching young children the basic "rules" of reading. In the context of digital storybook reading, comments unrelated to content are often evaluated negatively and described as detracting children from meaningful engagement with the story. Whereas there has been extensive research on digital and analog media, hybrid reading media remain understudied, both in terms of their presence in children's DHLE statistics and in terms of parent–child interactions. To address these research gaps, our pilot study investigates parent–child interactions with the digital audio learning system Tiptoi® and specifically examine parents' behavioral talk.

2 The present study

The present pilot study addresses three main objectives: (1) Given the sparse existing research on hybrid reading media in children's DHLE (Pfost et al., 2018; Rechlitz et al., 2016), our initial goal is to extent current statistics on children's DHLE by adding digital audio systems. Our questionnaire is designed to identify which reading media are currently favored among preschoolers and first graders including analog, digital, and hybrid reading devices along with other media. Furthermore, we seek to examine the frequency, autonomy/type, and location of usage of the digital audio learning systems. (2) Our second objective is to assess parental comments during shared reading interactions with this hybrid book format, under consideration of children's age and Tiptoi® experience. We hypothesize that the age of children may influence parental comments, with younger children potentially being more distracted by interactive features. This assumption is grounded on prior literature on printed books with manipulative features (Chiong and DeLoache, 2012; Muhinyi et al., 2024; Shinskey, 2021) demonstrating that interactive features, such as "pop-up" elements or lift-the-flap features, can distract children's attention from the book's content. These studies focused primarily on young children, but our research aims to compare preschoolers with first graders to determine whether preschoolers may require more behavior-related comments from parents who navigate the reading interaction. Additionally, we posit that parents of children with minimal or no experience with this format might employ more behavior-related language than parents of children who are familiar with it. This assumption is justified by literature indicating that during early interactions with traditional books, parents focus initially on helping infants grasp the basics of reading, gradually shifting to more complex discussions about the story content (DeLoache and DeMendoza, 1987; Goodsitt et al., 1988). Whereas all children in our study are generally comfortable with printed books, there are some children for whom digital books introduce a novel technology and storybook format that may initially be explored more for its functionality than for its content. (3) In light of the diverse evaluations of behavior-related talk in printed and digital storybooks (e.g., Parish-Morris et al., 2013; Munzer et al., 2019), our third goal is to investigate the purpose of behavior-related talk in parent–child interactions with Tiptoi®. This involves categorizing parental behavioral comments to understand their role in reading interactions with hybrid storybooks.

2.1 Participants

This pilot study was conducted with 40 German-speaking children (M_{age} = 4,8 years; 20 male and 20 female children) and their parents who were reading a storybook with the Tiptoi®-pen. Of these children, 26 were preschoolers (M_{age} = 4.0 years; 11 male and 15 female children), and 14 were first graders (M_{age} = 6.3 years; 9 male and 5 female children). We chose preschoolers and first graders as our target group for two important reasons: First, one of our goals was to consider children's age as a possible factor influencing parents' comments during reading interactions. Second, most research focuses on shared storybook reading with children up to the age of five. Because previous research has focused primarily on toddlers and preschoolers, we aim to broaden the scope by including an older group: first graders.

We justified our sample size of n = 40 based on two main considerations: First, because this is a pilot study exploring a hybrid reading medium within a seminaturalistic parent–child interaction, our research is inherently exploratory. Given the novelty of our topic and the lack of comparable data from similar studies involving digital audio systems, we had no prior effect sizes to guide our sample size estimation. The exploratory nature of our discourse analysis necessitates this approach, and we opted not to conduct a *post hoc* power analysis as critically discussed in literature "[b]ecause a *post-hoc* or retro-spective power analysis is based on the effect size observed in the data that has been collected, it does not add any in-formation beyond the reported p value, but it presents the same information in a different way" (Lakens, 2022, p. 17). Second, our sample size is justified heuristically. We aimed to have a balance between a practical and statistically meaningful sample size, setting 30 participants as the minimum required and 50 as the upper limit (Lakens, 2022). We successfully collected data from 40 participants, which we deemed adequate for our study's objectives, and a good starting point for further replication studies with larger samples. In reporting our results, we include partial eta squared (η^2) as recommended for effect size measures (Cumming et al., 2012). Because even small differences can become significant with larger sample sizes, effect sizes provide a way to assess not only statistical significance but also practical relevance (Lakens, 2013).

Our sample was recruited from our database of families who had agreed to be contacted for participating in studies as well as through advertisements (Flier) in kindergartens in the region of Paderborn (Germany). We invited all contacted families who agreed to participate in our study, regardless of their experience with Tiptoi®. When participants visited the laboratory, they completed a consent form and a questionnaire[1] that included questions about general demographics and their child's DHLE prior to participation. Based on the general demographic questionnaire, children were from families with a middle or higher socioeconomic (SES) background as measured by their caregivers' level of education. All children were monolingual with typically developed hearing and language abilities. For the standardized questionnaire on children's DHLE, we based our approach on Pfost et al.'s (2018) survey of children's use of digital media, including digital audio systems. Our survey aims to provide recent statistics on children's usage of printed books and digital (reading) media. In particular, parents reported on their children's frequency of usage of not only traditional picture books but also digital (reading) media including digital audio systems, E-books, audiobooks, TV, Smartphone, Tablet, and voice assistant. For those children with Tiptoi®-familiarity, we additionally assessed usage patterns such as the location (at home, on the go, or both) and type/autonomy (independently, jointly, or both) of usage.

2.2 Materials

The three books used in the study were all nonfiction books integrating factual knowledge into a story. They were chosen in line with the children's age (preschoolers vs. first graders). Preschool children could select a book from the "Wieso? Weshalb? Warum?" (English: "Why? Why? Why?") series, choosing between a fire station theme or a forest theme, both suitable for ages four to seven. Because this book series is also available in an analog format (without the Tiptoi® pen) and is very popular among preschool children in Germany, we decided to offer both options to ensure that children had a choice in case they were already familiar with one of the books. For the first graders, we offered a book from the "Expedition Wissen" (English: "Expedition Knowledge") series with a dinosaur theme, suitable for ages seven to ten. This book was a new publication available exclusively for Tiptoi®.

1 The questionnaire (English and German Version) and the data files can be found on the OSF: Wildt, E. (2024, September 24). Reading with Digital Audio Pens (RAUPE). https://doi.org/10.17605/OSF.IO/WK4ZQ.

2.3 Procedure

To elicit spontaneous communicative behavior from both caregivers and children, they were observed in a seminaturalistic setting within a laboratory room equipped with a couch and a table where the reading interaction took place. After children chose a book, the experimenter requested the dyad to explore this book together after she left the room. However, they were allowed to contact the experimenter, who sat in the room next door, at any time if they had any issues (e.g., if the pen battery ran out or they wanted to stop the experiment). After the experimenter turned on both video cameras and left the room, dyads were allowed to open the book and turn on the pen. Dyads were free to choose the type and duration of interaction. On average the reading interactions lasted 33.34 min ($SD = 15.83$; minimum = 10; maximum = 65). The whole interaction was recorded from two viewpoints: One camera was positioned in front of the dyad; the other, above with a bird's eye view (so that it was possible to recognize the book page).

2.4 Coding schema

The videotaped data were transcribed with the annotation software ELAN (Eudico Linguistik Annotator) (Sloetjes and Wittenburg, 2008). In contrast to other studies (Parish-Morris et al., 2013) in which video data was coded for ∼5 min of parent–child interaction, we decided to transcribe the entire reading interaction to assess parents' comments throughout. This is crucial, because at the beginning of an interaction, parents might explore how to activate the digital reading pen, thereby using more behavior-related language than in the middle of the interaction. The coding of an interaction started once the experimenter left the room, and it concluded either when the dyad turned off the digital pen or verbally indicated that they had finished reading. Based on the coding categories in prior literature (e.g., Strouse and Ganea, 2017; Parish-Morris et al., 2013), we categorized parents' comments into four main categories (Table 1): content-related, behavior-related, off-topic, and other. Parents' content-related comments refer to either the book content or the audio file. These utterances may encompass reading the book text aloud (coded as one annotation [reading]), verbal repetitions (e.g., of the audio file) (see also Strouse and Ganea, 2017), further content-related descriptions of things directly observable in the book (e.g., pictures) (see also Strouse and Ganea, 2017), decontextualization (see also *distancing prompts* in Parish-Morris et al., 2013), and additional explanations.

In contrast, the category *behavior-related comments* encompasses a range of verbal interactions initiated by parents that specifically aim to guide, modify, or reflect upon not only their own but also the child's behaviors and actions within the reading interaction. Because our third goal was to explore the purpose of parents' behavior-related comments, we carefully observed all behavior-related comments and categorized them into subcategories. Because there is limited literature on behavior-related talk in shared storybook reading, we began our exploration with the descriptions and codings we found in research on analog and digital storybook reading. For example, *orientation* to emphasize that these behaviors are intended to hold the child's

TABLE 1 Coding categories, definitions, and examples of parent comments during shared storybook reading.

Category	Definition	Examples
Content-related	Parents' content-related comments relate to either the book content or the audio file. These utterances may encompass reading the book text aloud (coded as one annotation [reading]), verbal repetitions (e.g., of the audio file), further content-related descriptions of things directly observable in the book (e.g., pictures), decontextualization, and additional explanations.	"There is a lot going on here. There was an accident!" (description of a picture) "That sounded like rain, didn't it?" (description of the sound) "*Documenting* means to record something." (explanation of a word meaning) "The larch was the one that loses its needles in winter." (additional explanation) "Headphones, just like your dad wears in a meeting." (decontextualization)
Behavior-related	These comments relate to parents' own or the child's behavior in the reading interaction that can be further differentiated into three subcategories.	
	Operations: This subcategory focuses on the immediate, local aspects of an interaction in which the child is directed to perform a specific action, typically within the confines of a game or a structured task. Operations are characterized by their directive nature, aiming to guide the child's physical engagement with the task *without* providing an extra explanation to the requested action. These prompts are usually framed as direct imperatives (positive or negative formulated) or as suggestive invitations that are often accompanied by a pointing gesture.	"Please stop clicking now!" (negative formulated directive) "Switch it [the pen] on!"; "Just try it out!" (positive formulated directives) "Should *we* click on this symbol [pointing]?"; "Do *we* want to try again?" (invitations formulated as questions) "*We* could listen to the cat." (invitation)
	Structure and organization of interaction: Here, parents discuss the overarching framework of the parent–child reading interaction. This includes metaconversations about the general procedural elements such as the order of the exercises or icons, whether they should turn the page, the repetition of certain sections, and clarifying who takes on the role of the reader (the parent or the pen). The language used by parents often includes temporal adverbs such as "first," "then," and "again" that emphasize the sequential or structured nature of the suggested actions, and they often make suggestions by offering two options.	"Do you want to explore anything else on this page?"; "Are you done?" "What do we want to do?" (general procedure) "Should we move on, or do you want to play a game?"; "Which one do you want: a quiz or a game with sounds?" (offering two options how to proceed) "Should I read what it says here, or do you just want to click?"; "Should I read? Should the pen read?" (defining the reader)
	Function of the technology: This subcategory delves into the exploration and elucidation of the functionalities of the reading device (e.g., a digital pen, icons) used within the activity. Parents either adapt to a tutor-like demeanor, offering explicit guidance on using the tool's features and assuming the role of a of a curious companion, or they adapt to the role of a companion by encouraging exploratory interaction with the tool. These interactions are often framed using conditional "if–then" statements, aiming to provoke curiosity and understanding of the tool's potential uses.	"*If* you press the light bulb here, *then* it will explain more." (tutoring: explanation by using if-then statements) "What happens if you press on this?"; "What happens if you click on the stars [icons] here?"; "Can it also read that aloud?" (exploring in the role of a curious companion) "Maybe they will explain something if you click on it." (companion role by encouraging)
Off-topic	These comments occur within the reading situation but are not related directly to the reading activity itself. Instead, they focus on the environment (e.g., questioning about the experiment, the cameras) or the child's need (e.g., wants to drink).	"They [the experimenters] observe what we are doing with the pen."; "It [the camera] is recording us." (environment) "Apparently, I do not have a tissue."; "Do you need to go to the toilet?"; "You are pretty tired, right?"; "Do you also want to drink a bit of sparkling water?" (child's need)
Other comments	These are incomplete or interrupted utterances of parents, or one-word interjections, including exclamations, expressions of feedback, short agreements or disagreement or thinking aloud.	"Well, ... " (interruption) "eh"; "oops" (interjections) "Super!"; "Wow!" (short feedback) "mhm" (agreement) "mmh" (disagreement) "Hmm" (thinking aloud)

attention and guide their behavior (DeLoache and DeMendoza, 1987), and *format-related vs. negative format-related instructions* (Munzer et al., 2019) that tell the child to do or not do something related to the book or tablet features. This bottom-up approach of observing and categorizing these utterances took many iterations to arrive at a final coding scheme with three subcategories—*operation*, *structure*, and *function* of the technology (see Table 1 for coding schema)—to encapsulate the nuanced ways in which parents invite their child or direct their child's behavior during such interactions. *Operations* entail prompts pertaining to the *local* level of an interaction, which means that the child is prompted to perform a specific action (e.g., within a game). In this context, parents typically frame operations as imperatives ("Please stop clicking now! ") or as invitations ("Should we click on this symbol [pointing]?"). These prompts are often accompanied by a pointing gesture using either a finger or the pen. In contrast to the category *function*, operations occur without any accompanying explanation. With *structure*, parents focus on *global* aspects of the reading interaction such as page turning, repetitions, and clarifying who takes on the role of the reader. These discussions revolve around actions that are independent of the specific content of the Tiptoi® book. Moreover, these prompts are often marked linguistically by temporal adverbs such as "first," "then," or "again." When exploring the potential *functions* of the digital pen, parents often adopt either a tutor role providing guidance such as "If you press the light bulb here, it will explain more, "or a companion role posing questions about functions such as "What happens if you press on this?" These utterances are frequently marked by "if–then" statements.

Off-topic comments concern aspects that do not relate to the reading interaction at all, but rather to the environment (e.g., questioning about the experiment, the cameras) or child's need (e.g., wants to drink). Thus, these utterances occur within the reading situation, but do not pertain to the reading activity itself. The category *other comments* relates either to incomplete or interrupted utterances or to one-word interjections, including short exclamations, short expressions of feedback, short agreements or disagreements, or thinking. The total scores for each category were compiled for each participant. This compilation resulted in a dataset representing the quantitative frequency of all categories of parental comments.

All video data were coded by one independent coder. Reliability was assessed by giving 20% of the data to a second coder and calculating Krippendorff's alpha (Krippendorff, 2011). Intercoder reliability was high for all variables ($\alpha = 0.53–0.98$).

3 Results

3.1 Parent questionnaire on digital media experience

Regarding our first objective and the limited statistical data on children's DHLE that specifically incorporate digital audio systems, we surveyed the parents participating in our study. This gives interesting insights into how digital audio systems are integrated into children's DHLE and helps us to understand the patterns of their use (Table 2). Findings from the parental questionnaire revealed that traditional storybook reading predominates as the most frequent media engaged with in children's HLE. One quarter (25%) of the surveyed parents reported that they read aloud to their children at least once a day, and the remaining 75% indicated that their children experience storybook reading multiple times per day. When shifting focus to hybrid and digital reading media, audiobooks emerge as the most popular platform. Parents reported that their children engage with audio stories through various sources such as CDs, Tonie box, Spotify, or the Mira Podcast. Out of 40 children, only a minority of 12 (30%) had either no prior experience with digital audio learning systems or had tried them only once, whereas a significant majority of 28 (70%) were familiar with Tiptoi® and owned this device at home. A large portion of the children ($n = 37$) had not been exposed to or had only minimal interaction with e-books, with merely three participants using e-books regularly. Regarding other digital devices, results show that most children have regular access to television (92.5%) and tablets (72.5%) at least once per month. In contrast, familiarity with certain other devices is lower; for example, 75% of the children have never used or have tried voice assistants (e.g., Alexa) only once, and 55% demonstrate a similarly low level of familiarity with smartphones.

Our survey on children's usage patterns with Tiptoi® explored the nuances of their interaction with this hybrid reading tool, focusing on both the locations where they use it and the ways in which they engage with it. Regarding the location of usage, a significant portion of the children (46.4%) engage with Tiptoi® exclusively at home. This preference underscores the tool as a familiar, home-based learning medium. On the other hand, exactly one half of the participants report a mixed use of the tool, integrating it into both home environments and mobile contexts. Only 3.6 % report that Tiptoi® is used only for activities on the go. This adaptability is particularly facilitated by the device's headphone functionality, which parents noted as especially useful during periods of waiting or during car journeys, allowing children to have enriching engagements outside the confines of their home. Regarding the type/autonomy of use, most children (67.9%) use Tiptoi® independently. This emphasizes the tool's capability to foster autonomous learning and exploration among its users. Conversely, 32.1% of the children experience Tiptoi® not solely by themselves but also jointly with others. This mode of mixed use, combining independent and shared reading, was predominantly observed in preschoolers ($n = 8$), with a much smaller occurrence in first graders ($n = 1$). It is particularly interesting to note that none of the parents reported using Tiptoi® exclusively with their children, highlighting the opportunity for children to engage with this hybrid reading device unaccompanied.

In sum, the questionnaire revealed that all children experience picture book reading at least once a day, making it a part of their everyday life. However, digital reading media appear to be used in addition to rather than as a replacement for traditional reading routines, serving as supplementary rather than primary reading media in children's literacy environment. The parental questionnaire also revealed that children's digital audio systems were used very frequently, second in popularity after audiobooks. The similarities between these two media types suggest that parents may follow certain principles when selecting a reading device for their DHLE: Both media types are easy to handle and can be used independently by children, as evidenced by our findings showing that most children use Tiptoi® autonomously. Additionally, both devices are screen-free, relying solely on auditory digital enhancements. From this we conclude that parents might prefer screen-free reading devices that can be used by children on their own.

3.2 Parental comments

Given the extensive research on printed and digital storybook reading, we have only limited understanding of hybrid storybook reading with digital audio learning systems. Our second objective was to examine parental comments during hybrid storybook interactions with their child while taking children's age and Tiptoi®-experience into account. For the following analyses, we examined whether parents' content-related, behavior-related, off-topic, and other comments (dependent variables) differ depending on their children's age and Tiptoi®-experience (independent variables). We conducted a mixed-design ANOVA in SPSS. This type of analysis captures both within-subject factors and between-subject factors. In the present study, the between-subject factor was *age group* (preschoolers, first graders), and *Tiptoi® experience* (with vs. without experience). The within-subject factors consisted of *parental comments* (content-related, behavior-related, off-topic, other comments) as a repeated measure variable. The Greenhouse–Geisser adjustment was used to correct for violations of sphericity.

A mixed ANOVA with a Greenhouse–Geisser correction determined a significant effect of parental comments, $F_{(1.3,46.9)} =$

TABLE 2 Frequency of usage of various media types (analog picture books, hybrid and digital reading media, other digital devices) among preschool and first-grade children.

Media type	Frequency of use	Preschoolers ($n = 26$)	First graders ($n = 14$)	All children ($n = 40$)	All children
Picture books	No regular experience	0	0	0	0%
	1 x per month	0	0	0	0%
	> 1 x per month	0	0	0	0%
	1 x per week	0	0	0	0%
	> 1x per week	0	0	0	0%
	1 x per day	4	6	10	25%
	> 1x per day	22	8	30	75%
E-Book	No regular experience	25	12	37	92.5%
	1 x per month	0	1	1	2.5%
	> 1 x per month	0	0	0	0%
	1 x per week	0	0	0	0%
	> 1x per week	1	0	1	2.5%
	1 x per day	0	1	1	2.5%
	> 1x per day	0	0	0	0%
Audiobook (e.g., CDs; Toniebox; Mira-Podcast; Spotify)	No regular experience	0	1	1	2.5%
	1 x per month	1	0	1	2.5%
	> 1 x per month	1	0	1	2.5%
	1 x per week	0	1	1	2.5%
	> 1x per week	1	3	4	10%
	1 x per day	10	4	14	35%
	> 1x per day	13	5	18	45%
Digital audio systems (e.g., Tiptoi)	No regular experience	8	4	12	30%
	1 x per month	5	7	12	30%
	> 1 x per month	2	1	3	7.5%
	1 x per week	2	0	2	5%
	> 1x per week	7	0	7	17.5%
	1 x per day	3	1	4	10%
	> 1x per day	0	0	0	0%
TV	No regular experience	3	0	3	7.5%
	1 x per month	2	0	2	5%
	> 1 x per month	0	1	1	2.5%
	1 x per week	1	1	2	5%
	> 1x per week	9	4	13	32.5%
	1 x per day	10	7	17	42.5%
	> 1x per day	1	1	2	5%
Smartphone	No regular experience	16	6	22	55%
	1 x per month	2	0	2	5%
	> 1 x per month	0	2	2	5%
	1 x per week	0	2	2	5%
	> 1x per week	4	1	5	12.5%
	1 x per day	3	3	6	15%

(Continued)

TABLE 2 (Continued)

Media type	Frequency of use	Preschoolers ($n = 26$)	First graders ($n = 14$)	All children ($n = 40$)	All children
	> 1x per day	1	0	1	2.5%
Tablet	No regular experience	10	1	11	27.5%
	1 x per month	5	3	8	20%
	> 1 x per month	2	2	4	10%
	1 x per week	9	1	1	2.5%
	> 1x per week	3	4	7	17.5%
	1 x per day	6	3	9	22.5%
	> 1x per day	0	0	0	0%
Voice assistant (e.g., Alexa)	No regular experience	19	11	30	75%
	1 x per month	1	0	1	2.5%
	> 1 x per month	1	0	1	2.5%
	1 x per week	0	0	0	0%
	> 1x per week	1	0	1	2.5%
	1 x per day	2	3	5	12.5%
	> 1x per day	2	0	2	5%

Percentages are calculated based on the total number of children surveyed (n = 40). The term "no regular experience" refers to children who have either not used a specific device at all or whose experience with it is limited to only a few occasions (e.g., trying it out at a friend's home).

70.94, $p < 0.001$, partial $\eta^2 = 0.66$, when considered independently of age group and children's Tiptoi® experience. However, we found no significant interaction of parental comments, implying that parental comments differ depending on children's age [$F_{(1.30,46.91)} = 0.44$, $p = 0.56$, $\eta^2 = 0.01$], children's Tiptoi® experience [$F_{(1.3,46.91)} = 0.19$, $p = 0.73$, $\eta^2 = 0.01$], or age and Tiptoi® experience [$F_{(1.30,46.91)} = 1.12$, $p = 0.31$, $\eta^2 = 0.03$]. Moreover, the analysis revealed no main effect of children's age [$F_{(1,36)} = 0.36$, $p = 0.55$, $\eta^2 = 0.01$], of Tiptoi® experience [$F_{(1,36)} = 0.001$, $p = 0.98$, $\eta^2 = 0.00$], or any interactions between age and experience [$F_{(1,36)} = 0.09$, $p = 0.77$, $\eta^2 = 0.002$].

Because there were no significant interaction effects, but a main effect of parental comments, we ran additional pairwise comparisons to determine where significant differences in parental comments occurred. Bonferroni-adjusted *post hoc* analyses revealed significantly ($p < 0.001$) more content-related than behavior-related ($M_{Diff} = 88.43$, 95%-CI [53.91, 122.96]), off-topic ($M_{Diff} = 144.93$, 95% CI [101.98, 187.87]), and other comments ($M_{Diff} = 92.47$, 95% CI [60.21, 124.73]). The analysis also revealed significantly ($p < 0.001$) more behavior-related than off-topic comments ($M_{Diff} = 56.49$, 95% CI [43.10, 69.88]), and more other comments than off-topic comments ($M_{Diff} = 52.46$, 95% CI [34.2,70.71]) (see Table 3 for descriptive statistics).

These results demonstrate that parental comments during hybrid storybook interactions with Tiptoi® differed significantly in frequency, regardless of children's age group (preschoolers and first graders), or experience with the device. This suggests that parents adapt their interaction style to the hybrid storybook format rather than to the child's age or familiarity with the device. Content-related comments were the most frequent type of parental utterance during these interactions. *Post hoc* analyses revealed that after content-related comments, parents made behavior-related and other comments more frequently than off-topic comments.

3.3 Purpose of parental behavior-related comments

Our third goal was to explore the purpose of parents' behavior-related comments. We found that parents predominantly use *operations* ($M = 35.05$, $SD = 17.3$) to direct their child to perform specific actions in the reading interaction. Furthermore, parents lead discussions about the *structure* and organization of their reading interaction with the child by talking about the framework of their interaction ($M = 22.65$, $SD = 12.07$). The category *function* represents the smallest proportion ($M = 9.57$, $SD = 6.06$).

In the next step, we examined whether the categories operation, structure, and function (dependent variables) differ depending on their children's age and Tiptoi® experience (independent variables). Again, the between-subject factor was *age group* (preschoolers, first graders), and *Tiptoi® experience* (with vs. without experience). The within-subject factors consisted of *parental behavior-related talk* (operation, structure, and function) as a repeated measure variable. A mixed ANOVA determined a significant effect of parental behavior-related talk, $F_{(2, 72)} = 58.4$, $p < 0.001$, partial $\eta^2 = 0.61$, when considered independently of the age group and children's Tiptoi® experience. However, we found no significant interaction of parental behavior-related talk, implying that these comments did not differ depending on children's age [$F_{(2, 72)} = 0.64$, $p = 0.53$, $\eta^2 = 0.02$], Tiptoi® experience [$F_{(2, 72)} = 0.05$, $p = 0.95$, $\eta^2 = 0.00$], or age and Tiptoi® experience [$F_{(2, 72)} = 2.21$, $p = 0.12$, $\eta^2 = 0.06$]. Moreover, the

TABLE 3 Descriptive statistics on each parental comment type within the reading interaction.

Parental comments	M	SD	Min	Max	Percentage
Content-related	158.43	88.15	42	446	53%
Behavior-related	67.28	30.16	11	42	22%
Off topic	10.18	10.69	0	52	3%
Other comments	64.58	39.36	8	164	22%
Comments total	300.38	150.85	80	788	100%

analysis revealed a marginal effect of children's age [$F_{(1, 36)} = 3.89$, $p = 0.06$, $\eta^2 = 0.1$], no effect for Tiptoi® experience [$F_{(1,36)} = 0.28$, $p = 0.6$, $\eta^2 = 0.01$], and a marginal interaction between age and experience [$F_{(1, 36)} = 0.3.44$, $p = 0.07$, $\eta^2 = 0.09$].

Because there were no significant interaction effects, but a main effect of parental behavior-related talk, we ran additional pairwise comparisons to determine where significant differences in parental comments occurred. Bonferroni-adjusted *post hoc* analyses revealed significantly ($p < 0.001$) more parental comments on operations than on the structure of the interaction ($M_{Diff} = 12.46$, 95% CI [6.12, 18.8]), and on the function of technology ($M_{Diff} = 25.83$, 95% CI [19.26, 124.73]). The analysis also revealed significantly ($p < 0.001$) more comments on the structure of the interaction than on the function of technology of the interaction ($M_{Diff} = 13.37$, 95% CI [8.41, 18.34]).

Although we did not find significant differences in parental behavior-related comments based on the children's age or their experience with Tiptoi®, the overall pattern of parental behavioral talk shows a clear preference for discussing operations over the structure of interaction and the function of the technology. Operational comments are formulated directly and are action oriented without further explanations. With structure-related comments, parents help create a framework for the reading experience, potentially enhancing the child's understanding of the reading process with this hybrid format. Interestingly, parents spend less time explaining or exploring the technological features of the Tiptoi® system. Moreover, the varying linguistic structures used in each category (e.g., imperatives for operations, temporal adverbs for structure, and "if–then" statements for function) demonstrate how parents adapt their language to effectively communicate different aspects of the reading interaction.

4 Discussion

The market for storybooks has experienced rapid growth in recent years, and now includes a variety of printed, digital, and hybrid book formats. Whereas previous research has extensively investigated shared reading of both print and digital storybooks, hybrid storybook reading has received relatively little attention. In the present study, we investigated how the digital learning system Tiptoi® is integrated into the DHLE of 4- to 7-year-old children. Moreover, we examined parental comments in the parent–child reading interaction, controlling for children's age and for Tiptoi® experience.

Research widely agrees on the benefits children gain from engaging in verbal and affective interactions during traditional printed storybook reading (e.g., Baker et al., 2001). In these contexts, parents' behavior-related talk is described as a common practice to teach children the "rules" of reading (Goodsitt et al., 1988), while content-related talk has been shown to facilitate language development (Fletcher and Reese, 2005; Reese and Cox, 1999). However, findings on the potential benefits of digital storybooks are mixed regarding whether this format reshapes the dynamics of shared reading interactions in positive or negative ways. Upon the reviewed literature, there is strong evidence that parents produce a higher proportion of behavior-related talk when reading digital compared to printed books, with some critical voices describing behavior-related talk as less meaningful compared to content-related talk. Drawing on parental comments, we additionally explored the purpose of behavior-related talk in hybrid reading interactions.

We found that digital audio systems (especially Tiptoi®) are a popular reading device across surveyed families. Most children use Tiptoi® regularly, at least once a month; and, in most cases, at home and predominantly independently. The predominance of independent usage suggests that children are comfortable in navigating digital interfaces at a young age. This finding aligns with previous research (Pfost et al., 2018; Rechlitz et al., 2016). Given the findings that audio books and Tiptoi® are the most popular literacy devices in children's DHLE and meet the criteria of being easy to use and possible to use independently, we conclude that this might be one of the criteria for using digital reading devices in addition to shared traditional reading. Further questionnaires with parents and teachers could provide more valuable insight into their attitude toward digital reading devices and on which criteria they rely when choosing a digital reading device for preschoolers and elementary school children.

Furthermore, we found that parents predominantly engage in content-related comments (53%) during reading interactions with children using Tiptoi®, followed by behavior-related (22%) and other comments (22%). These results are in line with research on digital books (Parish-Morris et al., 2013, p. 204)., indicating that only nearly one half of all comments (50–57%) are content-related and 35–42% relate to behavior-related talk. In contrast, printed books elicit about 73–76% comments on story content and a lower proportion (10–18%) of behavior-related talk (p. 204). From this, we can conclude that similar to digital books, hybrid book formats such as Tiptoi® also to tend to elicit a high proportion of behavior-related talk from parents. However, it is important to note that our study did not include a comparison group using traditional printed books. Moreover, we found no main effects of children's age (see also Parish-Morris et al., 2013) or Tiptoi® experience, indicating that these variables do not influence the types of comments made by parents during storybook interactions. However, despite children's familiarity with the book format, it should be noted that for all children, the book they chose was new. Because reading and exchange about story content also depends on whether the dyad reads a novel or a familiar book (Goodsitt et al., 1988), there is a crucial need for longitudinal studies investigating parent–child interaction as they become more familiar with the story content across sessions.

Previous research has suggested that behavior-related talk during parent–child interactions may be less meaningful, because it tends to involve fewer dialogic comments (use fewer story-related utterances and more behavior-related utterances). However, our study extends this line of research by delving deeper into the purpose and significance of behavior-related comments within the context of parent–child interactions during hybrid storybook reading. From the categorization of behavior-related comments, we can discern three types of behavior-related comments—operation, structure, function of technology—that serve the goal of guiding children on how to interact appropriately with the digital reading medium. This guidance is achieved by providing clear instructions on what actions to take and what actions to avoid with Tiptoi®. Because the digital pen serves as a medium that becomes part of the triadic reading interaction and can also assume the role of a reader, it was also important for parents to discuss the structure of interaction with their children. This includes clarifying roles, such as who is using the pen or who is reading the text, as well as explaining the sequence of steps required to access the book content with the help of the digital pen ("*first*, you have to, and *then*..."). Such discussions are essential to prevent children from randomly tapping images and icons in the book and to encourage and enable them to use Tiptoi® autonomously. Commenting on the function of technology is another important category, because parents not only provide instructions but also offer explanations or questions to children. Even if the parent is not fully acquainted with the technology, it is still valuable to engage in discussions with the child about its functions (e.g., the pen has a sensor) and to discuss its capabilities and limitations (e.g., the pen has a limited range of audio files for each page; the pen cannot write) in order to foster children's critical technological thinking (Tolksdorf et al., 2024). Moreover, it is worth noting that the identified categories primarily relate to the book format, and thus, would not occur in analog reading sessions. However, the category *structure* seems to stand out as the only one in which parents provide some comments within the interaction without specifically referring to digital features, but rather to global reading interactions ("should we read again?").

While our pilot study provides valuable insights into parental comments during shared storybook reading with Tiptoi®, it is important to acknowledge several limitations. First, our sample size was relatively small, and the number of preschoolers and first graders was not equally distributed. Future research with larger and more diverse samples could help validate and extend our findings. Second, participants in our study came predominantly from middle- or high-SES backgrounds. Literature consistently reports SES-linked disparities in quality and quantity of HLE (Buckingham et al., 2014). For example, children from low-income households often have fewer picture books and other educational resources at home compared to their higher SES peers. In our study, a substantial number of participants reported owning a Tiptoi® set at home. It might be that Tiptoi® is more likely to be found in households with greater financial resources, which are typically those of middle or high SES. Future studies should aim to include participants from a wider range of SES backgrounds to better understand the influence of SES on children's DHLE. Moreover, our study primarily examined the quantity and types of parental comments during digital storybook reading, but did not explore the quality or effectiveness of these interactions in promoting children's literacy skills or word learning. Future research could investigate the impact of different types of parental comments on children's word learning, or text comprehension. Further research on which features of Tiptoi® are cognitively engaging for children could provide a valuable perspective for research in this field. For instance, further analyses of children's interactions with Tiptoi® (Wildt, in preparation) suggest that preschoolers primarily engage in listening to theme-related content ("knowledge" icon), and playing interactive games ("games" icon), whereas engaging with the story itself by tapping on the text is utilized infrequently or not at all. Furthermore, our study was cross-sectional in nature, capturing a snapshot of parent–infant interactions at a single point in time. Longitudinal studies could offer valuable insights into parental engagement and comments during parent–child reading interactions over time. Additionally, it is worth noting that none of the dyads in our study were familiar with the books that were offered. Therefore, in future longitudinal research, it would be pertinent to investigate whether behavior-related talk might decrease while content-related talk increases as the features in the book become more familiar to both parents and children. Finally, future research on behavior-related talk could be expanded by comparing different book formats—printed books without interactive features, printed books with interactive features, hybrid and digital storybooks. Chiong and DeLoache (2012) demonstrated that interactive features such as "pop-up" elements can distract children's attention from the text itself, potentially hindering their ability to comprehend the relationship between the elements and their referents. Furthermore, another study found that young infants exposed to touch-and-feel patches in books exhibited decreased performance in subsequent word learning tasks, indicating potential disruptions in their learning process (Muhinyi et al., 2024). Similarly, Shinskey (2021) observed that two-year-olds' word learning was hindered when reading books with lift-the-flap features compared to those without, suggesting that tactile features distract attention from the book's content.

In sum, our study shows that with the rise of digital and hybrid book formats, traditional reading practices need to be expanded to incorporate new "rules" for these evolving media. This is evidenced by the numerous behavior-related comments through which parents' guide their children on how to use or not use the medium (e.g., where to tip with the digital pen), how to structure the reading process to access the book content, and in order to discuss the technology and its functions. Given these findings, it is recommended that educators and caregivers participate in the reading interaction, accompany the child in the practice of digital reading, and include explanations of functions, possibilities, and limitations of interaction with the book format. This is particularly important as hybrid media are often used autonomously by children, who need to be well-prepared to engage effectively with the reading medium. Hence, adults have a critical role to play in helping children navigate and become comfortable with the reading medium and its features, thereby fostering their digital literacy.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: Wildt, E. (2024, September 24). Reading with Digital Audio Pens (RAUPE). https://doi.org/10.17605/OSF.IO/WK4ZQ.

Ethics statement

The studies involving humans were approved by Prof. Dr. Peter F. E. Sloane, Head of the Ethic Committee, Paderborn University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

EW: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Technoference in infant feeding: the impact of maternal digital media use during breastfeeding on maternal attention and mother-infant interactions

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Introduction: Parents' sensitivity and responsiveness to their infants may be affected by the widespread availability and use of mobile devices. The present study examined the impact of maternal digital media use on maternal attention and the quality of mother-infant interaction during breastfeeding.

Methods: Mothers and infants ($n = 25$ dyads) participated in a within-subject experiment. Mothers breastfed their infants under one experimental and one control condition, counterbalanced across two laboratory visits. During the Digital Media condition, mothers watched a television show on a tablet. During the Control condition, mothers listened to classical music at ambient levels. Video records were later coded to assess maternal attention to the infant, tablet, or elsewhere and evaluate the quality of mother-infant interaction.

Results: There were more disruptions in maternal attention to the infant during the Digital Media ($M = 3.7$, $S.E. = 0.2$ per minute) vs. Control condition ($M = 1.7$, $S.E. = 0.2$ per minute, $p < 0.001$). The proportion of the meal duration mothers spent focused on their infant was significantly lower during the Digital Media ($M =$ 52.5%, $S.E. = 3.9$) vs. Control condition ($M = 83.9\%$, $S.E. = 4.0\%$, $p < 0.001$). Lower maternal attention to the infant was associated with lower maternal sensitivity to cues ($p = 0.03$) and cognitive growth fostering ($p = 0.002$), as well as lower infant clarity of cues ($p = 0.001$). Lower maternal attention was also associated with less socioemotional growth fostering ($p < 0.001$) and lower infant responsiveness to the mother ($p < 0.001$) regardless of whether digital media was present or absent, but during the Digital Media condition, mothers engaged in more socioemotional growth fostering ($p = 0.004$) and infants were more responsive to mothers ($p = 0.03$).

Discussion: The presence of digital media during infant feeding led to more interruptions to mothers' attention to their infants and the time mothers spent focused on digital media displaced time spent focused on their infants. The degree to which mothers were attentive to their infants vs. digital media was a more important predictor of most aspects of interaction quality than the mere presence of digital media.

KEYWORDS

digital media, technology use, technoference, mother-infant interactions, breastfeeding, infant feeding, attention, parent's personal technologies

1 Introduction

Caregiver responsiveness supports healthy development during infancy (Eshel et al., 2006). During responsive caregiver-infant interactions, caregivers recognize and contingently respond to infants' cues in predictable, developmentally appropriate ways that support behavioral regulation, socioemotional and cognitive growth, and autonomy. A caregiver's ability to sensitively respond to infant cues and needs is an important support for their infant's developing abilities to self-regulate and navigate discomforts. Over time, caregiver responsiveness helps children learn to regulate cognitions, emotions, and behaviors to accomplish their goals and adapt to the cognitive and social demands of specific situations (Berger et al., 2007).

During early infancy, feeding is a central form of caregiver-infant interaction because caregivers spend a significant portion of each day feeding their infants. Caregiver sensitivity and responsiveness during early feeding interactions support infants' abilities to self-regulate intake in response to physiological needs, which is an important foundation for the development of healthy eating behaviors and the prevention of rapid weight gain and obesity (Black and Aboud, 2011). Thus, promoting responsive caregiving behaviors—especially during early feeding interactions—is a key target for prevention and intervention efforts.

The responsiveness of today's parents may be affected by the widespread availability and use of personal technologies, such as smartphones and other mobile devices. It is estimated that 96% of U.S. adults own a mobile device, and parents engage with their mobile devices more than 60 times per day (Pew Research Center, 2024; Yuan et al., 2019). Technology and digital media use during infant feeding are common (Coyne et al., 2022), with 78% of mothers reporting they engage with a technological distractor (e.g., television, mobile device) during one or more feedings per day (Golen R. P. and Ventura A. K., 2015) and over one-third of mothers reporting they often or always watch television or use a mobile device while feeding their infant (Ventura et al., 2020). Caregivers of young infants may be particularly vulnerable to habitual technology use during interactions with their infants because the first few months postpartum are primarily dedicated to infant feeding and care, reducing caregivers' time and energy for self-care or other interests (Ventura et al., 2020).

While there are potential benefits of technology and digital media use for mothers, such as social connection, quick access to advice and information, and reduced feelings of stress and boredom (Coyne et al., 2022; Baker and Yang, 2018; McDaniel et al., 2012; Radesky et al., 2016; Wolfers, 2021), these benefits may come with a cost of disruptions to mothers' attention and, subsequently, mother-infant interactions. In particular, today's technologies are especially absorptive because they are always available, considered an "extension of the self," and capture and sustain users' attention through mechanisms such as notifications and autoplay (Campbell, 2008; Bayer et al., 2015). In addition, parents report that consumption of digital media on mobile devices (e.g., streaming television shows, engaging with social media) is typically more personal and interactive—and thus more immersive and absorptive—than non-technological forms of distraction (Radesky et al., 2016). Indeed, previous research illustrates that mothers who use technology and digital media during mealtime interactions with young children exhibit lower sensitivity and responsiveness to their infants' feeding and social cues (Golen R. P. and Ventura A. K., 2015; Ventura et al., 2023; Vanden Abeele et al., 2020; Ochoa et al., 2021; Tharner et al., 2022). Observational research employing covert observations of families in public settings (e.g., playgrounds and restaurants) illustrates parent device use is common and that parents are less responsive to their children's bids for attention and needs when using devices, reducing the quality of parent-child interactions and parent support for children's emotional wellbeing and safety (Elias et al., 2020; Lemish et al., 2020; Radesky et al., 2014; Wolfers et al., 2020). However, to date, most studies examining potential impacts of technological interference—or technoference—in mother-infant interactions are observational, making it unclear whether mothers' technology and digital media use during mealtimes directly decreases sensitivity, responsiveness, and the overall quality of the interaction or whether mothers who are already less sensitive and responsive are more likely to use technology.

We recently investigated the effect of maternal digital media use on the quality of feeding interactions within a laboratory-based experimental study of 25 mothers and their healthy full-term infants <6 months of age (Ventura et al., 2019). Mothers were asked to feed their infants under two conditions: (1) while watching a television show on a small tablet (Digital Media condition) and (2) while listening to classical music at ambient volumes (Control condition). Behavioral coding of video records of these feeding observations illustrated that mothers spent significantly less time engaging their infants in cognitive growth fostering experiences during the Digital Media vs. Control condition, suggesting that maternal digital media use negatively impacted one aspect of the quality of mother-infant feeding interactions. Mothers tended to be less sensitive to infant cues during the Digital Media than the Control condition, but this difference did not reach significance. However, a limitation of this study is that the data were analyzed on the level of condition. Examining individual differences in the extent to which mothers engaged with digital media vs. their infant during experimental feeding conditions may provide additional insights into associations between digital media use and mothers' sensitivity and responsiveness to infant cues. Thus, further research is needed to understand the extent to which mothers engage with technology and whether individual differences in mothers' attention to technology are associated with feeding outcomes.

The present study was a secondary analysis of the abovementioned experimental study (Ventura et al., 2019). We aimed to describe individual differences in how much mothers attended to digital media vs. their infant and the implications of these differences for the quality of feeding interactions. We hypothesized that mothers would spend a lower proportion of the meal duration focused on their infant when digital media was present vs. absent due to more frequent interruptions in maternal attention. We also hypothesized that displacement of attention to the infant with attention to digital media would be associated with lower maternal sensitivity and responsiveness to infant cues and fewer socioemotional and cognitive growth fostering behaviors, leading to overall lower quality interactions when mothers attended to digital media instead of their infant during feeding.

2 Materials and methods

2.1 Participants

Mothers and infants of either biological sex participated in this study ($n = 25$ dyads). Inclusion criteria for mothers were: (1) between 18 and 40 years of age and (2) did not experience any complications during pregnancy or birth that could lead to child feeding issues. Inclusion criteria for infants were: (1) born full-term (>37 weeks); (2) healthy; (3) 32 weeks of age or younger; and (4) not yet introduced to complementary foods and beverages. Recruitment happened primarily at Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) program offices, breastfeeding support groups, local pediatric offices, and social media (e.g., targeted Facebook ads). Potential participants were informed that the study's purpose was to "better understand infant feeding behaviors during typical feeding interactions;" study objectives and hypotheses were not disclosed to potential participants. Participants received a onesie and a book for their infant as compensation for participation. Informed consent was obtained from all participants before the study's start, and the university Institutional Review Board approved all study procedures.

2.2 Experimental design

This study employed a within-subject design, wherein each dyad served as its own control. Participants visited our laboratory on two separate days, separated by an average of 2.4 ± 1.8 days. Visits were scheduled for the same time each day to control for diurnal variations in intake and behavior. At each visit, mothers were asked to breastfeed their infants under one experimental or one control condition; conditions were counterbalanced across the two visit days.

1) During the Digital Media condition, mothers were asked to watch a 22-min-long television show on a small tablet (Apple iPad Air [Apple Inc., Cupertino, CA]) provided by the researchers. Mothers chose a sitcom from a list of pre-selected and pre-screened sitcom episodes free of commercials, violence, sexual content, and references to infants and feeding practices. If the feeding continued past the 22-min-long episode, a second episode of the selected show would autoplay immediately following the first. Mothers were allowed to hold the tablet or place it on a small table located in front of the feeding chair. When mothers were done feeding, they informed the research assistant, who then turned off the tablet.
2) During the Control condition, mothers were asked to listen to Rachmaninoff's Second Symphony based on previous research illustrating that classical music is preferred to silence to prevent discomfort or boredom (Blass et al., 2006). The research assistant set the volume to 40 decibels, which is considered an ambient sound level (Mehta et al., 2012). Any other potential technological or non-technological distractions were removed from the room. When mothers were done feeding, they informed the research assistant, who then turned off the music.

We elected to have mothers stream a television show on a mobile device because previous research suggests this is a common form of technology and digital media use during infant feeding (Golen R. P. and Ventura A. K., 2015; Ventura et al., 2020; Ventura and Teitelbaum, 2017); thus, this condition was deemed to be representative of one common way mothers report using technology and digital media during infant feeding. In addition, streaming a television show on a mobile device allowed for some standardization of mothers' exposure to digital media because a research assistant started the television show at the beginning of the feeding and the show ran for the entire duration of the feeding. Thus, duration of exposure was not dependent upon the mother deciding when to initiate or terminate use.

2.3 Protocol and measures

During the 3 days before the first visit, mothers were asked to keep a daily record of when and what their infants ate. Within these feeding diaries, mothers were also asked to indicate what else, if anything, they were doing while feeding their infants to provide the experimenters with a sense of the infant's normal feeding patterns and the mothers' typical level of technology use during feeding.

2.3.1 Feeding observations

Mother-infant dyads were observed during breastfeeding to control for effects of feeding mode (directly from the breast vs. from a bottle) and milk type (breast milk vs. formula) on feeding interactions. The feeding interaction was recorded with a Canon VIXIA HF M41 Full HD Camcorder (Canon, New York, USA). The camera was placed approximately 10 feet away from the dyad, ensuring both mothers' and infants' faces were visible. The research assistant waited behind a partition to minimize their influence on the interaction.

2.3.2 Objective assessment of maternal attention and the quality of mother-infant interactions

Two trained coders unaware of the study aims, research questions, and hypotheses rated maternal attention using a frame-by-frame behavioral coding approach within Noldus Observer XT 16.0 software (Observer XT; Noldus Information Tech, Heerlen, the Netherlands). Coders identified three mutually exclusive attention states, with codes capturing both the frequency and duration of each attention state:

1) Maternal attention to the infant, defined as the mother looking at the infant
2) Maternal attention to the tablet, defined as the mother looking at the tablet
3) Maternal attention elsewhere, defined as the mother looking elsewhere

Coders mainly attended to the mother's gaze but also used contextual cues to determine the direction of maternal attention. After coding, maternal attention state data was summarized as the total number of bouts for each state and the total duration (in minutes) spent in each state. Maternal attention state data was also summarized as bouts per minute of each state (calculated as total number of bouts/total meal duration) and the proportion of the meal duration spent in each state (calculated as [total duration in state / total meal duration] ∗ 100) to control for variations in meal duration. Bouts per minute represented the extent to which mothers' attention was sustained vs. interrupted during each condition, with greater bouts per minute corresponding to more interruptions to mothers' attention. Coders were trained by a study investigator (AKV) to reach inter-rater and intra-rater reliabilities of Kappa > 0.90. Inter-rater reliability was determined by common coding of 25% of study videos, and intra-rater reliability was determined by double-coding of an additional 25% of study videos. The average Kappa for inter-rater reliability was 0.98, and for intra-rater reliability was 0.97, indicating almost perfect agreement (McHugh, 2012).

A different set of two trained coders unaware of the study aims, research questions, and hypotheses scored the video records using the Nursing Child Assessment Caregiver-Child Interaction Feeding Scale (NCAFS) (Oxford and Findlay, 2015). This scale is validated for assessing the quality of early feeding interactions (breastfeeding, bottle-feeding, or solid food-feeding) for mothers and their infants aged ≤12 months during laboratory- and home-based feeding observations. This scale is comprised of 76 observable behaviors that are organized into six subscales, four of which describe the mother's contributions to the feeding interaction and two of which describe the infant's contribution (Oxford and Findlay, 2015). Maternal subscales include *Sensitivity to Cues* (possible score range = 0–16 with higher scores indicating greater sensitivity to infant cues), *Response to Child's Distress* (possible score range = 0–11 with higher scores indicating greater contingent responsiveness to infant distress), *Social-Emotional Growth Fostering* (possible score range = 0–14 with higher scores indicating greater engagement in behaviors that support infant social-emotional development), and *Cognitive Growth Fostering* (possible score range = 0–9 with higher scores indicating greater engagement in behaviors that support infant cognitive development). Infant subscales include *Clarity of Cues* (score range = 0–15 with higher scores indicating greater clarity of cues) and *Responsiveness to Caregiver* (score range = 0–11 with higher scores indicating greater engagement with and responsiveness to the caregiver). Before coding, raters were trained by a certified NCAFS trainer to reach 90% agreement using the NCAFS training materials (Oxford and Findlay, 2015).

2.3.3 Assessment of maternal demographics

Mothers were asked to complete a family demographic questionnaire at the end of the second visit to assess maternal sociodemographic characteristics and parity.

2.4 Data analysis

Using methods previously described (Golen R. P. and Ventura A. K., 2015; Ventura et al., 2019; Ventura and Teitelbaum, 2017), a qualitative analysis of feeding records was conducted to measure mothers' typical levels of technology use during feeding. These data were then used to determine the proportion of daily feedings during which mothers used technology (= [number of feedings wherein use of a technological device was reported/total number of feedings reported] * 100).

SAS v.9.4 (SAS Institute Inc., North Carolina, USA) was used to conduct all quantitative analyses. *A priori* power analysis conducted using G*Power version 3.1.9.7 (Faul et al., 2007) indicated that the study sample size was sufficient to achieve 80% power for detecting a medium effect at a significance level of $\alpha = 0.05$. Descriptive statistics were calculated to describe sample characteristics, and intraclass correlation (ICC) was used to assess the association between the proportion of the meal duration mothers spent focused on their infants during the Digital Media condition and the Control condition. Mixed linear models using SAS PROC MIXED were used to assess the effects of condition (Digital Media vs. Control), maternal attention to the infant (defined as the proportion of the meal duration the mother spent focused on the infant), and condition by maternal attention interactions on maternal sensitivity to cues, response to distress, social-emotional growth fostering, and cognitive growth fostering and infant clarity of cues and responsiveness to the mother. All models were controlled for infant age and the time elapsed since the infants' last feeding. A p-value < 0.05 was used to identify statistical significance of main and interaction effects.

3 Results

3.1 Sample characteristics

Table 1 summarizes sample characteristics. The average age of mothers was 31.2 ± 3.4 years (range = 24.9 to 36.1 years), and the majority (76%, $n = 19$) were primiparous. The majority of mothers in this study reported they held a bachelor's or graduate degree (68%, $n = 17$), 72% ($n = 18$) reported their annual family income level was ≥$75,000, 92% ($n = 23$) were married, and 80% ($n = 20$) identified as non-Hispanic white. The sample consisted of 14 female infants (56%) with an average age of 19.3 ± 6.4 weeks (range = 6.2 to 32.0 weeks). Most infants were exclusively breastfed (92%, $n = 23$), while the remaining two participants were fed breast milk and formula. The average proportion of typical feedings during which mothers reported using technology was 23% ± 17% of daily feedings (range = 0–83.3%).

3.2 Associations between technology use and maternal attention during mother-infant feeding interactions

Total meal duration ranged from 2.7 to 31.8 min and did not differ between the Control ($M = 14.0$, $S.E. = 1.3$ min) and Digital

TABLE 1 Sample characteristics ($n = 25$).

Mother characteristics	
Age, mean (SD) years	31.2 (3.4)
Parity, % (*n*) primiparous	76.0 (19)
Marital status, % (*n*) married	92.0 (23)
Education level % (*n*)	
Some college or vocational degree	32.0 (8)
College or graduate degree	68.0 (17)
Annual family income, % (*n*)	
$15,000–$34,999	4.0 (1)
$35,000–$74,999	12.0 (3)
$75,000 and above	72.0 (18)
Not reported	12.0 (3)
Race/ethnicity, % (*n*)	
White Alone, non-Hispanic	80.0 (20)
Black or African American, Hispanic	4.0 (1)
Native American Alone, non-Hispanic	4.0 (1)
Asian Alone, non-Hispanic	8.0 (2)
Hispanic White	4.0 (1)
Infant characteristics	
Sex, % (*n*) female	56.0 (14)
Age, mean (SD) weeks	19.3 (6.4)

Media ($M = 13.9$, $S.E. = 1.3$ min) conditions ($p = 0.86$). There were more interruptions to mothers' attention to their infants during the Digital Media vs. Control conditions, as indicated by significantly greater bouts per minute for time spent looking at the infant during the Digital Media ($M = 3.7$, $S.E. = 0.2$) vs. Control ($M = 1.7$, $S.E. = 0.2$) condition ($p < 0.001$). This difference between the Digital Media and Control conditions for the number of interruptions to mothers' attention to their infants is illustrated in Figure 1, which presents a data visualization for one representative dyad.

Table 2 shows the proportion of the meal duration mothers spent focused on the infant, tablet, or somewhere else in the room during both conditions. The proportion of the meal duration mothers spent focused on their infant was significantly lower during the Digital Media vs. Control condition; on average, mothers spent 52.5% ($S.E. = 3.9$) of the meal duration focused on their infant during the Digital Media condition, compared to 83.9% (S.E. = 4.0) of the meal duration focused on their infant during the Control condition ($p < 0.001$). However, as illustrated in Figure 2, it is notable that there was wide inter-individual variability in mothers' attentiveness to their infants during the Digital Media condition. There was a moderate association between the proportion of the meal duration mothers spent focused on their infants during the Digital Media condition and the Control condition (ICC = 0.59).

3.3 Associations between technology use, maternal attention to the infant, and the quality of mother-infant feeding interactions

Mixed linear models were used to examine effects of condition and maternal attention to the infant on maternal sensitivity to infant cues, responsiveness to infant distress, socioemotional growth fostering, and cognitive growth fostering, and infant clarity of cues and responsiveness to caregiver. Models with independent and interactive effects of condition and maternal attention to the infant were tested, but the interactions between condition and maternal attention to the infant were not significant in any model. Thus, models with independent effects of condition and maternal attention to the infant were retained for analysis.

No effect of condition was seen for sensitivity to infant cues ($p = 0.31$), but lower maternal attention to the infant was associated with lower sensitivity to cues across both conditions ($p = 0.03$; Figure 3). No effects of condition ($p = 0.64$) or maternal attention to the infant ($p = 0.36$) were seen for responsiveness to infant distress (Figure 4). Effects of both condition ($p = 0.004$) and maternal attention to the infant ($p < 0.001$) were seen for socioemotional growth fostering (Figure 5), with mothers engaging in greater socioemotional growth fostering during the Digital Media vs. Control condition, but the lower the mother's attentiveness to the infant, the less the mother engaged their infant in socioemotional growth fostering experiences. No effect of condition was seen for cognitive growth fostering ($p = 0.27$), but there was an effect of maternal attention to the infant, with lower maternal attention to the infant associated with less engagement of the infant in cognitive growth fostering experiences ($p = 0.002$; Figure 6).

With respect to infant contributions to the feeding interaction, no effect of condition was seen for infant clarity of cues ($p = 0.06$), but there was an effect of maternal attention to the infant, with lower maternal attention associated with lower infant clarity of cues ($p = 0.001$; Figure 7). Effects of both condition ($p = 0.03$) and maternal attention to the infant ($p < 0.001$; Figure 8) were seen for infant responsiveness to the caregiver, with infants showing greater responsiveness to their mothers during the Digital Media compared to the Control condition but lower maternal attention to the infant was associated with lower child responsiveness.

4 Discussion

The present study examined the impacts of maternal digital media use on mothers' attention to their infants and the quality of mother-infant interactions during infant feeding. We hypothesized there would be more frequent interruptions in mothers' attention to their infants during the Digital Media condition compared to the Control condition, leading to a lower proportion of the meal duration spent focused on the infant. Furthermore, we hypothesized that the displacement of mothers' attention to their infants by attention to digital media would be associated with lower

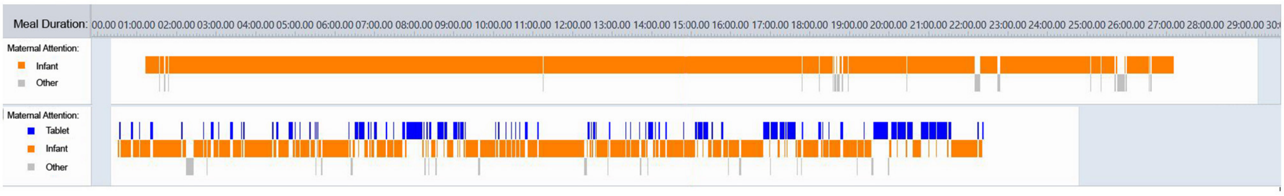

FIGURE 1
Data visualization of attention states. The X-axis provides the timeline for the meal duration in minutes, starting at 0:00 and continuing until the meal concludes. The Y-axis shows the two feeding conditions: Control (top row) vs. Digital Media (bottom row). The colored bars show where the mother's attention was focused (tablet, infant, other) and the duration of focused attention. Comparison of the two feeding observations illustrate there were more disruptions to maternal attention to the infant during the Digital Media compared to Control condition.

TABLE 2 Proportion of observation duration mothers spent in each attention state.

	Digital media condition		Control condition		F-value	*P*-value
	Mean (S.E.)	Range	Mean (S.E.)	Range		
Tablet	42.7 (3.2)	5.6–83.4	0	0	-	-
Infant	52.5 (3.9)	12.5–91.7	83.9 (4.0)	29.7–99.5	64.12	<0.001
Other	4.4 (2.4)	0.3–24.3	16.5 (2.5)	0.5–70.3	12.06	0.0025

Models controlled for infant age and time since last feeding.

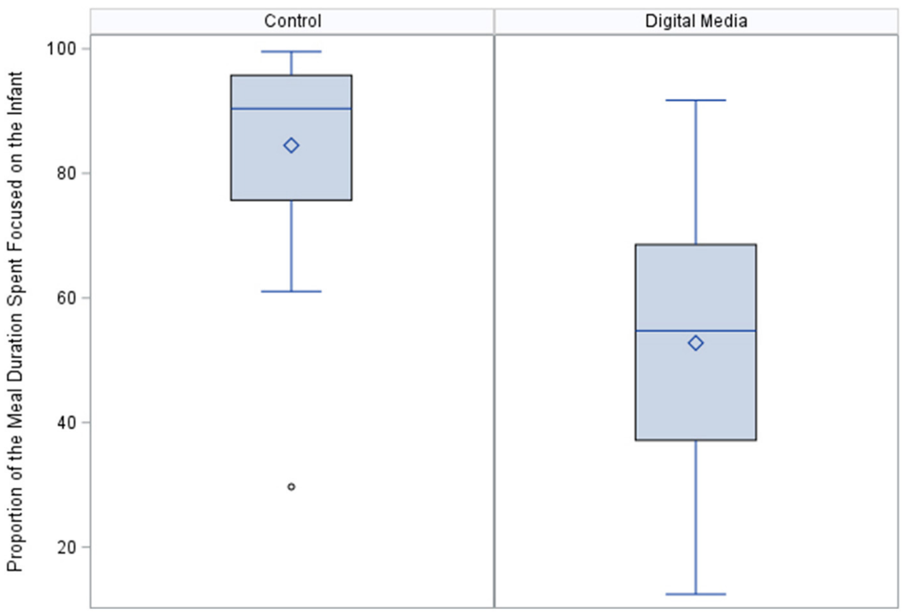

FIGURE 2
Box Plots Illustrating Inter-Individual Variability in Maternal Attention to Infant During the Control vs. Digital Media Conditions. The proportion of the meal duration mothers spent focused on their infants was significantly lower during the Digital Media vs. Control condition ($p < 0.001$).

maternal sensitivity and responsiveness, fewer socioemotional and cognitive growth fostering behaviors, and diminished quality of mother-infant interactions.

In line with these hypotheses, we found that attention shifts were significantly greater during the Digital Media vs. Control condition due to more interruptions in mothers' attention to their infants when digital media was present. The proportion of time mothers spent attending to their infants was significantly lower during the Digital Media than during the Control condition, illustrating that time spent attending to digital media directly displaced time focused on the infant. When both condition and maternal attention to the infant were examined as predictors of interaction quality, lower maternal attention to the infant was a more important predictor of some aspects of interaction quality than the mere presence of digital media. This was evidenced by findings that lower maternal attention to the infant, but not condition, was associated with lower maternal sensitivity to cues, cognitive growth

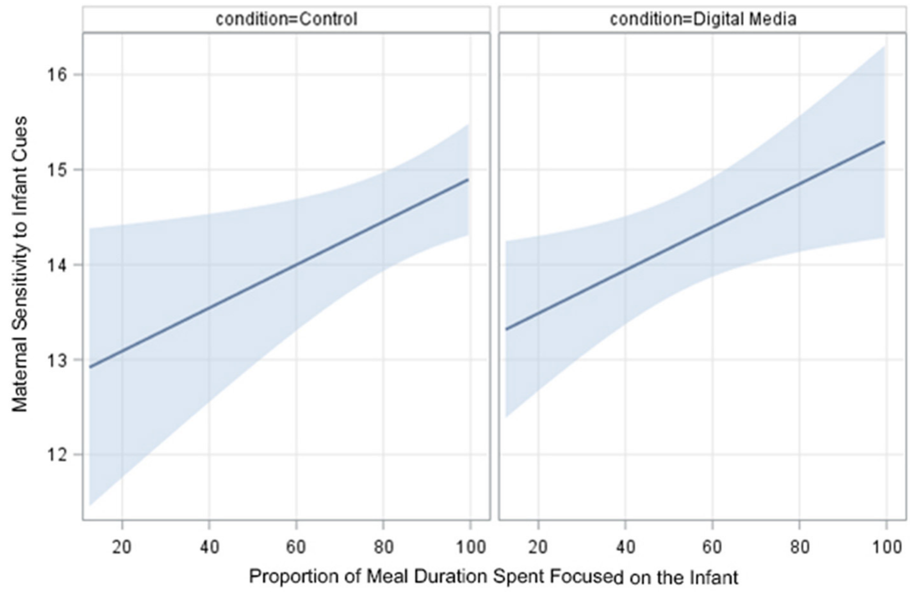

FIGURE 3
Effects of condition and maternal attention on maternal sensitivity to infant cues. No effect of condition was seen for sensitivity to infant cues ($p = 0.31$), but lower maternal attention to the infant was associated with lower sensitivity to cues ($p = 0.03$).

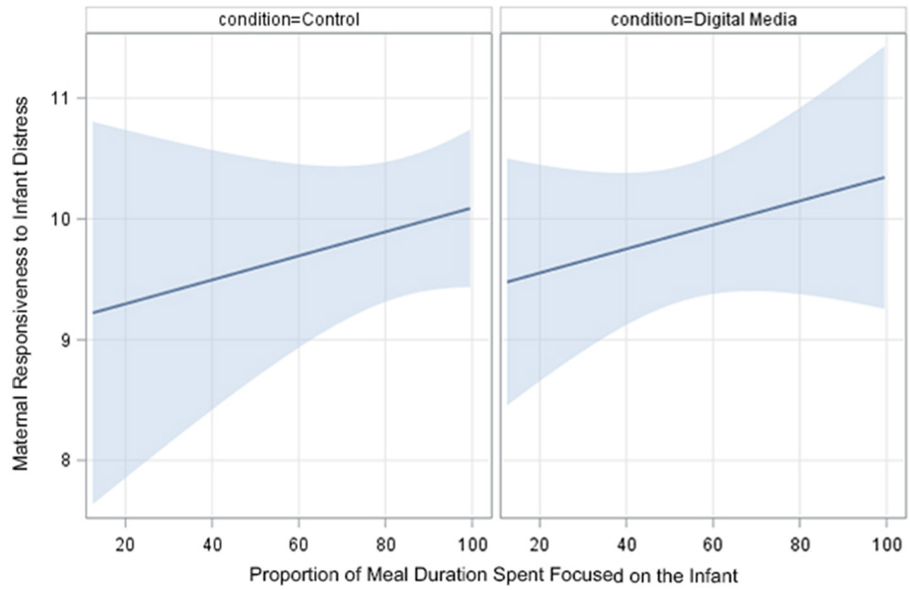

FIGURE 4
Effects of condition and maternal attention on maternal responsiveness to infant distress. No effects of condition ($p = 0.64$) or maternal attention to the infant ($p = 0.36$) were seen for responsiveness to infant distress.

fostering, and infant clarity of cues across both conditions. Lower maternal attentiveness to the infant was also associated with less socioemotional growth fostering and lower infant responsiveness to the mother, regardless of whether digital media was present or absent, but during the Digital Media condition, mothers engaged more in socioemotional growth fostering and infants were more responsive to their mothers than during the Control condition.

Our finding that the presence of digital media during infant feeding interactions led to more interruptions in maternal attention to the infant than when digital media was absent supports the idea that technoference may occur when technology and digital media are used during caregiver-child interactions (McDaniel and Radesky, 2018a,b; McDaniel and Coyne, 2016). In addition, our results indicated that time spent focusing on digital media directly displaced time spent focusing on the infant,

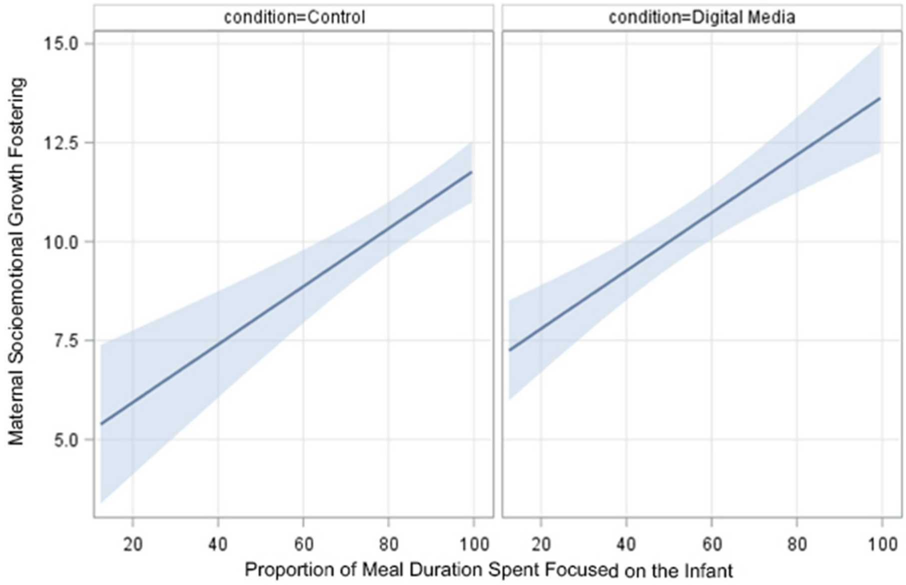

FIGURE 5
Effects of condition and maternal attention on maternal socioemotional growth fostering. Effects of both condition ($p = 0.004$) and maternal attention to the infant ($p < 0.001$) were seen for socioemotional growth fostering. Mothers engaged in significantly more socioemotional growth fostering during the Digital Media compared to Control condition. Lower maternal attention to the infant was associated with less socioemotional growth fostering experiences.

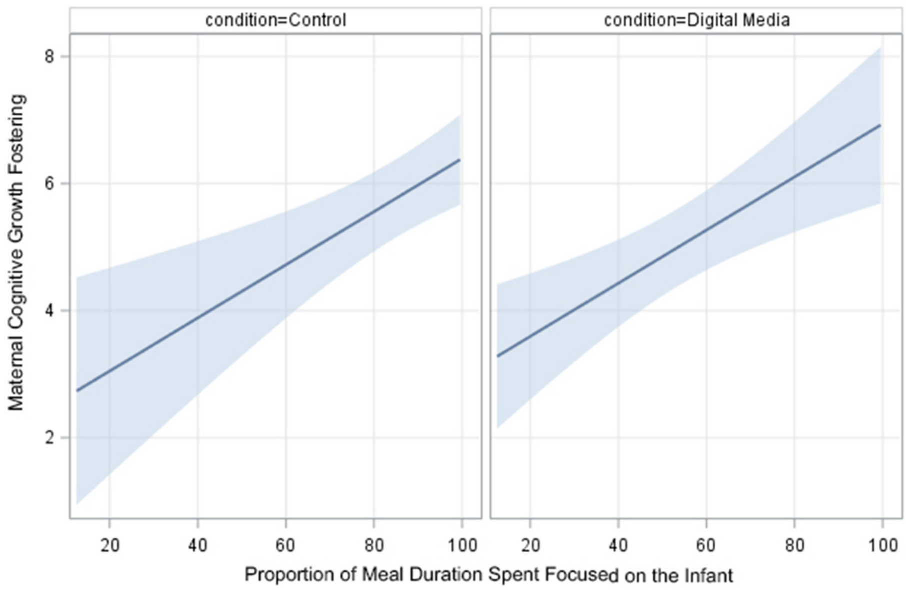

FIGURE 6
Effects of condition and maternal attention on maternal cognitive growth fostering. No effect of condition was seen for cognitive growth fostering ($p = 0.27$), but lower maternal attention to the infant was associated with less engagement of the infant in cognitive growth fostering experiences ($p = 0.002$).

which is consistent with findings from a recent experiment that used eye-tracking glasses to assess maternal gaze patterns objectively and illustrated that mothers spent more time focused on their smartphone than on their infants when asked to use their smartphone during breastfeeding (Nomkin and Gordon, 2021).

The potential implications of technoference and displacement of maternal attention can be understood within the context of the Barnard Model (Oxford and Findlay, 2015), which emphasizes that components of high-quality feeding interactions are caregivers' abilities to attend to infants' hunger, satiation, engagement, and disengagement cues and contingently respond to these cues in

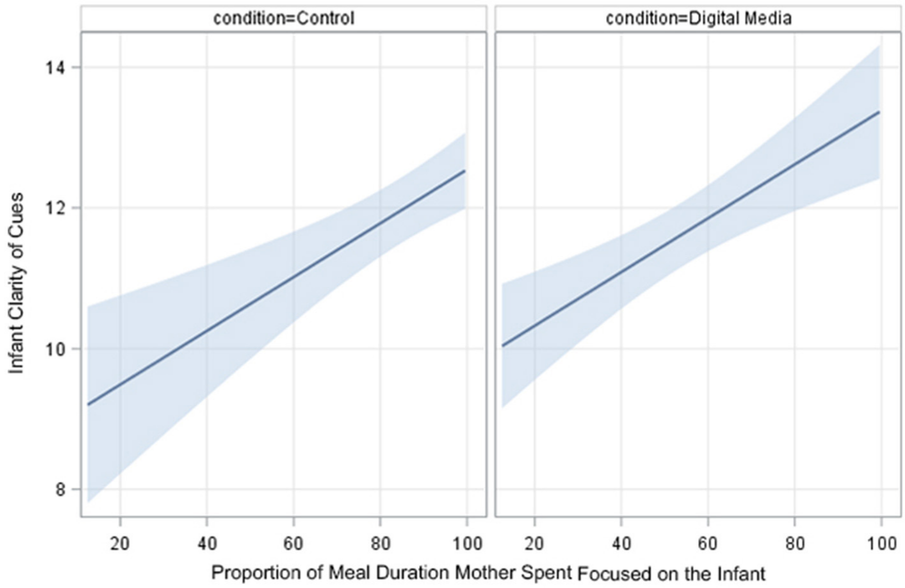

FIGURE 7
Effects of condition and maternal attention on infant clarity of cues. No effect of condition was seen for infant clarity of cues ($p = 0.06$), but lower maternal attention to the infant was associated with lower clarity of cues ($p = 0.001$).

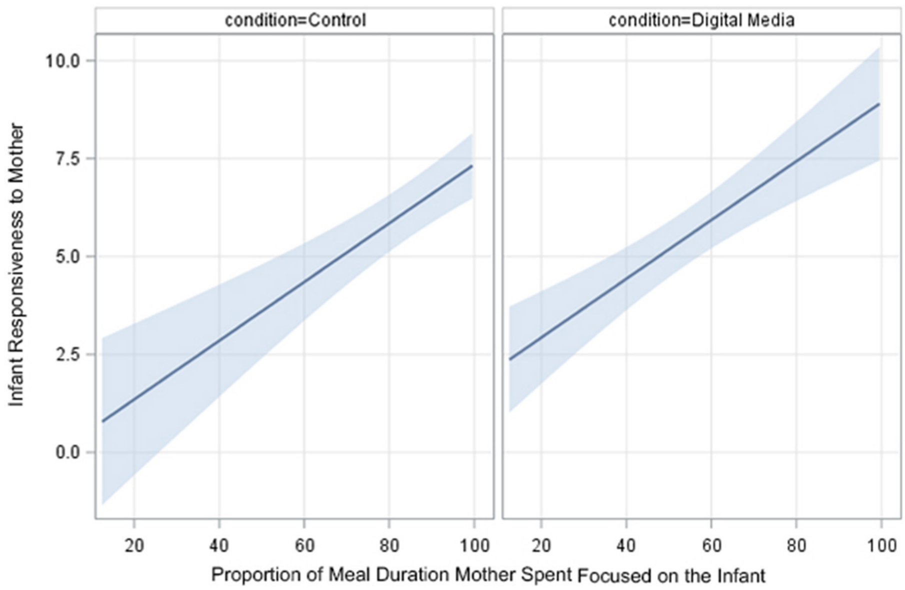

FIGURE 8
Effects of condition and maternal attention on infant responsiveness to caregiver. Effects of both condition ($p = 0.02$) and maternal attention to the infant ($p < 0.001$) were seen for infant responsiveness to the caregiver. Infants showed greater responsiveness to their mothers during the Digital Media compared to Control condition. Lower maternal attention to the infant was associated with lower infant responsiveness to the mother.

developmentally appropriate ways. Also important is the dyad's ability to adapt and engage in mutual regulation. Thus, lowered attentiveness due to technology and digital media use may lead caregivers to miss opportunities to recognize and respond to infant cues, engage their infant in socioemotional and cognitive growth fostering experiences, and create feeding environments supportive of healthy infant growth and development.

Indeed, lower maternal attention to the infant was associated with lower sensitivity to infant cues, socioemotional growth fostering, and cognitive growth fostering, suggesting the extent to which mothers engage with digital media, and not just the mere presence of digital media, may reduce their sensitivity to infant cues and their likelihood of engaging their infants in socioemotional and cognitive growth fostering experiences during feeding interactions.

These findings are consistent with previous observational research illustrating maternal technology and digital media use during infant feeding and care interactions is associated with greater use of non-responsive feeding practices (e.g., lack of involvement in feeding), less joint attention, and lower sensitivity and responsiveness to children's cues (Golen R. P. and Ventura A. K., 2015; Ventura et al., 2020; Golen R. B. and Ventura A. K., 2015; Ventura et al., 2023; Vanden Abeele et al., 2020; Ochoa et al., 2021; Tharner et al., 2022; Ventura and Teitelbaum, 2017; Vik et al., 2021). Previous experimental studies similarly illustrate that mothers' technology and digital media use decreases attentiveness, sensitivity, and responsiveness to their children (Nomkin and Gordon, 2021; Konrad et al., 2021; Krapf-Bar et al., 2022). However, we did not see associations between maternal attention and responsiveness to infant distress (e.g., crying), possibly because infant distress is a potent stimulus for mothers (Bell and Ainsworth, 1973). Thus, mothers' responsiveness to these potent cues may be less affected by the presence of technological distractions or low general attentiveness.

Of note, during the Digital Media condition, we observed wide variability in mothers' attentiveness to the tablet, with some mothers attending to the tablet for ∼6% of the meal duration and others attending for ∼83%. Thus, some mothers were more impacted by the presence of digital media than others. Previous research highlights several possible reasons for individual differences in mothers' reactivity to the presence of technology. For example, mothers may have differing views on engagement with technology and digital media, with some more relaxed and others more concerned about when and how they use technology and digital media in the presence of their children (Radesky et al., 2016; Oduor et al., 2016). In addition, some mothers may engage with technology and digital media more frequently because they experience benefits of technology and digital media use, such as feelings of social support from the family and friends they interact with online (McDaniel et al., 2012). However, technology and digital media use may also serve as a coping mechanism, as suggested by findings that parents who feel stressed by difficult interactions with their children report using technology to withdraw and cope (McDaniel and Radesky, 2020). Furthermore, mothers experiencing more depressive symptoms report more problematic device usage and greater perceptions of technoference during parenting compared to mothers experiencing fewer depressive symptoms (Newsham et al., 2020). Thus, not all mothers are similarly impacted by the presence of technology or are at risk for technology-induced disruptions in their interactions with their infant, and variability in mothers' absorption with digital media likely reflects variability in mothers' motivations and perceived benefits from engaging with technology and, thus, willingness to engage with it during feedings. These findings support the possibility that targeted interventions aimed at mothers at greater risk for having their mother-infant interactions negatively impacted by technology and digital media are needed to support infants' socioemotional and cognitive growth.

We also noted associations between maternal attention and infant contributions to the feeding interaction, with lower maternal attention to the infant associated with lower infant clarity of cues and responsiveness to the caregiver. Associations between maternal attention to the infant and infant clarity of cues and responsiveness could represent learned responses on the part of the infant, wherein infants who have learned their mothers are not attentive communicate less and are less responsive to their mothers during mealtime interactions. This interpretation aligns with prior research suggesting that maternal attentiveness shapes infant communicative behaviors (Ainsworth et al., 1991) and is consistent with transactional models of parent-infant interaction, which propose that infants adapt their behaviors in response to repeated patterns of caregiving (Sameroff, 2009). On the other hand, these findings may also represent a learned response on the part of the mother, such that mothers who find their infants' signals unclear or find that their infants do not respond to them are likely to be less engaged during feeding interactions (Goldberg, 1978).

It was also notable that mothers engaged their infants in more socioemotional growth fostering, and infants showed greater responsiveness to their mothers during the Digital Media compared to the Control condition. Previous research suggests that infants' greater responsiveness could be adaptive on the part of the infant (Ventura et al., 2023; Radesky et al., 2014; Ventura et al., 2019; Myruski et al., 2018), meaning that infants responded to the presence of digital media by trying to get their mothers to be more engaged in the interaction. For example, toddlers of mothers who used television or mobile devices during family mealtime interactions showed greater strength of early and subtle satiation cues compared to children of mothers who did not use television or mobile devices (Ventura et al., 2023), which aligns with other observational research illustrating that children responded to parent device use during family mealtime interactions by amplifying their bids for attention (Radesky et al., 2014). Furthermore, an experimental study of 7–24-month-olds found that infants increased the frequency of their social bids for attention when mothers disconnected from a play interaction to engage with a mobile device (Myruski et al., 2018). Similarly, mothers' increases in socioemotional growth fostering during the digital media compared to control condition may have been responsive to infant behaviors or an adaptive response to the presence of digital media (e.g., Coyne et al., 2022). Of note, the NCAFS socioemotional growth fostering subscale includes items that assess whether the mother changes her facial expression, smiles, and laughs during the feeding; thus, it is possible that use of enjoyable digital media elicited these behaviors, which could explain higher socioemotional growth fostering scores during the Digital Media vs. the Control condition. Additional experimental and longitudinal research is needed to understand possible learned and adaptive responses to technology and digital media use during infant feeding interactions and the long-term implications of these responses for infant development.

Study limitations may limit the generalizability of our findings, but also provide possible avenues for future research. Our sample was small, predominantly white, and limited to breastfeeding mothers. In addition, this study occurred within a controlled laboratory environment, not a naturalistic home environment. Exposure to digital media was dictated by our study design but was not typical for some dyads. A strength of this approach is that it allowed us to examine causal impacts of digital media on mother and infant behaviors. However, digital media use during feeding may have been more familiar and comfortable for mothers with typically high use and less familiar and comfortable for mothers with typically low use, which may have differentially impacted the effects of digital media use on mother and infant behaviors. Within a previous study (Ventura et al., 2019), we did not find that mothers' typical technology and digital media use moderated effects of the digital media condition on mothers' behaviors, but further research with larger, more diverse samples, conducted in home environments, and with additional consideration of typical technology and digital media use is warranted. Video coders were unaware of study research questions, aims, and hypotheses, but it was not possible to mask the experimental conditions to which mothers were exposed; thus, coders may have been biased by their own views on technology and digital media use and how it might influence mother-infant interactions. Within the present study, mothers were asked to watch a television show on a mobile device; this condition was selected because mothers most frequently report watching television during infant feeding (Golen R. P. and Ventura A. K., 2015; Ventura et al., 2020; Ventura and Teitelbaum, 2017), but mothers also frequently text and use mobile apps on smartphones during feeding (Ventura et al., 2020). Texting and use of mobile apps may be more interactive and immersive experiences than watching a television show on a mobile device; thus, further research is needed to examine whether the present study's findings generalize to other types of digital media and mobile device use. Further research examining the implications of different types of mobile device use will provide additional insights regarding the potential impact of maternal technology and digital media use during infant feeding interactions. Finally, this study was cross-sectional and thus can only demonstrate the short-term effects of maternal digital media use on maternal attention and mother-infant feeding interactions. Longitudinal research is needed to understand potential long-term effects on infant development.

In conclusion, the present study demonstrated that maternal digital media use during infant feeding was associated with significant disruptions in maternal attention and lower maternal attention was associated with lower sensitivity to infant cues and reduced engagement in socioemotional and cognitive growth-fostering behaviors. For most dimensions of mother-infant interaction quality, displacement of maternal attention onto digital media was a stronger predictor of interaction quality than the mere presence of digital media. Given the variability in mothers' attentiveness to digital media, future research should explore individual differences and underlying factors contributing to resilience or susceptibility to technological distractions. Additionally, targeted interventions may be necessary to support mothers more adversely affected by digital media use, enhance the quality of mother-infant interactions, and promote infants' socioemotional and cognitive growth. Further studies with larger, more diverse samples and in naturalistic settings are needed to generalize these findings and examine the long-term developmental impacts of maternal digital media use during infant feeding.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by California Polytechnic State University Institutional Review Board (IRB). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants (for mothers) and by the participants' legal guardians/next of kin (for infants).

Author contributions

EM: Formal analysis, Investigation, Writing – original draft, Writing – review & editing. TR: Formal analysis, Investigation, Writing – original draft, Writing – review & editing. AV: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Digital media in early childhood: risk factors for online harm and psychosocial correlates

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Introduction: Early and middle childhood are times of rapid development, and critical periods for laying the foundations of life-long trajectories of socioemotional well-being. High levels of screen media use are of growing concern to parents, health professionals, and researchers, given the increasing body of research demonstrating detrimental impacts of excessive screen use in young children. One particular consequence is the risk that children encounter online content or experiences that are upsetting or distressing, including exposure to inappropriate or adult content, cyberbullying, and interactions with strangers that they don't know.

Methods: This research examined experiences of online harm reported in a sample of 8-year-old children, with a focus on identifying risk factors and psychosocial correlates of online harm. Data for this study were collected from children and their mothers as part of the prospective longitudinal Growing Up in New Zealand (GUiNZ) study (n = 4,920 children with data at age 8). Children were assessed at 4.5-years-old and 8-years-old.

Results: The findings of this research indicate that approximately a quarter of New Zealand children have experienced online harm (that is, have encountered online content that worried, upset, or bothered them) by the age of 8. Our analysis indicates that children with behavioral difficulties are at greater risk of online harm, as are children with more personal devices. Experiences of online harm were found to be negatively associated with child self-worth and positively associated with depressive symptoms.

Discussion: Findings highlighting the critical importance of considering online harm as a contributing factor to child and youth well-being and mental health in our media-saturated world. Our results also point to practical solutions for parents, such as limiting the number of personal media devices that children have in early and middle childhood.

KEYWORDS

online harm, online risk, Growing Up in New Zealand, mental health, self-worth, digital media

Introduction

The internet has become increasingly integrated into our daily life, with approximately 95% of New Zealanders using it at home daily (InternetNZ, 2022; Pacheco and Melhuish, 2020a). While offering various affordances such as access to information, educational resources, entertainment, and social connections, it is also a conducive environment for online risks. These risks include exposure to inappropriate and/or explicit content, cyberbullying, engaging with developmentally inappropriate materials or games, and inappropriate marketing and advertising. However, research examining these online risks have disproportionately focused on school-age children and adolescents, whereas exposure to online risks likely occurs much earlier in life with young children being particularly vulnerable. Recently concerns about children's access and exposure to inappropriate content have surged (see InternetNZ, 2022; Stoilova et al., 2021), yet there remains a paucity of research examining the frequency and impact of young children's exposure to online risks globally and in New Zealand. This paper aims to address this gap by exploring online risk and online harm when children are 8 years old.

Online risk and online harm

Online *risks* are described as the hazards or dangers individuals encounter while online. In contrast, online *harm* is the consequence or negative impact that results from exposure to these online risks (Livingstone, 2013). The spectrum of online risks is broad, with individuals either actively seeking out such risks or inadvertently stumbling upon them through algorithmic and socio-technical designs inherent in online platforms. Online risks have been categorized in terms of content (e.g., viewing inappropriate or illegal material), contact (e.g., unwanted, harassing, or harmful communication), and conduct (e.g., revealing or misusing personal information or illegally downloading content). New Zealand children aged 9–17 specifically reported being contacted by a stranger, having either seen or received media that made them feel uncomfortable, having felt under pressure to send photos or other information about themselves, and having accidentally spent money online that they did not mean to spend (Pacheco and Melhuish, 2020a).

Online contexts, including chat rooms, video games, and social media, provide an environment conducive to perpetrating and experiencing harm given the anonymity and lack of regulation often inherent to these applications. Most online platforms are not child-centered by default, rather they are based on industry incentives that prioritize engagement and advertising revenue at the expense of children's safety and privacy (Radesky and Hiniker, 2022). For example, Papadamou et al. (2020) found an alarming number of disturbing and inappropriate videos that were recommended when browsing preschooler-oriented content on YouTube. The monetization opportunities on YouTube and other platforms as well as the advent of algorithmic content creation are likely contributors to this issue (Papadamou et al., 2020). Given there may be less parental monitoring of children's online activities compared to offline activities (e.g., Ellonen et al., 2021; GerŽičáková et al., 2023), understanding the risks and harms associated with children's online activities is paramount.

Once exposed to online risks, the factors influencing an individual's vulnerability to harmful consequences remain unclear. Researchers have argued that children who are vulnerable to offline risks are also more likely to be vulnerable to exposure to online risks (Livingstone, 2013). Similarly, factors that contribute to vulnerability and protection offline may also be relevant online. Given that internet use begins at an early age, and that young children's internet use predominately occurs in the family home (Pacheco and Melhuish, 2020a), this study investigated the role of child characteristics, parenting styles and behaviors, and digital media use factors related to young children's susceptible to exposure to online risks and, consequently, online harms—particularly over time.

While previous research has tended to focus on exposure to online risks and the psychosocial outcomes associated with this exposure, in this study we move to examining online *harm* and the psychosocial consequences of this harm. It is important to note that exposure to online risks is a precursor to online harm, not a determining factor. Not every exposure to online risk will lead to harm. As described above, further research is required to identify the moderating factors determining whether risk eventuates to harm in an online context.

Child characteristics

Research led by the European Kids Online network of over 25,000 children aged 9–16 and their parent found that 41% of children had been exposed to an online risk with exposure increasing considerably with age (Livingstone et al., 2011). However, with increasing numbers of younger children watching videos and playing games online (Pacheco and Melhuish, 2020a), they are not immune from online risks. Exposure to online risk has also been shown to differ for boys and girls. In a cross-national study of young people aged 15–30 in the United States and Finland, Keipi et al. (2015) found that boys were more likely to report viewing online content related to self-injury and suicide, whereas girls were more likely to report viewing online content related to pro-eating disorders. Similar gender differences in exposure to online risks have been identified in younger people (aged 11–16) across 25 European countries (Almenara et al., 2016). With the exception of privacy risks, Livingstone and Helsper (2008) found that boys aged 12–17 were significantly more likely to encounter all types of online risks compared to same age girls. How the associations between child age, gender and exposure to online risk manifest during early childhood when young children are first exploring their online worlds, is unknown.

Child temperament, including emotional and behavioral traits have been shown to be related to children's use of media (Coyne et al., 2017; Radesky et al., 2016; Thompson et al., 2013; Zimmerman and Christakis, 2007). Increased socio-emotional difficulties in children such as frequent crying, irritability, and behavioral difficulties have led some parents to use media to calm their child down (Radesky et al., 2016) or cope with and control their child (Elias and Sulkin, 2019; Tang et al., 2018). During this process of regulation, children may not be supervised, with the parent opting to give the child (and themselves) space to regulate from a heightened and intense emotional experience. Inadvertently, this unsupervised time online may contribute to vulnerability to online risks, to the extent that children use this unsupervised time to engage in risky online behavior. Further, increased autonomy and boundary-testing related to children's temperament during early childhood may also influence the types of online experiences and activities children partake in. Indeed, some children have stronger risk-taking propensity which may be seen in both online and offline environments (Livingstone, 2013). However, we are yet to understand how emotional and behavioral traits of young children relate to their exposure to online risks, and consequently, online harm. Further investigation of these associations will improve our understanding of some of the early individual factors contributing to young children's vulnerability to online risks.

Parenting styles and behaviors

As the majority of young children's media use occurs in the home, parents are the gatekeepers of children's media use. With greater attention and concern being shown for children's access and exposure to inappropriate content (InternetNZ, 2022; Stoilova et al., 2021), parents may seek out ways to regulate their child's online activities. Media-specific parenting, such as parental mediation of media represent various strategies that parents use to maximize the positive benefits and reduce vulnerability to online risk and harm (Livingstone et al., 2017). Mediation strategies for the internet specifically include active co-use (e.g., talking and providing guidance to children about online activities, in real time in front of the computer or in the same room), technical restrictions (e.g., filtering, monitoring, or blocking risky online activities or material), interaction restrictions (e.g., setting rules restricting or banning certain peer-peer activities), and parental monitoring (e.g., covert or overt checking of children's online activity) (Livingstone and Helsper, 2008). Theoretically, parental mediation should reduce young people's exposure to online risks, however, research examining these associations in middle childhood and adolescence has been mixed. Some researchers report that providing a rationale for screen time and content restrictions reduced 10–14-year-olds exposure to online media violence (e.g., Fikkers et al., 2017), whereas others have found no association between commonly practiced mediation strategies such active co-use and 12–17 year olds' exposure to online risks (e.g., Livingstone and Helsper, 2008). These mixed findings may be explained by parents' involvement in their child's activities. More specifically, parents typically use more parental mediation strategies for younger children (Livingstone and Helsper, 2008), suggesting greater involvement in their online activities, thereby reducing exposure to online risks. Conversely, low parental involvement may heighten a child's vulnerability to online risks. To our knowledge, no studies have investigated parental involvement in children's activities alongside media-specific and general parenting behaviors as potential predictors of children's exposure to online harm.

General parenting styles, characterized by dimensions of parental responsiveness, warmth, demandingness, and control (Baumrind, 1991) have been studied in the context of children's and parent's media-related behaviors. Several studies have shown that primary school age children from permissive families (high warmth, low demand) were >5 times more likely to watch >4 h of television per day (Jago et al., 2011) and have the highest internet usage (Valcke et al., 2010), whereas older (10–11 year olds), primary school age, and younger (5 year olds) children from authoritarian (low warmth, high demand) and authoritative (high warmth, high demand) families had lower levels of screen exposure (Jago et al., 2011; Veldhuis et al., 2014) and internet use (Valcke et al., 2010). However, these associations between general parenting styles and children's vulnerability to online risks are only assumed through increases or decreases in time spent online. It is well recognized in the literature that focusing on screen time, without including variables related to the quality of screen content, seriously constrains our understanding of the types of activities that are more or less likely to contribute to short- and long-term online harm (see Stoilova et al., 2021 for a review). Notably, parent-child interactions characterized by warmth and open communication about internet use and content may help parents to scaffold and teach their child about e-safety, reducing potential exposure to online risks (Cho and Cheon, 2005).

Family context

Beyond parenting styles and behaviors, other aspects of children's home environment may influence their exposure to online harm. In this research, we examined socioeconomic status (SES) and the presence of older siblings as predictors of harm. While there is a relation between SES and adverse life events generally, research is mixed on whether SES influences the likelihood of online harm. Skogen et al. (2022) found that low SES was associated with greater frequency of negative experiences on social media, including negative acts, exclusion, and unwanted attention from others, within high school students. However, other studies have found no association between SES and cybervictimization (Rodríguez-Enríquez et al., 2019).

Research on the influence of siblings on exposure to online risks and harm is also still in its infancy. Despite a body of research examining peer influences on online risk (e.g., Festl, 2021; Mascheroni et al., 2015), research has yet to determine the influence of siblings. Ólafsson et al. (2018) found that while the presence of older siblings increases the range and number of online activities pursues by younger siblings, there was no increase in risk for harm. However, from a social learning perspective, younger siblings may observe and model the online behaviors of their older siblings, potentially imitating risky online behaviors. This modeling could make younger siblings more vulnerable to online harm. Given the lack of research on the presence of older siblings in relation to experiences of online harm, this was investigated as a potential predictor of online harm in the present research.

Digital media use factors

With greater accessibility and affordability of mobile technologies, personal ownership of devices is occurring earlier in childhood. Recent evidence from New Zealand's Netsafe suggests that cellphone ownership increases with children's age; however, less is known about ownership of other mobile devices such as tablets. Rideout and Robb (2020) reported that 48% of 0–8-year-olds in the United States own their own mobile device (either a tablet, smartphone, iPod touch or similar). The type of device owned by a child may contribute to exposure to online risks. For instance, gaming devices are typically an activity that children do independently of their parents. These devices may be set up in the child's room, or in a separate area of the living space, where regular monitoring is difficult or infrequent. Conversely, cellphones and tablets used by the family (or owned by the parent) may be restricted to communal areas of the house. Research has shown that children aged 8 to 12 were more likely to engage with screen for longer periods of time if they had a device set up in their bedroom (Lee et al., 2018), potentially putting them at higher risk for being exposed to risks online.

Guidelines published by child health authorities, such as the American Academy of Pediatrics, advocate restricting screen use to video chatting for children until 18 to 24 months of age; limiting children aged 2–5 years to an hour or less of screen time per day; and emphasizing parental regulation and monitoring of young children's media use (Hill et al., 2016). However, a recent meta-analysis of 95 studies and screen time data for 89,163 children revealed that adherence to these recommendations is low, with only 1 in 4 children under 2 years and 1 in 3 children between 2 and 5 years following suggested guidelines (McArthur et al., 2022). Increased time spent online affords young children the opportunity to develop digital skills and reap the benefits of the internet. However, concurrently, excessive time spent online increases the potential for encountering online risks and harm. While various factors related to digital media use have been documented, there remains limited understanding of which specific factors contribute to young children's susceptibility to online risks and harm.

Consequences of experiencing online risk

With young children's media use continually increasing, the propensity for exposure to online risk is also ever increasing. Recent research (Pacheco and Melhuish, 2020a; Stoilova et al., 2021) has called for more research to examine online risks in young children. As noted earlier, with online risks comes the potential for online harm. A recent rapid review of the literature on online risks and wellbeing demonstrates that considerable attention has been given to harmful effects of cyberbullying, online harassment, and sexual online activities on the psychosocial outcomes of school-age children and adolescents (see Stoilova et al., 2021 for a review). The findings typically demonstrate that online risks are differentially associated with psychosocial outcomes. More generally, young people aged 15–30 years across three European countries and the United States described feeling lower levels of happiness after exposure to negative content online (Oksanen et al., 2016). Further, research conducted with adolescents aged 10–17 years indicated that 25% described feeling upset or extremely upset after exposure to harmful content online while 19% felt stressed in the days following exposure to online risks. While our understanding of the associations between online risk and psychosocial outcomes is expanding, it is still limited to a focus on school-age and adolescent populations; very little is known about the potential long-term psychosocial outcomes associated with experiencing online harm for younger children.

The current research

In this research we go beyond measuring *online risks*, such as exposure to adult content, to measure *online harm*, the distress caused by exposure to online risks (Livingstone, 2013). The vast majority of previous research on online risks and online harm has focused on teenagers and adolescents (from age 9 onwards; e.g., Machimbarrena et al., 2018; Smahel et al., 2020). Given the rapidly growing prevalence of screen media use in younger children, including internet use, we aimed to understand how many children experience online harm by the age of 8. Using a large, prospective sample of children, we examined vulnerability and protective factors for experiencing online harm by age 8, spanning aspects of child characteristics, parenting styles and behaviors, and digital media use factors. We also examined the psychosocial correlates of experiencing online harm, including depressive symptoms, emotional symptoms, and self-worth. Our specific research aims were as follows:

1. To understand the frequency with which children have had experiences on the internet that worried or upset them (online harm) by age 8.
2. To determine vulnerability and protective factors for children experiencing online harm.
3. To determine concurrent associations at age 8 of online harm with depressive symptoms, emotional adjustment, and self-worth.

Materials and Methods

Participants

The data used in this analysis came from the *Growing Up in New Zealand* (GUiNZ) study, a prospective longitudinal study following more than 6,000 New Zealand children since before birth. A total of 6,822 pregnant women with an estimated delivery date between April 2009 and March 2010 were recruited from the Auckland, Counties Manukau, and Waikato District Health Board regions of New Zealand. See Morton et al. (2010, 2013, 2015) for a detailed description of the study's design, conceptual framework and recruitment procedures. In these analyses, we use data collected at two assessment points, when children were aged 4.5-years-old and 8-years-old. Data was collected using face-to-face interviews with mothers at the 4.5-year assessment point, and through face-to-face interviews with mothers and children at the 8-year assessment point. At both time points Computer Assisted Personal Interviews (CAPI) were conducted by trained interviewers, usually in the child's home.

Measures

Child-reported measures

Online harm (age 8)

At age 8, children were asked to self-report on harmful internet experiences. They were asked "*What have you come across on the internet that has worried, bothered, or upset you, or that you don't like seeing?*" Response options were:

- Nothing,
- Site, games, or images that are meant for grownups,
- Bullying (of you or others),
- Advertising on websites,
- Someone I don't know/or shouldn't talk to,

- Peer pressure to watch particular content, play certain games, follow particular sites or YouTubers,
- Buying something by mistake,
- Don't know.

Children could select as many types of online harm as was applicable.

Child depressive symptoms (age 8)

Child depressive symptoms at age 8 were measured with the child-administered Center for Epidemiologic Studies Depression Scale (CESD-10; Fendrich et al., 1990; Andresen et al., 1994). This scale includes 10 items that ask children to report on how much they "felt this way during the past week". Example items are "I felt down and unhappy", "It was hard to get started doing things", and "I felt happy" (reverse-coded). All items were rated on a 4-point scale from *Not at all* (0) to *A lot* (3). A total score out of 30 was calculated by summing across the 10 items (after reverse coding 2 items). Cronbach's alpha across the 10 items in the present sample was 0.69.

Child self-worth (age 8)

Child self-worth at age 8 was assessed using the child-reported global self-worth subscale of the Self-Perception Profile for Children (SPPC; Harter, 2012). This subscale has 6 items that are each scored a value between 1 and 4. All scale items are phrased as follows: "*Some kids like the kind of person they are BUT other kids often wish they were someone else.*" Children select which option is most like them, and then indicate whether the statement is "*Really true for me*" or "*Sort of true for me*". A self-worth score was calculated by summing the 6 items. Reliability and validity of the scale have been demonstrated by Harter (1999), with an internal reliability of 0.8.

Personal media devices (age 8)

At the 8-year assessment, children were asked to report whether or not they had their own personal device (yes or no). Those who answered yes were then asked to indicate whether or not they owned each of the following types of devices: a tablet (e.g., iPad), a desktop computer or laptop, a TV, a smartphone (e.g., an iPhone or a Samsung Galaxy), a gaming console (e.g., an Xbox, PSP, or Playstation), an iPod, iPod touch, or MP3 player, a kindle or other eReader, a Smart watch, a virtual reality headset, a camera (also includes digital and GoPro), and other. A total score was created to indicate the total number of personal devices a child owned by summing across devices, with scores of 0 for children who indicated they did not own a personal device.

Parent-reported measures

Child emotional symptoms (age 4.5)

Child emotional symptoms at age 4.5 were measured using the Emotional Symptoms subscale of the parent-report version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). This subscale includes the five items of: "Often complains of headaches", "Has many worries", "Often unhappy, downhearted", "Nervous or clingy in new situations", and "Many fears, easily scared". All items are rated by parents as Not true (0), Somewhat true (1), or Certainly true (2). A total score was calculated as the sum of these 5 items. These 5 items had a Cronbach's alpha of 0.65 in the present sample.

Child behavioral difficulties (age 4.5)

Child behavioral adjustment at age 4.5 was measured using total scores on the SDQ (described above), reflecting overall behavioral difficulties across the domains of peer problems, conduct problems, hyperactivity-inattentiveness, emotional symptoms and (low) prosocial behavior. Thus, note that this measure includes the emotional symptoms subscale described above. All items are rated by parents as Not true (0), Somewhat true (1), or Certainly true (2). A total score is typically calculated as the sum of the 25 items (5 items per subscale). In the present sample, an item from the conduct problems subscale was mistakenly omitted from the questionnaire. To correct for this error, the 4 conduct problems items have been re-scaled to reflect a score out of 10, by multiplying the mean of individual item scores by 5. This results in a total behavioral difficulties score out of 50 (maximum of 2 points per item) despite only including 24 items in the measurement. For more information see the GUiNZ Data User Guide (Growing Up in New Zealand, 2023). Previous research has demonstrated the and predictive validity of the SDQ (Stone et al., 2010, 2015). Cronbach's alpha for the 24 items used in the present sample was 0.68.

Electronic media use (ages 4.5 and 8)

Parents reported on the amount of time children spent per day using screen media outside of school time. We focused on electronic media use (and did not include watching television or movies), given this is when children would be accessing the internet. At age 4.5, mothers were asked to report how much time their child spent on a typical weekday "*Using electronic media eg computer or laptop, including children's computer systems such as Leapfrog, iPad, tablets, smart phones and any electronic gaming devices*" Parents reported an amount of time in hours and minutes per day.

At age 8, mothers were asked to report on a normal weekday how much time their child "*Spent time doing activities and tasks, e.g., homework, playing games, or sending messages, on any screen-based device including computers, laptops, tablets, smartphones, or gaming devices*". Parents reported an amount of time in hours and minutes per day.

Given that time duration at both ages 4.5 and 8 were positively skewed (age 4.5: skewness = 2.64, kurtosis = 9.41; age 8: skewness = 2.48, kurtosis = 6.83), both variables were divided into quartiles for analysis. At age 4.5, children were assigned to quartiles using the following values (equating to duration of daily electronic media use in hours): Q1 = 0.08, Q2 = 0.50, and Q3 = 1.00. At age 8, children were assigned to quartiles using the following values: Q1 = 0.33, Q2 = 1.00, and Q3 = 2.00. Thus, final scores on both electronic media use variables ranged from 1 to 4.

Parenting style (age 4.5)

Parenting style was assessed when children were 4.5-years-old using a shortened version of the Parenting Styles and Dimensions Questionnaire (PSDQ; Robinson et al., 1995, 2001). A total of 21 items assessed the three subscales of Authoritative parenting (8 items), Authoritarian parenting (8 items), and Permissive parenting (5 items). Authoritarian items reflect a style of parenting guided by reasoning and responsiveness to the child's thoughts and needs. Authoritarian items reflect a style of parenting guided by punitive punishment, and permissive items reflect a lack of discipline.

Each of the 21 items was rated from 1 (Never) to 5 (Always). The three subscale scores were computed by taking the mean of the items making up each of authoritarian, authoritative, and permissive parenting. The PSDQ is used worldwide for measuring parenting style and the reliability and validity of the scale, including the shortened version, have been demonstrated (Robinson et al., 2001; Oliveira et al., 2018). Cronbach's alpha for the three subscales was as follows: Authoritative $\alpha = 0.82$, Authoritarian $\alpha = 0.78$, and Permissive $\alpha = 0.60$.

Parental involvement (age 8)

At the 8-year assessment, parental involvement was assessed using 11 items that asked mothers to report how often they engaged in certain activities with their child. Items included reading books to/with their child, getting the child ready for school, baking or cooking together, and talking about their child's feelings or issues, or comforting them. These items were rated on a 5-point scale of: *Never/almost never* (1), *Once a week* (2), *Several times a week* (3), *Once a day* (4), or *Several times a day* (5). The 11 items had a Cronbach's alpha of 0.72. A total score of parental involvement was calculated as the mean of the 11 items.

Digital parenting (age 8)

Mothers reported on the extent to which rules around media use were used in the household at the 8-year assessment. Nine items were used to assess the existence of rules about media content and screen time, the extent to which these rules were enforced, use of parental control settings, adherence to recommended age requirements for media content, and the frequency with which parents talked to their child about the dangers and the possibilities associated with internet usage. Five of these items were taken from the Internet Parenting Style Instrument (IPSI; Valcke et al., 2010; Álvarez et al., 2014). These items were rated on a 5-point scale either from "*Never/almost never*" to "*Always/almost always*" or from "*Never*" to "*All of the time*" depending on the specific item. A principal components analysis was used identify the factor structure of the nine items. Examination of the rotated factor loadings produced using Quartimax rotation indicated three factors with eigenvalues >1, accounting for a combined 54.6% of variance in the items. Table 1 provides the items loading on each of the three factors identified (Screen Rules, Screen Rule Enforcement, and Communication about Internet) along with factor loadings. For ease of interpretation, only the highest factor loading is presented, identifying the factor each item loads to. Factor scores on each of the three factors (each with mean of 0, SD of 1) were used for analysis.

Demographic characteristics

Finally, three demographic characteristics were obtained from the GUiNZ data:

- *child gender*, as reported by parents when the child was 9-months old,
- the *presence of older siblings* in the household, as identified at the 8-year assessment point, and
- *household income*, reported by mothers at the 4.5-year assessment point and classified into seven categories ranging from <\$20,000 to >\$150,000.

Results

Experiences of online harm

Data was available for 4,920 children who had completed the questions on online harm at age 8. Within this sample, 26.6% of children ($n = 1,307$) indicated they had experienced at least one type of online harm, while 62.7% ($n = 3,086$) indicated no online harm. The remaining 10.7% of children ($n = 527$) had responded with "Don't Know" when asked whether they had encountered anything on the internet that worried, bothered or upset them (see Figure 1).

Figure 2 provides the frequencies of each type of online harm enquired about, as a proportion of the total sample. The most common type of experience that worried or upset children was encountering sites, games or images meant for grownups (reported by 12.6% of children). Roughly 5% of the sample reported being worried or upset by each of: buying something by mistake, advertising on websites, and bullying. Peer pressure was the least common form of online harm that was enquired about.

There were 314 children (6.4% of the sample) who reported being worried or upset by more than one type of online harm.

Vulnerability and protective factors for online harm

There are a number of child and family factors that may increase or decrease risk of experiencing online harm. Based on existing literature and theory, we examined the following set of child and family predictors: child gender, presence of older sibling(s), household income, parenting style (age 4.5), daily time spent using electronic media (ages 4.5 and 8), child behavioral difficulties (age 4.5), parental involvement (age 8), the child's number of personal devices (age 8), and three variables relating to digital parenting—screen rules, screen rule enforcement, and internet communication and safety (all assessed at age 8).

For these analyses, we examined online harm collapsed across all forms. We compared those who have and have not been worried/upset by negative internet experiences, and we have excluded "Don't Know" responses from analysis. This resulted in a sample of 4,393 children who have (29.8%) and who have not (70.2%) been worried or upset by at least type of online harm.

Table 2 provides means (SDs) or percentages and statistical tests for each of the vulnerability and protective factors based on presence or absence of online harm experiences at age 8. Chi-square tests were used for categorical predictors and independent samples t-tests were used for continuous predictors. Hedges' g effect size was used to examine the strength of association for continuous variables

TABLE 1 Factor loadings for screen rules, enforcement, and communication.

	Factors		
	Screen rules	Internet communication and safety	Screen rule enforcement
Eigenvalue	2.32	1.33	1.26
Variance accounted for	25.80%	14.78%	14.03%
Items			
In your household are there rules for [child] about media content?	0.598		
How often does someone in your household make sure that [child] follows these rules?			0.844
In your household are there rules for [child] about the amount of screen time they are allowed?	0.545		
How often does someone make sure that [child] follows these rules?			0.851
I use software and/or parental controls to block certain internet sites or app access for [child]		0.454	
I talk with [child] about the rich possibilities of the internet		0.861	
I talk with [child] about the dangers relation to the internet		0.827	
I follow the recommended viewing ages for [child] when [child] watches movies or TV	0.682		
I follow the recommended minimum age requirement for [child] when [child] uses social media	0.692		

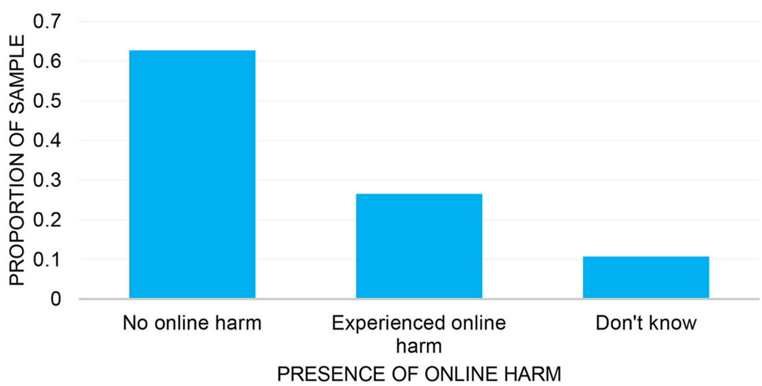

FIGURE 1
Prevalence of experiencing online harm by age 8.

and the Phi statistic (ϕ) was used for categorical outcomes. For Hedges' g, which is similar to Cohen's d but adjusted for unequal group sizes, effect sizes of 0.2, 0.5, and 0.8 are considered to be small, medium, and large, respectively (Cohen, 1988, 1992). For the ϕ effect size, values of 0.1, 0.3, and 0.5 are considered small, medium, and large effects, respectively (Cohen, 1988).

We next used a logistic regression to predict the experience of online harm by age 8 from the predictors simultaneously. For this analysis, we included any predictors in Table 2 with effect sizes of $\phi > 0.05$ or $g > 0.10$, as our threshold for a meaningful effect size. Thus, our logistic regression included the predictors of child gender, behavioral difficulties at age 4.5, electronic media use at ages 4.5 and 8, internet communication and safety at age 8, and the number of personal devices at age 8. For ease of interpretation, SDQ behavioral difficulties were standardized to a mean of 0 (SD = 1) prior to inclusion in the logistic model. The overall logistic

FIGURE 2
Proportion of sample who have experienced online harm by type of harm.

TABLE 2 Comparison of child and family predictors between children with and without experiences of online harm.

	No online harm ($n = 3{,}086$)	Experienced online harm ($n = 1{,}307$)	p-value	Effect size
Percentage				
Child gender	50.5% female	44.1% female	$p < 0.001$	$\phi = 0.06$
Older sibling(s)	55.0%	55.4%	$p = 0.80$	$\phi = -0.004$
Mean (SD)				
Predictors assessed at age 4.5				
Household income (age 4.5)	5.19 (1.47)	5.11 (1.50)	$p = 0.17$	$g = 0.05$
Permissive parenting (age 4.5)	1.95 (0.57)	1.99 (0.58)	$p = 0.03$	$g = -0.07$
Authoritarian parenting (age 4.5)	1.97 (0.48)	2.01 (0.52)	$p = 0.03$	$g = -0.07$
Authoritative parenting (age 4.5)	4.44 (0.44)	4.47 (0.43)	$p = 0.03$	$g = -0.07$
Electronic media use (age 4.5)	2.10 (0.86)	2.18 (0.89)	$p = 0.008$	$g = -0.10$
Child behavioral difficulties (age 4.5)	16.84 (4.64)	17.36 (4.86)	$p < 0.001$	$g = -0.11$
Predictors Assessed at Age 8				
Electronic media use (age 8)	2.24 (1.01)	2.34 (0.96)	$p = 0.01$	$g = -0.10$
Screen rules (age 8)	−0.01 (0.97)	0.06 (0.85)	$p = 0.01$	$g = -0.08$
Screen rule enforcement (age 8)	0.02 (0.92)	−0.04 (0.96)	$p = 0.04$	$g = 0.07$
Internet communication and safety (age 8)	−0.06 (0.94)	0.10 (0.92)	$p < 0.001$	$g = -0.17$
Parental involvement (age 8)	2.76 (0.47)	2.75 (0.47)	$p = 0.60$	$g = 0.02$
Number of personal devices (age 8)	1.16 (1.09)	1.45 (1.24)	$p < 0.001$	$g = -0.26$

model was significant [$\chi^2_{(6)} = 71.38$, $p < 0.001$; Nagelkerke $R^2 = 0.03$]. The Hosmer-Lemeshow test was not significant [$\chi^2_{(8)} = 8.21$, $p = 0.41$], indicating an acceptable model fit. Table 3 presents the results for each parameter in the model.

Once including the predictors simultaneously, the predictors remaining significant were child behavioral difficulties, internet communication and safety, and the child's number of personal devices. As indicated by the odds ratios in Table 3, an increase of one standard deviation in behavioral difficulties corresponded with a 13% increase in the odds of experiencing online harm. Notably, every additional personal device a child had resulted in a 21% increase in the odds of experiencing online harm. Once accounting

TABLE 3 Logistic regression predicting experiences of online harm.

Parameter	B (SE)	Wald	*p*-value	Odds ratio	95% CI for odds ratio
Female gender	−0.13 (0.08)	2.56	0.11	0.88	0.75–1.03
Behavioral difficulties (age 4.5)	0.12 (0.04)	8.00	0.005	1.13	1.04–1.23
Electronic media use (age 4.5)	−0.002 (0.05)	0.001	0.97	1.00	0.91–1.10
Electronic media use (age 8)	0.02 (0.04)	0.28	0.60	1.02	0.94–1.11
Number of devices (age 8)	0.19 (0.04)	30.14	<0.001	1.21	1.13–1.30
Internet communication and safety (age 8)	0.15 (0.04)	12.17	<0.001	1.16	1.07–1.26

for all other variables, there was no longer a significant predictive effect of gender or the amount of electronic media use (neither longitudinally nor concurrently). Counterintuitively, our results indicate that higher levels of internet communication and safety in the home (as reported by parents) are associated with increased odds of online harm, which may reflect an effect in the opposite direction, as discussed further in the Discussion section.

The fact that gender and extent of electronic media use were not significant in the final model is due to the shared variance amongst predictors. For example, children in the highest quartile of electronic media use at age 4.5-years-old scored higher in behavioral difficulties at the same age than the rest of the sample (see Figure 3).

Personal devices

Given the results of the above analysis, demonstrating a strong association between the number of personal devices and online harm, a *post-hoc* analysis was undertaken examining individual types of personal devices. We ran a logistic regression predicting experience of online harm from indicator variables for all types of personal devices occurring with frequencies >5% of the sample. These were: a desktop computer or laptop, a TV, a smartphone, a gaming console (e.g., Xbox, Playstation), an iPod/iPod touch/MP3 player, and a tablet (e.g., an iPad).

The overall logistic model was significant [$\chi^2_{(6)} = 48.18$, $p < 0.001$; Nagelkerke $R^2 = 0.02$]. The Hosmer-Lemeshow test was not significant [$\chi^2_{(5)} = 4.16$, $p = 0.43$], indicating an acceptable model fit. Table 4 presents the results for each parameter in the model.

The results of this analysis indicate that the odds of online harm are significantly increased when children have the personal devices of desktop computers or laptops, TVs, gaming consoles, and tablets. The largest increase in risk was observed for gaming consoles. In contrast, there was no significant impact on online harm risk from the personal devices of smartphones and music players.

Associations between online harm and psychosocial adjustment

Our final set of analyses compared psychosocial adjustment between children who had experienced online harm and those who had not. Our dependent variables were child depressive symptoms assessed with the CESD-10 and child-reported self-worth. Table 5 provides the means and standard deviations for child-reported depressive symptoms and self-worth at age 8 and parent-reported emotional symptoms at age 4.5 (our control variable) based on the experience of online harm.

We used a multivariate analysis of covariance (MANCOVA) to predict both outcome variables at age 8 from the presence vs. absence of online harm, while controlling for earlier emotional adjustment at age 4.5 and gender.[1] Earlier emotional adjustment at age 4.5 was assessed with the SDQ emotional symptoms subscale. We also examined the interaction between online harm and gender in predicting emotional outcomes.

The overall multivariate tests indicated a significant effect of both earlier emotional adjustment at age 4.5 [$F_{(2,4324)} = 8.29$, $p < 0.001$; $\eta^2_p = 0.004$] and online harm [$F_{(2,4324)} = 116.62$, $p < 0.001$; $\eta^2_p = 0.05$]. There was not a significant effect of either gender or the interaction of gender with online harm (p's > 0.07, both $\eta^2_p = 0.001$).

When examining the effects for each dependent variable, it was seen that earlier emotional adjustment was a significant predictor of both outcomes (F's > 7.92, p's < 0.006). Further, experiencing online harm was a significant predictor of child-reported depressive symptoms, with a medium sized effect ($F_{(1,4325)} = 232.92$, $p < 0.001$; $\eta^2_p = 0.05$), and child-reported self-worth, with a small effect size ($F_{(1,4325)} = 43.36$, $p < 0.001$; $\eta^2_p = 0.01$). Figure 4 provides the adjusted mean depressive symptoms (after controlling for earlier emotional adjustment) based on the presence or absence of online harm. Children who had experienced online harm scored higher on self-reported depressive symptoms (M = 9.02, SD = 4.60) than children who had not experienced online harm (M = 6.73, SD = 4.34).

Discussion

Given the rapidly growing presence of digital media in the lives of children and youth, it is critically important to understand the potential risks of this media use and to identify vulnerability and protective factors for those risks. In this research, we examined

1 Note that the same pattern of results was found when using SDQ total behavioral difficulties as the covariate instead of the emotional symptoms subscale.

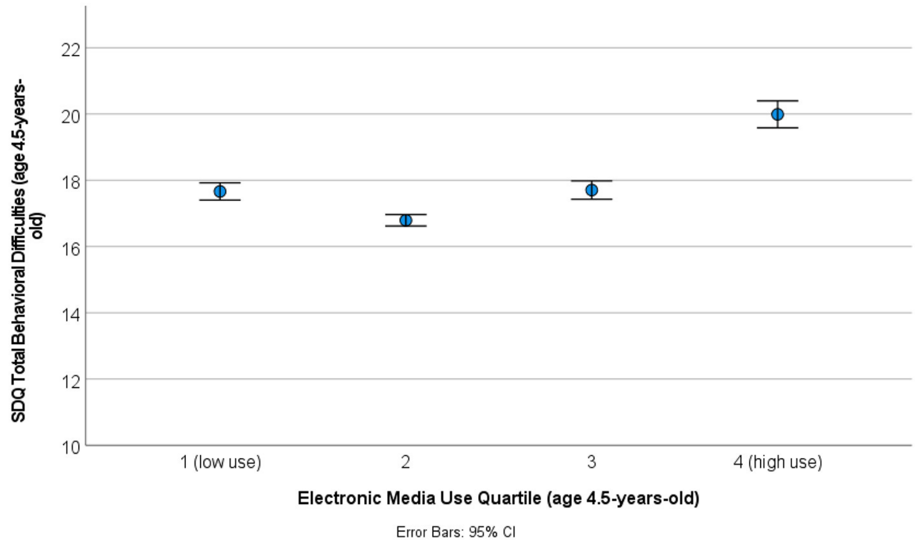

FIGURE 3
Mean behavioral difficulties by electronic media use at age 4.5-years-old.

TABLE 4 Logistic regression predicting online harm from type of personal device.

Parameter	% of sample	B(SE)	Wald	*p*-value	Odds ratio	95% CI for odds ratio
Desktop computer/laptop	19.6%	0.23 (0.08)	7.64	0.006	1.26	1.07–1.48
TV	11.7%	0.21 (0.11)	3.91	0.05	1.23	1.00–1.51
Smartphone	14.9%	0.11 (0.09)	1.47	0.23	1.12	0.93–1.34
Gaming console	18.0%	0.31 (0.09)	12.51	<0.001	1.36	1.15–1.62
iPod/iPod touch/MP3 player	8.3%	0.06 (0.12)	0.24	0.63	1.06	0.84–1.34
Tablet	42.7%	0.16 (0.07)	5.65	0.02	1.18	1.03–1.34

TABLE 5 Means and standard deviations for emotional adjustment based on experience of online harm.

	No online harm ($n = 3{,}086$) Mean (SD)	Experienced online harm ($n = 1{,}307$) Mean (SD)
SDQ emotional symptoms age 4.5	1.82 (1.67)	1.94 (1.79)
CESD-10 depressive symptoms age 8	6.82 (4.37)	9.10 (4.68)
Self-worth age 8	20.96 (2.97)	20.26 (3.24)

reports of online harm at age 8 and aimed to determine predictive factors for experiencing online harm, as well as the psychosocial correlates of online harm.

Our results show that approximately a quarter of 8-year-old children have experienced online harm. Most research on online harm has examined older populations, focusing on teenagers and adolescents (e.g., Machimbarrena et al., 2018; Smahel et al., 2020); however, our analysis shows that these experiences start early for some children, with a substantial number experiencing harmful experiences in middle childhood or earlier. The most commonly experienced form of online harm was exposure to adult content (content intended for grown-ups, as determined by the child). It is important to note that online harm was assessed through children's own reports of internet experiences that caused them distress, which will differ among individual children and may differ from what adults perceive to be harmful experiences. In light of prior research indicating a discrepancy between parents' and children's accounts of online harm (Pacheco and Melhuish, 2020b), it was important to investigate the child's subjective experience and recollection of the event as distressing.

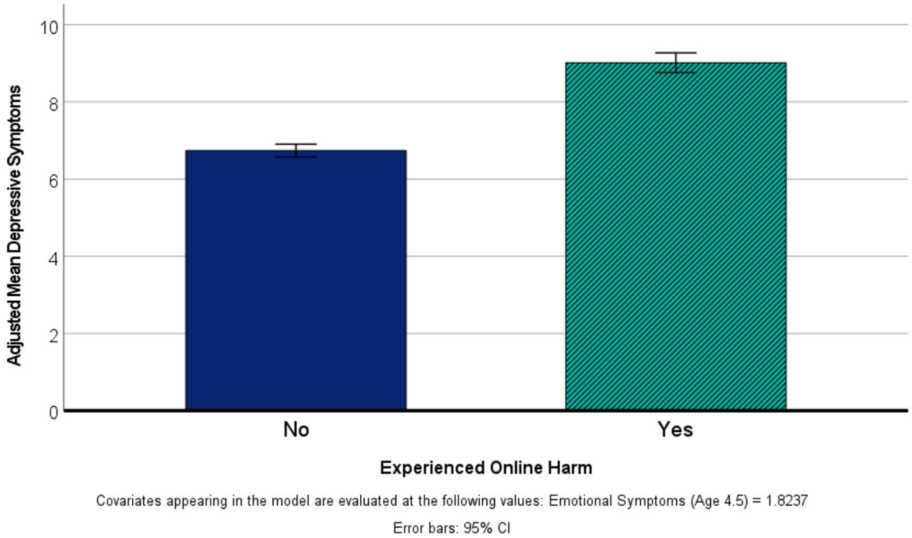

FIGURE 4
Depressive symptoms based on experience of online harm, with adjustment for earlier emotional symptoms.

As data for this study was collected as part of a large, longitudinal study with an extensive battery of measures collected, the data available on online harms was less detailed than would be the case if a study specific to online harms was conducted. Future research is required to provide a more nuanced understanding of the types of online situations and experiences that young children find to be distressing.

Predictors of online harm

We found evidence of both longitudinal and concurrent predictors of children experiencing online harm by age 8, and these included child characteristics, parenting behaviors, and child digital use factors. Males were more likely to report experiences of online harm than females, and children who spent more time using electronic media, as assessed earlier at age 4.5-years-old and concurrently at 8-years-old, were more likely to experience online harm. However, in our final predictive model, these two factors (gender and extent of electronic media use) were not significantly predictive of online harm once accounting for the other factors in the model.

The factors remaining predictive of online harm in the final model were child behavioral difficulties, parent communication and behavior related to internet safety, and the number of personal devices owned by the child. Children with higher levels of behavioral problems, as reported by their parents when the child was 4.5-years-old, were more likely to experience online harm by age 8. These children may be more prone to risky and defiant behavior, both offline and online, consistent with previous literature identifying overlapping vulnerability for harm online and offline due to risk factors common to both, including proclivity for risk-taking (Livingstone, 2013). Further, children with more behavioral difficulties may end up spending more time using electronic media, if parents use this as a means to cope with and control child behavior (e.g., Elias and Sulkin, 2019; Tang et al., 2018). In the present sample, children in the highest quartile of electronic media use at 4.5-years-old were reported by their parents as having significantly higher levels of behavioral difficulties than the rest of the sample.

As noted above, previous research such as that by Livingstone (2013), has found that children vulnerable to offline risks are also more likely to be at risk online. Interestingly, however, in the present sample we found no impact of socioeconomic status, with children's risk of online harm not differing based on household income. This finding is surprising given differences often found in the way that screen media is used by children of differing socioeconomic backgrounds (e.g., Mollborn et al., 2022; Nagata et al., 2022); however, these differences in patterns of screen use may not translate to differential risk for online harm in young children.

We found that the strongest predictor of online harm was the number of personal devices owned by the child at age 8. Gaming devices had the greatest impact on increasing the odds of online harm, followed by computers/laptops, and TVs. Note that this question asked about personal devices, not those shared within the household, perhaps reflecting situations where children have TVs and computers set up in their bedrooms and they engage with media content outside of any adult supervision. Indeed, previous research has identified bedroom media (either a TV or a gaming device in the bedroom) as a risk factor for exposure to media violence and video game addiction (Gentile et al., 2017). Continuing to explore the specific harms associated with different types of devices presents an interesting area for future research.

Finally, we found that online harm was associated with internet communication and safety, a factor reflecting the parenting behaviors of talking with children about the benefits and the risks of using the internet and using software and/or parental controls to restrict child internet access. In this case, our results showed the opposite pattern to what we expected–parents scoring higher on the use of internet communication and safety were more likely to have children who had experienced online harm. One explanation for this counterintuitive finding may be that the discussions about internet safety and use of parental controls were prompted by online harm experiences; in response to a child's distressing internet experience, parents may be more likely to talk with their child about internet dangers and implement control measures, resulting in the significant association between these variables. Similarly, children who are using screen media in more inappropriate ways (whether or not they have yet experienced online harm) might be more likely to (1) have parental restrictions placed on them, and (2) experience online harm. However, there is some evidence that control-oriented managing of children's media use can actually exacerbate problematic media use (Lee and Ogbolu, 2018), so further work in this area is required. In general, parenting strategies for preventing online harm that are more collaborative (such as co-viewing) are more effective than those that are control-based (like restricting internet use; Elsaesser et al., 2017).

Overall, the model only accounted for a small amount of the variance in predicting the likelihood of online harm, suggesting that there are other important factors not considered in this analysis. However, our results point to a few key risk factors for early experiences of online harm.

Psychosocial adjustment

Our analysis of the psychosocial functioning of children at age 8 indicates that those who reported experiencing online harm also reported higher levels of depressive symptoms and lower self-worth, even after controlling for earlier emotional symptoms (assessed at age 4.5). While these reports were gathered concurrently (and all self-reported by the child), the results could indicate adverse psychological consequences for young children who experience distressing situations online, including viewing adult content, bullying, and talking to strangers. Previous research has demonstrated in teenagers that more time spent using the internet and on social media predicts higher depressive symptoms and lower self-esteem (Twenge and Farley, 2021) and that specific types of online harm, such as cyberbullying, are associated with poorer mental health and psychosocial outcomes (Kwan et al., 2020). The present research extends upon this literature to show disadvantageous associations with psychosocial functioning as early as age 8. The results suggest that adverse or distressing experiences online may impact psychological functioning and mental health in the same way that experiencing offline adverse events in childhood can lead to mental health problems such as anxiety and depression (e.g., Chapman et al., 2007).

Given the rapid changes in digital technology use by young children, our findings highlight the importance of ensuring age-appropriate online activities for minimizing risks for online harm in our youngest children. Importantly, research has shown that there is substantial overlap in online and offline harm (for example, youth who experience cyberbullying often experience offline bullying as well; Finkelhor et al., 2021). It will be important in future research to disentangle the unique association of online harm with psychosocial functioning, after controlling for offline experiences of harm.

Given the previous literature in this field, we have interpreted our results as indicative of online harm influencing young children's depressive symptoms and self-worth. However, it may also be the case that children with poor psychosocial adjustment (lower self-worth and higher depressive symptoms) either (1) are more likely to use the internet in risky or problematic ways and in turn more likely to experience online harm, or (2) are more likely to report experiencing distressing situations online than other children (for example, because they differ in how they perceive these situations in the first place or in how they recall these situations later on).

While the effect size for group differences in self-worth was relatively small, the mean difference in depressive symptoms was substantial (half a standard deviation). It is important to note, however, that although significant differences were observed based on experiences of online harm, the actual level of depressive symptoms in the online harm group (9.10 out of a possible score of 30) is still low in an absolute sense.

It is also important to note that when children experience online harm, there may also be the opportunity to build resilience, and these adverse experiences may lead to coping, adaptation and the development of resilience (e.g., Ólafsson et al., 2018). While we did not find evidence of this in the present study, investigation of longer-term outcomes for these children (which will be possible as the Growing Up in New Zealand study continues) has the potential to demonstrate that these children end up developing stronger digital safety skills and digital resilience. For example, Mensonides et al. (2023) theorize that "digital risky play" may help to build resilience in the same way that offline risky play is important for building resilience in childhood. This remains to be demonstrated empirically.

Finally, it is worth noting that all measures of psychosocial functioning included in this analysis are measures of broad/everyday functioning and are not media-specific. Understanding specific emotional and depressive symptoms and self-worth related to media and when exposed to online risks is an important avenue for future research. Some research with older children has found that exposure to different online risks leads to differential consequences (González-Cabrera et al., 2018; Montiel et al., 2016; Temple et al., 2014). In the present sample, given the relatively low frequency of each individual type of online harm we grouped all types of harm together; however, it will be important for future research to examine the differential impacts of different types of online harm in young children as well. Additionally, it is crucial to acknowledge the evolution of the internet since the collection of this data in 2009–2010. While online applications have been designed specifically with the safety of young children in mind (e.g., YouTube Kids), parents are still required to be vigilant and monitor their child's online engagement due to the detection of inappropriate and risky content on these "child-friendly" platforms (Tahir et al., 2019).

Conclusions

The findings of this research indicate that approximately a quarter of New Zealand children have experienced online harm (that is, have encountered online content that worried, upset, or bothered them) by the age of 8. While our growing digital landscape offers new opportunities and advantages, understanding the risks that come with early online experiences and how to protect young children is critically important. Our analysis indicates that children with behavioral difficulties are at greater risk of online harm, as are children with more personal devices. Limiting children's personal devices, particularly those that are accessed without adult supervision, and using collaborative rather than controlling strategies for managing child media use are two key steps parents can take to prevent online harm. Preventing early experiences of online harm is particularly important given our finding that children who report experiencing online harm also report more depressive symptoms and lower self-worth at age 8 than children who have not experienced online harm.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: access to the data used in this study can be obtained through application to the Growing Up in New Zealand team. Requests to access these datasets should be directed to https://www.growingup.co.nz/.

Ethics statement

The studies involving humans were approved by Ministry of Health Northern Y Regional Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

MG: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. CS: Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Language development in Slovenian toddlers: the role of electronic media, parental knowledge of language development, and parental input

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Introduction: This study examines the relationships between toddlers' language production, parental language input, media exposure, and parental knowledge of early language development.

Methods: We used a unique collection of daylong recordings of Slovenian toddlers (age: 16–30 months, $N = 40$, 18 girls) to measure the language environment, toddlers' language production and media exposure. In addition, parental reports of toddlers' media exposure and language ability (using the Slovenian adaptation of the CDI) were collected.

Results: The results indicate that toddlers' average exposure to electronic media was rather low, with exposure varying widely across the sample. Parental language input was related to various measures of toddlers' language. Parents with a greater knowledge of early language development used more parentese, while their toddlers had less exposure to electronic media. In addition, toddlers' media exposure was related to their age, with older toddlers having more exposure to electronic media, and was marginally related to the number of words spoken by adults and parents' education. No significant relationship was found between toddlers' language ability and media exposure when controlling for toddlers' age.

Discussion: The findings underline the importance of parental knowledge about language development and the characteristics of the language environment for toddlers' language ability.

KEYWORDS

media exposure, language development, parental knowledge and practice, vocabulary, language input

1 Introduction

The impact of electronic media exposure on early language development is a topic of significant interest and debate among researchers. Infants and toddlers are in a critical period for brain development and language acquisition (Kolb and Fantie, 2008; Wolf et al., 2018) and are highly receptive to linguistic input from their environment (Ferjan Ramírez et al., 2024a; Huber et al., 2023; Ramírez-Esparza et al., 2016; Romeo et al., 2021; Tamis-LeMonda et al., 2001; Weisleder and Fernald, 2013). Understanding how media exposure affects this process is crucial for guiding parents in making informed decisions about media use.

Professional recommendations (e.g., American Academy of Paediatrics, Council of Communication and Media, 2016; Slovenian Association of Paediatrics, 2021) in general advise against any screen media use for infants and toddlers under the age of two, while for children between 2 and 5 years of age, a maximum of 1 hour of daily screen time is advised but only under the supervision of parents and with high-quality content. Previous research has shown that excessive early exposure to electronic media presents can lead to numerous negative outcomes for a child, such as difficulties in language development, attention, and executive functions (Cheng et al., 2010; Christakis et al., 2009; Li et al., 2020; Nathanson et al., 2014).

The sociocultural theory of development and learning (Vygotsky, 1962, 1987) offers insights into how electronic media might affect early language development, emphasizing the role that social interaction plays in early psychological development and posits that language acquisition occurs through dynamic interactions with more knowledgeable others, primarily parents. It suggests that human learning is largely a social process and that our cognitive functions are formed based on our interactions with those around us who are more skilled. In line with the sociocultural theory of development and learning, research using daylong recordings of parents' and children's language within a home setting has identified strong, positive associations between parental child-directed speech (particularly the use of parentese, a style of infant-directed speech distinguished by its higher pitch, slower tempo, and exaggerated intonation) and child language outcomes, as well as between turn-taking and children's language outcomes in infancy, toddlerhood, and early childhood (Ferjan Ramírez et al., 2024a; Huber et al., 2023; Ramírez-Esparza et al., 2014, 2016; Romeo et al., 2018, 2021). These findings support the notion that the social-interactional features of parental language input are the foundation of infants' and toddlers' language skills. However, exposure to electronic media may displace critical face-to-face interactions necessary for language learning.

In the present study, we aimed to establish how media exposure in Slovenian toddlers aged 16–30 months relates to parental linguistic input, on one hand, and toddlers' language production, on the other. We were also interested in the role of parental knowledge of early language development in toddlers' media exposure. Slovenian toddlers' use of electronic media has yet to be systematically studied, particularly in naturalistic settings or in relation to early language development. Existing research indicates there may be some cultural differences in media use among toddlers (e.g. Ferjan Ramírez et al., 2022; Kulakci-Altintas, 2020; Radesky et al., 2020). Most children in Slovenia grow up monolingually speaking Slovenian, a Slavic (Indo-European) language spoken by approximately 2.4 million people. The majority enter the public early education and care system at approximately 11 months old, following a government-funded, 12-month paid parental leave (Statistical Office of RS, 2023). Although preschool enrollment is not mandatory, 94% of Slovenian children aged 1–5 attend preschool (Statistical Office of RS, 2023), making Slovenia one of the EU countries with the highest enrollment rates for children younger than 3. All public preschools in Slovenia adhere to the "Preschool Curriculum," a national framework developed by the Slovenian Ministry of Education (https://www.gov.si/en/policies/education-science-and-sport/early-childhood-education-and-care). This curriculum ensures high-quality early education, provides a foundation for professional planning, and, with its nationwide implementation, upholds the principle of equal opportunity for all children.

1.1 Associations between children's media exposure, language environment, and early language development

In most Western societies, children are exposed to electronic media from a very young age (Dumuid, 2020; Reid Chassiakos et al., 2016). Furthermore, rapid increases have been documented in the amount of time toddlers and young children spend using various device types (American Academy of Paediatrics, Council of Communication and Media, 2016; Canadian Paediatric Society, 2017; Collier et al., 2016; Seršen et al., 2024). Despite official recommendations, many modern-day children begin experiencing screens in infancy; in toddlerhood and early childhood, many show well-established patterns and habits of screen time use (Chaudron et al., 2018). Children from families with a low socioeconomic status (SES) have been documented to have higher rates of exposure to media compared to children from families with a higher SES (Kwon et al., 2024; Mendelsohn et al., 2008; Tomopoulos et al., 2010). As such, children from families with a low SES are likely to be most vulnerable to any adverse effects of media exposure on early development.

Empirical studies on the relationship between electronic media exposure and various domains of language development, such as vocabulary and grammar, have yielded mixed results. Some studies have described no significant relationship between children's screen exposure and language abilities (e.g., Dore et al., 2020; Dynia et al., 2021; Martinot et al., 2021; Taylor et al., 2018). However, multiple studies have linked early onset and/or high media exposure to slower language development (e.g., Massaroni et al., 2023; Zimmerman et al., 2007). Extensive use of electronic devices was found to be a risk factor for delayed language development in children younger than 5 years (Contreras-Silva et al., 2023; Karani et al., 2022; Perdana et al., 2017). Zimmerman et al. (2007) report that among infants aged from 8 to 16 months, each hour per day of viewing baby DVDs/videos was associated with a 16.99-point decrement in infants' vocabulary score on the Communicative Development Inventory (CDI)–Short Form. Similarly, Byeon and Hong (2015) found that the risk of language delay, measured in terms of communication skills, in 2-year-old toddlers increased proportionately with the increase in toddlers' TV-watching time. These authors also report a significant rise in the risk of language development delay with an increase in average screen time from 2 to 3 h. Martinot et al. (2021) especially emphasize the negative effect of toddlers' exposure to TV during family meals, which was found to be consistently associated with lower expressive vocabulary at the age of 2 years. In their review of 18 articles, Massaroni et al. (2023) found that prolonged screen time and exposure to screens in the first 2 years of life can negatively affect language development and communication skills in terms of comprehension and vocabulary size. In addition, these authors report that overexposure to screens in the early years can affect overall cognitive development, social experiences, problem-solving, and communication with others. Another meta-analysis of 16 studies conducted by Bhutani et al. (2024) found that 9 studies reported a negative impact of screen time on language development, 5 studies reported no significant impact, and 2 studies reported a positive effect.

Negative associations have also been reported between media exposure and parental use of parentese and turn-taking (Cycyk and De Anda, 2021; Ferjan Ramírez et al., 2022). Specifically, it has been observed that children who spend more time on screens have decreased parent–child interactions, which may hinder their development (Christakis et al., 2009). An Australian study (Brushe et al., 2024) examining the longitudinal relationship between screen time and parent–child talk between the ages of 12 and 36 months found that an additional minute of screen time in 36-month-old children was associated with a reduction of 6.6 adult words, 4.9 child vocalizations, and 1.1 conversational turns (CTs) in 16-h daylong recordings. In particular, these findings suggest that electronic media exposure may decrease opportunities for children to engage in conversation with parents, which is a critical mechanism for successful language acquisition.

By comparison, some research suggests that high-quality educational media can support language learning, particularly the acquisition of vocabulary (e.g., Linebarger and Vaala, 2010; Madigan et al., 2020; Rai et al., 2023). Specifically, some studies indicate that infants can learn new words from screen media, especially when the content is of high quality and designed for their age group. A meta-analysis of 63 studies (Jing et al., 2023) on media use in early childhood, word learning, and vocabulary size revealed an overall low, positive relation between the use of screen media and the children's vocabulary. In particular, the experimental studies showed stronger effects for e-books than for TV/video or games/apps and non-significant effects for video chats. As far as the correlational studies were concerned, the authors reported no overall relationship between vocabulary size and naturalistic media exposure, except for educational media use. Linebarger and Vaala (2010) argue that screen media effects are dependent on the degree to which media content resembles infants' and toddlers' real-life experiences, including the use of simple stories and familiar objects or routines. This research line argues that the presence of a competent co-viewer can support infants' language learning from screen media in ways similar to live scenarios. Thus, the presence of an adult co-viewer seems to significantly enhance the potential benefits of electronic media (Tu et al., 2024), with infants learning more effectively when parents engage with them during and after screen time, reinforcing the content and providing additional linguistic input. Having a parent who participates and comments on screen content has a positive effect on the child's learning even before the age of 3 (Guellai et al., 2022).

1.2 Why parental knowledge of child language development matters?

Parental knowledge refers to factual information or empirical evidence, usually endorsed by members of the scientific community that is critical to parents' evaluation of their children's behavior and development and parents' daily decisions about their children's care (Ribas and Bornstein, 2005). In particular, parental knowledge of child development has been shown to be the most important dimension of parenting competency (Vale-Dias and Nobre-Lima, 2018). This is because parental knowledge and beliefs about child development affect how they shape children's home learning experiences, which, in turn, affect children's developmental outcomes (Luo et al., 2021; Sahidullah, 2015). In fact, parents who are well aware of language development milestones are more likely to provide appropriate linguistic input and create an environment that supports the child's language acquisition (Ferjan Ramírez et al., 2021; Hwang et al., 2022; Rowe, 2008). Parents who understand that responsive communication and social engagement are key to language acquisition may therefore be more cautious about using screen media as a substitute for face-to-face interaction.

Research suggests that parents with lower levels of education may know less about early cognitive and language development (Luo et al., 2021; Suskind et al., 2017). Higher parental knowledge of early cognitive and language development has been found to be related to higher parental education levels, language ability, and more language stimulation available to the child at home (Suskind et al., 2017). By comparison, lower levels of maternal education have been associated with a belief that children acquire basic cognitive skills (e.g., vision, hearing, and language comprehension) somewhat later and that introducing certain cognitively stimulating activities (e.g., talking to the baby, telling stories, talking about absent objects, buying the first book) should occur later in a child's life (e.g., Williams et al., 2000).

Parents play a very important role in a child's introduction to and engagement with different types of electronic media as a child's screen habits are co-formed by family or parental characteristics (Gentile and Walsh, 2002; Livingstone et al., 2017; Nathanson, 2001). Knowledge about the differential impact of the quality and quantity of media exposure on children's early development and learning can help parents make better decisions about their child's media use. For example, recognizing that high-quality, interactive media can be beneficial in moderation and that excessive or inappropriate media consumption can be harmful allows parents to more effectively manage and consider media exposure with their child (Seršen et al., 2024). Many parents believe that screen media, especially educational programs and apps, can promote their child's learning and language development. This belief can lead to increased media exposure as parents seek to provide their children with perceived educational benefits. Conversely, some parents are concerned about the potential negative effects of screen media on their child's development, including language delays and decreased social interaction. These parents may limit screen time and prioritize other activities that they believe are more conducive to language development, such as reading and talking. Because parents are often considered to be responsible for their children's screen use, children's excessive screen exposure can cause parental feelings of guilt, which, in turn, increases the amount of stress parents feel about their children's screen use and is also linked to lower satisfaction in the parent–child relationship (Findley et al., 2022; Wolfers et al., 2024).

1.3 The present study

The main goal of the present study was to assess the relationships between toddlers' language production and early media exposure, parental language input and knowledge about early language development. Our main method included daylong audio recordings within a home setting (Language ENvironment Analysis, LENA), used for the first time in a sample of toddlers residing in Slovenia, to assess both parental and toddlers' language as well as toddlers' media exposure (see also Ferjan Ramírez et al., 2024c). In addition, both the toddlers' media exposure and their language ability were assessed using parental reports [using the Slovenian version of the MacArthur-Bates Communicative Development Inventory: Words and Sentences (CDI; Marjanovič Umek et al., 2013) to assess vocabulary, mean length of utterance, and sentence complexity]. The study is of particular importance as the use of electronic media by Slovenian toddlers has not yet been systematically investigated in naturalistic settings. However, recent data suggest that Slovenian children aged 1–6 years are indeed frequently exposed to various electronic media at home (e.g., television, computer, cell phone, video games, etc.; Seršen et al., 2024). At the same time, the vast majority (more than 70%) of Slovenian toddlers aged 1–3 years attend full-time programs in public preschools, that is, 6–9 h per day from Monday to Friday (SiStat, 2024). As has been shown for other languages, exposure to electronic media among Slovenian toddlers is expected to be related to demographic factors (e.g., parents' education levels or child's age), parental language input, and child's language development; however, such relationships have not yet been demonstrated in this particular context. Of particular interest here is the high enrollment of toddlers in preschools, which could influence the previously discussed relations between media exposure, parental language input, and child language development. This study is also important because, to our knowledge, no study has examined parental knowledge of early language development in relation to toddlers' early media exposure.

In alignment with broader goals, we ask four specific research questions:

Research Question 1: How frequently are Slovenian toddlers exposed to electronic media according to daylong audio recordings and parental reports? Are the two measures of toddlers' media exposure related?

Research Question 2: Which demographic or family factors (parental education levels, toddler's age, and sex) are related to toddlers' media exposure? What are the associations between toddlers' media exposure, their language environment (adult word counts [AWCs], CTs, and exposure to parentese), and measures of toddlers' language production (e.g. vocalization, vocabulary, and sentence complexity)?

Question 3: Does parental knowledge of early language development correlate with toddlers' media exposure, on one hand, and with parental language input and toddlers' language ability, on the other?

Question 4: What are the predictors of toddlers' media exposure, on one hand, and parental use of parentese within the home setting, on the other?

2 Methods

2.1 Participants

Toddlers were recruited via advertisements through flyers, social media, and public preschools in Slovenia. The preschool teachers who helped with the recruitment within the preschools did not receive any compensation or incentive for participating. The criteria for inclusion were the child was between 16 and 30 months of age; the child was born full-term (within +14 days of their due date), of normal birth weight (5.5–10 lb or 2.5–4.5 kg), and had no birth or postnatal complications; and Slovenian is the only language spoken in the home. The desired sample size ($n = 40$) was determined based on prior research that used the LENA technology for recording parental and toddlers' language with North American samples (see Bergelson et al., 2019; Ferjan Ramírez et al., 2022; Ramírez-Esparza et al., 2014, 2016; Shapiro et al., 2021, all of which report between 18 and 61 participants). Recruitment continued until the target sample size of 40 infants was achieved. The power analysis showed that to achieve the power of at least 80%, the Pearson correlation coefficient for the anticipated sample size ($n = 40$) must be at least 0.43 (with a significance level of 0.05, two-sided test). To achieve the power of at least 80% in multiple regression using the model with five parameters, a significance level of 0.05 and a Cohen's f effect size of 0.35, which is considered a large effect size (Cohen, 1992), the sample size should also include 40 individuals.

Forty families (18 with girls, 22 with boys) were included in the present study. The toddlers enrolled in the study ranged in age from 492 days to 935 days ($M = 705$ days, $SD = 144$ days). All toddlers resided with their mothers and fathers; attended full-time programs in public preschools, which means 6–9 h per day; and were not systematically exposed to another language in preschool. Parental education level was measured via a questionnaire: Parents indicated, for mothers and fathers separately, which of the 9 levels of education they completed: (1) incomplete primary education, (2) primary education, (3) vocational education, (4) technical secondary education, (5) general secondary education, (6) 2-year postsecondary degree, (7) bachelor's degree, (8) master's degree, or (9) doctorate. Parents' answers were then converted into "points," that is "primary education": 2 points, "vocational education": 3 points, and so on. For each family, we then calculated a joint parental education score by adding the points entered for maternal and paternal education. Parents in the present sample achieved, on average, relatively high levels of education (the median education level was 7: bachelor's degree), although parents ranged from completed primary school (one parent) to a doctorate (five parents).

2.2 Measures

2.2.1 Assessment of language environment, child language, and electronic media exposure via LENA recordings

Participating families received a package with a LENA recorder and a LENA T-shirt and were instructed to record a "typical" weekend day. While there is no agreement in the literature as to how one should select a "typical" day to collect daylong recording, we opted for a weekend recording because weekends tend to be the only days when the toddlers were at home and not in preschool. We further stipulated that within a typical weekend, parents select a day when both would be home and not working, with the goal of including both parents in the recordings. Parents were asked to start each recording in the morning when the child woke up and turn off the recorder at night when the child went to sleep. They were asked to go about their activities as usual while their toddler wore the lightweight LENA device inside the front pocket of the LENA T-shirt. The average duration of the LENA recordings was 13 h 25 min (range: 9–16 h). The data were collected in 2022 and 2023.

The LENA data preparation procedures followed those outlined in previously published studies conducted in North America (Ferjan Ramírez et al., 2020, 2021, 2022; Ramírez-Esparza et al., 2016, 2017). Parent and child speech were quantified by combining the LENA software's automatic annotation and manual (human) annotation. The LENA software produces an automatic count of child vocalizations (child vocalization count [CVC]), words produced by nearby adults (AWC), adult–child conversational turns (conversational turn count [CTC]), based on acoustic modeling of sounds (Christakis et al., 2009).

Our main variables of interest were manually annotated in the present data set, as in multiple previously published studies with North American families (Ferjan Ramírez et al., 2020, 2021, 2022; Orena et al., 2020; Ramírez-Esparza et al., 2016, 2017). The LENA Advanced Data Extractor Tool was also used to identify intervals with the language activity of interest (high AWC) for manual analysis to avoid manual annotation when there is no social or linguistic activity (e.g., during naps). Each participant's recording was segmented into 30-s intervals. This decision was based on previous research demonstrating that a 30-s snapshot of ambient sound provides sufficient information for reliable judgment of behaviors (Mehl et al., 2007; Ramírez-Esparza et al., 2009). Then, for each participant, one hundred 30-s intervals with the highest adult word count were selected for further manual annotation. To collect a broad range of environments, we further required that the selected intervals be spaced at least 2 min apart. Four research assistants, students, or recent graduates of the Department of Psychology at the University of Ljubljana, and native speakers of Slovenian followed the procedures outlined in Ramírez-Esparza et al. (2014, 2016, 2017) and Ferjan Ramírez et al. (2020, 2021, 2022). During training, annotators listened to examples of each coding category (discussed later). Any uncertainties about annotation (typically between zero and five 30-s segments per participant) were resolved after discussion with the annotation supervisor. To identify parentese and distinguish it from standard child-directed speech, the same criteria were adopted as described previously by Ramírez-Esparza et al. (2014), who verified that the intervals defined as parentese or standard speech contained the acoustic differences characteristic of these two speech styles (i.e., higher pitch and larger pitch range for parentese). In these analyses, 60 occurrences of the word *you* were analyzed. The 60 occurrences of *you* represented 30 pairs (30 produced as parentese and 30 as standard speech) produced by the same adult addressing the same toddler. The mean pitch and pitch range were significantly higher for parentese than standard speech ($ps < 0.001$); see Table 1 for variable definitions.

Annotators listened to each 30-s interval and entered a "YES" (present) or a "NO" (absent) for each of the following coding categories: (1) Parentese speech: The mother, father, or other adult spoke directly to the child wearing the recorder; parentese speech was used; and one or more than one adult voice was recorded during the interval. (2) All child speech: The child produced fully resonant vowels; consonant–vowel syllables; variegated strings of consonant–vowel syllables (see Smith et al., 1989); speech utterances intermixed with non-speech, word-like strings; words (see 3); or word combinations (see 4). (3) Child words: The child produced one or more than one Slovenian word(s). Child vocalizations were counted as words if they were recognized by the annotator as Slovenian words, even if their pronunciation was not completely correct. (4) Child word combinations: The child produced one or more than one utterance, defined as a combination of two or more Slovenian words. Words within an utterance should fall into their own meaning categories (e.g., actor, descriptor, action, etc.). Repetitions of the same word do not count as word combinations. (5) Electronic media: These segments had sounds emanating from an electronic speaker (TV, radio, video chat, electronic toy, etc.) present. Note that the five coding categories are not exhaustive and not mutually exclusive. For example, a given interval may contain child words and child word combinations, just one of these, or neither.

The resulting matrix of YES and NO responses for each 30-s interval indicated that a specific category occurred or did not occur in that interval. The data matrices were aggregated to provide relative time use data by calculating the percentage of intervals coded for each category. For any individual child, a specific percent value for any one variable means that a particular variable occurred in that particular percentage of the annotated segments (i.e., for a specific child, 56% for "% baby words combined" means that the child produced word combinations in 56 out of 100 segments that were annotated). These percentages were then aggregated to produce group statistics (reported in Table 2).

The annotators also counted the number of CTs within each 30-s segment, following the same procedures as Ferjan Ramírez et al. (2021). While the LENA software automatically identifies adult and child speech in close temporal proximity (termed CTC), recognizing that these "turns" are estimated without distinguishing between child-directed and overheard speech is important. This means that turns can be identified in error due to "accidental contiguity" (i.e., the mom is talking on the phone to a friend and the child is babbling nearby), the frequency of which has recently been shown to be high for the age range studied here (Ferjan Ramírez et al., 2021, 2024b). As a result, the present analyses rely exclusively on manually identified CTs. In brief, as with the LENA algorithm, CTs were counted in discrete pairs, and pauses of 5 s or more constituted the end of a conversation. Critically, and unlike with the LENA algorithm, cases of accidental contiguity were not counted as CTs. The total number of CTs was counted across all 100 intervals for each participant.

After training, all coders were tested independently with a training file from the present data set, used to evaluate intercoder reliability (ICC; Shrout and Fleiss, 1979). The reliability analysis produced an average intra-class correlation of 0.96 (maternal parentese: 0.96; paternal parentese: 0.95; child vocalization: 0.98; child words: 0.96; child word combinations: 0.96; electronic media: 0.93; conversational turns: 0.99), indicating effective training and reliable coding based on a two-way random effects model (ICC [2, *k*]; Shrout and Fleiss, 1979; see also Ferjan Ramírez et al., 2021, 2022; Ramírez-Esparza et al., 2016, 2017). The definitions of all

TABLE 1 Daylong recordings: variable names, types, and definitions.

Variable name	Variable type	Variable definition
AWC	LENA	Total number of adult words heard by the child during the recording, estimated automatically by LENA.
Parentese	Manual	Percentage of segments where mother, father, or other adult spoke directly to the infant, parentese speech style was used (high pitch, larger pitch range), and one or more than one adult voice was recorded during the interval.
CVC	LENA	Number of vocalizations containing speech-related activity produced by the child wearing the recorder, estimated automatically by LENA. Child vocalizations can be of any length, as long as they are surrounded by 300+ milliseconds of non-speech.
C_Words	Manual	Percentage of annotated segments where the child wearing the recorder produced one or more than one Slovenian word(s).
C_ Combinations	Manual	Percentage of annotated segments where the child wearing the recorder produced one or more than one Slovenian utterance. Utterances are defined as a combination of two or more Slovenian words.
CTC	Manual	Total number of adult utterances directed to child, followed within 5 s by child utterances directed to adult, or vice versa; counted in discrete pairs (child to parent = 1 turn, parent to child to parent = 1 turn, child to parent to child to parent = 2 turns; see Ferjan Ramírez et al., 2021)
Media_LENA	Manual	Percentage of annotated segments in which any sounds (dominant or background) originating from an electronic speaker were identified in the child's environment.

AWC, adult word count; CTC, conversational turn count; CVC, child vocalization count; LENA, Language ENvironment Analysis estimate; Manual, manually coded.

TABLE 2 Descriptive statistics for language measures, media exposure, and parental knowledge of language development.

	M	*SD*	Skew	Kurt
AWC	24,310.5	9,724.2	0.71	0.82
CVC	2,927.4	1,304.5	0.76	0.49
C_Words	0.6	0.3	−1.05	−0.21
C_Combinatons	0.4	0.3	0.18	−1.6
CTC	225.2	97.0	0.14	−0.62
Parentese	0.8	0.1	−0.72	0.92
PLDK	89.6	5.2	−0.19	−0.97
Media_LENA	0.2	0.2	0.87	−0.32
Media_Report	17.7	14.82	2.34	6.56
CDI_Vocab	269.4	212.3	0.17	−1.59
CDI_M3L	3.0	2.5	0.31	−0.9
CDI_Compexity	10.1	11.5	0.74	−0.83

Descriptive statistics for Media_Report (daily media exposure in minutes as reported by parents) were calculated with 20 %winsorization. SE (standard error) for skewness = 0.39; SE for kurtosis = 0.78.
AWC, adult word count; CVC, child vocalization count; CTC, conversational turn count; PLDK, Parental language development knowledge; LENA, Language Environment Analysis; CDI, MacArthur-Bates Communicative Development Inventory: Words and Sentences; Media_Report, screen time (in minutes) reported by parents; CDI_Vocab, vocabulary size as measured with CDI; CDI_M3L, mean length of utterances as measured with CDI; CDI_Complexity, sentence complexity as measured with CDI; Skew, skewness; Kurt, kurtosis.

final variables are summarized in Table 1. The total number of annotated 30-s segments was 4,000 (100 segments per participant, 40 participants), which equals 2,000 min of annotated audio in total.

Because the LENA recordings varied in duration, projected 12-h values were used for all LENA automatic measures. The 12-h projections are part of the standard LENA package, are automatically generated by LENA for recordings at least 10 h in length, and represent the interpolated values for AWC and CVC at the 12-h mark for the day's recording (see Gilkerson et al., 2017; see also Tion et al., 2009, which uses the same method to report the normative data for a sample of U.S. English-speaking children).

2.2.2 MacArthur-Bates CDI

Families received the Slovenian adaptation of MacArthur-Bates CDI (Marjanovič Umek et al., 2013). Three CDI measures were included in the present study: (a) Productive vocabulary, which contains a list of words divided into 22 categories (e.g., food and drinks, interjections, animals, interrogatives, etc.). Parents are asked to indicate the words their child uses, and the maximum score equals the number of words checked by the parent (i.e., 680 words; CDI_Vocab). (2) M3L (mean length of three longest sentences) is used to assess children's ability to form multiword utterances. Parents write down the three longest sentences they recall their child using recently, from which the average utterance length is calculated (CDI_M3L). (3) Sentence complexity contains 37 pairs of utterances, of which one is grammatically less complex than the other. Parents mark the utterance that is typical of their child's speech. The highest possible score is 37 (CDI_Complexity). See Marjanovič Umek et al. (2013) to learn more about how the Slovenian CDI was adapted from the American English version (Fenson et al., 1994, 2006) and its psychometric characteristics.

2.2.3 The background survey

A background survey was created for the purposes of the present study and consisted of two sections. The first section included a Demographic and Toddler Media Exposure Questionnaire. This section collected the information about the demographics of both parents and the toddler: the basic information regarding the toddler's health, family composition, exposure to Slovenian and potential exposure to additional languages, enrollment in preschool, and the parents' education levels. In addition, parents reported on their toddler's average daily use of various electronic media (in minutes); namely, they estimated the average time their child spends (1) watching video content (on TV or portable video device), (2) using a computer, (3) using a mobile device or webcam to video chat, (4) using a mobile phone to talk to someone (without video), (5) playing video games, (6) using a touchscreen device (e.g., iPad, mobile phone, Kindle), and (7) using other electronic media (parents reported on possible additional devices a toddler might use). Time (in minutes) reported by parents for each of the above activities was summed into a variable Media_Report. Parents were also asked if their toddler owns their own electronic device (e.g., iPad or mobile phone). According to parental reports, none of the toddlers had their own device. By far, the most frequent use of electronic media was "Watching video content (TV, portable video device)," all the other categories were stated at least 10 times less frequently than this category. Next in order was "Using a mobile device or webcam to video chat," followed by "Using a touch screen device" and then "Using a mobile phone to talk to someone (without video)."

The second section of the survey asked parents about their knowledge on early language development. For this purpose, an adapted subset of the questions from the Survey of Parent/Provider Expectations and Knowledge (SPEAK) survey was used (Suskind et al., 2017; Ferjan Ramírez et al., 2022). Specifically, a total of 25 statements about early language development were listed, and parents were asked whether they agreed or disagreed with each, on a 4-point Likert scale. Example statements included: *"Television sound in the background is an excellent way for infants and toddlers to learn new words"* and "*When infants make sounds, such as 'bababa' or 'papapa', it is helpful if parents respond and try to have a conversation*". Responses were scored on a point value out of 100 possible points, yielding a "parental language development knowledge" (PLDK) score (see Ferjan Ramírez et al., 2022, which used this adaptation of the SPEAK survey in a sample of American toddlers).

Experimental procedures were approved by the institutional review boards of the University of Washington and the University of Ljubljana, and written informed consent was obtained from all parents of participating children.

2.3 Statistical analysis

Two toddlers had extreme values on the media exposure variable (i.e., more than two standard deviations from the mean). Because there was no indication that these data points are from a reporting error, we kept them in the sample. To correct for the possible effects of these outliers, we report the 20% winsorized descriptive statistics for the affected variables.

The 20% winsorized Pearson correlations with corresponding 95% confidence intervals were calculated between different measures of toddlers' media exposure, family factors, parental knowledge of early language development, and toddlers' language environment and language production.

We aimed to predict parentese and daily media exposure as reported by parents (Media_Report) through two robust multiple linear regression models. The first model consisted of Media_Report, toddlers' ages and sex, and parental education as possible predictors of parental use of parentese. The second model included PLDK, toddlers' ages and sex, and parental education as possible predictors of daily media exposure as reported by parents. The bootstrap approach with 5,000 random repetition samples from the original data set was used to estimate the *p*-values and confidence intervals for the regression coefficients. We computed the coefficient of determination corresponding to WLS regression, computed from the original residuals before the WLS transformation (Willett and Singer, 1988). The authors noted that R^2 calculated from weighted least-squares (WL)- transformed data is generally higher than corresponding ordinary least-squares (OLS) one because it capitalizes on lowering heteroscedasticity of the data. Therefore, reporting the R^2 from original data is more appropriate. The formula used was $1-\frac{SSe}{SSt}$, where *SSe* was computed from unweighted residuals.

All statistical calculations were carried out with the R 4.4.0. software environment for statistical computing and data visualization (R Core Team, 2023) using the packages *psych* (Revelle, 2023) and *car* (Fox and Weisberg, 2019) for descriptive statistics and data visualization, respectively; *correlation* (Makowski et al., 2019) for partial correlation calculation; and *WRS2* (Mair and Wilcox, 2020) for robust analyses. Statistical significance was calculated with the two-sided risk for an alpha error of 0.05.

3 Results

3.1 Research question 1

Based on parental report, the amount of daily exposure to electronic media in Slovenian toddlers was 18 min ($SD = 15$), as calculated with 20% winsorized mean. The variable was positively skewed (see Table 2), indicating a clustering of values around the left tail of the distribution. As such, this variable is more accurately described by its median value, which indicates that half of the participants were exposed to electronic media for <13 min daily; however, there were a few noticeable outliers for whom the daily electronic media exposure was higher. Namely, for two toddlers, media exposure was more than twice the value of two standard deviations for that measure. In addition, six (15%) toddlers were not exposed to media at all; they were about 5 months younger than those who had already been exposed to media, with the difference in age between the two groups being statistically significant ($M_{\text{younger}} = 19.0$, $SD_{\text{younger}} = 81.3$, $M_{\text{older}} = 23.9$, $SD_{\text{older}} = 140.9$, $t = -3.684$, $df = 11.23$, $p = 0.004$, $d = 1.12$). Looking at the two measures of toddlers' media exposure estimated by the LENA records and reported by parents, they were positively related, although the correlation was only marginally significant ($p = 0.08$; see Table 3).

3.2 Research questions 2 and 3

The descriptive statistics for the measures of parents' and toddlers' language, toddlers' media exposure, and PLDK are presented in Table 2, while the winsorized correlations of forementioned measures and family demographic characteristics are shown in Table 3. Normality assumptions for the included variables were not too severely violated, as the raw values of skewness and kurtosis did not exceed 1.96 times the standard error for the corresponding measure (see Table 2), indicating approximately normally distributed data (Kim, 2013).

As can be seen in Table 3, toddlers' age was related to their language production. This was evident from their LENA speech production estimates (CVC), as well as their CDI scores. There was also a positive correlation between toddlers' age and turn taking. Parental language input was significantly related to several measures of toddlers' language, namely to toddlers' vocalizations (CVC), word production (C_Words), the number of conversational turns (CTC), as well as with toddlers' CDI vocabulary. Parents with

TABLE 3 20% winsorized correlations with 95% confidence intervals for language measures, media exposure, and parental knowledge of language development.

	Age	Education	AWC	CVC	C_Words	C_Combinations	CTC	Parentese	Media-LENA	PLDK	Media_Report	CDI-Vocab	CDI-M3L
Age	1.00												
Education	0.13 [−0.19, 0.42]	1.00											
AWC	0.03 [−0.28, 0.34]	0.17 [−0.15, 0.46]	1.00										
CVC	0.46** [0.18, 0.68]	0.08 [−0.24, 0.38]	0.34* [0.03, 0.59]	1.00									
C_Words	0.70*** [0.49, 0.83]	0.23 [−0.09, 0.51]	0.37* [0.07, 0.61]	0.69*** [0.49, 0.83]	1.00								
C_combinations	0.79*** [0.64, 0.89]	0.26 [−0.06, 0.53]	0.18 [−0.14, 0.47]	0,56*** [0.30, 0.74]	0.82*** [0.68, 0.90]	1.00							
CTC	0.37* [0.06, 0.61]	0.11 [−0.21, 0.41]	0.49** [0.22, 0.70]	0.60*** [0.36, 0.77]	0.80*** [0.65, 0.89]	0.57*** [0.31, 0.75]	1.00						
Parentese	−0.09 [−0.39, 0.23]	0.08 [−0.24, 0.38]	0.60*** [0.36, 0.77]	0.37* [0.06, 0.61]	0.40* [0.11, 0.64]	0.19 [−0.13, 0.47]	0.63*** [0.40, 0.79]	1.00					
Media-LENA	0.19 [−0.13, 0.47]	−0,31 [−0.57, 0.00]	−0.28 [−0.55, 0.03]	−0,12 [−0.42, 0.20]	−0,09 [−0.39, 0.22]	−0.01 [−0.32, 0.31]	−0.13 [−0.43, 0.19]	−0,17 [−0.46, 0.15]	1.00				
PLDK	−0,39* [−0.62, −0.08]	0.26 [−0.05, 0.53]	0.18 [−0.14, 0.47]	−0,20 [−0.48, 0.12]	−0.12 [−0.41, 0.20]	−0,16 [−0.45, 0.16]	0.07 [−0.25, 0.37]	0.49** [0.21, 0.70]	−0,17 [−0.46, 0.15]	1.00			
Media_Report	0,40* [0.10, 0.63]	−0.08 [−0.38, 0.24]	−0,20 [−0.48, 0.12]	0,19 [−0.13, 0.47]	0.17 [−0.15, 0.46]	0.27 [−0.04, 0.54]	−0.01 [−0.32, 0.30]	−0,34* [−0.59, −0.03]	0.28 [−0.03, 0.55]	−0.49** [−0.70, −0.21]	1.00		
CDI-Vocab	0.72*** [0.53, 0.84]	0.12 [−0.20, 0.42]	0.33* [0.02 0.58]	0.49** [0.21, 0.70]	0.65*** [0.43, 0.80]	0.75*** [0.57, 0.86]	0.41* [0.11, 0.64]	0.20 [−0.11, 0.49]	0.06 [−0.25, 0.37]	−0.25 [−0.52, 0.06]	0.32* [0.01, 0.57]	1.00	
CDI-M3L	0.75*** [0.58, 0.86]	0.13 [−0.19, 0.43]	0.12 [−0.20, 0.42]	0.39* [0.09, 0.63]	0.70*** [0.50, 0.83]	0.79*** [0.64, 0.89]	0,55*** [0.29, 0.74]	0.13 [−0.19, 0.43]	0.11 [−0.21, 0.41]	−0.16 [−0.45, 0.16]	0.20 [−0.12, 0.48]	0.70*** [0.50, 0.83]	1.00
CDI-Complexity	0.78*** [0.62, 0.88]	0.18 [−0.14, 0.46]	0.14 [−0.18, 0.43]	0.45** [0.16, 0.67]	0.66*** [0.44, 0.81]	0.79*** [0.63, 0.88]	0.33* [0.02, 0.58]	0.05 [−0.26, 0.36]	0.10 [−0.22, 0.40]	−0.35* [−0.60, −0.04]	0,43** [0.13, 0.65]	0.91*** [0.83, 0.95]	0.73*** [0.54, 0.85]

Age, toddler's age; Education, Parental education. In order to achieve the power of at least 80 %, the Pearson correlation coefficient for the anticipated sample size must be at least 0.43.
AWC, adult word count; CVC, child vocalization count; CTC, conversational turn count; PLDK, Parental language development knowledge; LENA, Language Environment Analysis; CDI, MacArthur-Bates Communicative Development Inventory: Words and Sentences; Media_Report, screen time (in minutes) reported by parents; CDI_Vocab, vocabulary size as measured with CDI; CDI_M3L, mean length of utterances as measured with CDI; CDI_Complexity, sentence complexity as measured with CDI; Skew, skewness; Kurt, kurtosis.
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

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a higher score on the knowledge of early language development questionnaire used more parentese, while their toddlers were less exposed to electronic media (according to parental reports). By comparison, children whose parents showed higher knowledge of early language development used less complex sentences as assessed by CDI; however, this association was no longer statistically significant after controlling for age, $r = -0.04$, 95% CI [−0.34, 0.28], $p = 0.829$.

Compared to parents of older toddlers, parents of younger toddlers expressed a greater knowledge of language development. While media exposure estimated by LENA was marginally related to the number of words spoken by adults (AWC; $p = 0.056$) and parental education ($p = 0.057$), parental report of toddlers' media exposure was related to toddlers' age (with older toddlers being more frequently exposed to electronic media), the use of parentese, and PLDK (with parents who reported a lesser media exposure of their toddlers using more parentese and expressing a greater knowledge of early language development). By comparison, toddlers who were more exposed to electronic media, according to their parents' reports, expressed a larger vocabulary and formed grammatically more complex sentences as assessed by CDI (see Table 3). However, these correlations were no longer significant after controlling for the toddlers' age: Partial correlations between Media_Reports and CDI_Complexity and between Media_Reports and CDI_Vocab were, respectively, 0.29, 95% CI [−0.02, 0.55], $p =$ 0.14, and 0.01, 95% CI [−0.30, 0.32], $p = 0.94$, after controlling for toddler's age. Furthermore, the results showed that boys were more exposed to electronic media compared to girls ($M_{boys} = 21.04$, $SD = 16.88$; $M_{girls} = 12.57$, $SD = 8.38$, $t = 2.065$, $df = 31.98$, $p = 0.048$; $d = 0.63$).

3.3 Research question 4

To establish the predictors of parental use of parentese and toddlers' daily media exposure, two robust multiple regressions were conducted, due to the daily media exposure variable being influenced by two influential outliers (see Table 1 for descriptive statistics). Additionally, diagnostic plots used to assess violations of regression assumptions indicated the presence of influential cases, as identified by Cook's distances, as well as abnormalities in the residual distribution. Table 4 shows the outputs of both regression analyses in which p-values and confidence intervals were calculated using the bootstrap approach with 5,000 repetitions. Using parentese was not significantly associated with any of the included predictors; however, toddlers' daily media exposure reported by parents could be considered a marginally important predictor of parentese ($p = 0.053$). By contrast, the model predicting toddlers' daily media exposure reported by parents as the outcome variable contained two significant predictors, namely, PLDK and toddlers' sex. In particular, a higher PLDK score and being a girl predicted less media exposure. With the predictors included in both regression models, we explained 11% of the variance in the use of parentese and 31% of the variance in toddlers' daily media exposure; however, a power analysis computed on five model parameters, a significance level of 0.05, and a sample size of 40 individuals showed insufficient power for the first model (0.37) and appropriate power for the second model (0.90).

4 Discussion

The empirical findings outlined in this study shed light on various factors influencing toddlers' media exposure and language development within naturalistic home settings. The goal of the present study was to explore four specific questions, and we discuss our findings in relation to each.

4.1 Research question 1

According to the parents' reports, we found that toddlers are exposed to media for an average of 18 min per day, with the most common use of electronic media being watching video content on TV or portable video devices. This represents a low level of media exposure overall compared to the results of several other studies, in which the authors report significantly higher media exposure among infants and toddlers. For example, Radesky et al. (2020) report that at least a third of U.S. preschool children by the age of 3 years had access to a mobile device, which they used for an average of ∼2 h per day. Australian infants and toddlers younger than age 2 were also found to use screens for an average of 2 h per day (Rhodes, 2017). Furthermore, Dynia et al. (2021) report 3.79 h per day for 2-year-old American toddlers in low-income households, while Kulakci-Altintas (2020) finds that almost half of Turkish infants and toddlers use at least one technological device for an average of 2–5 h per day. However, when interpreting the results of our study, which was conducted after the COVID-19 pandemic, it should be noted that the parents in our sample were relatively highly educated and that higher levels of parental education were found to be associated with lower levels of media exposure (e.g., Kwon et al., 2024; Tomopoulos et al., 2010). In addition, parents may knowingly or unknowingly report what they perceive to be socially desirable. In fact, the questionnaire on parental knowledge about early language development included two statements directly related to toddlers' screen exposure. On average, parents demonstrated a high level of knowledge on both statements, namely, "Infants and toddlers can learn just as much language from television as they can from their parents during the first two years of life" ($M = 3.72$, $SD = 0.64$) and "Infants can learn more from watching children's educational programs on television than from being read to by their parents" ($M = 3.95$, $SD = 0.22$).

In our sample, the toddlers' low media exposure in their home environments may also be influenced by a broader cultural factor: like most Slovenian toddlers, the toddlers in our study attended a full-day preschool program and therefore spent only part of the day with their parents. That is, it may be that when parents are able to complete their work and some other obligations while their child is in preschool, they may be better able to control their child's media exposure in the home when they are together.

The daylong LENA recordings provided a more objective measure of the toddlers' media exposure; however, it included all media in a child's environment, including, for example, the radio. The media exposure as measured by LENA correlated positively with the parents' reports, although the correlation was marginally significant. The percentage of annotated LENA segments in which electronic sounds were present was 20%,

TABLE 4 Results of multiple robust regressions for two models predicting the use of parentese and toddlers' daily media exposure.

Outcome	Predictor	*B*	CI lower	CI upper	*t*	*p*
Parentese						
	Media_Report	2.3 × 10 − 5	−5.4 × 10 − 5	2.5 × 10 − 8	−1.83	0.053
	Age	−1.0 × 10 − 5	−3.1 × 10 − 4	3.0 × 10 − 4	−0.07	0.988
	Sex-girls	−0.027	−0.106	0.061	−0.69	0.501
	Education	0.003	−0.012	0.020	0.40	0.701
Media_report						
	PLDK	−106.9	−187.9	−24.8	−2.78	0.002
	Age	2.471	−0.369	5.235	1.81	0.090
	Sex—girls	−815.1	−1,533.7	−91.0	−2.36	0.024
	Education	−20.8	−173.2	112.4	−0.30	0.764

CI lower, confidence interval lower bound; CI upper, confidence interval upper bound for regression coefficients; PLDK, parental language development knowledge.

which is lower than in a U.S. sample of infants and toddlers aged 1–24 months (Ferjan Ramírez et al., 2022). Thus, our findings may suggest that parents in the present study may have been familiar with the recommendations for early media use (American Academy of Paediatrics, Council of Communication and Media, 2016; Slovenian Association of Paediatrics, 2021). Recommendations for parents on early media use may also be provided by preschools, which, in Slovenia, employ well-educated preschool teachers and regularly organize lectures for parents on creating a quality environment for children's development and learning. It is important to note, however, that while the average media exposure was low, there were significant individual differences between the toddlers, with the shortest time toddlers were exposed to media being 1 min and the longest being 2.5 h, demonstrated that some toddlers were exposed to the media for much longer than recommended. This type if variability has previously been reported in the literature (e.g., Nikken and Schols, 2015; Seršen et al., 2024).

4.2 Research question 2

The results of our study show large variability in terms of the amount of media exposure in Slovenian toddlers. One factor contributing to this variability is age, as we found that daily media exposure was significantly higher among older toddlers. We found that 15% of toddlers were not exposed to media at all. These toddlers were ∼3 months younger than those who had already been exposed to media.

Research suggests that parental education level is related to children's media exposure (Kwon et al., 2024; Mendelsohn et al., 2008; Tomopoulos et al., 2010). In our sample of relatively highly educated parents, only media exposure recorded by LENA was marginally related to parental education level, with toddlers of parents with higher education being less exposed. By comparison, parental report of daily media exposure was not related to parental education level. In our study, this may be due to the parents' high educational levels, resulting in low variability in parental education levels. Consistent with several studies (e.g., Ferjan Ramírez et al., 2024a; Ramírez-Esparza et al., 2016; Romeo et al., 2021), our results suggest that characteristics of the home language environment are related to several measures of toddlers' language. Toddlers who heard more words from adults vocalized more, produced more words themselves, and participated in more CTs as measured by LENA. They also demonstrated a larger vocabulary as measured by the CDI. Parental use of parentese also seemed to be associated with infants' more frequent vocalization and higher word production, as well as a higher number of CTs. These results outline the importance of parental language input for toddlers' early language development; both the number of words toddlers hear at home and how parents talk to the child were shown to be important in the present study.

Furthermore, the evidence from our study suggests that toddlers' media exposure may be related to the amount of language input provided by parents. Namely, parents of toddlers who experienced more media exposure spoke fewer words and used less parentese when talking to their child. In this regard, the results suggest that higher media exposure might have a negative effect on parent–child conversations, which is in line with several studies (Cycyk and De Anda, 2021; Ferjan Ramírez et al., 2022), indicating that children who spend more time on screens have decreased parent–child language interactions. It seems important to note that although the overall media exposure of toddlers was low, the negative effect on parents' language was nevertheless demonstrated. Conversely, media exposure was not associated with toddlers' language, aligning with several studies that have found no significant link between children's screen exposure and language ability (e.g., Dore et al., 2020; Dynia et al., 2021; Martinot et al., 2021; Taylor et al., 2018). However, multiple studies have connected early and/or high media exposure with slower language development (e.g., Massaroni et al., 2023; Zimmerman et al., 2007). Future research should examine the quality of media content accessible to Slovenian toddlers and investigate the role of parental involvement during screen time to better understand the observed relationships.

4.3 Research question 3

Our results suggest that parental knowledge of early language development might play an important role in the media exposure of toddlers younger than age 3. Toddlers whose parents had better knowledge about language development appeared to be less exposed to electronic media, suggesting that these parents are more aware of the potential negative effects of early media exposure on their child's language development and therefore limit exposure and engage in other activities with the child. Parents with greater knowledge of language development also tended to use more parentese when talking to their children, suggesting that better informed parents may engage in more effective language-promoting behaviors and may be more cautious about their children's media consumption. They may also be more familiar with the recommendations for their children's media consumption. Several studies suggest that parents who are well aware of language development milestones are more likely to provide a supportive environment for the child's language acquisition (Ferjan Ramírez et al., 2021; Rowe, 2008). In the present sample, these parents were also more educated, which is consistent with several other studies (Luo et al., 2021; Suskind et al., 2017). Interestingly, toddlers' age also appeared to be related to parents' knowledge of language development, with parents of younger toddlers expressing a greater knowledge of language development.

4.4 Research question 4

The regression analyses provide further depth in understanding the factors that influence toddlers' early media exposure, on one hand, and parental use of parentese, on the other. Parentese has previously been shown to have a positive effect on the language development of infants and toddlers in North American samples (Ferjan Ramírez et al., 2024a; Huber et al., 2023). In predicting parental use of parentese, of the predictors included (parental education level, toddler media exposure, age, and sex), only toddlers' daily media exposure was found to be a marginally significant predictor in the negative direction. That is, higher toddler media exposure predicted lower parentese use. With the predictors included, we were able to explain a small proportion (11%) of the variance in parental use of parentese.

More robust results were observed in the model predicting toddlers' media exposure, which identified parental knowledge of language development and toddlers' sex as significant predictors. In particular, higher parental knowledge and being a girl were associated with lower media consumption and explained 31% of the variance in toddlers' daily media exposure. Research on media exposure of boys and girls is not consistent, with some authors reporting that girls are more exposed (e.g., Brushe et al., 2023), while others report higher media exposure for boys (Rodrigues et al., 2020). Our findings thus suggest that better informed parents and the sex of the child might influence media exposure practices, potentially impacting language development outcomes. However, due to the small number of girls and boys in our sample, further studies are needed to identify possible gender differences in media exposure and the factors that may contribute to these differences.

5 Conclusion

The present study represents the first attempt to document toddlers' media exposure in Slovenia via naturalistic daylong recordings and parental questionnaires. Using these methodologies allowed us to explore the links between parental knowledge, parental language input, children's media exposure, and children's language production. The findings of our study underline the importance of parental knowledge about language development and the characteristics of the language environment for toddlers' language ability. Namely, parental language input appeared to be related to various measures of toddlers' language, while parents with a greater knowledge of early language development used more parentese and their toddlers were less exposed to the electronic media. By comparison, no significant relationship was found between early media exposure and language production in toddlers. However, the obtained results should be interpreted with caution because of the study's small sample size. Specifically, considering the power analysis results, several observed correlations should be viewed as marginal, highlighting the need for further research. Future studies should explore these dynamics more thoroughly with larger, more diverse samples of children, including those from disadvantaged families, to gain a more comprehensive understanding. Specifically, longitudinal studies that track early media exposure and parental practices over time are essential for understanding the causal relationships and potential long-term effects of media exposure on children's language development in both the present and the future.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/6pybt/?view_only=55cbc976c2dc4c69b92ed7555d0de03b.

Author contributions

UF: Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. LM-U: Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Writing – review & editing. NP-J: Data curation, Formal analysis, Methodology, Writing – review & editing. NF: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Screen on = development off? A systematic scoping review and a developmental psychology perspective on the effects of screen time on early childhood development

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Research on the associations between screen time and child development suggests that various forms of screen time might pose a risk for various aspects of child development. However, data on the impact of exposure to screen media on the development of children under 3 years of age is comparatively scarce. Although the evidence available on the topic is evolving rapidly, no review of existing literature has yet encompassed a comprehensive set of developmental outcomes with a focus in the first 3 years of life. To address this research gap, the present literature review focused on the influences of screen time on various developmental outcomes of children aged zero to 36 months. These outcomes were sleep-related parameters, physical health, cognition, learning efficiency, language, motor skills, socio-emotional skills, social interaction, and overall development. To this end, ten databases were searched systematically, and 158 studies that were published between the launch of the iPhone in early 2007 until 2024 were included. Only studies that reported specific results for the age range of zero to 36 months were examined, including longitudinal studies with samples of children aged zero to 36 months at the first wave of assessment. For most outcomes, a comparable amount of undesirable and non-significant associations was found with children's screen time, while few desirable associations were reported. In line with the notion of resilience, these results indicate that characteristics of the child, the context, and/or the content moderate the associations between screen time and child development in early childhood, thus contributing to mitigating the potential of displacement of learning opportunities or even creating new learning opportunities. More studies with designs that can examine the causal effect of screen time on child development and that explicitly address the role of child, content, and context variables are needed.

KEYWORDS
screen time, early child development, review, scoping analysis, moderation, mediation

Introduction

Screen time in early childhood

Advances in empirical science have shown that early childhood is a particularly sensitive time for experiences that promote development (Black et al., 2017; Britto et al., 2017). Moreover, research indicates that promoting healthy development in early childhood has long-term benefits, not only from a medical and psychosocial point of view but also from an economic one, as early childhood has been shown to provide the greatest return on investment (Doyle et al., 2009; Heckman, 2011; Shonkoff et al., 2017). Thus, it is important to identify opportunities and risks of societal changes to early childhood development to best address them.

One such societal change is digitalization. Various studies highlighted a significant increase in screen media availability in households with young children over the past decade (Bernath et al., 2020; Kieninger et al., 2021; Rideout and Robb, 2020). This widespread availability is believed to contribute to increased usage of both foreground and background screen media among young children (Golden et al., 2020; Rodrigues et al., 2020). A study of 9–11-year-olds that was carried out in Australia, Brazil, Canada, China, Colombia, Finland, India, Kenya, Portugal, South Africa, the United Kingdom, and the United States reported that more than half of the sample failed to meet screen time guidelines (LeBlanc et al., 2015). The authors reported that average screen time (i.e., average TV hours plus average gaming and computes hours per day) varied from 1.8 h ($SD = 1.3$) in India, to 3.7 h ($SD = 2.3$) in Brazil. Indeed, children worldwide spend significant time with screens, with average daily screen time increasing as children age. By age seven, children have spent a full year of 24-h days watching screen media and are spending up to 3 years of 24-h days watching screen media by age 18 (Sigman, 2012).

In the US, children under two spend 49 min per day in front of a screen, mainly watching TV or videos/DVDs. Children aged two to four spend an average of 2.5 h a day with a screen, also mostly watching TV, videos, and DVDs (Rideout and Robb, 2020). Thus, children start using screen media from very early in life (Chonchaiya et al., 2011; Lawrence et al., 2020; Levine et al., 2019; Nathanson et al., 2014; Richert et al., 2010; Yang et al., 2017). The combination of the importance of (A) early childhood for lifelong development (Black et al., 2017; Britto et al., 2017) and (B) the increasing availability of and exposure to screens during early childhood, has led to increasing concerns about the impact of young children's screen time on various aspects of their development (Bleckmann et al., 2022). However, there are also studies that suggest that there worries in this regard might not be based on empirical data (Ferguson et al., 2024). To outline the relevance of the topic at hand, we will provide both a theoretical and empirical overview of the correlates of screen time in the following sections.

Theoretical perspective on the effects of screen time on child development

Some of the most central hypotheses about the effects of screen time on child development are outlined in the following. These hypotheses lack specificity as to which developmental aspect is likely to be affected. In fact, most hypotheses can be used to draw inferences about the effects of screen time on multiple interdependent aspects of child development.

The learning hypothesis (Bandura, 1994, 2001) and information processing theory (Huesmann, 1986) both support the idea that screen media can be a source of learning for children. On the one hand, exposure to a video displaying violent acts can lead a child to imitate such behaviors, as shown in the classic Bobo doll experiment (Bandura et al., 1961). On the other hand, screen media can also be a source of educational content, teaching children about numbers, letters, colors, and shapes (Anderson et al., 2001; Singer and Singer, 2001; Shin, 2004), along with more complex skills such as songs or prosocial behaviors, especially from content designed to be educational and informative.

The video deficit hypothesis (Barr, 2008; Anderson and Pempek, 2005) suggests that while young children can learn from screen media, they tend to be less effective at doing so compared to learning from real-life experiences. According to the video deficit hypothesis, young children are generally less effective at learning from screen media compared to real-life experiences (Barr and Wyss, 2008; Nielsen et al., 2008). The diminished learning from videos is attributed to the absence of important elements that facilitate information processing, including socially relevant signals, the direction of gaze, and the integration of visual, auditory, and spatial information that are present in live interactions (Jing and Kirkorian, 2020).

The displacement hypothesis (Mutz et al., 1993; Roberts et al., 1993) postulates that screen media would displace vital activities that are crucial for a child's healthy development. For example, the hours spent in front of a screen could otherwise be spent on interactions with parents, caregivers, and peers, which are key to developing socio-emotional abilities. As such, a rise in screen time among children is believed to potentially hinder their development by displacing these critical learning experiences (Oswald et al., 2020).

Furthermore, the mental-effort hypothesis (Koolstra and van der Voort, 1996) and the passivity hypothesis (Valkenburg and van der Voort, 1994) argue that passive engagement with screen media, such as television or videos, causes passivity in children. The mental-effort hypothesis (Koolstra and van der Voort, 1996) suggests that such passive use of screens could lead to a decrease in mental engagement. Similarly, the passivity hypothesis (Valkenburg and van der Voort, 1994) posits that the cognitive demands of processing information from passive screen use are lower compared to more active tasks such as reading. The fast pace of many programs may provide limited opportunities for deep thinking, which could hinder the development of critical and reflective thinking processes in children.

These hypotheses about potential negative consequences of too early consumption of screen media are reflected in some of the guidelines for parents. For example, in 2019, the World Health Organization (WHO) published recommendations for physical activity, sedentary activities, and sleep for children up to the age of 5 years (World Health Organization, 2019). For children younger than 2 years of age, sedentary screen time is discouraged entirely, and from 2 to 4 years of age, a maximum duration of sedentary screen time of 60 min per day is recommended, with the recommendation that less is better. Furthermore, the WHO emphasizes that its recommendations are based on a sparse and qualitatively very low evidence base: "The overall quality of evidence was rated as very low" (p. 8).

Empirical perspective on the effects of screen time on child development

In recent years, several literature reviews and meta-analyses have addressed the effects of young children's screen time on early childhood development (Stiglic and Viner, 2019). The vast majority of findings reported in these reviews and meta-analyses suggest that young children's screen time has undesirable associations with sleep-, body- and fitness-related parameters and on children's socio-emotional skills (Janssen et al., 2020; Mallawaarachchi et al., 2022; Puzio et al., 2022; Ren, 2023; Swider-Cios et al., 2023; Paulus et al., 2021), and the links between young children's screen time and their cognitive, language, and motor outcomes range from undesirable through insignificant to desirable (Mallawaarachchi et al., 2022; Puzio et al., 2022; Ren, 2023; Swider-Cios et al., 2023; Paulus et al., 2021; Guellai et al., 2022; Karani et al., 2022), as is outlined in the following.

Regarding sleep, Lund et al. (2021) reviewed 49 studies investigating the associations between electronic media use and sleep in children aged 0 to 15 years across European countries. They concluded that the evidence for an undesirable link to various sleep parameters, such as sleep duration, delayed bedtime, or sleep quality, was stronger among school-aged children compared to preschool children. In preschool children, televiewing appeared to be associated with less desirable sleep parameters, while evidence regarding the potential effects of video gaming, smartphone use, or the presence of media in the bedroom was deemed insufficient.

Several systematic reviews and meta-analyses indicated a potential for a negative impact of screen time on language development in early childhood. For instance, Massaroni et al. (2024) highlighted the risk of prolonged screen time on language. Further, Karani et al. (2022) emphasizes the multifactorial nature of this relationship, with the negative influences of screen time outweighing the positive. However, Madigan et al. (2019) also notes that the quality of screen use, such as educational programming and co-viewing, can have a positive impact on language skills. This suggests that while screen time should be limited, the type of content and the context of use can also play a role in language development.

Similarly, various literature reviews indicate that excessive screen time in early childhood increases the risk of undesirable associations with cognitive development, including language acquisition, attention, and learning (Kostyrka-Allchorne et al., 2017; Panjeti-Madan and Ranganathan, 2023). Again, the impact of screen time on cognition is influenced by contextual factors such as the behavior of adult caregivers, the content being viewed, and the interactivity of the screen (Guellai et al., 2022). Therefore, while some studies suggest the potential for a desirable link, the consensus is that excessive screen time can be detrimental to cognitive development in early childhood.

Research on early childhood screen time and its impact on socio-emotional development is mixed. In their systematic review, Panjeti-Madan and Ranganathan (2023) conclude that screen time can have both benefits and drawbacks for socio-emotional development. Results of a meta-analysis by Eirich et al. (2022) reveal that screen time is significantly but only weakly related to both internalizing and externalizing problems among children aged up to 11 years. Lissak (2018) further emphasizes the adverse physiological and psychological correlates of excessive screen time, including depressive symptoms and ADHD-related behavior.

Several of reviews on the correlates of screen time on child development have been published (Mallawaarachchi et al., 2022; Ren, 2023; Swider-Cios et al., 2023; Guellai et al., 2022; Karani et al., 2022; Lissak, 2018). However, these reviews mostly focused on selected developmental outcomes and do not provide insight into the overall impact of screen time across a wide range of developmental domains, including motor skills, cognitive skills, and socio-emotional skills. The inclusion of a broad range of development outcomes is crucial, as it has been shown that the different areas of development are interrelated and influence one another (Thelen and Smith, 2006). Furthermore, the age range considered in these reviews varies greatly, with some covering ages zero to three and others spanning from birth to late childhood or even adolescence. Additionally, the study design was not consistently addressed in some of these reviews. Thus, a review on studies about the correlates of all types of traditional and modern screen media on a comprehensive range of children's development in the first 3 years of life and addresses the study design of these studies is still missing.

The current study

The aim of the present study was thus to give an overview about the associations between screen time and multiple aspects of child development in the first 3 years of life. Herein, we aimed to consider both traditional and modern screen devices and to differentiate the results by study design. A review that covers all these aspects is necessary for three main reasons: First, rapid and crucial neural development takes place in the first 3 years of life, and this can have effects on other areas of development. Second, the technological development that has taken place since the invention of portable and smart devices has opened new possibilities that go far beyond passive, socially isolated television, and thus modern digital media cannot be assumed in principle to equate with television, especially for child development. Although young children may not fully grasp all aspects or functions of interactive devices, their experiences might still differ from traditional television, as even in instances where a child lacks understanding, they may still be learning. Third, the study design of the studies needs to be taken into consideration to enable more differentiated implications to be identified for parents, practitioners, researchers, and policy makers.

Regarding the time frame under consideration, we focused on studies published since 2007 because 2007 marked the release of the first iPhone, which revolutionized screen-based technology. By selecting this period, our review builds on earlier literature that primarily examined traditional screen media, such as television, and extends the focus to more recent developments in digital media use. Consequently, we posed two research questions for the present literature review: How is children's screen time with traditional and modern devices related to a broad range of developmental outcomes in the first 3 years of life? What are the prevailing methodological approaches and considerations in this specific field of research? To address these questions, we conducted a systematic scoping review by combining a scoping review with a systematic literature review. The characteristics of a scoping review include the non-systematic assessment of the quality of the studies, for instance using scoring grids, and thus incorporate all the empirical quantitative studies available regardless of their quality (Grant and Booth, 2009). In contrast, the characteristics of a systematic review include the systematic search and inclusion of evidence, such as inclusion and exclusion criteria, and the systematic evaluation of methodological approaches of the studies included (Grant and Booth, 2009). By combining these two approaches, the scope of quantitative research on this topic can be presented and critically evaluated methodologically.

Methods

Protocol

PRISMA-ScR guidelines for reporting scoping reviews (Tricco et al., 2018) were followed when preparing this manuscript (see Supplementary Table S.2).

Eligibility criteria

To be included in this review, studies had to fulfill five criteria (for further details see Supplementary Table S.3): (A) Studies had to be published between January 2007 and October 2024. This start date was chosen because the iPhone 1 was first presented by Apple on January 9th 2007; we take this date as marking the beginning of a revolution in the concept of digital media (Block, 2007). (B) The study sample had to include children between birth and 36 months of age, without clinical diagnoses, and from parents no younger than 18 years of age. For multiple age groups within a study, results needed to be reported specifically for the age group of birth to 36 months of age. In longitudinal studies, children needed to be the age of interest at the first measurement time point. (C) The study had to include an assessment of screen usage including time, content, and/or context. (D) The studies needed to include a measurement of at least one developmental outcome, such as sleep, physical health and diet, cognition, language, learning efficiency, motor skills, socio-emotional development, social interaction, or overall development. (E) The relationship between children's screen use and their development had been examined with quantitative research methods in an experimental, longitudinal, or cross-sectional study design. The study had to be an original study. Meta-analyses and reviews were excluded.

Search strategy and information sources

Four rounds of literature search were conducted. The first round was carried out on October 23, 2019, when ten databases were searched for peer-reviewed articles published between 2007 and 2019: PsycInfo, PsycArticles, PsycExtra, Psyndex, Medline, MIDIRS, ERIC, Web of Science, PubPsych, and PubMed. The keywords for this search were divided into three groups (see Table 1). The first group consisted of keywords that identified the age range of interest, and the second group, linked to the first block with "AND," included keywords that identified the behavior of interest, use of digital media. Finally, the third group, linked to the second block with "NOT," included keywords that would exclude irrelevant studies as efficiently as possible. A second round of literature search for peer-reviewed articles published between 2007 and 2019 was carried out on May 10th, 2021, because additional crucial keywords were identified during the review of the first batch of studies (e.g., DVD). A new set of keywords was used as a replacement for the second group of keywords. Four databases were systematically searched: PsycInfo, Medline, PubPsych, and Web of Science. Initial exploratory searches revealed that the remaining six databases primarily generated duplicates. In the third round of literature search, also conducted on May 10th, 2021, we compiled all keywords and searched for peer-reviewed articles published between 2019 and May 10th 2021 in PsycInfo, Medline, PubPsych, and Web of Science to ensure that the search results would be up to date. The fourth and final round of literature search was conducted on October 25th, 2024, we used the compiled keywords and searched for articles published between May 11th 2021 and October 25th, 2024 in PsycInfo and Medline. All searches were performed on the titles of articles. The full search strategy is provided in Supplementary Table S.5. Additional studies were identified by reviewing the reference lists of the key articles.

Selection process

The articles identified by the four search rounds were imported into the Zotero literature management software, and most duplicates were automatically deleted. Titles and abstract were then screened by two independent raters and remaining additional duplicates were deleted. Two undergraduate students assisted in this process. Articles found to be relevant in this initial screening were subsequently subjected to full text screening to determine final eligibility for inclusion in the review synthesis. Disagreements about study inclusion among reviewers were resolved through consultation of criteria in the protocol and critical discussion among the authors.

Data items

To interpret the results for various outcomes, studies identified by final screening were grouped into nine main developmental categories: sleep, physical health, cognition, learning efficiency, language, motor skills, socio-emotional skills, social interaction, and overall development. This final category included studies that

TABLE 1 Blocks of keywords.

Block of keywords	Keywords
1st Block: Age range of interest	(child$4 OR baby OR babies OR kid$1 OR infant* OR toddler* OR pre-school* OR preschool*).ti **AND**
2nd Block: Behavior of interest	(screen-time OR screen-use OR screen-view$3 OR media-use OR mobile-time OR media-time OR screen-based-media OR screen-media OR digital-media OR digital-play OR media-exposure OR tablet-use OR television-view$3 OR TV-view$3 OR television-watch$3 OR tv-watch$3 OR touch-screen$1 OR smart-phone* OR mobile-device$1 OR computer$1 OR PC$1 OR gaming OR video-gam$3).ti **NOT**
3rd Block: Exclusion of non-relevant studies	(malaria OR infection OR disease OR allergic OR diabet* OR cancer OR tumor OR asthma OR otitis media OR chronic medical conditions OR intima-media thickness OR heart disease OR cerebral palsy OR visual impair* OR hearing impair* OR hearing loss OR intellectual disabilit* OR disabilit* OR spinal muscular atrophy OR amblyopia OR cleft OR pharmacokinetics OR HIV OR autism spectrum disorder OR autism OR ASD OR ASC OR cognitive behavior* therapy OR compensatory training OR PTSD OR posttraumatic stress reaction OR trauma* OR assessment OR computer-aided OR computer-assisted OR computer-simulation OR computer-based OR computer-analysis OR computer-mediated OR non-contact monitoring OR automated OR computerized OR computer algorithm OR screening OR treatment OR computer tomography OR online surveillance OR sex offenders OR world cup OR wrestling OR Olympics).ti
New set of keywords: Behavior of interest	(background-media-exposure OR digital-games OR digital-media OR digital-screen-media OR DVD OR electronic-application-use OR handheld-screen-time OR media OR media-exposure OR media-use OR media-viewing OR mobile-media-use OR interactive-media-use OR mobile-screen-media-use OR screen-media-content OR screen-media-exposure OR screen-media-use OR screen-based-media OR video OR sedentary behavior).ti

Ti, title; the search for keywords was performed on the title.

described an overall development status as outcome. Further, the category of learning efficiency is a research branch of cognitive development. Given that this research branch is characterized by homogeneous experimental studies, it was analyzed separately. This review sample also included studies that examined other learning transfers from screens, such as word learning. Although these studies could have been included in the cognition category, we included them in the specific developmental area, such as language development. Furthermore, subcategories were defined where appropriate: for example, for cognition we subcategorized studies into general cognition, attention, executive functions, and other cognitive outcomes. An overview of the subcategories of these development areas can be found in Supplementary Table S.7.

Results

Figure 1 shows the PRISMA flowchart for study inclusion. An overview of all included studies is provided in Supplementary Table S.1.

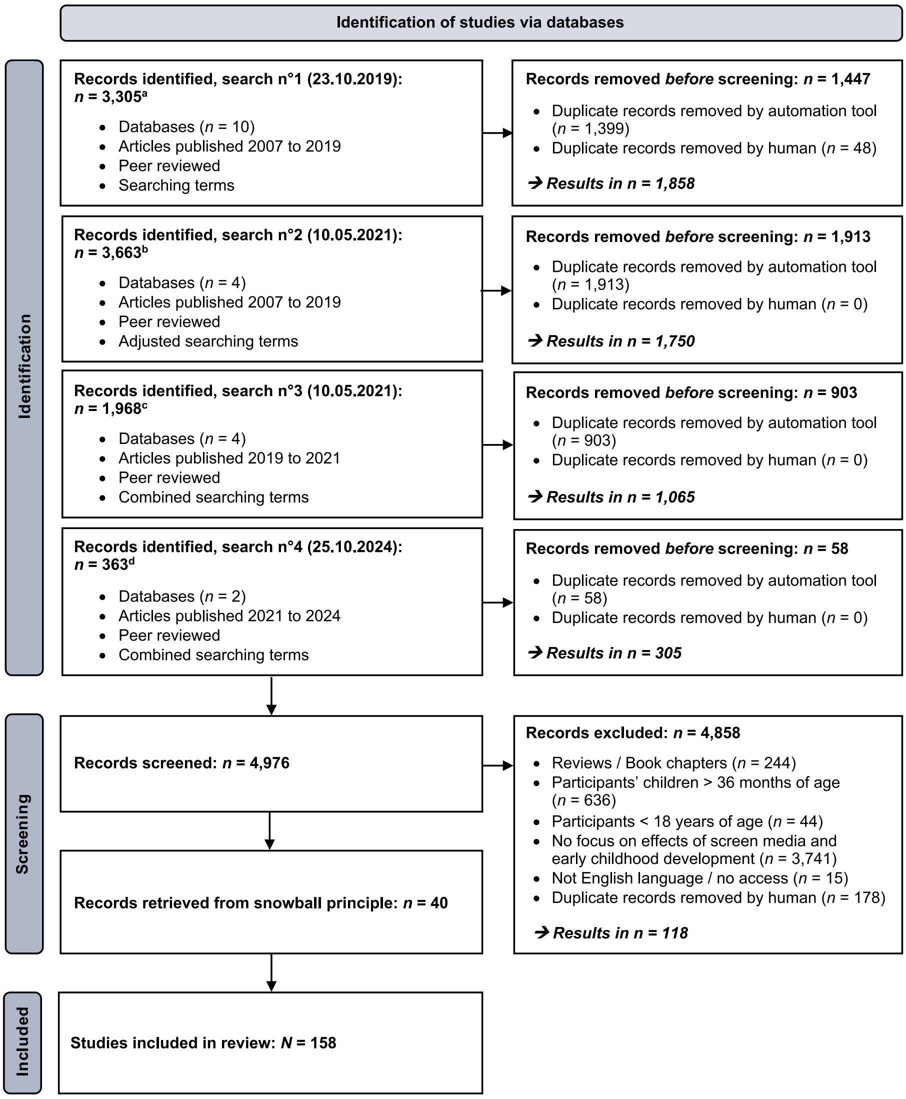
Results are reported for nine development categories: (1) sleep, (2) physical health, (3) cognition, (4) learning efficiency, (5) language, (6) motor skills, (7) socio-emotional skills, (8) social interaction, and (9) overall development. The specific aspects that are subsumed to these categories are outlined in the results section of the respective developmental category. For each developmental category, we aimed to differentiate between experimental and correlational studies. Further, we divided studies with a correlational design, but not those with an experimental design to differentiate between correlational studies with a longitudinal and those with a cross-sectional design. In this review, the term "semi-longitudinal studies" is used for correlational studies that are longitudinal in nature but that measured the outcome variable only at one time point, usually the last one. In such cases, the baseline measurement for the outcome of interest is lacking, and thus no modeling of change in the outcome variable can be done. Cross-sectional findings reported in longitudinal studies are described in the cross-sectional studies section. Thus, the results of the studies are arranged in the following order: (1) experimental studies, including both longitudinal and cross-sectional designs, (2) correlational longitudinal studies, (3) correlational semi-longitudinal studies, and (4) correlational cross-sectional studies.

For some of the developmental categories, subcategories are presented separately (e.g., bedtime and sleep latency as subcategories of sleep), as associations vary among subcategories and must therefore be differentiated. An overall summary can be found after the presentation of the results for each developmental category. Herein a table showing the counts of all undesirable (–), non-significant (=), and (+) desirable associations that were reported in the studies (see Table 2 for an example).

The studies included in this review used a wide variety of terms for screen time: TV watching, televiewing, media exposure, screen exposure, viewing time, total screen time, touchscreen time, and foreground or background screen time; this variety indicates both the diversity of screen experiences for children and the complexity of screen time as a construct. The reporting of results uses the terms cited in the studies whenever possible. However, definitions of the same terms may vary across studies. For example, the term "total media exposure" may be understood as the sum of foreground and background screen time in one study and as total foreground screen time on various devices in another. The same issue applies to the variety of screen devices, which is why we adopt the terminology of the study in question whenever possible.

Sleep

Studies on the association between screen time and sleep-related parameters ($n = 23$) are reported in the following sections. One study was included even though the age range was up to 37 months instead of 36 (Hackl-Wimmer et al., 2021).



[a] PsycInfo (n = 701); PsycArticles (n = 28); PsycEXTRA (n = 45); Psyndex (n = 16); Medline (n = 708); MIDRIS (n = 38); ERIC (n = 238); Web of Science (n = 975); PubPsych (n = 75); PubMed (n = 481)
[b] PsycInfo (n = 1,032); Medline (n = 1,026); Web of Science (n = 1,495); PubPsych (n = 110)
[c] PsycInfo (n = 259); Medline (n = 648); Web of Science (n = 772); PubPsych (n = 289)
[d] PsycInfo (n = 107); Medline (n = 256);

FIGURE 1
PRISMA flowchart of study selection.

TABLE 2 Sample summary of results.

Development area/ subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Outcome A	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
Outcome B	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
Total for outcome	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*

"−," undesirable association; "=," non-significant association; "+," desirable association; n, number of results.

Bedtime

Bedtime refers to the time when the child goes to bed. If bedtime is delayed due to screen time, this would indicate an undesirable correlate of screen time. A longitudinal study yielded an undesirable link between total screen time (Xu et al., 2016), and cross-sectional studies also found support for an undesirable association with screen time (Bellagamba et al., 2021) and TV viewing (Dong et al., 2015). No desirable associations were reported in any study. Neither experimental studies nor semi-longitudinal assessments were found that included bedtime.

Sleep latency

Sleep latency, or sleep onset latency, is the length of time someone takes to fall asleep. Increased children's sleep latency would be an undesirable correlate of children's screen time. One experimental study found no effects of a reduction of before bedtime screen time on sleep onset latency (Pickard et al., 2024). One longitudinal study pointed to undesirable correlates of screen time (Xu et al., 2016), but others found no significant associations with total media exposure, total viewing time, evening media use, onset of media use (Chonchaiya et al., 2017), or screen time (Benita et al., 2020). Results from cross-sectional studies and from cross-sectional components of longitudinal studies hint at undesirable associations with total screen time (Chonchaiya et al., 2017), screen time (Xu et al., 2016), time with portable screen devices (Cheung et al., 2017; Chindamo et al., 2019), and time spent watching adult programs (Chonchaiya et al., 2017). Shorter sleep latency was found to be linked to more screen use during bedtime routine but not to pre-bedtime screen use (Staples et al., 2021). Non-significant cross-sectional associations were found with overall digital media use including audio media (Hackl-Wimmer et al., 2021), time spent watching educational and non-educational programs targeted at children (Chonchaiya et al., 2017) and with TV exposure (Cheung et al., 2017). No experimental studies and no semi-longitudinal studies were found that included sleep latency.

Total sleep duration

Total sleep duration refers to the amount of time children spend sleeping during a 24 h period. Increased total sleep time as an association with screen time would indicate a desirable association. Longitudinal studies showed negative effects for total screen time (Xu et al., 2016), and TV viewing time (Cespedes et al., 2014; Marinelli et al., 2014). Cross-sectional findings yielded undesirable associations with television watching time (Marinelli et al., 2014; Twenge et al., 2019; Diler and Başkale, 2022), use of portable screen devices (Cheung et al., 2017; Chindamo et al., 2019; Twenge et al., 2019; Diler and Başkale, 2022), screen use during bedtime routine but not pre-bedtime screen use (Staples et al., 2021), and composite scores of screen time (Diler and Başkale, 2022; Chen et al., 2019). Non-significant cross-sectional associations were found with overall digital media use (Hackl-Wimmer et al., 2021), tablet use (Porter et al., 2022), onset of media use (Chonchaiya et al., 2017), duration of media exposure (Chonchaiya et al., 2017; Chen et al., 2019; Cartanya-Hueso et al., 2021), and TV exposure (Cheung et al., 2017). No desirable associations were reported in any study. No experimental studies and no semi-longitudinal studies were found that included total sleep duration.

Nighttime sleep duration

An experimental study found that reducing screen time before bed had no impact on the duration of nighttime sleep (Pickard et al., 2024). Two longitudinal studies found an undesirable effect of total screen time (Xu et al., 2016; Benita et al., 2020), and another one reported a non-significant effect (Vijakkhana et al., 2015). However, cross sectional results from a semi-longitudinal study showed that bedtime TV viewing was linked to shorter nighttime sleep duration among a sample of Medicaid-eligible racial/ethnic minorities (Miller et al., 2022). Results from cross-sectional studies indicate a negative link with tablet use (Porter et al., 2022), total screen time (Xu et al., 2016; Bellagamba et al., 2021; Vijakkhana et al., 2015), and touchscreen time (Cheung et al., 2017), while non-significant associations were found with overall digital media use (Hackl-Wimmer et al., 2021), onset of media use (Chonchaiya et al., 2017), duration of media exposure (Chonchaiya et al., 2017), bedroom media use (Vijakkhana et al., 2015), and TV exposure (Cheung et al., 2017). No desirable associations were reported in any study. No semi-longitudinal studies were found that included nighttime sleep duration.

Daytime sleep duration

An experimental study indicated that cutting down on screen time before bed had a minimal and non-significant effect on daytime sleep duration (Pickard et al., 2024). In cross-sectional studies, undesirable links were reported for TV exposure (Cheung et al., 2017), and non-significant associations were found with onset of media use (Chonchaiya et al., 2017), duration of media exposure (Chonchaiya et al., 2017), and touchscreen time (Cheung et al., 2017). No desirable associations were reported in any study.

Nighttime awakenings

Nighttime awakenings refer to how often a child wakes during the night. An increased number of nighttime awakenings would indicate an undesirable association with screen time. An experimental study indicated that cutting down on screen time before bed had a minimal and non-significant effect on nighttime awakenings as well as sleep efficiency, although sleep efficiency and to some degree also nighttime awakenings changed in a desirable direction for the intervention group that not only received a bedtime box but also was instructed to reduce before-bedtime screen time (Pickard et al., 2024). A single longitudinal study showed an undesirable effect for total screen time (Xu et al., 2016). Cross-sectional results indicate undesirable links with total screen time (Xu et al., 2016) and non-significant associations with onset of media use (Chonchaiya et al., 2017), duration of media exposure (Chonchaiya et al., 2017), TV exposure (Cheung et al., 2017), and touchscreen time (Cheung et al., 2017). No desirable associations were reported in any study. No semi-longitudinal studies were found that included nighttime awakenings.

Sleep problems

This section includes results from studies in which sleep problems were assessed more broadly using a specific sleep-related questionnaire such as the Children's Sleep Habits Questionnaire. Indications of worsening sleeping problems were reported in a study that assessed sleep problems at ages two and 3 years but only assessed screen use at age three (Genuneit et al., 2018). One semi-longitudinal study found that children who watched more than 2 h of TV both around the age of 30 months and at 5.5 years had more sleep problems at 5.5 years (Mistry et al., 2007), but another identified no association between increased TV exposure and adult TV programs with sleep problems at age 18 months (Chonchaiya et al., 2015). Cross-sectional results from a semi-longitudinal study showed bedtime TV viewing was associated with more sleep problems in Medicaid-eligible racial/ethnic minority children (Miller et al., 2022). Cross-sectional studies suggest undesirable links to pre-bedtime as well as bedtime routine screen use (Staples et al., 2021), TV and DVD watching (Genuneit et al., 2018; Chonchaiya et al., 2015), and other computer or internet use, but not to computer gaming (Genuneit et al., 2018), and touch screen usage (Lin et al., 2020), as well as between tablet use and parental concerns about their children's (Porter et al., 2022). Further, bedtime routine screen use was found to be linked to potential indicators of sleep problems such as sleep timing and variability but not to sleep activity or consolidation, and pre-bedtime screen use was found to be linked to sleep timing but not to sleep variability, consolidation, or activity (Staples et al., 2021). An undesirable association was also found between overall digital media use (including audio media) and heart rate during sleep (Hackl-Wimmer et al., 2021). However, it should be noted that some of these indicators are not necessarily considered sleep problems on their own, whereas a combination of multiple such indicators may provide a more robust indication of a sleep problem (Staples et al., 2021). No desirable associations were reported in any study.

Methodological considerations

Most sleep-related outcomes were assessed with parent-reported data collected in questionnaires. One study combined parent-reported data and actigraphs (Pickard et al., 2024; Staples et al., 2021), portable sensing devices assessing heart rate (Hackl-Wimmer et al., 2021), and another study used a 1-week sleep diary (Vijakkhana et al., 2015). Most studies assessed screen time from one-time parent reports (i.e., single retrospective assessment) with varying time frames of reference. Some studies used a single 24-h recall (Bellagamba et al., 2021; Chonchaiya et al., 2017; Vijakkhana et al., 2015) or a screen time diary (Pickard et al., 2024), whereas others assessed screen time for an average weekday and weekend day and then computed an average score for screen time (Hackl-Wimmer et al., 2021; Benita et al., 2020; Cespedes et al., 2014; Diler and Başkale, 2022; Chen et al., 2019; Cartanya-Hueso et al., 2021). Many studies relied on categorization procedures to examine the links between screen time and outcomes (Chonchaiya et al., 2017; Chindamo et al., 2019; Marinelli et al., 2014; Vijakkhana et al., 2015; Genuneit et al., 2018; Mistry et al., 2007; Hu et al., 2019). Extreme-group comparisons were also used in some studies to show the effects of extreme scores of screen time (Chindamo et al., 2019; Cespedes et al., 2014; Mistry et al., 2007). Moreover, several studies focused only on TV and DVD (Dong et al., 2015; Cespedes et al., 2014; Marinelli et al., 2014; Miller et al., 2022; Mistry et al., 2007; Chonchaiya et al., 2015; Hu et al., 2019), whereas one study assessed only touch screen use (Lin et al., 2020) and one focused on tablet use (Porter et al., 2022). Some studies considered the content of screen time as a predictor (Chonchaiya et al., 2017; Vijakkhana et al., 2015; Chonchaiya et al., 2015) and another considered the context in which screen time occurs (Bellagamba et al., 2021). Although some studies took parental involvement in children's activities (Mistry et al., 2007) and outdoor playtime into account (Xu et al., 2016), other non-digital activities were not taken into account in most studies. Further, few studies took active play or another indicator of physical activity into account (Cespedes et al., 2014; Marinelli et al., 2014; Twenge et al., 2019; Cartanya-Hueso et al., 2021; Hu et al., 2019).

Summary of evidence on sleep

Table 3 shows the summary of results for sleep. Overall, results show that there were mostly longitudinal and cross-sectional studies, while only few experimental or semi-longitudinal studies were found. The number of studies reporting undesirable associations was close to the number of studies reporting non-significant associations, while no desirable associations were found in any study. This overall pattern suggests that results on the links between screen time and sleep parameters are inconclusive, with a tendency to undesirable associations. Objective measurement of sleep might enhance the quality of the study, although perhaps

TABLE 3 Summary of results pertaining to sleep.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Bedtime	0	0	0	1	0	0	0	0	0	2	0	0	*3*	*0*	*0*
Sleep latency	0	1	0	1	5	0	0	0	0	6	5	0	*7*	*11*	*0*
Total sleep duration	0	0	0	2	0	0	0	0	0	7	7	0	*9*	*7*	*0*
Nighttime sleep duration	0	1	0	2	2	0	0	0	0	4	6	0	*6*	*9*	*0*
Daytime sleep duration	0	1	0	0	0	0	0	0	0	1	3	0	*1*	*4*	*0*
Nighttime awakenings	0	2	0	1	0	0	0	0	0	1	4	0	*2*	*6*	*0*
Sleep problems	0	0	0	0	2	0	1	0	0	10	9	0	*11*	*11*	*0*
Total	*0*	*5*	*0*	*7*	*9*	*0*	*1*	*0*	*0*	*31*	*34*	*0*	*39*	*48*	*0*

"−," undesirable association; "=," non-significant association; "+," desirable association.

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reducing the feasibility of research in this area. Finally, other contextual aspects of screen time such as time of day and non-digital activities should be considered in future research.

Physical health

This section reports studies on the association between screen time and obesity and diet, blood pressure, and muscular fitness ($n = 17$). Given that the number of outcomes that were studied is comparatively limited, results are not divided by specific outcome.

Results of an experimental study revealed that watching a DVD leads to lower salivary cortisol levels than playing with blocks (Christakis et al., 2013), thus providing evidence of differing neurocognitive processes. An experimental study with preterm infants showed, that video calls combined with singing lullabies by the mothers had desirable effects on infants' respiratory rates, while only video calls (without singing lullabies) had no effect as compared to a no-video call control group (Kaynak and Yilmaz, 2024). In the same study, video calls both with and without singing lullabies had desirable effects on infants' oxygen saturation as compared to the no-video control group. Another experimental study was able to show that respiratory sinus arrhythmia increased while heart rate decreased during a co-viewing task as compared to a control baseline activity, which indicates that children were more relaxed while co-viewing educational content (Porter et al., 2022). Similarly, children's hearth rate variability was found to increase while co-viewing emotionally salient videos, which indicates better regulation as compared to a baseline measurement (Stockdale et al., 2023).

Longitudinal (Fuller-Tyszkiewicz et al., 2012; Saldanha-Gomes et al., 2017) and semi-longitudinal (Collings et al., 2018; Fitzpatrick et al., 2012; Padmapriya et al., 2019; Pagani et al., 2010) studies reported undesirable associations between TV viewing and body mass index (BMI) and waist circumference (Fuller-Tyszkiewicz et al., 2012; Collings et al., 2018; Fitzpatrick et al., 2012), general fitness (Pagani et al., 2010), and standing long jump performance (Fitzpatrick et al., 2012). Additionally, non-significant associations between TV viewing and BMI (Saldanha-Gomes et al., 2017; Collings et al., 2018), sum of skinfolds (Collings et al., 2018), and blood pressure (Padmapriya et al., 2019) were found. Furthermore, Padmapriya et al. (2019) found that total screen time, TV time, and handheld screen time were consistently linked to larger skinfolds and higher BMI scores only in boys. A positive link between TV and DVD time and body fat was reported only for boys (Saldanha-Gomes et al., 2017), while fat mass index was not systematically found to be linked to screen time in semi-longitudinal and cross-sectional models in another study, although some undesirable associations were found for boys and for girls (Kracht et al., 2023). A study examining the bidirectional link between televiewing and food intake in children aged up to 1 year found no relationship between food intake and more televiewing, nor was food intake found to be a mediator of the relationship between televiewing and BMI (Fuller-Tyszkiewicz et al., 2012).

Turning to cross-sectional studies, one study found overall screen time to have an undesirable association to diet in terms of higher odds of following a processed dietary pattern and lower odds of a following a healthy dietary pattern in children with screen time above 30 min per day as opposed to children with no screen time (Masztalerz-Kozubek et al., 2024). Moreover, cross-sectional studies found TV viewing not to be linked to overweight or obesity in children younger than 3 years of age (Hu et al., 2019; Saldanha-Gomes et al., 2017; Manios et al., 2009; Plitponkarnpim et al., 2018). Cross-sectional findings from a longitudinal study hint at undesirable correlates of TV viewing and BMI (Fuller-Tyszkiewicz et al., 2012). One study yielded no association between eating while watching TV and BMI, sum of skinfolds, or waist circumference (Collings et al., 2018). Another study found a link between having feeding difficulties and regularly using screen media while eating (Teekavanich et al., 2022). Other cross-sectional studies found no link between having a TV in children's bedrooms and the children's BMI, sum of skinfolds, or waist circumference (Collings et al., 2018). Children's televiewing during meals was found to be linked to consumption of unhealthy food (Manios et al., 2009; Horodynski et al., 2010), but only if mothers' consumption of unhealthy food was not taken into account (Horodynski et al., 2010). Further, televiewing for more than 1 h per day was found to be linked to more televiewing while having meals, having snacks while televiewing, and exposure to junk food advertising (Hu et al., 2019). No studies were found showing desirable correlates of screen time.

Methodological considerations

Outcomes were widely assessed during on-site visits by trained personnel. Screen time was assessed by parent reports in all non-experimental studies, mostly for an average weekday and weekend day. Data on screen time was categorized in some studies, and group comparisons were used to assess the effects of screen time (Hu et al., 2019; Saldanha-Gomes et al., 2017; Collings et al., 2018; Masztalerz-Kozubek et al., 2024; Manios et al., 2009). Most studies focused on TV and DVD viewing (Hu et al., 2019; Christakis et al., 2013; Stockdale et al., 2023; Fuller-Tyszkiewicz et al., 2012; Saldanha-Gomes et al., 2017; Collings et al., 2018; Fitzpatrick et al., 2012; Pagani et al., 2010; Kracht et al., 2023; Manios et al., 2009; Teekavanich et al., 2022; Horodynski et al., 2010), and one study reported separate but consistent results for total, TV, and handheld screen time (Padmapriya et al., 2019), while one experimental study focused on the effects of video calls of infants with their mothers as well as singing lullabies (Kaynak and Yilmaz, 2024), thus considering both the content and the context. One experimental study specifically focused on co-viewing educational content (Porter et al., 2022), while another focused on co-viewing emotionally salient content (Stockdale et al., 2023). Some studies examined TV watching during meals and snacks during screen time (Hu et al., 2019; Teekavanich et al., 2022). Two studies reported separate results for gender and found that boys seem to be more susceptible to the effects of screen time as measured by overweight, blood pressure (Padmapriya et al., 2019), and body fat (Saldanha-Gomes et al., 2017). One study did not find age to be a moderator (Collings et al., 2018), and another study reported undesirable effects only for older children (Hu et al., 2019). Food intake was not found to mediate the longitudinal link between TV viewing and BMI (Fuller-Tyszkiewicz et al., 2012).

TABLE 4 Summary of results pertaining to physical health.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Cortisol levels	1	0	0	0	0	0	0	0	0	0	0	0	*1*	*0*	*0*
Body fat (BMI, waist circumference etc.)	0	0	0	3	4	0	5	3	0	3	11	0	*11*	*18*	*0*
Diet	0	0	0	0	0	0	0	0	0	4	0	0	*4*	*0*	*0*
Respiratory rates	0	0	1	0	0	0	0	0	0	0	0	0	*0*	*0*	*1*
Oxygen saturation	0	0	1	0	0	0	0	0	0	0	0	0	*0*	*0*	*1*
Respiratory sinus arrhythmia	0	0	1	0	0	0	0	0	0	0	0	0	*0*	*0*	*1*
Heart rate	0	0	1	0	0	0	0	0	0	0	0	1	*0*	*0*	*2*
Feeding difficulties	0	0	0	0	0	0	0	0	0	1	0	0	*1*	*0*	*0*
Total	*1*	*0*	*4*	*3*	*4*	*0*	*5*	*3*	*0*	*8*	*11*	*1*	*17*	*18*	*5*

"−," undesirable association; "=," non-significant association; "+," desirable association.

Summary of evidence on physical health

Findings on associations between the use of screen media and body-related parameters and nutrition show a mixed pattern of undesirable and non-significant associations, while few desirable correlates were found (see Table 4). Studies were mostly cross-sectional or semi-longitudinal, which limits the potential for strong causal inferences. More longitudinal and experimental studies are needed, ideally focusing on the multidirectional relationship between screen time, body-related parameters, and diet. Another aspect that might be relevant is the type of content viewed, for instance whether unhealthy food advertising or interactive content is consumed. Further, most of the studies focused mostly on the associations with TV and DVD. Consequently, the role of modern screen devices has yet to be explored.

Cognition

Results from studies that examined the association between screen time and general cognition, attention problems, and executive functions as well on other cognitive outcomes ($n = 31$) are summarized here.

General cognition

The studies discussed here examined cognition in general. Their dependent variables comprise a cognition-related total score. Results from two experimental studies report no significant link to general cognition: Playing non-educational games on an iPad was found to lead to the same cognitive flexibility score in a card sorting test as physical play and to higher scores than drawing and coloring, but only for children who played the game on the iPad as a socially interactive game (Antrilli and Wang, 2018). Further, the link between watching a child-oriented DVD and cognition was not found to be significant (Richert et al., 2010). Only one longitudinal study was identified, and the results did not support the association between televiewing and composite IQ score at age 4.5 years (Aishworiya et al., 2019). Results from a semi-longitudinal study suggest that there is an undesirable association of being in the upper quartile of media exposure from 6 months to 2 years of age on early learning at age 2 years. This association appears to be more robust for older children and adult media content (Supanitayanon et al., 2020). Another study yielded an undesirable association between adult-oriented content at 6 months and cognition at 14 months (Tomopoulos et al., 2010). Further, screen media multitasking from age 18 months to 4 years was found to be linked to lower scores on cognition at age 4 years (Srisinghasongkram et al., 2020). Further, cognition was not systematically found to be linked to screen time in semi-longitudinal and cross-sectional models in another study (Kracht et al., 2023). Finally, two cross-sectional studies found an undesirable correlate of televiewing (Lin et al., 2015) in children 15 to 35 months of age and total screen time with traditional and modern devices (Plitponkarnpim et al., 2018) in children aged 6 months to 2 years on general cognition.

Attention

An experimental study found that reducing screen time before bed had no significant impact on number of indicators of attention as measured by eye-tracking (Pickard et al., 2024). In a longitudinal study, an undesirable association between cumulative media use at age 18 months and focused attention at 22 months was found, but the same path was non-significant from 22 months to 26 months (Gueron-Sela and Gordon-Hacker, 2020). In semi-longitudinal studies, an undesirable link was found between televiewing at ages 1 and 3 years and attention problems at age 7 years (Christakis et al., 2004). However, a reanalysis of the same data set with more thorough statistical controls failed to replicate the original finding (Foster and Watkins, 2010). Moreover, an undesirable link between more than 2 hours of sustained TV exposure at both 30–33 months and 5.5 years and attention problems at age 5.5 years was found, but not for children whose TV exposure declined with age from over 2 hours at age 30–33 months to below 2 hours at age 5.5 years (Mistry et al., 2007). Non-significant results were reported for televiewing for more than 4 hours per day (Cheng et al., 2010), of duration and media content exposure (Tomopoulos et al., 2007), of increased TV exposure and adult TV programs (Chonchaiya et al., 2015), and of educational television

(Zimmerman and Christakis, 2007). However, both violent and non-violent entertainment television before the age of 36 months were found to be linked to later attention problems (Zimmerman and Christakis, 2007). A semi-longitudinal study found that screen time at 12 months of age was linked to lower levels of teacher-reported attention by age nine (Law et al., 2023). Further, children with high touchscreen users from age 12 months to age 3.5 years reacted faster to external stimuli on a screen, but were slower in controlling their own attention without external stimuli (Portugal et al., 2021a) and high users showed higher attention performance in a single feature search task but not in a conjunction search task on screens (Portugal et al., 2021b). Cross-sectional studies found undesirable associations between attention problems and televiewing for more than 4 h per day (Cheng et al., 2010), for touch screen use (Lin et al., 2020), for increased television exposure at 18 months (Chonchaiya et al., 2015), and for total duration of media exposure as well as non-educational young child content exposure (Tomopoulos et al., 2007). However, no associations with attention-deficit or hyperactivity problems were found (Chonchaiya et al., 2015).

Executive functions

An experimental study found that reducing screen time before bed had no significant impact on effortful control and inhibitory control (Pickard et al., 2024). A longitudinal undesirable effect was found of screen time at 24 months on executive functioning at 36 months (McHarg et al., 2020a). Further, results from semi-longitudinal studies indicate an undesirable link between higher adult-directed televiewing during infancy and parent-reported executive functioning at age 4 years (Barr et al., 2010a). However, non-significant associations with total household television, overall television exposure, or child-directed exposure in infancy were found on parent-reported executive functioning, school readiness, vocabulary, IQ, or executive functioning (standardized test) at age 4 years (Barr et al., 2010a). Further, previous day total screen, TV/video, interactive media, and touchscreen time (as assessed through questionnaires) were found to have a non-significant correlation with working memory and search performance in an experimental task about contingency between a video and a subsequent real world search task (Choi et al., 2021). In a semi-longitudinal study, screen time at age 12 months was found to be negatively associated with executive functions at age 9 years (Law et al., 2023). Another undesirable association was identified between total TV exposure in infancy and hot executive functions, but not with cold executive functions (Corkin et al., 2021). Non-significant correlates of co-viewing or type of content were also reported (Corkin et al., 2021). A cross-sectional study found an undesirable association between screen time in minutes and inhibitory self-control as well as metacognition at age 24 months (McMath et al., 2022). In the same study, meeting screen time recommendations of <1 h per day had a desirable association with executive functions, inhibitory self-control as well as metacognition.

Other cognitive outcomes

Results from a longitudinal study suggest an undesirable effect of screen time in infancy on verbal IQ score at age 4.5 years (Aishworiya et al., 2019). Another longitudinal study found no direct but a small although not significant indirect undesirable association between screen time (watching shows/movies and gaming) and problem solving though peer play from age 12 to 36 months, with no moderation by gender (Putnick et al., 2023). In a semi-longitudinal study examining multiple developmental outcomes, screen time at 1 year of age was found to be associated with poorer problem-solving abilities at ages two and four, particularly when daily screen time exceeded 4 h (Takahashi et al., 2023). Further semi-longitudinal studies confirm an undesirable association between increased daily televiewing in children 29 months of age and numeracy and early arithmetic skills at age 65 months (Pagani et al., 2013) and screen time at 4 months was found to be undesirably linked to inhibition, but not to cognitive flexibility or working memory at 14 months (McHarg et al., 2020b). Another study also suggests an undesirable association between early televiewing at 29 months of age, but not between change in televiewing from 29 months to 53 months or of concurrent televiewing and mathematics success at age 10 years (Pagani et al., 2010). Finally, the link between televiewing and visual-motor abilities was found to be non-significant (Evans Schmidt et al., 2009). No experimental or cross-sectional studies were found that included other cognitive outcomes.

Methodological considerations

Outcomes were assessed with questionnaires and screenings (Mistry et al., 2007; Chonchaiya et al., 2015; Aishworiya et al., 2019; Srisinghasongkram et al., 2020; Gueron-Sela and Gordon-Hacker, 2020; Cheng et al., 2010; Tomopoulos et al., 2007; Zimmerman and Christakis, 2007; Law et al., 2023; Barr et al., 2010a; Corkin et al., 2021; McMath et al., 2022; Putnick et al., 2023; Takahashi et al., 2023; Evans Schmidt et al., 2009; Foster et al., 2010), standardized tests (Richert et al., 2010; Pickard et al., 2024; Kracht et al., 2023; Plitponkarnpim et al., 2018; Antrilli and Wang, 2018; Aishworiya et al., 2019; Supanitayanon et al., 2020; Tomopoulos et al., 2010; Srisinghasongkram et al., 2020; Lin et al., 2015; Law et al., 2023; Portugal et al., 2021a,b; McHarg et al., 2020a; Choi et al., 2021; Corkin et al., 2021; Pagani et al., 2013; McHarg et al., 2020b; Evans Schmidt et al., 2009), ratings from teachers (Pagani et al., 2010; Law et al., 2023), and behavioral observations (Antrilli and Wang, 2018). Screen time was mostly assessed as one-time parent report (Mistry et al., 2007; Lin et al., 2020; Pagani et al., 2010; Aishworiya et al., 2019; Lin et al., 2015; Christakis et al., 2004; Cheng et al., 2010; Portugal et al., 2021a,b; McHarg et al., 2020a; Choi et al., 2021; Corkin et al., 2021; McMath et al., 2022; Takahashi et al., 2023; Pagani et al., 2013; McHarg et al., 2020b; Evans Schmidt et al., 2009), but some studies employed 24 h-recall diaries or other diaries (Pickard et al., 2024; Chonchaiya et al., 2015; Plitponkarnpim et al., 2018; Supanitayanon et al., 2020; Tomopoulos et al., 2010; Srisinghasongkram et al., 2020; Tomopoulos et al., 2007; Zimmerman and Christakis, 2007; Barr et al., 2010a), while others measured screen time on multiple occasions (Putnick et al., 2023). Screen time was categorized in some studies, with varying degrees of extreme-group modeling (Mistry et al., 2007; Kracht et al., 2023; Supanitayanon et al., 2020; Lin et al., 2015; Cheng et al.,

TABLE 5 Summary of results pertaining to cognition.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
General cognition	0	2	0	0	1	0	3	1	0	2	1	0	*5*	*5*	*0*
Attention	0	1	0	1	1	0	5	8	2	4	1	0	*10*	*11*	*2*
Executive functions	0	1	0	1	0	0	3	8	0	0	7	0	*4*	*16*	*0*
Other cognitive outcomes	0	0	0	2	1	0	4	3	0	0	4	0	*6*	*7*	*0*
Total	*0*	*4*	*0*	*4*	*3*	*0*	*15*	*20*	*2*	*6*	*13*	*0*	*25*	*40*	*2*

"−," undesirable association; "=," non-significant association; "+," desirable association.

2010; Portugal et al., 2021a,b; Barr et al., 2010a; McMath et al., 2022; Takahashi et al., 2023). Most studies examined only the effects of televiewing or DVD watching (Richert et al., 2010; Mistry et al., 2007; Chonchaiya et al., 2015; Pagani et al., 2010; Kracht et al., 2023; Aishworiya et al., 2019; Lin et al., 2015; Foster and Watkins, 2010; Cheng et al., 2010; Zimmerman and Christakis, 2007; Barr et al., 2010a; Corkin et al., 2021; Pagani et al., 2013; Evans Schmidt et al., 2009), some studies examined only touchscreen use (Lin et al., 2020; Antrilli and Wang, 2018; Portugal et al., 2021a,b), and some examined multiple types of devices (Plitponkarnpim et al., 2018; Supanitayanon et al., 2020; Tomopoulos et al., 2010; Srisinghasongkram et al., 2020; Gueron-Sela and Gordon-Hacker, 2020; Law et al., 2023; McHarg et al., 2020a; Choi et al., 2021; McMath et al., 2022; Putnick et al., 2023; Takahashi et al., 2023; McHarg et al., 2020b). A number of studies addressed questions about the content of media (Richert et al., 2010; Chonchaiya et al., 2015; Antrilli and Wang, 2018; Supanitayanon et al., 2020; Tomopoulos et al., 2010; Christakis et al., 2004; Tomopoulos et al., 2007; Zimmerman and Christakis, 2007; Barr et al., 2010a; Corkin et al., 2021), co-viewing (Richert et al., 2010; Corkin et al., 2021), verbal interaction during screen use (Supanitayanon et al., 2020), and the role of social interaction (Antrilli and Wang, 2018), as well as the mediating role of peer-play and the moderating role of gender (Putnick et al., 2023).

Summary of evidence on cognition

Studies on the link between screen time and cognition suggest either a weak undesirable link to cognitive development or no significant link, while very few desirable associations were reported (see Table 5). Studies were mostly cross-sectional or semi-longitudinal, which limits the causal inferences that can be drawn. Notably, studies mostly reported non-significant associations of screen time and various aspects of cognition, with a relevant proportion of studies showing undesirable associations. The type of content seems to play an important moderating role in this regard and needs to be studied in more experimental and longitudinal studies. No displacement effect through reduced peer play was found in a longitudinal study. Given the large amount of semi-longitudinal studies, longitudinal studies should assess the baseline of the outcome studied to examine bidirectional associations and to model the change in the outcome over time.

Learning efficiency

Experimental studies ($n = 28$) have examined young children's learning by imitation from screen media under a variety of conditions. In this review, the studies were categorized by topic and the sections are labeled accordingly. The presentation of the results in this section differs from other sections because this field is exclusively defined by experimental studies. We chose to separate learning efficiency from cognition based on a conceptual distinction: cognition refers to an individual's mental abilities and characteristics, while learning is an active process of acquiring new knowledge or skills.

Live vs. screen demonstration

Children as young as 12 to 21 (Barr et al., 2007b) and 24 months (Barr and Wyss, 2008; Nielsen et al., 2008) have been shown to be more able to imitate a target task when the task was demonstrated by a person live than when the demonstrator was videotaped, indicating a video deficit effect. Another experimental study found that children imitated the target action significantly better when their mothers performed the action live than via video. However, this was only true for children aged 13 to 20 months, not for children younger than 13 months of age or older children between 21 and 24 months (Krcmar, 2010). In an experimental study that adapted a real-world paradigm that showed children's ability to update their representation of an absent object's properties based on verbal information (Ganea et al., 2007), children were not able to show such an update to their representation based on an event shown on video, although they were able to remember which category the object belonged to Shinskey (2021).

Other studies focused on how well children would remember actions demonstrated by video. One study showed that 18-month-old children remembered actions from videos or books for 2 weeks and forgot them again after 4 weeks, while 24-month-old children remembered them for 4 weeks and forgot them again after 8 weeks, with no retention difference between books and videos for both ages (Brito et al., 2012). Another study found that video reminders helped toddlers remember actions they had learned from videos over 4 weeks, but picture book reminders did not help them remember book demonstrations. Cross-mode recall, e.g., from book to video, was not promoted (Barr et al., 2013). In a study examining deferred imitation (as an indicator of memory performance) for live events and for video presented events, watching video content, smartphone use, and tablet use were not found to be linked to memory for live presented events. As for video presented events, only time spent watching video had an undesirable association with memory performance (Koch et al., 2024). In contrast, children having seen a target action presented live showed better memory performance than those who saw the task on 2D video with and without support from their parents (Heimann et al., 2021).

Further studies examined whether children were able to learn puzzle tasks from video. It has been found that children showed better performance with 3D puzzles after a ghost demonstration in which virtual pieces moved to form the corresponding shape than with 2D puzzles on touchscreens, with no improvement from touchscreen practice beforehand. However, children's performance on 2D touchscreen puzzles improved more with live, social demonstrations than with ghost demonstrations (Zimmermann et al., 2016). Moreover, experiments showed that televised demonstrations were less effective than live ones, with meaningful context, such as the ocean, if the puzzle depicted a fish, enhancing puzzle assembly but not overcoming the video deficit (Zimmermann et al., 2015; Dickerson et al., 2013). Other studies conducted the same puzzle imitation task under different conditions. They found that young children imitated both video and live demonstrations similarly well on touchscreens (Moser et al., 2015), and children who were able to label the complete puzzle after the test phase could better imitate the target action, especially when a live demonstrator was present compared to absent (Moser et al., 2018). Furthermore, children struggled with translating 2D video demonstrations to 3D tasks but succeeded with 2D to 2D (Moser et al., 2015; Zack et al., 2009), with specific linguistic cues not enhancing children's imitation performance (Zack et al., 2013). However, children improved their learning transfer from 2D to 3D when instructed by their mothers, and higher-quality mother-child interactions further enhanced this learning (Zack and Barr, 2016).

Repeated viewing

The frequency with which video demonstrations are played may influence young children's learning transfer. They reported that children aged between 12 to 24 months, but not younger, experience a video deficit effect. This video deficit was mitigated, disappeared entirely, or even turned in the opposite direction, the more often children watched the same television content. This holds true even if there were no verbal labels provided by parents (Barr and Wyss, 2008). In contrast, another experimental study found that repeated demonstration of a target action on video did not enhance children's imitation performance (Krcmar, 2010).

Sound effects and language prompts

Children aged 18 to 24 months can imitate novel actions equally well from TV as from books, even without meaningful narration (Simcock et al., 2011). Similarly, it has been reported that 12- to 18-month-olds can learn just as effectively from both live and screen presentations when language and gaze cues are matched (Barr et al., 2009; Lauricella et al., 2016), whereas 6-months-olds imitated actions from videos regardless of sound effects (Barr et al., 2009). Additionally, instrumental soundtracks during video demonstrations may hinder imitation in young children, though action-related sound effects mitigate this effect without increasing the performance of the imitation task (Barr et al., 2010b). Furthermore, verbal labels presented either by parents co-viewing or on television via voice-over similarly facilitated an imitation task for 2-year-olds (Barr and Wyss, 2008).

Familiarity with presenting character

In addition, familiarity with the character presenting the task may enhance learning from videos in children under the age of two (Lauricella et al., 2011; Howard Gola et al., 2013). Conversely, no improvement in task performance with familiar characters were found in other studies (Nielsen et al., 2008; Seehagen and Herbert, 2010) through narratives based on mothers' descriptions helped children learning from videos (Seehagen and Herbert, 2010). Furthermore, another study reported that children's learning is enhanced when they are exposed to unfamiliar screen characters personalized to address them by name, in contrast to exposure to both familiar characters and non-personalized unfamiliar characters (Calvert et al., 2014).

Video chat

A study that focused on the effects of video chat found that 12- to 25-month-old children learned new actions and patterns better from adults in video chats than from prerecorded videos. The children who interacted with adults through video chat learned more novel patterns and preferred and recognized their adult partners a week later, while the children who watched the prerecorded video did not (Myers et al., 2017).

Interactivity

Further studies also indicate that children's learning from screens can be enhanced by interactive, contingent experiences with screen media. They reported that children aged 2 to 3 years performed significantly better on a given task when it was shown through an interactive computer game (Lauricella et al., 2010), or if they had the opportunity to interact with the person demonstrating the task via television (Nielsen et al., 2008), compared to seeing the demonstration on a screen without any interaction. Conversely, children aged 24 to 36 months were found to make increased perseverative errors in an object retrieval task (i.e., looking for an object in a spot where it did hide in a previous condition), particularly in a condition in which they did not interact with the screen or in which they interacted with the screen in a relevant way (Kirkorian et al., 2022). In the same study, children's media use at home was not found to be correlated to correct retrieval of objects (a bear) in a real-world task after observing on a screen where the bear did hide. There was also no correlation with the number of perseverative errors or with visual attention.

Methodological considerations

The outcome variables were determined by experimental behavioral observations in all studies. Screen time was generally assessed through standardized experimental conditions (Barr and

TABLE 6 Summary of results pertaining to learning efficiency.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Learning efficiency	17	34	12	0	0	0	0	0	0	0	0	0	17	34	12

"–," undesirable association; "=," non-significant association; "+," desirable association.

Wyss, 2008; Nielsen et al., 2008; Krcmar, 2010; Brito et al., 2012; Barr et al., 2013; Heimann et al., 2021; Zimmermann et al., 2016, 2015; Dickerson et al., 2013; Moser et al., 2015, 2018; Zack et al., 2009, 2013; Barr et al., 2007b; Simcock et al., 2011; Barr et al., 2009; Lauricella et al., 2016; Barr et al., 2010b; Lauricella et al., 2011; Howard Gola et al., 2013; Seehagen and Herbert, 2010; Calvert et al., 2014; Myers et al., 2017; Lauricella et al., 2010), with few exceptions (Koch et al., 2024). The majority of studies only examined the effects of experimental televiewing or DVD watching (Barr and Wyss, 2008; Barr et al., 2007b; Krcmar, 2010; Brito et al., 2012; Barr et al., 2013; Heimann et al., 2021; Dickerson et al., 2013; Barr et al., 2007a; Simcock et al., 2011; Barr et al., 2009; Lauricella et al., 2016; Barr et al., 2010b; Lauricella et al., 2011; Howard Gola et al., 2013; Seehagen and Herbert, 2010; Calvert et al., 2014; Myers et al., 2017), other studies examined only touchscreen use (Zimmermann et al., 2016; Zack et al., 2009, 2013; Zack and Barr, 2016), and some examined multiple types of devices (Koch et al., 2024; Moser et al., 2015, 2018; Myers et al., 2017; Lauricella et al., 2010). All studies addressed the content of media, some the verbal interaction during screen use, the role of social interaction (Barr and Wyss, 2008; Moser et al., 2015, 2018; Zack and Barr, 2016; Simcock et al., 2011; Seehagen and Herbert, 2010), social demonstration (Zimmermann et al., 2016; Zack et al., 2013; Krcmar, 2010; Moser et al., 2018; Barr et al., 2007a,b; Brito et al., 2012; Myers et al., 2017; Zimmermann et al., 2015; Zack et al., 2009; Moser et al., 2015; Dickerson et al., 2013; Lauricella et al., 2016; Barr and Wyss, 2008), and interaction with the media (Nielsen et al., 2008; Myers et al., 2017; Lauricella et al., 2010; Kirkorian et al., 2022).

Summary of evidence on learning efficiency

Results related to learning efficiency are presented in Table 6. The terms *undesirable* and *desirable associations* carry slightly different meanings in the context of learning efficiency compared to the other outcomes discussed in this study. Specifically, we use the term *undesirable* associations for those associations where learning from screens is less efficient than learning from real-world presentations. Conversely, we use *desirable* associations for instances where learning from screens demonstrates greater efficiency. The review of associations between task presentation via screens and children's learning efficiency stem almost exclusively from experimental studies and mostly show non-significant associations. However, there was a similar amount of undesirable and desirable associations. Children learn better when a target task is demonstrated live than via video, suggesting the presence of a video deficit. However, aspects of media presentation, such as repetition, language prompts, and social contingency or familiarity with the character are significant contextual and content-related factors that can enhance young children's learning from videos and consequently reduce the video deficit effect.

Language

Results from studies ($n = 55$) that examined associations with overall language competencies, receptive and expressive language skills, and vocabulary are summarized here.

Language competence

One experimental study found an undesirable effect of intensive televiewing on language competence (Tanimura et al., 2007), whereas another study found no link from repeatedly watching a specific DVD (Richert et al., 2010), but noted that early watchers had poorer language scores. One longitudinal study found an undesirable association with televiewing over 2 h a day, especially for child-directed, but not adult-directed content (Duch et al., 2013), while another failed to find any longitudinal association (Zimmerman et al., 2009). Further, another study found that children with "low descending" televiewing patterns over time had the highest language achievement scores, whereas those with "high ascending" televiewing patterns had the lowest (Kim and Chung, 2021). Another longitudinal study found that children who had up to 2 h of screen time daily showed no increased risk for delayed language development. However, children exposed to three or more hours of screen time each day were significantly more likely to experience delays in language skills compared to all other groups (McArthur et al., 2022). A study involving children aged 12 to 36 months found no direct, but a small, undesirable indirect association between screen time and communication skills through peer play, with no moderation based on gender (Putnick et al., 2023). Mixed results were found in another longitudinal study that reported different models with different timepoints at which the outcomes and predictors were assessed (Slobodin et al., 2024). The authors also found indications of a moderation by socio-economic status that favored the group with a low status. The vast majority of results of semi-longitudinal studies supports the existence of undesirable associations (Aishworiya et al., 2019; Tomopoulos et al., 2010; Takahashi et al., 2023; Mendelsohn et al., 2010), whilst one study reported no association (Ruangdaraganon et al., 2009). However, an important note is that Mendelsohn et al. (2010) have shown that verbal interactions during screen time reduce the undesirable correlates, whereby undesirable correlates were only observed after more than 1 h of use without such interactions. As for the correlates of different content, undesirable correlates were found for consuming adult-oriented and older-child-oriented content but not for educational and non-educational young-child-oriented content (Tomopoulos et al., 2010). Language development was not systematically found to be linked to screen time in semi-longitudinal and cross-sectional models in another study (Kracht et al., 2023). Cross-sectional studies found no associations with increasing duration of screen time (Lin et al., 2020; Zimmerman et al., 2009; Bedford et al., 2016; van den Heuvel et al., 2019). However, undesirable links were reported for longer duration (Operto et al., 2020), more than 30 minutes (Plitponkarnpim et al., 2018), 2 h (Lin et al., 2015; Duch et al., 2013; Byeon and Hong, 2015), and 4 h (Perdana et al., 2017) of screen time. Co-viewing and media content as moderators did not influence this relationship (Operto et al., 2020). TV programs in two languages (Perdana et al., 2017) and child-directed content, but not adult-directed content (Duch et al., 2013), have been found to be undesirably related to language development. In this regard, a study found that children with delayed language skills and regular televiewing favored "realistic animations" or "baby education" content (Okuma and Tanimura, 2009). Furthermore, TV in the bedroom and first exposure to televiewing were not related to language development (Perdana et al., 2017).

Receptive language

Results of a short longitudinal experimental field study revealed that children are able to learn baby signs from video even in the absence of parental support during viewing (Dayanim and Namy, 2015). Another one reported greater gains in receptive vocabulary in children after watching a specific Baby DVD for 1 month (Vandewater, 2011). However, other such studies found no association (Richert et al., 2010; Robb et al., 2009). A longitudinal study that examined trajectory patterns in children's televiewing failed to find a link with receptive language scores (Kim and Chung, 2021). Semi-longitudinal studies reported that more fore- and background televiewing (Pagani et al., 2013; Bittman et al., 2011), a longer duration of media exposure (Tomopoulos et al., 2010), a television in the child's bedroom (Bittman et al., 2011), or more than 1 h daily of screen time (Mendelsohn et al., 2010) were undesirably associated with later receptive language. However, the latter study reported an undesirable link in the absence of media verbal interactions but not in their presence (Mendelsohn et al., 2010). Regarding the types of content, consuming adult-oriented and older child-oriented content was found to have undesirable links, whereas educational and non-educational content aimed at younger children was not (Tomopoulos et al., 2010). However, other semi-longitudinal studies failed to find a link for daily televiewing or media exposure and later receptive vocabulary (Evans Schmidt et al., 2009; Bittman et al., 2011; Dynia et al., 2021). A cross-sectional study showed that electronic sounds captured by the Language Environment Analysis system (LENA) were undesirably linked to receptive language development in children (Nyberg et al., 2020). Another study reported an undesirable association of longer duration of watching baby DVDs and videos, but other content such as educational shows, non-educational TV, and adult-directed TV show no associations (Zimmerman et al., 2007). However, the same data was reanalyzed a few years later with a different model specification regarding the inclusion/exclusion of covariates. The authors found that educational content led to improved receptive vocabulary in children aged 6 to 16 months, whereas other content remained non-significant (Ferguson and Donnellan, 2014). In a large-scale study among Danish children, mobile screen time was found to have an undesirable association with language comprehension, although the undesirable effect was moderated by frequent reading to the child but not by parental education or time spent with TV or PC (Rayce et al., 2024). A study focusing on the role of media quantity, context, and content found no association of any of these aspects with number of words understood across ages 12 to 16 months (Alroqi et al., 2023). Other cross-sectional studies on young children's televiewing and use of mobile touchscreen devices (Taylor et al., 2018), as well as on overall background television exposure and background television during dyadic toy play (Masur et al., 2016) found no significant associations.

Expressive language

Several short longitudinal experimental field studies yielded no association for children watching a specific DVD several times over a specific period in comparison to children who did not watch the target DVD (Richert et al., 2010; Vandewater, 2011; Robb et al., 2009). Longitudinal studies reported that greater exposure to background television during dyadic toy play has undesirable effects (Masur et al., 2016), and children with "high ascending" patterns of televiewing over time score lowest on later expressive language scores (Kim and Chung, 2021). Semi-longitudinal studies reported an undesirable link for longer duration of media exposure and later expressive language (Tomopoulos et al., 2010; Dynia et al., 2021), however one study found no significant link for more than 1 h of daily media exposure, regardless of the presence or absence of media verbal interactions (Mendelsohn et al., 2010). Further, undesirable longitudinal effects were found for consuming adult-oriented and older child-oriented content on expressive communication but not for educational and non-educational young child-oriented content (Tomopoulos et al., 2010). Several cross-sectional studies reported no associations between screen exposure (Taylor et al., 2018), more electronical sounds measured by LENA (Nyberg et al., 2020), or increasing duration of any content of screen time and expressive vocabulary in young children and expressive language outcomes (Zimmerman et al., 2007). A reanalysis of finding by Zimmerman et al. (2007) showed that educational contents led to improved expressive vocabulary in children aged 6 to 16 months, but not aged 17 to 27 months, while other content did not (Ferguson and Donnellan, 2014). Another study also reported no association between different forms of screen time and sentence use (Gago-Galvagno et al., 2023). A large-scale study found that mobile screen time was negatively associated with expressive language skills. This association was not influenced by factors such as frequent reading to the child, parental education level, or time spent with TV or PC (Rayce et al., 2024). Furthermore, two studies found that each additional 30-minute increase in media device use (van den Heuvel et al., 2019), and background television exposure during dyadic toy play (Masur et al., 2016) were undesirably linked to children's expressive language outcomes. A study found no link between media quantity, context, or content and word production in children aged 12 to 16 months. However, in children aged 17 to 36 months, higher media exposure was negatively associated with word production, and certain media contexts were linked to shorter utterances (Alroqi et al., 2023), although several non-significant findings were also reported for the remaining combinations of predictors and outcomes. Moreover, sentence use was found to be positively linked to PC time, but negatively to TV time and educational content use, while no link to verbal scaffolding and joint engagement was reported. Further, joint media engagement and verbal scaffolding were not found to act as moderators (Medawar et al., 2023). In addition, Masur et al. (2016) demonstrated that maternal speech acts as a mediator during toy play.

Vocabulary

Several experimental studies on the association between vocabulary and screen time were identified. It has been shown that children may learn novel words from screens, depending on their age and certain conditions. A study reported that children were able to learn novel words from video alone (Vandewater et al., 2010), whereas other studies only found associations in combination with social interactions. These studies stated that children seem to learn novel verbs from video or video chat only in combination with social interactions, either live or via video chat (Myers et al., 2017, 2018; Roseberry et al., 2009, 2014; Tsuji et al., 2021), and the older they are, the better their learning results are (Myers et al., 2017). Moreover, depending on their age, children were able to learn new verbs from contingent videos without reciprocal interactions with a live social partner, but only when the video content required specific responses (Kirkorian et al., 2016). However, there are also studies that showed that children were unable to learn new words from video chat or from a non-responsive video (Troseth et al., 2018), they seem to learn better in face-to-face contact than in contact with a virtual agent on screen (Krcmar, 2010; Tsuji et al., 2021). Another condition concerns the repeated viewing of content on screen. Depending on their age, children may learn novel words from screens if they are repeatedly exposed to particular screen content (Krcmar, 2010, 2014). However, other studies did not find such a desirable link between repeated viewing and learning new words, either co-viewing with a parent or alone (Richert et al., 2010; DeLoache et al., 2010). A cross-sectional study found that poor-quality televiewing, characterized by an earlier onset of televiewing, more background televiewing, exposure to TV content not intended for children, less co-viewing with a parent, was associated with lower overall vocabulary scores. Children's foreground but not background screen time was found to have an undesirable link to expressive vocabulary at age 12 and 24 months (Asikainen et al., 2021). Further, some studies revealed that the duration of televiewing (Hudon et al., 2013), or longer duration of any screen time (Ferguson and Donnellan, 2014) was not associated with vocabulary acquisition. Moreover, no association was found between different forms of screen time and child lexical density, except for child PC use, with an undesirable link (Gago-Galvagno et al., 2023). However, other studies found that the quantity of screen time is undesirably associated with a child's vocabulary and grammar (Operto et al., 2020; Sundqvist et al., 2021), while co-viewing and the content of the screen time did not moderate this relationship (Operto et al., 2020). In contrast, lexical density was found to be positively linked to joint media engagement, verbal scaffolding related to media use, and PC time, but negatively to TV time, app use and video gaming. Herein, joint media engagement and verbal scaffolding were not found to moderate the effects of TV and PC times (Medawar et al., 2023). Furthermore, smartphone and tablet use were not found to be linked to lower expressive and receptive vocabularies in children aged 12 months, but negatively to expressive vocabulary in those aged 24 months, with a small effect size. Additionally, the study showed that shared book reading buffered the effect of portable screen time on expressive vocabulary (Rosslund et al., 2024). Finally, one study found that co-viewing programs with the child is associated with better vocabulary at age 4 years (Bittman et al., 2011).

Methodological considerations

Outcomes were assessed with questionnaires and screenings (Richert et al., 2010; Lin et al., 2020; Plitponkarnpim et al., 2018; Putnick et al., 2023; Takahashi et al., 2023; Kim and Chung, 2021; McArthur et al., 2022; Slobodin et al., 2024; Bedford et al., 2016; van den Heuvel et al., 2019; Operto et al., 2020; Byeon and Hong, 2015; Perdana et al., 2017; Dayanim and Namy, 2015; Vandewater, 2011; Robb et al., 2009; Zimmerman et al., 2007; Ferguson and Donnellan, 2014; Rayce et al., 2024; Alroqi et al., 2023; Taylor et al., 2018; Masur et al., 2016; Medawar et al., 2023; Kirkorian et al., 2016; Krcmar, 2014; DeLoache et al., 2010; Asikainen et al., 2021; Hudon et al., 2013; Sundqvist et al., 2021; Rosslund et al., 2024; Duch et al., 2013), standardized tests (Kracht et al., 2023; Aishworiya et al., 2019; Tomopoulos et al., 2010; Lin et al., 2015; Pagani et al., 2013; Evans Schmidt et al., 2009; Myers et al., 2017; Zimmerman et al., 2009; Mendelsohn et al., 2010; Ruangdaraganon et al., 2009; Bittman et al., 2011; Dynia et al., 2021; Medawar et al., 2023; Myers et al., 2018; Roseberry et al., 2009, 2014; Tsuji et al., 2021; Troseth et al., 2018), and behavioral observations (Krcmar, 2010; Tanimura et al., 2007; Vandewater et al., 2010; Tsuji et al., 2021; Troseth et al., 2018). In one study, children were divided into delayed and non-delayed groups with respect to their language development based on the query of only one item, "speaking more than one meaningful word" (Okuma and Tanimura, 2009). One-time parent report was mostly used to measure screen time (Lin et al., 2020; Aishworiya et al., 2019; Lin et al., 2015; Takahashi et al., 2023; Pagani et al., 2013; Evans Schmidt et al., 2009; Kim and Chung, 2021; McArthur et al., 2022; Ruangdaraganon et al., 2009; Bedford et al., 2016; van den Heuvel et al., 2019; Operto et al., 2020; Byeon and Hong, 2015; Perdana et al., 2017; Okuma and Tanimura, 2009; Bittman et al., 2011; Dynia et al., 2021; Zimmerman et al., 2007; Ferguson and Donnellan, 2014; Rayce et al., 2024; Taylor et al., 2018; Medawar et al., 2023; Asikainen et al., 2021; Hudon et al., 2013; Sundqvist et al., 2021; Rosslund et al., 2024) or background screen time (Masur et al., 2016; Asikainen et al., 2021). However, a few studies applied 6 h-recall (Plitponkarnpim et al., 2018) or 24 h-recall diaries (Tomopoulos et al., 2010; Slobodin et al., 2024; Mendelsohn et al., 2010; Alroqi et al., 2023; Duch et al., 2013), an electronic diary using special hardware and software (e.g., LENA) (Zimmerman

TABLE 7 Summary of results pertaining to language.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Language competence	2	1	0	7	5	0	7	5	0	8	6	0	*24*	*17*	*0*
Receptive language	0	2	2	0	1	0	8	5	1	2	11	1	*10*	*19*	*4*
Expressive language	0	3	0	2	0	0	4	4	0	7	16	3	*13*	*23*	*3*
Vocabulary	1	11	10	0	0	0	0	1	0	12	10	3	*13*	*22*	*13*
Total	*3*	*17*	*12*	*9*	*6*	*0*	*19*	*15*	*1*	*29*	*43*	*7*	*60*	*81*	*20*

"−," undesirable association; "=," non-significant association; "+," desirable association.

et al., 2009; Nyberg et al., 2020), and viewing time diaries (Richert et al., 2010; Vandewater, 2011; Robb et al., 2009; Vandewater et al., 2010). Screen time was categorized in some studies with varying degrees of extreme-group comparisons (Kracht et al., 2023; Lin et al., 2015; Takahashi et al., 2023; Kim and Chung, 2021; McArthur et al., 2022; Mendelsohn et al., 2010; Ruangdaraganon et al., 2009; Byeon and Hong, 2015; Perdana et al., 2017; Okuma and Tanimura, 2009; Bittman et al., 2011; Asikainen et al., 2021; Sundqvist et al., 2021; Duch et al., 2013) or simply distinguished between TV on and off (Tanimura et al., 2007). One study used a specific type of categorization in quality and quantity of screen time, which resulted in a factor analysis (Hudon et al., 2013), and one study assessed trajectory patterns (Kim and Chung, 2021). A majority of the studies focused only on the effects of TV and DVD (Richert et al., 2010; Kracht et al., 2023; Pagani et al., 2013; Evans Schmidt et al., 2009; Krcmar, 2010; Tanimura et al., 2007; Zimmerman et al., 2009; Kim and Chung, 2021; Ruangdaraganon et al., 2009; Byeon and Hong, 2015; Perdana et al., 2017; Okuma and Tanimura, 2009; Dayanim and Namy, 2015; Vandewater, 2011; Robb et al., 2009; Bittman et al., 2011; Zimmerman et al., 2007; Ferguson and Donnellan, 2014; Masur et al., 2016; Vandewater et al., 2010; Roseberry et al., 2009; Krcmar, 2014; DeLoache et al., 2010; Hudon et al., 2013; Duch et al., 2013), while some studies considered video games in addition to televiewing (Putnick et al., 2023; McArthur et al., 2022; Mendelsohn et al., 2010; Dynia et al., 2021), a few experimental studies conducted the assessment by a computer (Myers et al., 2018; Roseberry et al., 2014) or on a monitor (Troseth et al., 2018), a few studies assessed the effect of tablet, handheld, and touchscreen devices (Lin et al., 2020; Myers et al., 2017; Bedford et al., 2016; van den Heuvel et al., 2019; Rayce et al., 2024; Kirkorian et al., 2016; Rosslund et al., 2024), and others considered multiple types of devices (Plitponkarnpim et al., 2018; Tomopoulos et al., 2010; Putnick et al., 2023; Takahashi et al., 2023; McArthur et al., 2022; Operto et al., 2020; Alroqi et al., 2023; Taylor et al., 2018; Gago-Galvagno et al., 2023; Medawar et al., 2023; Asikainen et al., 2021; Sundqvist et al., 2021; Duch et al., 2013). Some studies considered the content of screen time as a predictor (Tomopoulos et al., 2010; Okuma and Tanimura, 2009; Zimmerman et al., 2007; Ferguson and Donnellan, 2014; Alroqi et al., 2023; Hudon et al., 2013; Duch et al., 2013), others used specific content such as a specific DVD or videotape (Richert et al., 2010; Krcmar, 2010; Dayanim and Namy, 2015; Vandewater, 2011; Robb et al., 2009; Vandewater et al., 2010; Roseberry et al., 2009; Krcmar, 2014), one focused on the language of TV programs (Perdana et al., 2017), four experimental studies used specific videos made by the researchers (Krcmar, 2010; Myers et al., 2017; Roseberry et al., 2014; Kirkorian et al., 2016; Troseth et al., 2018), one used a virtual agent (Tsuji et al., 2021), and four studies performed live video chat (Myers et al., 2017, 2018; Roseberry et al., 2014; Tsuji et al., 2021; Troseth et al., 2018). It is worth mentioning that studies addressed the role of media verbal interactions and co-viewing (Mendelsohn et al., 2010; Operto et al., 2020), screen time content (Operto et al., 2020), and socio-economic status (Slobodin et al., 2024; Rayce et al., 2024), joint media engagement and verbal scaffolding (Medawar et al., 2023), or shared book reading (Rosslund et al., 2024) as moderators, and one study examined the quantity and quality of maternal speech in dyadic toy play as a mediator between background televiewing and vocabulary acquisition (Masur et al., 2016), while another study examined the mediating role of peer-play as well as the moderating role of gender (Putnick et al., 2023).

Summary of evidence on language

The findings across studies in this area were inconsistent, with some outcomes being more consistently and undesirably associated to screen time, such as language competence, and others being more consistently and desirably linked to screen time, such as vocabulary (see Table 7). Contextual and child-related factors, such as verbal interactions during screen time or co-viewing, screen content, frequency of children's exposure to screen media with the same content (Krcmar, 2010; Vandewater et al., 2010), shared book reading (Rosslund et al., 2024) and children's age (Krcmar, 2010), but not gender (Putnick et al., 2023) seem to be important moderators of the correlates of screen time on language development. In addition, there is still a lack of longitudinal studies, as well as studies focusing on various screen devices, especially modern ones.

Motor skills

Eight studies examined the link between screen time and motor skills among children under the age of three. One semi-longitudinal study reported that for each additional hour per day of parent-reported televiewing at age 29 months, a 9% decrease in locomotion (i.e., running, side shuffle) scores was observed at age 65 months (Pagani et al., 2013). In a cross-sectional study, children with more than 2 h of televiewing per day and children who had <2 h did

TABLE 8 Summary of results pertaining to motor skills.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Motor skills	0	0	0	2	5	0	0	3	0	1	2	1	*3*	*10*	*1*
Motor skills (age of attainment)	0	0	0	0	0	0	0	0	0	0	5	1	*0*	*5*	*1*
Locomotion	0	0	0	0	0	0	1	0	0	0	0	0	*1*	*0*	*0*
Total	*0*	*0*	*0*	*2*	*5*	*0*	*1*	*3*	*0*	*1*	*7*	*1*	*4*	*15*	*2*

"−," undesirable association; "=," non-significant association; "+," desirable association.

not differ in the odds of having delayed motor development, with children in the low-televiewing group having a higher percentage of delay. However, children aged 24 to 35 months with high televiewing were found to have 3.7 times higher odds of being delayed in their motor development (Lin et al., 2015). Bedford et al. (2016) reported no cross-sectional association between first touchscreen use and gross motor milestones attainment. Additionally, children with earlier first touchscreen use were found to attain the "stacking blocks" fine motor milestone earlier, with a small effect size. Importantly, this was only the case for scrolling, not for video watching on a touchscreen device. Motor development was not systematically found to be linked to screen time in semi-longitudinal and cross-sectional models in another study, although one undesirable cross-sectional association was found for girls at age 12 months (Kracht et al., 2023). A study focusing on children aged 12 to 36 months found no direct association, yet revealed a small, undesirable indirect link between screen time and both fine and gross motor skills through peer play, with no gender-based differences (Putnick et al., 2023). Another longitudinal study yielded mixed results, reporting various models with differing time points for assessing predictors and outcomes (Slobodin et al., 2024). Herein, no indications of a moderation by socio-economic status were found. In a semi-longitudinal study about multiple developmental outcomes, screen time at age 1 year was not systematically found to be linked with gross and fine motor development at age 2 and 4 years (Takahashi et al., 2023). Furthermore, no cross-sectional association was found between different forms of screen time and attainment of motor development milestones (Gago-Galvagno et al., 2023).

Methodological considerations

Motor-related outcomes were assessed with parent-reported data collected with questionnaires (Putnick et al., 2023; Takahashi et al., 2023; Slobodin et al., 2024; Bedford et al., 2016; Gago-Galvagno et al., 2023) or standardized test batteries (Kracht et al., 2023; Lin et al., 2015; Pagani et al., 2013). Most studies measured screen time by one-time parent report (Lin et al., 2015; Takahashi et al., 2023; Pagani et al., 2013; Bedford et al., 2016; Gago-Galvagno et al., 2023). Screen time was categorized in two studies (Kracht et al., 2023; Lin et al., 2015). Three studies examined only the effects of televiewing or DVD watching (Kracht et al., 2023; Lin et al., 2015; Pagani et al., 2013), and one assessed the effect of tablet, handheld, or touchscreen devices (Bedford et al., 2016), while another also encompassed gaming (Putnick et al., 2023). Some studies considered media content or contextual aspects such peer play as a mediator and gender as a moderator (Putnick et al., 2023) or socio-economic status as a moderator (Slobodin et al., 2024).

Summary of evidence on motor skills

The paucity of studies in this area and the inconsistent results render any conclusion about the effects of screens on motor development in the first 3 years of life difficult to draw (see Table 8). Overall, results indicating non-significant associations seem to prevail by a large margin. Results that were obtained so far in this field are limited by a complete absence of experimental and a limited number of longitudinal studies. However, a valuable aspect of some of these studies is the use of validated tests to assess outcomes studied, while a limitation of most studies is their reliance on one-time parent reports of screen time indicators.

Socio-emotional skills

Studies on the association between screen time and overall socio-emotional skills, internalizing and externalizing problems, social skills, and self-regulation ($n = 24$) are reported here.

Overall socio-emotional skills

A longitudinal study yielded a desirable association between televiewing and socio-emotional skills composite scores from age 1 year to age 3 years (Intusoma et al., 2013). The authors also reported that this desirable effect (Black et al., 2017) became an undesirable effect with an exposure of more than 2 h per day but (Britto et al., 2017) was more pronounced for educational content. However, the authors highlighted that cultural aspects might explain the link between televiewing and socio-emotional skills, as there was a positive link between televiewing and the socio-economic status of the family. Results from another longitudinal study suggest that screen media multitasking from age 18 months to 4 years might be linked to higher total problem scores on the Child-Behavior Check List (Achenbach, 1999) but not to parent-reported or teacher-reported total problem scores on the Strengths and Difficulties Questionnaire (Goodman, 1997) at age 6 years (Srisinghasongkram et al., 2020). A further study showed no link between children's screen time at age 18 months and negative emotionality at age 26 months (Gordon-Hacker and Gueron-Sela, 2020). Semi-longitudinal studies found that children showing "high-persistent" screen time from 24 to 60 months were found to have lower adaptive behavior scores, in contrast to children with "low to moderate" screen time (McArthur et al., 2020). A cross-sectional study with children aged 6 to 24 months of age found screen time to be undesirably related to socio-emotional skills, an association that was partly mediated by reduced parent–child play without screens (Wan et al., 2021). Another study reported a series of non-significant associations of different indicators of screen time with temperament (i.e., effortful control, surgency, and negative affect) as well as joint attention skills (Gago Galvagno, 2021). No experimental studies were found that examined overall socio-emotional skills.

Internalizing problems

A longitudinal study found that children exposed to more than 2 h of screen time (TV, PC, and video games) at age 36 months had a higher risk of internalizing problems at age 36 months controlling for internalizing problems at age 24 months (McArthur et al., 2022). One semi-longitudinal study supports the existence of an undesirable association of televiewing with anxiety and depression but not with affective problems, anxiety, somatic complaints, withdrawal, or internalizing behaviors at age 18 months (Chonchaiya et al., 2015). Adult TV programs were linked to more emotional-reactive problems (Chonchaiya et al., 2015). Another semi-longitudinal study found an undesirable link between early exposure to television and emotional reactiveness but not to anxious or depressive symptoms at age 55 months (Mistry et al., 2007). A third semi-longitudinal study found no association between televiewing and emotional symptoms at age 30 months (Cheng et al., 2010), and semi-longitudinal trajectories of screen time from 24 to 60 months were not found to be linked to internalizing problems at age 60 months (McArthur et al., 2020). Finally, a cross-sectional study reported an undesirable association between touch-screen use and emotional problems, social withdrawal, and anxious and depressive symptoms (Lin et al., 2020). No experimental studies were found that examined internalizing problems.

Externalizing problems

One longitudinal study found that high exposures of more than 1 h per day, but not low or moderate exposure, across 2 to 3 years of age was linked to the incidence and persistence of externalizing behaviors at age 3 years (Verlinden et al., 2012). Another longitudinal study found no significant link to externalizing problems from 2 to 8 years of age (Levelink et al., 2020). Further, children who spent two or more hours on screens (including TV, computers, and video games) at 36 months of age faced a higher risk of developing externalizing problems at that same age. This association was observed after accounting for externalizing problems present at 24 months (McArthur et al., 2022). One semi-longitudinal study found that trajectories of screen time from 24 to 60 months linked to externalizing problems at age 60 months: membership in the "high-persistent" class was linked to higher externalizing problems scores than the "low to moderate" class (McArthur et al., 2020). Another study found no association between televiewing and conduct problems at age 30 months (Cheng et al., 2010) and oppositional defiant behaviors at age 18 months (Chonchaiya et al., 2015), and undesirable associations with aggressive behavior and externalizing problems at ages 33 months (Tomopoulos et al., 2007) and 55 months (Mistry et al., 2007) were reported in other studies. Adult TV programs were linked to aggression and externalizing problems at age 18 months (Chonchaiya et al., 2015) and to aggression, oppositional defiant behavior, and externalizing problems at age 33 months (Tomopoulos et al., 2007). Furthermore, bedtime TV viewing at age 18 months was associated with more aggressive behavior and attention problems in Medicaid-eligible racial/ethnic minority children. This link was found to be mediated through worsened sleep (Miller et al., 2022). Results from cross-sectional studies support an undesirable association between touch-screen use and aggressive behavior in children aged 18 to 36 months (Lin et al., 2020) and between screen time and externalizing problems in children aged 6 to 24 months, and the latter connection was not found to be mediated by reduced parent–infant play without screens (Wan et al., 2021). No experimental studies were found that examined externalizing problems.

Social skills and peer problems

A longitudinal study of children aged 12 to 36 months found no direct association, but identified a small, undesirable indirect link between screen time and personal-social skills via peer play, with no gender-based moderation (Putnick et al., 2023). Semi-longitudinal studies found undesirable associations between televiewing at age 18 months and prosocial behavior at age 30 months (Cheng et al., 2010), between total screen, TV, gaming time, and social skills (Carson et al., 2019), and between televiewing in early childhood and victimization in fourth grade (Pagani et al., 2010, 2013). Another semi-longitudinal study investigating various developmental outcomes found that screen time at 1 year of age was partially associated with personal and social skills at ages two and four, especially when daily screen time exceeded 4 hours (Takahashi et al., 2023). One cross-sectional finding from a semi-longitudinal study was that no significant link was found for televiewing and prosocial behavior at age 30 months (Cheng et al., 2010). No experimental studies were found that examined social skills and peer problems.

Self-regulation

A longitudinal study by Cliff et al. (2018) reported that total media exposure at age 2 years was linked to slightly lower scores of self-regulation at age 4 years, which was in turn linked to higher media exposure at age 6, but not vice versa. Further, the effect of self-regulation on media use from age 4 years to 6 years was not moderated by gender or hostile parenting but by parental education: The link was only found in parents with a tertiary education. Separate analyses for TV, computer use, and gaming showed that these results were mainly driven by TV viewing. In another longitudinal study, screen time at the age of 12 months was linked to negative affect but not to effortful control. Further, screen time at age 12 months was related to lower increases in negative

TABLE 9 Summary of results pertaining to socio-emotional skills.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Overall socio-emotional skills	0	0	0	2	2	0	1	0	0	1	5	0	*4*	*7*	*0*
Internalizing behavior	0	0	0	1	0	0	3	8	0	3	0	0	*7*	*8*	*0*
Externalizing behavior	0	0	0	2	3	0	5	2	0	2	0	0	*9*	*5*	*0*
Social skills and peer problems	0	0	0	1	0	0	4	1	0	0	1	0	*5*	*2*	*0*
Self-regulation	0	0	0	3	2	0	1	0	0	0	0	0	*4*	*2*	*0*
Bonding	0	0	1	0	0	0	0	0	0	0	0	0	*0*	*0*	*1*
Total	*0*	*0*	*1*	*9*	*7*	*0*	*14*	*11*	*0*	*6*	*6*	*0*	*29*	*24*	*1*

"−," undesirable association; "=," non-significant association; "+," desirable association.

affect from 12 to 35 months of age but not to the development of effortful control. In addition, changes in screen time were unrelated to changes in negative affect and effortful control and no indications of effects of negative affect or effortful control at age 12 months on the development of screen time were found (Brauchli et al., 2024). A semi-longitudinal study was conducted to examine prospective associations and changes between self-regulation problems at 9 months and 2 years of age and tele- and video viewing at 2 years of age (Radesky et al., 2014). The results showed that children with persistent self-regulation problems were even more likely to watch television or videos at age 2 years, suggesting that this relationship is most likely bidirectional. No experimental or cross-sectional studies were found that examined self-regulation.

While not being specifically related to self-regulation, one experimental study that focused on mother-infant bonding will be placed here (Kaynak and Yilmaz, 2024). The study found that video calling as well as video calling combined with singing lullabies to preterm infants shortly after birth had desirable effects on mother-infant bonding scores as compared to a control group on the seventh and final day of the intervention.

Methodological considerations

Outcomes were assessed with questionnaires and screenings in all studies. Only few studies used a 24-h diary to assess screen time (Srisinghasongkram et al., 2020; Tomopoulos et al., 2007; Brauchli et al., 2024), and all others relied on one-time parent reports (Miller et al., 2022; Mistry et al., 2007; Chonchaiya et al., 2015; Lin et al., 2020; Pagani et al., 2010; Cheng et al., 2010; Takahashi et al., 2023; Pagani et al., 2013; Intusoma et al., 2013; Gordon-Hacker and Gueron-Sela, 2020; McArthur et al., 2020; Wan et al., 2021; Gago Galvagno, 2021; Verlinden et al., 2012; Levelink et al., 2020; Carson et al., 2019; Cliff et al., 2018; Radesky et al., 2014). Screen time was categorized in three studies (Mistry et al., 2007; Cheng et al., 2010; Takahashi et al., 2023; McArthur et al., 2022; Verlinden et al., 2012), and four studies categorized their outcomes to identify clinically relevant outcomes (Tomopoulos et al., 2007; Intusoma et al., 2013; Wan et al., 2021; Verlinden et al., 2012). Although the majority of studies only examined TV and DVD (Miller et al., 2022; Mistry et al., 2007; Chonchaiya et al., 2015; Pagani et al., 2010; Cheng et al., 2010; Tomopoulos et al., 2007; Pagani et al., 2013; Intusoma et al., 2013; Verlinden et al., 2012; Radesky et al., 2014), three studies also focused on handheld devices (Gordon-Hacker and Gueron-Sela, 2020), computers (Cliff et al., 2018), and playing games (Putnick et al., 2023; Gordon-Hacker and Gueron-Sela, 2020; Levelink et al., 2020; Cliff et al., 2018), one solely on touch screen use (Lin et al., 2020), another explored the effects of screen media multitasking (Srisinghasongkram et al., 2020), and others examined overall screen time (Takahashi et al., 2023; McArthur et al., 2022, 2020; Wan et al., 2021; Carson et al., 2019; Brauchli et al., 2024). One while one experimental study focused on the effects of mothers' video calls and singing lullabies with their preterm infants (Kaynak and Yilmaz, 2024), thus considering both the content and the context. Four studies examined the role of content (Chonchaiya et al., 2015; Tomopoulos et al., 2007; Intusoma et al., 2013; Verlinden et al., 2012), and others examined the moderating role of child gender (Levelink et al., 2020; Cliff et al., 2018), parental education (Cliff et al., 2018), and hostile parenting (Cliff et al., 2018). The mediating role of play without screens, parent–child play (Wan et al., 2021), and peer play were examined (Putnick et al., 2023). Finally, only one study considered co-viewing as a contextual variable (Wan et al., 2021).

Summary of evidence on socio-emotional skills

Associations between screen time and socio-emotional outcomes seem to be inconsistent across studies, with a tendency to more undesirable associations, independent of the study design (see Table 9). The most frequent study design was the semi-longitudinal one, which again calls for more longitudinal studies with more than two assessments that can model change and bidirectional associations. Regarding self-regulation, bidirectional links to screen time seem to be plausible. Additionally, few experimental studies were found in this field, and most studies focused on televiewing.

Social interaction

The results of the studies that examined associations with parent–child interaction, media–verbal interaction, attachment security, social closeness, and children's toy play ($n = 15$) are summarized below in one subcategory, social interaction.

Experimental and experimental field studies found an undesirable effect of background television on parent–child interactions (Pempek et al., 2011) as well as a number of aspects of social interactions on the side of children as well as parents. Regarding children's social interactions, undesirable associations were found with duration of play (Evans Schmidt et al., 2008), social interactions and responsiveness (Kirkorian et al., 2009), vocalizations and conversational turns (Brushe et al., 2023), and duration of attention to play (Evans Schmidt et al., 2008; Courage et al., 2010). On the parents' side, undesirable associations were found between background television and active involvement, responsiveness, and interaction in play (Kirkorian et al., 2009), vocalizations (Courage et al., 2010), quality and quantity of utterances (Tanimura et al., 2007), and duration of play interactions with children (Courage et al., 2010). In contrast, no associations was found with children's overall focused attention and maturity of play in one study (Evans Schmidt et al., 2008). Undesirable effects were also found regarding reaction to joint attention prompts when playing a tablet game about caring for animals, especially in older children, but not when watching a video of a child playing with a toy or when playing with a puzzle app on a tablet (Webb et al., 2024). Studies also showed that children approached strangers more easily when they watched a video with them than when the stranger was in the same room but could not see the video and was reading a book instead (Wolf and Tomasello, 2020). Furthermore, potential for an increase in parent–child interactions was found in videos that are designed to model parent behavior and support co-viewing while also offering a child-friendly narrative and storyline (Pempek et al., 2011). Finally, a comparison of interactions between young children and their parents when viewing tablet books and print books show that social control behaviors and less social reciprocity were more prevalent when viewing and reading tablet books than print books (Munzer et al., 2019a) but that verbal interaction and collaboration are lower with electronic books than with printed books (Munzer et al., 2019b).

A short-term longitudinal study showed that background television exposure at age 13 months was linked to poorer quantity and quality of maternal vocalizations, which was in turn linked to children's vocabulary acquisition (Masur et al., 2016). However, another study found that televiewing is not longitudinally associated with conversational turns (Zimmerman et al., 2009). A semi-longitudinal study among low-income families found that media verbal interactions compensated for the undesirable associations of televiewing with language development and even had positive associations with language development when only educational videos were viewed (Mendelsohn et al., 2010). One cross-sectional study found the frequency of parent-child interactions during background and foreground televiewing to be lower than 25% of exposures and to be highest for educational child content and for content that was co-viewed (Mendelsohn et al., 2008). However, there were no indications of more co-viewing for educational content than for non-educational content for young children, school-aged children, teenagers, or adults. Cross-sectional findings from a longitudinal study found that an hour's more televiewing is associated with fewer conversational turns (Zimmerman et al., 2009). Further, neither screen time nor co-viewing was found to be linked to attachment insecurity, and parental absorption in media was found to have an undesirable link to attachment security (Linder et al., 2021). Moreover, the authors reported that active parental mediation was found to buffer against the potential negative effects of child televiewing.

Methodological considerations

Outcome variables were measured with screenings or questionnaires (Mendelsohn et al., 2010; Masur et al., 2016; Mendelsohn et al., 2008; Linder et al., 2021), observation of videotaped interaction situations (Tanimura et al., 2007; Masur et al., 2016; Pempek et al., 2011; Evans Schmidt et al., 2008; Kirkorian et al., 2009; Courage et al., 2010; Webb et al., 2024; Wolf and Tomasello, 2020; Munzer et al., 2019a,b), and electronic diaries using special hardware and software (e.g., LENA) (Zimmerman et al., 2009; Brushe et al., 2023). Screen time was measured through one-time parent reports (Masur et al., 2016; Linder et al., 2021), diaries (Mendelsohn et al., 2010; Pempek et al., 2011; Mendelsohn et al., 2008), hardware and software-based diaries (Zimmerman et al., 2009), and the LENA software (Brushe et al., 2023). A majority of the studies focused solely on televiewing and DVD watching (Masur et al., 2016; Pempek et al., 2011; Evans Schmidt et al., 2008; Kirkorian et al., 2009; Courage et al., 2010; Wolf and Tomasello, 2020), some on games (Mendelsohn et al., 2010; Webb et al., 2024; Mendelsohn et al., 2008), and other studies on modern portable screen devices (Tanimura et al., 2007; Munzer et al., 2019a,b; Linder et al., 2021). Some studies addressed the role of content (Mendelsohn et al., 2010; Okuma and Tanimura, 2009; Pempek et al., 2011; Evans Schmidt et al., 2008; Kirkorian et al., 2009; Mendelsohn et al., 2008), two studies examined electronic books (Munzer et al., 2019a,b), and two studies addressed the protective role of active parental mediation (Linder et al., 2021) and media verbal interactions (Mendelsohn et al., 2010).

Summary of evidence on social interaction

The pattern of results regarding the association between screen time and social interactions quite clearly shows undesirable links to various aspects of social interaction (see Table 10). Strong evidence from several experimental studies suggests that televiewing reduces the quantity and quality of parent–child interaction and might also negatively affect children's attention to play and its duration. However, other results indicate the role of content and context of screen time, an area that needs to be examined in more depth. Notably, that these results mostly pertain to televiewing, and the role of modern screen devices has yet to be explored in this age range.

Overall development

Although most studies examining association between screen time and child development focused on one or more specific outcomes, some studies ($n = 8$) elucidated links with overall

TABLE 10 Summary of results pertaining to social interactions.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Play duration (child)	1	0	0	0	0	0	0	0	0	0	0	0	*1*	*0*	*0*
Responsiveness (child)	1	0	0	0	0	0	0	0	0	0	0	0	*1*	*0*	*0*
Parent's vocalizations	1	0	0	2	1	0	0	0	0	0	0	0	*3*	*1*	*0*
Child vocalization	0	0	0	1	0	0	0	0	0	0	0	0	*1*	*0*	*0*
Parents' active involvement	1	0	0	0	0	0	0	0	0	0	0	0	*1*	*0*	*0*
Parents' responsiveness	1	0	0	0	0	0	0	0	0	0	0	0	*1*	*0*	*0*
Social interactions	7	0	2	1	0	0	1	0	0	2	1	0	*11*	*1*	*2*
Duration of attention to play	2	1	0	0	0	0	0	0	0	0	0	0	*2*	*1*	*0*
Response to joint attention	1	2	0	0	0	0	0	0	0	0	0	0	*1*	*2*	*0*
Parental utterances	2	0	1	0	0	0	0	0	0	0	0	0	*2*	*0*	*1*
Attachment insecurity	0	0	0	0	0	0	0	0	0	1	1	0	*1*	*1*	*0*
Total	*17*	*2*	*3*	*4*	*1*	*0*	*1*	*0*	*0*	*3*	*2*	*0*	*25*	*6*	*3*

"−," undesirable association; "=," non-significant association; "+," desirable association.

development, mostly in composite scores from developmental screenings or test batteries. These studies are reviewed below.

In a longitudinal study from 6 months to 8 years of age, children with different patterns of televiewing were not found to differ in their developmental status at age 6 months, but children who exhibited a "extremely high descending" pattern (i.e., children starting with more than 3 h of screen time per day at age 2.2 years and dropping to <2 h at age 7.3) were found to have the highest incidence of delayed development, while children in the "low descending" group had the lowest incidence at age 2 years (Kim and Chung, 2021). However, differences in changes in developmental scores were not examined among the various groups. One of the few longitudinal studies found that children's overall screen time at age 2 years had an undesirable association with their composite development score at age 3 years (Madigan et al., 2019). The same undesirable link was also found from screen time at age 3 years to composite development score at age 5 years. Notably, the reverse association was not statistically significant, although the link between development at age 3 years and screen time at age five had the largest effect size. Another publication that used the same dataset showed that two latent classes of screen use could be identified from age 24 months to 60 months: a "low to moderate" class and a "high-persistent" class (McArthur et al., 2020). The authors were able to show that children in the "high-persistent" class had lower total scores at age 60 months than children from the "low to moderate" class. However, analyses were not performed with latent class growth curve models for composite developmental scores. Another longitudinal study indicated that children who engaged in two or more hours of screen time (TV, computer, or video games) at 36 months had an increased likelihood of delayed achievement of developmental milestones at that age, even when controlling for developmental milestones at 24 months (McArthur et al., 2022). Another longitudinal study identified not direct but a small undesirable indirect negative association between screen time (including watching shows, movies, and gaming) and developmental delays via peer play from ages 12 to 36 months. This association showed no gender-based moderation (Putnick et al., 2023). One semi-longitudinal study identified an undesirable impact of televiewing and adult TV programs over time from 6 months to 18 months on children's pervasive developmental problems at age 18 months (Chonchaiya et al., 2015). Similarly, boys but not girls with higher, and in particular those with more than 1 h but <2 h per day of TV and/or DVD screen time at age 12 months were found to have an increased risk of having received an autism spectrum disorder diagnosis (ASD) by the age of 36 months, controlling for their development at age 12 months (Kushima et al., 2022). However, <1 h was not strongly related to ASD and was even associated with a lower risk in girls. In a cross-sectional study among a representative sample of French 2-year olds, weekly and daily TV, PC, tablet, and smartphone use was linked to slightly higher odds of an intermediate risk of autism, but with reduced odds of a high risk. A similar pattern was observed for number of hours on different devices (Melchior et al., 2022). No experimental studies were found that examined overall development.

Methodological considerations

All studies assessed developmental outcomes with questionnaires and screenings reported by parents. Only one study used a 24-h media diary instead of a one-time report from parents (Chonchaiya et al., 2015). Some studies examined the unique associations with televiewing or DVD watching (Chonchaiya et al., 2015; Kim and Chung, 2021; Kushima et al., 2022; Melchior et al., 2022), and others assessed the links to modern portable screen device use (McArthur et al., 2020; Madigan et al., 2019; Melchior et al., 2022). One study also addressed the role of content (Chonchaiya et al., 2015), but none of the studies considered aspects of media context such as co-viewing. Furthermore, two studies addressed the role of trajectories of media use (Kim and Chung, 2021; McArthur et al., 2020) and its link to the outcome

TABLE 11 Summary of results pertaining to overall development.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Overall development	0	0	0	6	1	0	2	1	0	1	1	1	9	3	1

"–," undesirable association; "=," non-significant association; "+," desirable association.

studied. One study examined the mediating role of peer-play and the moderating role of gender (Putnick et al., 2023). Two studies adopted a gold-standard technique for the modeling of change (Putnick et al., 2023; Madigan et al., 2019).

Summary of evidence on overall development

Conclusions about the role of screen time for children's overall development are tentative given that only a handful of studies examined this link (see Table 11). Nonetheless, results that were obtained so far point to undesirable correlates across early and middle childhood.

Discussion

This comprehensive review presents a systematic scoping analysis of 158 studies that explored the relationships between screen time and a broad spectrum of developmental outcomes, including sleep, physical health, cognition, learning efficiency, language, motor skills, socio-emotional skills, social interaction, and overall development in children aged zero to 36 months. A general overview and interpretation of the evidence summarized in the results section are presented below.

Overall summary of evidence

Results across all developmental aspects are summarized in Table 12. A total of 225 findings within the 158 studies indicated undesirable associations between screen time and child development. Another 268 findings showed that screen time was not significantly linked to child development. Finally, 46 findings described desirable associations between screen time and child development. Thus, the number of results that indicate undesirable and non-significant associations is comparatively high, whereas the number indicating desirable ones is low. In the following, this pattern of results is referred to as the *overall pattern* and is described with three numbers in parentheses (undesirable/non-significant/desirable). Thus, the overall pattern can be represented as (225/268/46). Regarding the overall pattern for the four types of design separately, results suggest that experimental studies mostly reported non-significant results but also yielded a meaningful number of undesirable associations as well as desirable ones. In contrast, longitudinal studies, semi-longitudinal studies as well as cross-sectional studies all reported both undesirable and non-significant associations, with comparable proportions, but virtually no desirable ones. In the following, we discuss how this pattern applies to the various developmental outcomes and what other patterns deviate from this overall pattern. Further, we discuss whether the overall pattern can be found in studies with different study designs and whether the pattern aligns with results from other systematic reviews and meta-analyses.

The overall pattern of mostly undesirable and non-significant results and a smaller number of desirable results was found for sleep (39/47/0), physical health (17/18/5), cognition (25/40/2), and socio-emotional skills (29/24/1). Cross-sectional and semi-longitudinal designs were most prominent in these fields, with a higher prevalence of cross-sectional studies on sleep and physical health and a higher occurrence of semi-longitudinal studies on cognition and socio-emotional skills. The overall pattern of undesirable and non-significant associations also predominated among all longitudinal studies in these areas, while experimental studies were rare. Thus, the evidence appears to be ambiguous. However, the number of undesirable associations is much higher than the number of desirable ones. This might indicate a tendency toward undesirable associations between screen time and sleep, physical health, cognition, and socio-emotional skills.

Results about sleep and physical health align with those from other reviews and meta-analyses in that there are comparable proportions of undesirable and non-significant associations (Guellai et al., 2022; Lund et al., 2021; Eirich et al., 2022). The tendency to undesirable associations might be interpreted as partial evidence for the displacement hypothesis (Mutz et al., 1993; Roberts et al., 1993). For instance, increased screen time might lead to less opportunities to interact with peers and to learn socio-emotional skills, or to less physical activity, which might lead to worse physical health and less healthy sleep. The video deficit hypothesis (Barr, 2008; Anderson and Pempek, 2005) and the mental-effort hypothesis (Valkenburg and van der Voort, 1994) might additionally explain undesirable associations of screen time on cognition, especially regarding television, as children might tend to habituate to being stimulated without any need for effort. In a recent review and meta-analysis, Mallawaarachchi et al. (2022) reported that mobile device use is associated with poorer sleep, but not with psychological and cognitive outcomes, which suggest that the content and the modality of use might warrant further investigation.

Several deviations from the overall pattern described above were identified: (1) a deviation toward a presence of desirable associations, (2) a deviation in the direction of dominant undesirable associations, and (3) an absence of a sufficient number of results. A noticeable presence of desirable associations was given for learning efficiency (17/34/12) and language (60/81/20). The presence of desirable associations in the context of dominantly undesirable associations aligns with other reviews on language development (Massaroni et al., 2024). Further, the balance between undesirable and desirable associations regarding learning

TABLE 12 Grand summary of all results.

Development area/subcategories	Experimental			Longitudinal			Semi-longitudinal			Cross-sectional			*Total*		
	−	=	+	−	=	+	−	=	+	−	=	+	−	=	+
Total sleep	0	5	0	7	9	0	1	0	0	31	34	0	*39*	*47*	*0*
Total physical health	1	0	4	3	4	0	5	3	0	8	11	1	*17*	*18*	*5*
Total cognition	0	4	0	4	3	0	15	20	2	6	13	0	*25*	*40*	*2*
Total learning efficiency	17	34	12	0	0	0	0	0	0	0	0	0	*17*	*34*	*12*
Total language	3	17	12	9	6	0	19	15	1	29	43	7	*60*	*81*	*20*
Total motor skills	0	0	0	2	5	0	1	3	0	1	7	2	*4*	*15*	*2*
Total socio-emotional skills	0	0	1	9	7	0	14	11	0	6	6	0	*29*	*24*	*1*
Total social interaction	17	3	3	4	1	0	1	0	0	3	2	0	*25*	*6*	*3*
Total overall development	0	0	0	6	1	0	2	1	0	1	1	1	*9*	*3*	*1*
Overall total	*38*	*63*	*32*	*44*	*36*	*0*	*58*	*53*	*3*	*85*	*117*	*11*	*225*	*268*	*46*

"−," undesirable association; "=," non-significant association; "+," desirable association.

underscores that while learning is possible through screen based media in experimental conditions, the context and content of the respective materials might be central to the learning effect (Guellai et al., 2022; Massaroni et al., 2024; Kostyrka-Allchorne et al., 2017). The dominance of undesirable associations that was obtained for social interaction (25/6/3) seems to be the most robust finding, especially given the high amount of experimental and longitudinal studies. These results show how attractive screens are for both children and adults and align with research on the phenomenon of technoference (Krogh et al., 2021), thus highlighting the importance of parental awareness of the potential for disruption of adult-child interactions through screen media.

On a methodological note, studies on learning efficiency and on social interaction were almost exclusively experimental in design. The studies on language also included a comparatively high proportion of experimental studies, although cross-sectional and semi-longitudinal studies still prevailed. Cross-sectional, semi-longitudinal, and longitudinal studies examining links to language tended to find more undesirable associations. In contrast, studies using an experimental approach tended to find more desirable associations. This was not the case for studies on social interaction, where experimental studies clearly report undesirable results, which is in line with results from previous reviews (Kostyrka-Allchorne et al., 2017). This pattern suggests that controlled experimental studies can shed light on both desirable correlates of screen time on isolated processes such as word learning as well as on undesirable correlates of social interaction. Conversely, field studies examining the same associations within a real-world context yield less clear results. An explanation for this finding might be that cause-effect relationships in this field are very complex and hard to capture in real-world settings due to a high number of potential moderating and confounding variables. While experimental studies can address this complexity by isolating specific components of interest, correlational field studies may find it more challenging to isolate the unique effects of children's screen time on development, particularly when cross-sectional designs are employed. Further, ethical issues and general concerns about the exposure of infants and toddlers to screens pose an additional challenge in this field of research. Besides experimental designs, longitudinal designs with more than two assessments and state-of-the-art modeling of change (i.e., random intercept cross-lagged models, latent growth models), ideally accompanied by methods that allow the inspection of intraindividual processes, such as experience sampling studies might also be valuable to strengthen our understanding of this complex field. Such methods might also tackle social desirability and memory distortions.

Finally, two outcomes that are comparatively understudied are motor skills (4/15/2) and overall development (9/3/1). Results about the associations between screen time and motor skills mostly stem from cross-sectional studies, but those about associations to overall development almost exclusively stem from longitudinal studies. Accordingly, the knowledge base about the associations between screen time and motor skills must be strengthened before any stable conclusions can be drawn. However, there is some evidence that screen time might have undesirable links to overall development, although we believe that the results of studies on specific development outcomes are more informative.

Several specific methodological and conceptual factors may have influenced the outcomes of the various studies. In the following section, we will elaborate on these aspects to discuss the results from a more theoretical perspective.

Does screen time displace learning opportunities and/or is screen time an inferior learning opportunity?

The present study demonstrates a heterogeneous pattern of associations between screen time and developmental outcomes across different domains. The most dominant tendency observed is toward undesirable associations between screen time and developmental outcomes. From the perspective of the displacement hypothesis (Mutz et al., 1993; Roberts et al., 1993), the tendency for screen time to act as a risk factor for child development can be explained by its displacement of other activities that are essential for development. In this view, screen time leads to a displacement of activities that would have otherwise positively influenced developmental outcomes. For instance, reductions in physical activity and social interaction (Rayce et al., 2024), both critical for healthy development, illustrate how screen time may indirectly contribute to undesirable developmental outcomes. While there are only few studies on the associations between screen time and motor development from ages zero to three, there is evidence that physical activity is linked to motor skills, language as well as cognition, and academic achievement (Zeng et al., 2017). Further, there is some evidence, although mixed, that physical activity is associated with poorer sleep (Antczak et al., 2020; Pesonen et al., 2011; Pano-Rodriguez et al., 2023). Assuming that screen time is mostly (although not exclusively) a sedentary activity (World Health Organization, 2019), the displacement of essential developmental outcomes seems plausible. Higher screen time may reduce physical activity, leading to undesirable effects on various developmental areas. The frequent association between screen time and reduced social interactions also supports the idea of a displacement process. When a screen is visible, it may divert attention from meaningful social interactions for both the child and others, potentially displacing opportunities for exchanges. This reduction in social interaction could indirectly affect language acquisition and socio-emotional development. For instance, as Masur et al. (2016) found, maternal speech declines when a screen is activated during parent-child play, which could mediate reductions in children's expressive vocabularies (Ferjan Ramírez et al., 2022). Similarly, screen time was found to have an undesirable indirect association with child development because it displaces peer play time, which would in turn be positively associated with child development (Rayce et al., 2024).

Thus, physical activity and social interaction may serve as central mediators in explaining the displacement effects of screen time, impacting not only motor development but also physical health, sleep, learning efficiency, and socio-emotional and cognitive skills. A longitudinal extension of the displacement hypothesis would suggest that as screen time increases with age (Brauchli et al., 2024; Anderson et al., 2008), the risk of developmental disruption grows, forming a bidirectional cycle (Cliff et al., 2018; Magee et al., 2014; Neville et al., 2021). This conceptual mechanism, displayed in Figure 2, could be expanded to include additional mediators and complex mechanisms beyond those addressed in this study. For example, sleep was found to mediate the link between bedtime TV viewing and aggressive behavior and attention problems, which also indicates a possible displacement mechanism (Miller et al., 2022). In this sense, Figure 2 offers a simplified representation of the displacement hypothesis.

The video deficit hypothesis (Barr, 2008; Anderson and Pempek, 2005) further supports the tendency toward undesirable outcomes, as the quality of stimulation and learning efficiency from screen media may reduce the likelihood of positive developmental results. When combined with the displacement hypothesis, a compounded risk emerges. Not only are important learning opportunities missed due to time spent on screens, but the learning opportunities presented via screens often lack the quality that other, non-screen activities provide. Incorporating the mental-effort hypothesis (Koolstra and van der Voort, 1996) and the passivity hypothesis (Valkenburg and van der Voort, 1994) into this framework suggests that, beyond missing key learning experiences (displacement hypothesis) and encountering lower-quality learning (video deficit hypothesis), children may adopt a passive stance. Together, these hypotheses highlight the layered risks of excessive screen time for young children's development.

This combination of hypotheses presents a rather pessimistic view of screen time's impact on child development. Given the complexity of developmental processes, however, the displacement hypothesis may require refinement to account for different mechanisms of change across various developmental outcomes. For instance, the way screen time affects motor development could differ significantly from its effects on socio-emotional development. This idea is echoed in the Dimensional Model of Adversity (McLaughlin and Sheridan, 2016; McLaughlin et al., 2019), which posits two key environmental dimensions: deprivation (e.g., low levels of social and cognitive stimulation) and threat (e.g., exposure to violence). The model suggests that these environmental factors influence physiological and psychological outcomes in specific ways, rather than having broad, generalizable (and merely cumulative) effects. In the context of screen time, the deprivation dimension may align with the displacement hypothesis for *excessive* screen time, while the threat dimension could relate to exposure to highly inappropriate content. Within this framework, the type of stimulation a child is deprived of due to digital media use must be examined in relation to specific outcomes. For example, a child who is encouraged to be physically active during screen time might not experience motor deprivation, or a child who takes a video call with a grandmother might still benefit from interaction and language exposure. Missing stimuli necessary for experience expectant plasticity (Greenough et al., 1987) taking place during early childhood might play a crucial role in the mechanisms of how digital media use affects early childhood development. This model could help explain differential effects on developmental outcomes, depending on the specific ways in which digital media is used and underlines once more early childhood as a critical period, also for digital media use. Hence, the effects of screen time on different aspects of child development likely vary to such an extent that broad generalizations about its impact are untenable. This limitation highlights the need for more nuanced guidelines that emphasize empowering parents as competent caregivers, rather than imposing strict screen time limits (Lerner and Barr, 2015). Moreover, the significant number of studies that do not report negative associations, both in early childhood (as shown in this review) and at later developmental stages (Ferguson et al., 2024), suggests that existing hypotheses and models do not fully capture the complexity of this phenomenon. This calls for additional frameworks to better explain the range of outcomes related to screen media use.

Differential susceptibility and resilience as additional perspectives

Interindividual differences in how screen time is linked to development can be explained by theories that address the complex interaction of individual and contextual factors. Two such theories

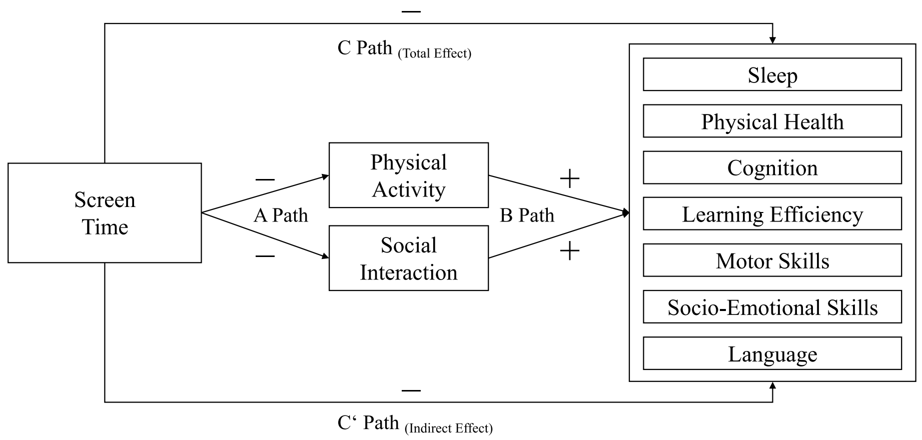

FIGURE 2
Conceptual model of the displacement hypothesis as a mediation mechanisms in the link between screen time and development. −, Negative association; +, Positive association; A, Direct effect of screen time on mediators; B, direct effect of mediators on development; C, Total effect of screen time on development; C′, Indirect effect of screen time on development.

or models are the theory of resilience (Masten and Barnes, 2018; Werner, 1993) and the Differential Susceptibility to Media Effects Model (Valkenburg and Peter, 2013).

Resilience is a concept from developmental systems theory (Ford and Lerner, 1992) that describes a system's ability to maintain healthy functioning in adversity (Masten, 2011). It emerges as a multi-layered process involving interactions among risk, promotive, and protective factors (Chmitorz et al., 2018). Risk factors increase the likelihood of adverse outcomes, promotive factors have positive effects regardless of risk, and protective factors mitigate risk-dependent effects (Masten and Barnes, 2018). Factors can be either promotive (Burke et al., 2017), protective (Wustmann Seiler et al., 2017), or both (Masten and Barnes, 2018). To understand the causal mechanisms of resilience, methodological approaches like longitudinal studies with multiple measurements are crucial (Hamaker et al., 2015). Promotive effects can be tested through main effects, while protective effects require modeling interactions or moderating effects (Burke et al., 2017; Sticca et al., 2017, 2020).

Regarding screen time as a risk factor, there is significant variability in how children engage with screen media, which complicates efforts to link screen time with early childhood development. As highlighted in our results section, many studies focus on more passive forms of screen use, such as televiewing or DVD watching, while others examine newer devices like smartphones and tablets. Even within these categories, the range of activities is vast, differing in interactivity (Kirkorian, 2018), educational content (Cerniglia and Cimino, 2020), or cognitive load (Zack et al., 2013), among other factors. This variability makes it difficult to draw definitive conclusions about the impact of screen time on child development. Additionally, the diversity of screen-based activities creates challenges in defining what constitutes "high" or "excessive" screen time, particularly when considering differences in children's age and developmental stage. For example, 30 min of watching Sesame Street might have a vastly different effect on a three-year-old's vocabulary development compared to 30 min of watching the news. Further, low doses of screen time might not have an impact on child development (Dynia et al., 2021; Ferguson, 2017), while very high exposure might carry a high level of risk (Takahashi et al., 2023). This underscores the need for more nuanced approaches when studying screen time's effects.

In addition to the diversity of screen devices, children can also participate in a wide range of digital activities. These activities include watching TV shows or movies, taking photos, playing interactive games, making video calls, and background televiewing. Some studies therefore focused on the duration that children spent engaged with screens in the foreground or background, while others examined the type of content being viewed, such as child-directed or adult-directed content, and educational or entertainment content. Furthermore, some studies analyzed the context in which screens were used, such as co-viewing (Kim et al., 2020), media verbal interactions (Mendelsohn et al., 2010), and usage during the week or weekend (Sigmundova and Sigmund, 2021). Some studies considered a combination of these aspects. In line with current discussions (Barr et al., 2018), our findings suggest that future research on screen time effects should go beyond merely quantifying screen time. Contemporary frameworks like the DREAMER model have synthesized these concepts and provide valuable theoretical and methodological guidance for organizing research efforts to address the complex challenges associated with screen time's impact on development (Barr et al., 2024). These frameworks encourage a more nuanced approach, considering not just the amount of screen time, but also the quality, context, and content of screen-based activities.

Regarding the role of promotive and especially protective factors, only a limited number of studies examined psychological mechanisms that could have moderated the association of children's screen time and child development. These moderators include factors such as the child's age, the type of screen content, and contextual factors such as co-viewing and engagement in non-digital activities (Barr et al., 2018). One example of how moderators can impact the relationship between children's screen time and developmental outcomes is demonstrated in the study conducted by Mendelsohn et al. (2010), who found that the negative associations between children's screen time and developmental outcomes were only significant in the absence of verbal interactions during the child's screen time. This review highlights that more research on the mechanisms of change is needed. For example, individual factors such as children's working memory (Choi et al., 2021), gender (Padmapriya et al., 2019; Levelink et al., 2020), and age (Hu et al., 2019), type of content (Operto et al., 2020), particularly educational child-directed content (Corkin et al., 2021; Chonchaiya et al., 2015), frequency of viewing the same content (Barr and Wyss, 2008; Barr et al., 2007b), matching sound effects or language prompts (Barr et al., 2009; Lauricella et al., 2016), familiarity with the character displayed on the screen (Lauricella et al., 2016; Howard Gola et al., 2013), interactivity with the screen (Nielsen et al., 2008; Lauricella et al., 2010), and contextual factors such as verbal interactions, co-viewing (Porter et al., 2022; Mendelsohn et al., 2010; Corkin et al., 2021; Richert et al., 2010), active parental mediation (Linder et al., 2021), social interaction (Antrilli and Wang, 2018), and less parenting factors (Cliff et al., 2018) need to be studied in more detail. Further, considering that only few studies have examined the 1st and the 2nd year of life, the moderating role of child attributes such as age and temperament have not been intensively studied in this area and needs more attention in future research to examine the differential susceptibility among children.

Another relevant theoretical model that addresses individual differences in how screen time affects development is the *Differential Susceptibility to Media Effects Model* (Valkenburg and Peter, 2013). This model, akin to resilience theory, posits that the impact of screen time on development is moderated by various factors, including dispositional, developmental, and social susceptibility. It highlights the complex interplay between individual characteristics and contextual factors, suggesting that these variables may have longitudinal, self-reinforcing effects over time. By considering these moderating influences, the model provides a more nuanced understanding of how screen time can affect development differently across individuals. By not taking complex interplay into account, many studies may have missed potential desirable associations with children's screen time, or they may have overemphasized the negative associations. Figure 3 shows how the displacement hypothesis (as a mediation) could be translated into a buffering hypothesis (as a moderation).

The role of cultural context

Supplementary Table S.1 shows the countries in which the studies were carried out. The most prevalent studies were conducted in North America, with a total of 67 studies, largely due to the high number of studies from the USA and Canada. In contrast, only 3 studies were carried out in South America. In Asia, there were 32 studies, contributed by countries such as Thailand, Japan, and Singapore. Europe saw 33 studies, with significant contributions from the UK, Sweden, and Italy. Meanwhile, Oceania had 6 studies, mostly from Australia and New Zealand. Additionally, there were 2 studies that spanned multiple continents, and 3 studies where the countries were not reported or specified.

Building on the geographical distribution of the studies outlined in Supplementary Table S.1, it is important to address the cultural context in which these studies were conducted, as this can significantly influence the results and their generalizability. Most of the studies were conducted in North America, particularly the United States of America. A substantial portion of the reviewed studies likely comes from WEIRD (Western, Educated, Industrialized, Rich, and Democratic) populations, which raises concerns about the applicability of these findings to non-Western, non-industrialized societies. The results of the present study do not reveal a consistent pattern suggesting significant differences between continents, as mixed findings were reported across all regions and even within countries on the same continent. While it is well-established that screen time varies by geographical region (LeBlanc et al., 2015), it is crucial to examine whether the associations between screen time and developmental outcomes are moderated by cultural factors. Additionally, it is important to explore whether the effects of contextual variables are better examined within or across cultures. To our knowledge, no studies have directly investigated how cultural context might influence these associations, making this an important area for future research. Nonetheless, Barr et al. (2024) provide an overview of socio-contextual factors that may influence differential susceptibility, such as ethnicity/race and socio-economic status. They propose a new theoretical framework, DREAMER, which integrates many of the theories and models discussed above and emphasizes the role of family media ecology and mechanisms of change that unfold over time across various contextual levels (Barr et al., 2024).

Methodological considerations

It is also important to consider the impact of study design on the results, as this plays a crucial role in the quality and reliability of the findings. Along with differences in sample size and participant demographics, more than 60% of the results included in the review stem from cross-sectional or semi-longitudinal designs. These study designs can only measure correlations between variables at a single point in time or over a short period and thus are unable to assess causality. Another important consideration in interpreting the findings of these studies is the issue of reverse causality. Reverse causality is the possibility that developmental problems may lead to increased screen time, rather than screen time causing developmental problems (Radesky et al., 2014). This issue has been relatively understudied in the literature. Longitudinal studies that assess children's screen time and developmental outcomes at multiple time points and that use state-of-the-art multivariate longitudinal models (Hamaker et al., 2015) can help address this issue by providing a more comprehensive understanding of the relationship between children's screen time and children's developmental outcomes over time while also taking contextual moderators into account. Such studies might contribute to our understanding of whether screen time is a cause, a consequence, or an epiphenomenon of child development and/or of the context in which children live.

Differences in assessment and statistical modeling could also contribute to the heterogeneity of findings observed. Most of the studies reviewed here relied on single-time parental reports, which,

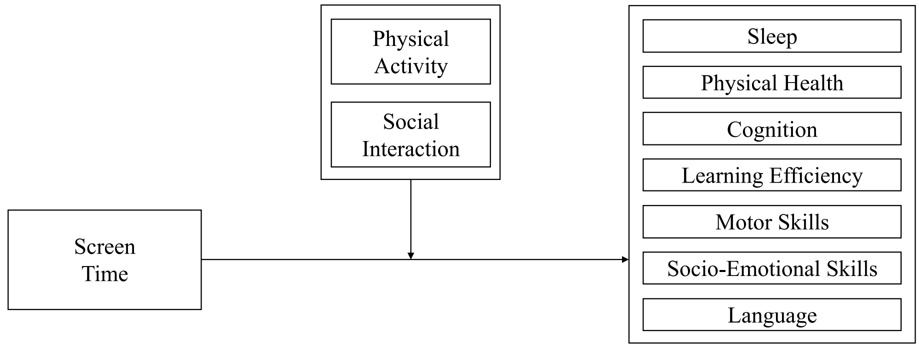

FIGURE 3
Conceptual model of the buffering hypothesis as a moderation mechanisms in the link between screen time and development.

while cost-effective and suitable for large-scale assessments, have several limitations. These include the potential for high social desirability biases, the possibility of recall and cognitive distortions affecting accurate reporting, and the lack of clarity around what constitutes "screen time" for participants. In this regard, Barr et al. (2020) recommend combining parental reports, activity diaries, and passive sensing apps to obtain a more comprehensive and precise picture of children's screen time. While this approach would certainly provide more accurate data, its feasibility may be limited, particularly in longitudinal studies where participant burden is high and obtaining representative samples can be challenging. Regarding statistical modeling, some studies used extreme-group modeling, which focuses on comparing children with high and low levels of screen time. Such a comparison of extreme groups is more likely to yield significant differences between groups than approaches that operationalize children's screen time as a continuous measure. Very high levels of screen time have been found to be related to a number of undesirable outcomes such as sleep (Chindamo et al., 2019; Cespedes et al., 2014; Mistry et al., 2007), physical health (Hu et al., 2019; Saldanha-Gomes et al., 2017; Collings et al., 2018; Manios et al., 2009), cognition (Mistry et al., 2007; Supanitayanon et al., 2020; Lin et al., 2015; Cheng et al., 2010; Barr et al., 2010a), language (Lin et al., 2015; Duch et al., 2013; Kim and Chung, 2021; Mendelsohn et al., 2010; Ruangdaraganon et al., 2009; Byeon and Hong, 2015; Perdana et al., 2017; Okuma and Tanimura, 2009; Bittman et al., 2011; Sundqvist et al., 2021), and socio-emotional skills (Mistry et al., 2007; Cheng et al., 2010; Verlinden et al., 2012). While this strategy might shed light on non-linear relation with screen time, questions about the reasons as to why such high levels arise in the first place. In particular, there might be other risk factors that lead to both a very high screen time and undesirable developmental outcomes (Duch et al., 2013). In line with the DREAMER framework (Barr et al., 2024), the present results suggest, that more complex methods of the assessment and modeling of screen time need to be pursued in future research.

Strengths and limitations

This study exhibits several strengths worth mentioning. First, results were summarized from 158 studies that examined the associations of children's screen time in early childhood with a variety of developmental outcomes to offer a broad picture of the correlates of screen time. Furthermore, the PRISMA-ScR checklist for reporting scoping reviews (Tricco et al., 2018) was followed throughout the review process (see Supplementary Table S.2) to ensure its replicability. In addition, as early childhood has been shown to be a sensitive time for experiences that influence development (Black et al., 2017; Britto et al., 2017), the age focus of this study, from birth to 36 months, is of particular importance. Finally, the study includes both traditional and modern screen media devices, which underlines how scarce research on modern screen media remains.

The study also has limitations. Studies were selected by two study co-authors without consideration of interrater reliability. We assume that the systematic comparison of studies included in hindsight and the snowball principle applied compensated for this. However, some studies might have been missed. Furthermore, the studies were not systematically assessed for potential bias and the role of covariates that were considered in the various studies could not be systematically addressed due to the very large amount of information; therefore, the findings of this review should be interpreted and compared with caution. Additionally, we opted not to include gray literature as the number of studies that were found was already very large and the amount of published non-significant results was quite large. This could be interpreted as a comparably low level of selective reporting of results (Kostyrka-Allchorne et al., 2017). Although some of the developmental outcomes included in the present review have been extensively studied, no meta-analysis was performed in the context of the present study.

Conclusion and future directions

While some theoretical approaches have been outlined in the introduction of this review, we believe that more research is needed to address why and under which conditions children's screen time can have undesirable or desirable associations with their development. For instance, such undesirable associations may be explained by the displacement hypothesis (Mutz et al., 1993). However, to demonstrate the existence of displacement, a holistic and longitudinal examination of young children's digital and non-digital activities is necessary. In more technical terms, future studies need to focus on mediator and moderator variables that help us understand the associations between children's screen time and early childhood development. Barr et al. (2018) have proposed that the associations between screen time and development depend on three C's: the *child*, including their age, development level, and temperament; the *context*, such as screen co-viewing with a parent, non-digital activities, family, and environment; and the *content* for instance whether it is suitable for children or permits interactivity. This will allow an examination of whether children's screen time is the cause of an impairment in early childhood development or whether it is rather a symptom of another unfavorable condition in the child's close environment that might impair early childhood development. Findings from this review support the consideration of these three C's as essential for future research on the effects of screen time on early childhood development.

Overall, the complex pattern of findings in the literature on the correlates of children's screen time and early childhood development is shaped by a combination of factors, including differences in screen time patterns, variability in digital activities, variations in the operationalization of constructs of interest, lack of consideration of potential moderators or mediators, and differences in study design. The present study shows that the effects of screen time on child development in early childhood are highly complex. This complexity arises from the interaction of multiple sources of variability and raises the question of whether any general conclusions can be drawn about the effects of screen time on child development. Based on the results of the present study, we argue that such conclusions can only be made at a very general level, and that specific conclusions can only be drawn with respect to a specific outcome of a specific type of activity, in a specific context, and for a specific target population. This complexity has been progressively recognized over the past decades, and both research and practice are addressing this complex topic in a more differentiated way, thus supporting children, parents, teachers, practitioners, and policymakers in making informed decisions about how to integrate screens into children's daily lives.

Author contributions

FS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. VB: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing, Project administration. PL: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing.

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During the preparation of this work the authors used ChatGPT to correct selected text elements as well as Elicit to search for literature. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fdpys.2024.1439040/full#supplementary-material

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Screen exposure, sleep quality, and language development in 6-month-old infants

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Introduction: Screen time can have important ramifications for children's development and health. Children exposed to greater screen time score lower on assessments of language development and tend to sleep less. However, most studies examining associations among screen time, language development, and sleep quality have focused on older children and/or have relied on subjective assessments of screen time exposure (i.e., parent report). The current study examined whether screen exposure, assessed via both maternal-report questionnaires and in-home audio recordings, was associated with differences in language development and sleep quality in infants at ~6 months of age ($N = 187$).

Methods: Mothers completed questionnaires to assess infant screen exposure, language production, and sleep quality, as well as family socioeconomic and demographic factors. The Language Environment Analysis (LENA) recorder was used to measure home screen use and the language environment.

Results: Higher family income and higher maternal education were associated with less infant screen time, as assessed by both maternal report and in-home LENA recordings. Neither measure of infant screen exposure was significantly associated with the home language environment, maternally-reported infant language production, or infant sleep quality. Maternally-reported screen exposure showed a small but significant positive correlation with LENA-derived screen exposure.

Discussion: We find no detectable association between screen exposure and differences in maternally reported language development or sleep quality in the first 6 months of life. Future studies will be needed to examine associations among screen time and subsequent infant development and health outcomes.

KEYWORDS

screen exposure, sleep quality, language production, socioeconomic status, infancy, Language Environment Analysis (LENA)

Introduction

Exposure to electronic media in early childhood is not only common but also on the rise, with young infants across the U.S exposed to electronic media at rapidly increasing rates (Wiltshire et al., 2021; Li et al., 2017; Tomopoulos et al., 2010; Ramirez et al., 2021; Chen and Adler, 2019). The prevalence of this phenomenon is significant; U.S. parents of children in the first 2 years of life report that their children were exposed to an average of 49 min of electronic screens per day in 2020 (Rideout and Robb, 2017). Moreover, evidence indicates a substantial increase in electronic media exposure among infants and toddlers even prior to the pandemic. By one estimate, infants experienced an average of two more hours per day of screen exposure in 2014 than they had in 1997 (Chen and Adler, 2019). Despite the widespread and growing use of electronic media among children, the American Academy of Pediatrics recommends avoiding digital media use in children under 18–24 months, except for video-chatting, to support their development and health (Hill et al., 2016). Indeed, multiple studies have revealed that electronic media exposure is associated with differences in children's language development and sleep quality (Madigan et al., 2020; Hale and Guan, 2015). Nonetheless, much of the existing research examining these associations has focused on older children, making it unclear how early in development electronic media-related differences in language and sleep outcomes emerge.

Early childhood is a period of immense growth in language development, as young children begin to rapidly acquire speech and language skills (Lew-Williams and Weisleder, 2017; Hart and Risley, 2003; Weisleder and Fernald, 2013; Bergelson, 2020; Hoff and Hoff, 2009). Research has shown that exposure to more words and engagement in reciprocal parent-child conversational interactions provides the foundation for children's later language and literacy skills (Forget-Dubois et al., 2009; Foster et al., 2005). In the same way, both the quality and quantity of parental language input during parent-child interactions is vital for young children's language skill and growth (Hirsh-Pasek et al., 2015; Weizman and Snow, 2001; Huttenlocher et al., 1991). Parental language quantity is defined as the total number of words or utterances spoken by the primary caregiver in a given timeframe, whereas parental language quality is defined as the diversity, richness, responsiveness, and complexity of words spoken by a parent over that timeframe. Studies have found that children who are exposed to both a high quantity and high quality of language input from their parents have differences in brain structure (Merz et al., 2020) and function (Brito et al., 2020), and tend to have greater vocabulary growth during the early years of elementary school (Weizman and Snow, 2001; Huttenlocher et al., 1991). While the two are closely related, the quality of parental input likely plays a more important role in children's language development (Hirsh-Pasek et al., 2015; Rowe, 2012; Anderson et al., 2021).

Numerous studies suggest that electronic media exposure is associated with lower language skills (Madigan et al., 2020; Li et al., 2024; Sundqvist et al., 2024; Massaroni et al., 2023; Alroqi et al., 2023; Zimmerman et al., 2007), possibly because parents interact less with their children when electronic media is present. Consistent with this, evidence shows that smartphones and television can interrupt parent-child interactions (Konrad et al., 2021; Kirkorian et al., 2009; McDaniel and Radesky, 2018), which are critical for language development in young children. However, much of the research on the relationship between electronic media exposure and language development has focused on older children and adolescents (Li et al., 2024; Sundqvist et al., 2024; Massaroni et al., 2023), rather than infants. Still, there is some evidence that greater electronic media exposure in the home is linked to reduced adult word exposure and fewer child vocalizations in infants and young children (Ramirez et al., 2021; Christakis et al., 2009), suggesting that early media exposure may shape emerging language milestones. To support emerging language development in young children, it is crucial to understand whether electronic media exposure is associated with differences in the home language environment and infants' language milestones, and to determine when such associations first emerge.

Sleep during infancy is associated with daytime functioning, memory, language learning, and physical growth (Ednick et al., 2009; Tham et al., 2017; Tikotzky et al., 2010). Sleep patterns undergo significant change during infancy, as infants begin to hit developmental milestones. One study that looked at infant sleep in the first year of life found that most changes in daytime and nighttime sleep occur during the first 6 months of life, and that sleep becomes more stable between 6 and 12 months of age (Bruni et al., 2014). Infant sleep quality is often defined around the sleep patterns of an infant: the number and duration of night awakenings, and the longest stretch of uninterrupted sleep at night (Mindell et al., 2019).

It is well established that electronic media use negatively impacts the sleep quality of older children, adolescents, and adults (Hale and Guan, 2015; Arshad et al., 2021; Nakshine et al., 2022). Although sleep is critical for healthy development, few studies have examined whether exposure to electronic media is associated with differences in infant sleep. Understanding these associations in infancy is particularly important because sleep plays a crucial role in supporting cognitive, emotional, and physical growth during this period (Ednick et al., 2009; Tikotzky et al., 2010). The limited number of studies that have examined associations between electronic media exposure and sleep in infants reveal mixed results. A handful of studies have found electronic media exposure to be associated with infants' night-time sleep duration (Chen et al., 2019; Lin et al., 2022; Vijakkhana et al., 2015; Ribner et al., 2019; Cheung et al., 2017; Emond et al., 2021). However, some indicate that greater electronic media exposure is associated with shorter day-time sleep duration in infants (Chen et al., 2019; Lin et al., 2022; Cheung et al., 2017), whereas other studies have not observed these associations (Ribner et al., 2019; Emond et al., 2021; Diler and Başkale, 2022). These mixed results in the literature suggest that further research examining whether electronic media is associated with sleep quality in young children is needed.

Despite evidence that electronic media exposure might be associated with language development and sleep quality in young children, much of this work has employed parent-report questionnaires to assess children's electronic media exposure (Tomopoulos et al., 2010; Lin et al., 2022; Cheung et al., 2017; Bergmann et al., 2022). However, parent-report questionnaires are susceptible to subjective biases, potentially leading to overestimation or underestimation of children's true electronic media exposure levels. The home language environment analysis (LENA) system might be a useful tool to objectively measure in-home electronic media exposure. This system records the sounds within a 16-h day from the child's perspective and automatically characterizes children's electronic media exposure, in addition to various aspects of the home language environment, including the number of adult words heard, the number of parent-child conversational turns, and the number of child vocalizations. Studies that have used the LENA to measure electronic media exposure have found greater screen media exposure to be associated with less adult word exposure and fewer conversational turns between young children and their caregivers (Ramirez et al., 2021; Christakis et al., 2009; Brushe et al., 2024).

In this preregistered study (https://doi.org/10.17605/OSF.IO/82HMY), we aimed to examine associations between electronic media exposure, sleep quality, and language development in 6-month-old infants. Specifically, we examined whether electronic media exposure, as measured by maternal-report and LENA, is associated with infant sleep quality and language production. Although language production is typically low in six-month-old infants, we focused on this age group because there is considerable variability in language production during this period (Ramirez et al., 2021; Hutton et al., 2021), which allows for the examination of factors that may contribute to variability in early language production. Based on past literature (Christakis et al., 2009; Ednick et al., 2009; Vijakkhana et al., 2015; Ribner et al., 2019), we preregistered the following hypotheses:

1. More electronic media exposure would be associated with lower maternal-reported language production and fewer vocalizations in infants.
2. More electronic media exposure would be associated with fewer parent-child conversational turns and lower adult word count.
3. More electronic media exposure would be associated with lower maternal-reported sleep quality in infants.
4. Electronic media exposure derived from LENA would show stronger associations with infant sleep quality, the home language environment, and infants' language production relative to maternally-reported electronic media exposure.

TABLE 1 Participant demographics and study variables.

Demographics	*M* (SD)	Range
Maternal age	32.2 (5.7)	19–46
Maternal education	15.4 (3.5)	6–22
Family income (USD)	163,334.66 (296,379.36)	1–2,563,501
Family income-to-needs	7.7 (13.69)	0–131
	%	*n*
Race and ethnicity		
White	38.8	81
Black or African American	23	48
Asian	8.6	18
American Indian/Alaska Native	1.9	4
Native Hawaiian or Other Pacific Islander	0.5	1
Other	26.3	55
Refused	1	2
Ethnicity		
Hispanic or Latino	46.4	97
Non-Hispanic or -Latino	53.6	112
Preferred language and bilingualism		
English	79.9	167
Spanish	19.6	41
Monolingual	56.9	119
Bilingual	43.1	90

Materials and methods

Preregistration and data availability

The analysis plan and hypotheses for this study were preregistered on Open Science Framework (https://osf.io/82hmy). All data and code (for tasks and analyses) are available on Open Science Framework as well (https://doi.org/10.17605/OSF.IO/QWVKD).

Participants

The present data are drawn from an ongoing longitudinal study investigating associations between early experience and child development in the first 3 years of life. Mothers were recruited via local prenatal clinics, community events, and social media. Participants were from the New York City metropolitan area and were intentionally recruited to have wide variation in educational attainment, ranging from having less than a high school education to holding an advanced degree. Mothers were recruited over two time periods because of a temporary interruption in data collection due to the COVID-19 pandemic: the first cohort of mothers was recruited from June 2019 through March 2020 ($N = 93$) and the second cohort of mothers was recruited from August 2021 to September 2022 ($N = 116$). Mothers were screened over the phone to confirm eligibility. To be eligible for the study, mothers were required to be 18 years of age or older, at least 35 weeks pregnant, carrying a singleton fetus with no known neurological or developmental issues, and to speak either English or Spanish. Once eligibility was confirmed, mothers were invited to participate in a prenatal visit in our lab or their home.

After the birth of the infant, eligibility for successive study visits was confirmed for subsequent participation. Inclusion criteria for infants included: gestational age ≥37 weeks and no known neurological or developmental issues at birth. Families were contacted to participate in subsequent visits every 6 months until their child was 36-months old (i.e., 1-, 6-, 12-months, and so on). The current study focuses on data that were collected when infants were ∼6-months old. Of the 209 mother-infant dyads recruited for the study, 1 was excluded because of a developmental disorder at birth, 5 withdrew from the study, and 16 didn't complete the 6-month visit. The final sample thus included 187 mother-infant dyads. Descriptive statistics of sample demographics are presented in Table 1. Descriptive statistics of study variables are presented in Supplementary Table S5.

All mothers provided written informed consent for their family's participation in the study. Research procedures were approved by the Institutional Review Board of Teachers College, Columbia University.

Measures

Family socioeconomic status

During the prenatal visit, mothers reported their educational attainment, the number of adults and children living in the household, and their annual family income. Family socioeconomic status (SES) was operationalized using maternal-reported educational attainment and an income-to-needs ratio (ITN). Income-to-needs (ITN) ratios were calculated by dividing total household income by the U.S. poverty threshold for the respective family size for the year of data collection. An ITN below 1 indicates that a family was living below the federal poverty threshold, whereas an ITN above 1 indicates that a family was living above the federal poverty threshold. Due to a positive skew, ITN values were log transformed. In addition, 11 mothers reported their income to be zero dollars. To enable log transformation, one dollar was added to all income values prior to calculating ITN. We had three participants with outlier values >3 standard deviations from the mean; these values were winsorized to the next lowest value within three standard deviations from the mean.

Maternal-reported screen exposure

Infant screen exposure was assessed during the 6-month visit via a parent-report questionnaire. First, mothers were asked whether their child had been exposed to screens (yes or no). If mothers reported that their child had been exposed to screens, they were then asked to complete the ScreenQ (Hutton et al., 2020). We administered an adapted version of the ScreenQ (for more details, see Wiltshire et al., 2021) which removed questions that were not appropriate for infants (e.g., whether the child has their own portable device they can carry and watch or play on). In the present analyses, we focused on responses from two items on the modified ScreenQ: whether the infant had been exposed to screen (0 = No, 1 = Yes), and the infants' total daily hours of screen exposure (i.e., how many hours in a typical day does your child watch TV/videos, play video games, or use apps?). In our sample, 89 mothers (43%) reported that their infants have been exposed to screens, and therefore completed the total daily hours of screen exposure item on the modified ScreenQ. We had two outlier values >3 standard deviations from the mean for participants that reported their infant's daily hours of screen exposure. These values were winsorized to the next lowest value within three standard deviations from the mean.

Home audio-recorded electronic media exposure and language environment

At the 6-month visit, screen/media exposure and the language environment in the home were measured using the language environment analysis (LENA) recorder. The LENA system (LENA Research Foundation, Boulder, CO) is an automated vocalization analysis device that can audio-record the child's language environment for up to 16 h. Participants were provided with specially designed child T-shirts to hold the digital language processor (DLP) throughout the recording duration. The average duration of the LENA recordings in our sample was 15 h (range: 7–16).

Mothers were provided with LENA materials during their visit and were instructed to have their child wear the DLP on a typical day in their household. Once the DLP was returned, the recording was uploaded to a computer and analyzed using the LENA software. The software automatically produces estimates of electronic media exposure (number of seconds when electronic media, such as TV and radio, was detected in the child's auditory environment), as well as counts of adult words (number of words spoken near the child), conversational turns (number of reciprocal vocalizations by an adult and the target child within 5 s), and child vocalizations (defined as a speech segment of any length surrounded by 300 ms or more of non-speech or silence). To understand how much screen time infants were exposed to, we calculated the number of minutes children were exposed to screens in 5-min segments of the 16 h long recordings. We then divided the total minutes of screen exposure by the duration of the LENA recording to create the average rate of screen/electronic media exposure per hour. To compute adult word counts, conversational turn counts, and child vocalizations, the word counts were divided by the duration of LENA recordings, to create average hourly counts of adult words, conversational turns, and infant vocalizations. For our TV/Media measure, we had six participants with outlier values >3 standard deviations from the mean; these values were winsorized to the next lowest value within three standard deviations from the mean. For our measure of average adult word count in the home, we had one participant with an outlier value >3 standard deviations from the mean; this value was winsorized to the next lowest value within three standard deviations from the mean as well.

To be included in LENA analyses, recordings needed to: (1) be ≥5 h in duration (excluded $N = 7$), (2) the DLP was not turned off more than three times during the recording (excluded $N = 1$), and (3) the recording did not take place on more than two calendar days (excluded $N = 1$). Therefore, 117 participants were included in our LENA analyses.

The LENA has shown excellent reliability and validity in segmenting adult speech, child speech, and electronic media; the software has an 80% agreement with human coders in segmenting adult words, 76% in identifying words coming from a child, and 71% in electronic media/tv (Ramirez et al., 2021; Christakis et al., 2009; Xu et al., 2009). As in past work (Ramirez et al., 2021), we examined the reliability of LENA's electronic media exposure counts. We randomly selected 23 of the 117 daylong recordings (20%), and seven trained coders listened to twelve 5-min segments within each of these recordings. In each recording, coders listened to the six segments identified by LENA as containing the highest and lowest presence of audible electronic media within the daylong recording. For both types of segments, coders listened to each of the 5-min segments and coded the duration of electronic media and the type of screen exposure they heard (e.g., tv, toy, Tablet/phone). Datavyu software (https://datavyu.org/) was used for coding. We compared human coders' electronic media counts in seconds to LENA's coded electronic media counts in seconds. The interclass correlation (ICC) of the LENA and human raters in our sample (calculated using a two-way random model, average measures, consistency) was moderate (ICC = 0.55). See **Protocol 1S** in the Supplementary Results for our coding protocol.

LENA developmental questionnaire

During the six-month visit, mothers reported on their infant's language milestones using the LENA developmental snapshot (LDS) (Gilkerson et al., 2017a). The LDS is a 52-item questionnaire that measures expressive and receptive language production in children ages 2–36 months. Items on the questionnaire progress in difficulty (e.g., "When you talk to your child, does he/she look in the direction of your voice?" "Does your child produce two or more vowel sounds, such as/ah/or/ooh/?"). For each item, parents were instructed to indicate "yes" if their child consistently demonstrates each milestone either currently or at an earlier developmental stage or "no" if the child had not consistently demonstrated the milestone. The LDS computed an age-normalized standard score, which was used in our analyses. The LDS has demonstrated excellent test-retest reliability and is strongly correlated (r's range from 0.84 to 0.96) with other standardized language assessments such as the Preschool Language Scale, 4th Edition, Receptive Expressive Emergent Language Test, 3rd Edition, and Child Development Inventory (Gilkerson and Richards, 2008). The mean LDS standard score in our sample ($M = 107.33$, SD = 14.24) is comparable to those reported in other studies with 6-month-old infants ($M = 112.6$, SD = 15.9) (Hutton et al., 2021; Xie et al., 2024).

Sleep quality

Infant sleep quality was measured at the 6-month visit using the Brief Infant Sleep Questionnaire (BISQ). The questionnaire contains 10 items that measure infant sleep patterns and environments, including a question about child sleep location, which was used as a covariate in our analyses. We measured infant sleep quality using the modified infant sleep subscale (mISS) of the BISQ (Mindell et al., 2019). The infant sleep subscale has a total of five questions: (1) frequency of nighttime wakening; (2) length of time to put baby to sleep; (3) time child spends sleeping at night; (4) time child spends awake at night; and (5) the longest stretch of time that child is asleep during the night without waking up. The original BISQ used in the present study contains the first four of the Infant Sleep Subscale items. In consultation with the BISQ-R creators, we calculated a modified Infant Sleep Subscale (mISS) for each participant, with a missing or null value for the missing 5th question in the function. Age-referenced mISS scores range from 0 to 100, with higher scores representing more desired sleep patterns. We had 15 participants with outlier values according to the range set in each subscale by the BISQ creators. To account for these, we winsorized their values to the next lowest or highest value within the range. The BISQ has demonstrated excellent test-retest reliability and is significantly correlated with sleep patterns measured by actigraphy and sleep diaries ($rs = 0.23–0.96$) (Sadeh, 2004). The mean BISQ score in our sample ($M = 62.75$, SD = 22.90) is comparable to those reported in other studies with 6-month-old infants ($M = 67.60$, SD = 19.90) (Mindell et al., 2019; Finkel et al., 2022).

Statistical analyses

All statistical analyses were conducted using SPSS (Version 28). For descriptive purposes, we calculated Pearson's r to examine bivariate associations among study variables.

A series of multiple regressions were conducted to examine associations among infant screen exposure, sleep quality and language production. In each regression model, screen exposure [i.e., maternally-reported screen exposure (Yes/No), maternally-reported hours of screen exposure, or LENA-derived screen time] was entered as the independent variable. In the first set of regressions, we examined whether screen exposure was associated with infant sleep quality. In each of these analyses, infant sleep quality was entered as the dependent variable. In the second set of regressions, we examined whether screen exposure was associated with the home language environment. In each of these analyses, adult word count or conversational turn count was entered as the dependent variable. Finally, in the third set of regressions, we examined whether screen exposure was associated with infants' language production. In each of these analyses, LENA-derived child vocalizations or maternal-reported LDS was entered as the dependent variable. We considered the following model covariates: maternal race, ethnicity, maternal education, family ITN, child sleep location, total household members, maternal bilingualism, and infant age. Covariates were included in our regression models if they were significantly associated with either our independent or dependent variables.

To account for multiple comparisons, false discovery rate (FDR) corrections was applied to analyses using the Benjamini and Hochberg (1995) procedure.

Correlations among study variables

Correlations among study variables are presented in Table 2. As indicated in Table 2, maternal-reported screen exposure and LENA-derived screen exposure were significantly correlated, though this association was small in magnitude. Maternal-reported screen exposure was not significantly associated with conversational turns, child vocalizations, adult word count, LDS, or infant sleep quality. Similarly, LENA-derived screen exposure was not significantly associated with child vocalizations, adult word count, LDS, or infant sleep quality. However, higher LENA-derived screen exposure was significantly associated with fewer parent-infant conversational turns. Additionally, higher family income and maternal education were significantly correlated with less infant screen time, as measured by both maternal report and LENA recordings.

Associations between screen exposure and infant sleep quality

We first examined whether screen exposure was associated with sleep quality in infants when controlling for maternal education, race, ethnicity, income-to-needs, infant sleep place, and total household members. The results indicated that maternal report of screen exposure was not significantly associated with infant sleep quality at 6-months ($\beta s = -0.07$ to -0.11, FDR-adjusted $p > 0.05$; see models 1a and model 1b in Table 3). Additionally, LENA-derived screen exposure was also not significantly associated with infant sleep quality at 6-months ($\beta = 0.12$, FDR-adjusted $p > 0.05$, see models 1c in Table 3).

Since evidence suggests that screen exposure is associated with shorter sleep duration in infants (Vijakkhana et al., 2015; Ribner

TABLE 2 Correlations among study variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Electronic noise (LENA)	–															
2. Screen exposure (ScreenQ)	0.24**	–														
3. Hours of screen exposure (ScreenQ)	−0.06	c.	–													
4. Conversational turns	−0.23*	−0.09	−0.04	–												
5. Child vocalizations	−0.10	0.04	0.03	0.67**	–											
6. Adult word count	−0.16	−0.16	0.12	0.55**	0.04	–										
7. Language production (LDS)	0.14	0.15*	0.02	0.09	0.10	0.01	–									
8. Sleep quality (BISQR)	−0.02	−0.13	−0.09	0.04	−0.17	0.20*	−0.10	–								
9. Child sleep location (BISQR)	0.14	0.18*	0.04	−0.02	0.11	−0.12	0.01	0.25**	–							
10. Family income-to-needs	−0.49**	−0.33**	−0.01	0.18	−0.05	0.25**	−0.19*	0.11	−0.24**	–						
11. Maternal education	−0.39**	−0.46**	−0.29**	0.20*	−0.07	0.22*	−0.08	0.21**	−0.19*	0.54**	–					
12. Total household members	0.21*	0.08	0.27*	0.01	0.24**	−0.15	0.16*	−0.14	0.17*	−16*	−0.33**	–				
13. Maternal ethnicity	0.14	0.31**	0.20	−0.03	0.16	−0.18	0.03	−0.06	0.20*	−0.39**	−0.56**	0.32**	–			
14. Maternal race	0.34**	0.36**	0.14	−0.27**	−0.12	−0.21*	0.17*	−0.12	0.18*	−0.35**	−0.47**	0.17*	0.40**	–		
15. Maternal bilingualism	−0.01	0.11	0.19	−0.09	−0.10	−0.16	−0.07	−0.05	0.10	– 0.06	−0.06	0.07	0.33**	0.22**	–	
16. Child age (weeks) at LENA recording	−0.11	0.04	0.02	−0.08	−0.01	−0.14	−0.02	−0.10	−0.07	0.13	−0.02	−0.05	0.13	0.12	0.08	–
17. LENA recording (hours)	−0.15	−0.02	−0.27	−0.12	−0.26	−0.03	−0.23*	0.12	0.00	0.23*	0.26**	−0.32**	−0.17	−0.20*	−0.01	0.00

Maternal Ethnicity (0 = Non-Hispanic, 1 = Hispanic); Maternal Race (0 = White, 1 = Non-White); Exposure to Screens (0 = No, 1 = Yes); Maternal Bilingualism (0 = Monolingual, 1 = Bilingual); c. Cannot be computed because at least one of the variables is constant.

**p < 0.01.

*p < 0.05.

TABLE 3 Associations between screen exposure and infant sleep quality.

Predictors	Child Sleep Quality (BISQ)			
	b	95% CI	SE	*β*
Model 1a				
Screen exposure (ScreenQ; 0 = No, 1 = Yes)	−3.05	−11.67, 5.57	4.36	−0.07
Maternal education	1.12	−0.27, 2.51	0.70	0.17
Race (0 = non-white, 1 = white)	−2.92	−11.35, 5.50	4.26	−0.06
Maternal ethnicity (0 = not hispanic, 1 = hispanic)	4.65	−4.37, 13.68	4.56	0.10
ITN	−0.25	−1.63, 1.13	0.70	−0.04
Child sleep place (0 = sleeps in parents' room, 1 = sleeps in separate room)	−10.18	−18.39, −1.98	4.15	−0.21*
Model 1b				
Screen exposure (ScreenQ; hours)	−1.04	−3.50, 1.41	1.23	−0.11
Maternal education	−0.99	−2.86, 0.89	0.94	−0.14
Child Sleep Place (0 = sleeps in parents' room, 1 = sleeps in separate room)	−9.07	−22.41, 4.28	6.68	−0.17
Total household members	−1.07	−4.83,2.69	1.88	−0.08
Model 1c				
Screen exposure (LENA)	0.55	−0.56, 1.67	0.56	0.12
Maternal education	0.99	−0.59, 1.67	0.80	0.15
Race (0 = non-white, 1 = white)	−2.68	−12.89, 7.53	5.14	−0.06
ITN	0.18	−1.56, 1.91	0.87	0.03
Child Sleep Place (0 = sleeps in parents' room, 1 = sleeps in separate room)	−8.91	−18.42, 0.60	4.79	−0.19
Total household members	−1.78	−5.54, 1.98	1.89	−0.10

FDR-adjusted *p < 0.05.

et al., 2019; Cheung et al., 2017), we conducted an exploratory analysis to test whether screen exposure was associated with infant night-time sleep duration when controlling for maternal education, race, ethnicity, income-to-needs, infant sleep place, total household members, and infant age. The results indicated that LENA-derived screen exposure was not significantly associated with infant sleep duration ($\beta = 0.02$, FDR-adjusted $p > 0.05$). In addition, maternal report of whether infants had yet been exposed to screens (i.e., yes or no) was also not significantly associated with infant sleep duration ($\beta = -0.07$, FDR-adjusted $p > 0.05$). Higher maternal report of infant screen exposure was significantly associated with shorter nighttime sleep duration in infants ($\beta = -0.34$, $p = 0.02$), although this association was only marginally significant after FDR correction ($p = 0.054$).

Associations between screen exposure and the home language environment

We then investigated whether screen exposure was associated with adult word count and conversational turns, when controlling for maternal education, race, maternal ethnicity, and income-to-needs. The results indicated that maternal report of screen exposure was not significantly associated with hourly adult word count ($\beta s = -0.02$ to 0.22, FDR-adjusted $p > 0.05$) or hourly conversational turn count ($\beta s = 0.04$–0.08, FDR-adjusted $p >$ 0.05; see models 1a—1d in Table 4). Additionally, LENA-derived screen exposure was not significantly associated with hourly adult word count ($\beta = -0.01$, FDR-adjusted $p > 0.05$; see model 1f in Table 4) or hourly adult-infant conversational turn count ($\beta = -0.15$, FDR-adjusted $p > 0.05$; see model 1e in Table 4).

Associations between screen exposure and infant language production

Finally, we explored whether screen exposure was associated with infant language production when controlling for maternal education, race, maternal ethnicity, income-to-needs, and duration of the LENA recording. The results indicated that maternal report of screen exposure was not significantly associated with the LDS ($\beta s = 0.07$ to 0.11, FDR-adjusted $p > 0.05$); see models 4a and 4b in Supplementary Table S1) or with LENA-derived hourly infant vocalization count ($\beta s = -0.06$ *to 0.10*, FDR-adjusted $p > 0.05$; see models 1a and 1b in Table 5). In addition, we found that LENA-derived screen exposure was not significantly associated with the LDS [$\beta = -0.03$, FDR-adjusted $p > 0.05$, 95% CI (−0.74, 0.55); see model 4c in Supplementary Table S1] or with LENA-derived hourly infant vocalization count [$\beta = -0.15$, FDR-adjusted $p > 0.05$, 95% CI (−3.18, 0.60); see model 1c in Table 5].

As a sensitivity analyses, we re-ran our models and included all possible covariates; results can be found in Supplementary Tables S2–S4.

TABLE 4 Associations between screen exposure and the home language environment.

Predictors	*b*	95% CI	SE	*β*
Model 1a		**Conversational turns**		
Screen exposure (ScreenQ; 0 = no, 1 = yes)	0.81	−3.79, 5.40	2.32	0.04
Maternal education	0.37	−0.41, 1.15	0.39	0.12
Race (0 = non-White, 1 = White)	−5.87	−10.70, −1.05	2.43	−0.28*
Maternal Ethnicity (0 = not Hispanic, 1 = Hispanic)	3.95	−1.35, 9.26	2.68	0.17
ITN	0.27	−0.47, 1.01	0.37	0.08
Model 1b		**Adult word count**		
Screen exposure (ScreenQ; 0 = no, 1 = yes)	−22.34	−253.66, 208.99	116.64	−0.02
Maternal education	3.08	−36.17, 42.32	19.79	0.02
Race (0 = non-White, 1 = White)	−110.95	−353.69, 131.79	122.40	−0.10
Maternal Ethnicity (0 = not Hispanic, 1 = Hispanic)	−71.72	−338.76, 195.31	134.65	−0.06
ITN	28.30	−8.83, 65.43	18.72	0.17
Model 1c		**Conversational turns**		
Screen exposure (ScreenQ; hours)	0.33	−0.84, 1.49	0.58	0.08
Maternal education	0.34	−0.65, 1.32	0.49	0.11
Race (0 = non-White, 1 = White)	−10.48	−17.85, −3.11	3.65	−0.43*
Model 1d		**Adult word count**		
Screen exposure (ScreenQ; hours)	38.20	−20.18, 96.58	28.78	0.22
Maternal education	29.20	−23.25, 81.65	25.86	0.20
Race (0 = non-White, 1 = White)	−162.73	−535.57, 210.12	183.84	−0.14
ITN	30.22	−15.16, 75.61	22.38	0.23
Model 1e		**Conversational turns**		
Screen exposure (LENA)	−0.35	−0.87, 0.17	0.26	−0.15
Maternal education	0.06	−0.66, 0.78	0.36	0.02
Race (0 = non-White, 1 = White)	−4.20	−8.78, 0.39	2.31	−0.20
ITN	0.07	−0.71, 0.85	0.39	0.02
Model 1f		**Adult word count**		
Screen exposure (LENA)	−1.18	−27.31, 24.95	13.18	−0.01
Maternal education	7.54	−28.46, 43.54	18.15	0.05
Race (0 = non-White, 1 = White)	−131.80	−362.08, 98.49	116.13	−0.12
ITN	28.36	−10.75, 67.48	19.73	0.17

FDR-adjusted $^{*}p < 0.05$.

Discussion

The present study sought to examine whether electronic media exposure is associated with differences in infants' sleep quality and language development. We hypothesized that greater electronic media exposure (as indexed by both maternal-report and automated recordings) would be associated with less adult word exposure, fewer vocalizations in infants, lower maternally-reported language production, and poorer maternally-reported infant sleep quality. We also hypothesized that the magnitude of associations between LENA-derived electronic media exposure and infant language and sleep outcomes would be larger than the magnitude of associations between maternally-reported screen exposure and infant outcomes. Contrary to our hypotheses, neither maternally-reported nor LENA-derived screen exposure was significantly associated with sleep quality or language development at 6 months of age when adjusting for demographic and socioeconomic factors. These data suggest that electronic media exposure may not be associated with differences in sleep quality and language development in the first 6 months of life.

Although neither measure of electronic media exposure was associated with the quantity of adult speech (i.e., adult word count) or infant language production, greater electronic media exposure

TABLE 5 Associations between screen exposure and infants' language production.

Predictors	Child vocalizations			
	b	95% CI	SE	*β*
Model 1a				
Screen exposure (ScreenQ; 0 = no, 1 = yes)	8.41	−8.22, 25.03	8.38	0.10
Maternal education	0.11	−2.73, 2.94	1.43	0.01
Race (0 = non-White, 1 = White)	−23.69	−41.14, −6.24	8.80	−0.30*
Maternal Ethnicity (0 = not Hispanic, 1 = Hispanic)	19.67	0.65, 38.68	9.59	0.24*
ITN	0.16	−2.49, 2.82	1.34	0.01
Duration of LENA recording	−5.91	−9.83, −1.99	1.98	−0.29*
Model 1b				
Screen exposure (ScreenQ; hours)	−0.88	−5.99, 4.23	2.53	−0.06
Maternal education	0.61	−3.68, 4.90	2.12	0.05
Duration of LENA recording	−7.45	−14.37, −0.52	3.43	−0.35*
Model 1c				
Screen exposure (LENA)	−1.29	−3.18, 0.60	0.95	−0.15
Maternal education	−0.1.51	−4.14, 1.13	1.33	−0.14
Race (0 = non-White, 1 = White)	−14.71	−31.46, 2.04	8.45	−0.19
ITN	−0.70	−3.53, 2.14	1.43	−0.06
Duration of LENA recording	−5.53	−9.47, −1.60	1.98	−0.27*

FDR-adjusted *$p < 0.05$.

derived from the LENA was associated with fewer parent-infant conversational turns.

This finding suggests that electronic media exposure may reduce the back-and-forth interactions between parents and children, a critical context for language development in infants. However, it is important to note that this association was no longer significant after controlling for socioeconomic and demographic factors. Prior studies have found that socioeconomic disparities, as measured by maternal education and income, are associated with differences in young children's language exposure at home (Weisleder and Fernald, 2013; Rowe et al., 2005; Hoff, 2003; Gilkerson et al., 2017b; Dailey and Bergelson, 2022), suggesting that such disparities may drive the association between media exposure and parent-child conversational turns at 6 months of age in our sample. This suggests that future studies should carefully consider socioeconomic factors when examining electronic media exposure and language outcomes.

The lack of significant associations between electronic media exposure, the home language environment, and infant language production may be due to several factors. First, significant associations between screen exposure and language development may not be evident at 6 months of age but could emerge later in development as children's language skills grow in both size and diversity. Second, meta-analytic studies examining associations between screen exposure and language development in infants and young children typically report small effect sizes (r = –0.10 to –0.14) (Madigan et al., 2020; Xie et al., 2024), suggesting that our study may have been underpowered to detect these effects. Third, it is possible that electronic media exposure is not associated with infant language production, and our findings represent a true null result. Finally, cross-study differences in study design (e.g., cross-sectional vs. longitudinal) or sample demographics (e.g., representativeness of racial/ethnic minorities) could explain our lack of significant associations as well. Given the limited research on these associations in young infants, future longitudinal studies are needed to better understand how early differences in electronic media exposure, adult word exposure, and language development emerge during infancy.

We additionally found no associations between maternally-reported media exposure, LENA-derived electronic media exposure, and sleep quality in 6-month-old infants; these results contradict findings from other studies with young infants (Chen et al., 2019; Lin et al., 2022; Vijakkhana et al., 2015; Ribner et al., 2019; Cheung et al., 2017; Diler and Başkale, 2022), which have found electronic media exposure to be associated with shorter sleep duration at night. Our results suggest that it is possible that associations between electronic media and differences in infant sleep might emerge over time and may therefore be best examined within the context of longitudinal designs. For instance, some studies that found associations between electronic media exposure and sleep duration have measured sleep patterns longitudinally instead of at a singular timepoint. Our study, on the other hand, was limited to measuring sleep quality at one timepoint. In addition, a prior longitudinal study that assessed sleep and electronic media exposure at 3, 6, 9, and 12 months of age found no associations at any specific age timepoint; however, when looking at these variables longitudinally, they found that infants exposed to 1 h of TV and DVD screen time averaged a total of 9.2 h of sleep by the time they reached 12 months, while infants who had no screen exposure averaged 9.6 h of sleep (Emond et al., 2021). Similarly, another study reported that infants who were not exposed to screens after 7 p.m. in the first year of life had higher 12-month nighttime sleep duration than infants who were exposed to screens after 7 p.m. during this time (Vijakkhana et al., 2015). Our results also suggest that there may be a need for large sample sizes for an effect to be detected; a meta-analytic study that examined the associations between screen time and sleep revealed an overall small effect size ($r = -0.09$) (Janssen et al., 2020), suggesting the need for large sample sizes for an effect to be detected among these associations. Finally, our study measured sleep quality differently than most studies, which can explain why our results contradict other studies. For example, our study examined a composite measure of infant sleep quality, encompassing sleep duration at night, the number of nighttime awakenings, the amount of time infants are awake at night, and the amount of time it takes them to fall asleep. In contrast, other studies have tended to focus solely on infant sleep duration (i.e., hours of sleep) during the day and at night. To probe this possibility, we ran an exploratory analysis and found that greater maternal-report of screen exposure was indeed associated with shorter infant nighttime sleep duration. However, this result was only marginally significant after multiple hypothesis correction, indicating that caution is warranted in interpreting this result. Future studies should continue to measure these variables longitudinally and using multiple measures of sleep patterns to better understand how they may influence each other.

Surprisingly, our two measures of screen exposure showed significant, but small, associations with each other (i.e., $r = 0.24$). This small correlation suggests that maternal report and LENA may be capturing different sources of variance in electronic media exposure. Maternal report may be solely capturing how much time an infant is directly exposed to electronic media. On the other hand, the LENA may be capturing the amount of direct and indirect exposure to any electronic media near the child, such as a smart phone their parent is using. Additionally, both measures are prone to different sources of error; for example, the LENA could count music coming from an electronic speaker as "media exposure," whereas this would not typically be considered as such in maternal report. In the same way, mothers may underreport media exposure for socially desirable reasons, which might weaken associations between maternal report and LENA derived electronic media exposure. Mothers may also not consider certain media to be "electronic media exposure" (e.g., an older sibling watching a television program near the target child), which may lead to under-reporting.

This study has several strengths, including its examination of the associations among screen exposure, infant sleep, and language outcomes in a socioeconomically, racially/ethnically, and linguistically diverse sample of young infants. Additionally, we employed both maternal report and LENA-derived screen exposure, allowing us to examine how two measures of electronic media exposure related to child outcomes. However, several limitations should be considered. First, our sample size was relatively small compared to other studies (Christakis et al., 2009; Ribner et al., 2019; Emond et al., 2021; Brushe et al., 2024), limiting statistical power and the generalizability of our findings. Second, while LENA offers a more objective and ecologically valid measure of screen exposure compared to maternal reports, it cannot distinguish between direct and indirect media exposure (e.g., whether the child is actively attending to the media). Additionally, LENA may underestimate screen exposure, home input, and vocal production because it can only record one sound at a time. When simultaneous sounds are detected, LENA records the sound with the highest volume (Gilkerson et al., 2017b). If two sounds of equal volume are detected, they are coded as "overlap" and not counted in either category (Gilkerson and Richards, 2020).

Third, because our study is cross-sectional, we cannot draw causal inferences. Finally, our statistical analyses are correlational and so our results cannot speak to the direction of associations between screen exposure and infant developmental outcomes. Indeed, it may be the case that certain child characteristics, such as individual differences in language development or sleep quality, may influence the amount of screen exposure. For instance, infants with delayed language development or poor sleep quality might experience more screen time to manage developmental challenges or behavioral issues.

In conclusion, our results indicate that associations between electronic media exposure and infants' sleep quality and language development are not detectable at 6 months of age. These associations may emerge later in development, require more sensitive measures of sleep quality and language development, or reflect a true null association. Future studies should consider incorporating both maternal report and an in-home assessment of electronic media exposure to provide a more comprehensive understanding of its impacts on young infants and children. The study of electronic media use during infancy is important for understanding early environmental exposures that may shape development and sleep. With the continuous rise in technology use, exploring how early media exposure impacts various domains of child development remains a crucial area for further investigation.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/qwvkd/.

Ethics statement

The studies involving humans were approved by Institutional Review Board of Teachers College, Columbia University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

DS-B: Conceptualization, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. AS: Conceptualization, Formal analysis, Supervision, Writing – original draft, Writing – review & editing. MA: Investigation, Project administration, Writing – review & editing. CW: Writing – review & editing. KN: Conceptualization, Funding acquisition, Resources, Supervision, Writing – review & editing.

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Conflict of interest

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fdpys.2025.1440605/full#supplementary-material

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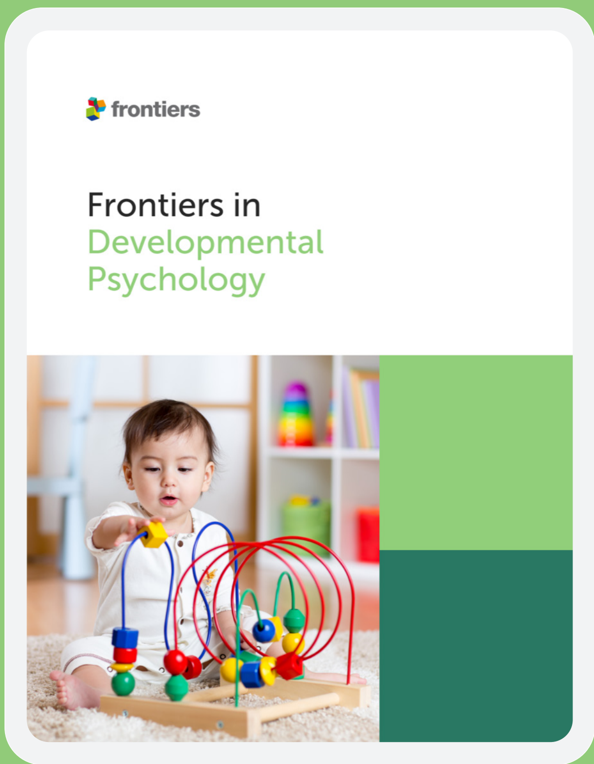

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