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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.

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.

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

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

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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

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.2025.1440605/full#supplementary-material

References

Alroqi, H., Serratrice, L., and Cameron-Faulkner, T. (2023). The association between screen media quantity, content, and context and language development. *J. Child Lang.* 50, 115511–115583. doi: 10.1017/S0305000922000265

Anderson, N. J., Graham, S. A., Prime, H., Jenkins, J. M., and Madigan, S. (2021). Linking quality and quantity of parental linguistic input to child language skills: a meta-analysis. *Child Dev.* 92, 484–501. doi: 10.1111/cdev.13508

Arshad, D., Joyia, U. M., Fatima, S., Khalid, N., Rishi, A. I., Rahim, N. U. A., et al. (2021). The adverse impact of excessive smartphone screen-time on sleep quality among young adults: a prospective cohort. *Sleep Sci.* 14:337. doi: 10.5935/1984-0063.20200114

Benjamini, Y., and Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *J. R. Stat. Soc. B Methodol.* 57, 289–300. doi: 10.1111/j.2517-6161.1995.tb02031.x

Bergelson, E. (2020). The comprehension boost in early word learning: older infants are better learners. *Child Dev. Perspect.* 14, 142–149. doi: 10.1111/cdep.12373

Bergmann, C., Dimitrova, N., Alaslani, K., Almohammadi, A., Alroqi, H., Aussems, S., et al. (2022). Young children's screen time during the first COVID-19 lockdown in 12 countries. *Sci. Rep.* 12:2015. doi: 10.1038/s41598-022-05840-5

Brito, N. H., Troller-Renfree, S. V., Leon-Santos, A., Isler, J. R., Fifer, W. P., Noble, K. G., et al. (2020). Associations among the home language environment and neural activity during infancy. *Dev. Cogn. Neurosci.* 43:100780. doi: 10.1016/j.dcn.2020.100780

Bruni, O., Baumgartner, E., Sette, S., Ancona, M., Caso, G., Di Cosimo, M. E., et al. (2014). Longitudinal study of sleep behavior in normal infants during the first year of life. *J. Clin. Sleep Med.* 10, 1119–1127. doi: 10.5664/jcsm.4114

Brushe, M. E., Haag, D. G., Melhuish, E. C., Reilly, S., and Gregory, T. (2024). Screen time and parent-child talk when children are aged 12 to 36 months. *JAMA Pediatr.* 178, 369–375. doi: 10.1001/jamapediatrics.2023.6790

Chen, B., van Dam, R. M., Tan, C. S., Chua, H. L., Wong, P. G., Bernard, J. Y., et al. (2019). Screen viewing behavior and sleep duration among children aged 2 and below. *BMC Public Health* 19:59. doi: 10.1186/s12889-018-6385-6

Chen, W., and Adler, J. L. (2019). Assessment of screen exposure in young children, 1997 to 2014. *JAMA Pediatr.* 173, 391–393. doi: 10.1001/jamapediatrics.2018.5546

Cheung, C. H. M., Bedford, R., Saez De Urabain, I. R., Karmiloff-Smith, A., and Smith, T. J. (2017). Daily touchscreen use in infants and toddlers is associated with reduced sleep and delayed sleep onset. *Sci. Rep.* 7:46104. doi: 10.1038/srep46104

Christakis, D. A., Gilkerson, J., Richards, J. A., Zimmerman, F. J., Garrison, M. M., Xu, D., et al. (2009). Audible television and decreased adult words, infant vocalizations, and conversational turns: a population-based study. *Arch. Pediatr. Adolesc. Med.* 163, 554–558. doi: 10.1001/archpediatrics.2009.61

Dailey, S., and Bergelson, E. (2022). Language input to infants of different socioeconomic statuses: a quantitative meta-analysis. *Dev. Sci.* 25:e13192. doi: 10.1111/desc.13192

Diler, F., and Başkale, H. (2022). The influence of sleep patterns and screen time on the sleep needs of infants and toddlers: a cross-sectional study. *J. Pediatr. Nurs.* 67, e201–e207. doi: 10.1016/j.pedn.2022.07.014

Ednick, M., Cohen, A. P., McPhail, G. L., Beebe, D., Simakajornboon, N., and Amin, R. S. (2009). A review of the effects of sleep during the first year of life on cognitive, psychomotor, and temperament development. *Sleep* 32, 1449–1458. doi: 10.1093/sleep/32.11.1449

Emond, J. A., O'Malley, A. J., Neelon, B., Kravitz, R. M., Ostbye, T., Benjamin-Neelon, S. E., et al. (2021). Associations between daily screen time and sleep in a racially and socioeconomically diverse sample of US infants: a prospective cohort study. *BMJ Open* 11:e044525. doi: 10.1136/bmjopen-2020-044525

Finkel, M. A., Troller-Renfree, S. V., Meyer, J. S., and Noble, K. G. (2022). Co-rooming accounts for socioeconomic disparities in infant sleep quality among families living in urban environments. *Children* 9:1429. doi: 10.3390/children9101429

Forget-Dubois, N., Dionne, G., Lemelin, J., Pérusse, D., Tremblay, R. E., and Boivin, M. (2009). Early child language mediates the relation between home environment and school readiness. *Child Dev.* 80, 736–749. doi: 10.1111/j.1467-8624.2009.01294.x

Foster, M. A., Lambert, R., Abbott-Shim, M., McCarty, F., and Franze, S. A. (2005). model of home learning environment and social risk factors in relation to children's emergent literacy and social outcomes. *Early Child. Res. Q.* 20, 13–36. doi: 10.1016/j.ecresq.2005.01.006

Gilkerson, J., and Richards, J. A. (2008). *The LENATM Developmental Snapshot*. Boulder, CO: LENA Foundation (2008).

Gilkerson, J., and Richards, J. A. (2020). *A Guide to Understanding the Design and Purpose of the LENA® System*. Boulder, CO: LENA Foundation, 15.

Gilkerson, J., Richards, J. A., Greenwood, C. R., and Montgomery, J. K. (2017a). Language assessment in a snap: monitoring progress up to 36 months. *Child Lang. Teach. Ther.* 33, 99–115. doi: 10.1177/0265659016660599

Gilkerson, J., Richards, J. A., Warren, S. F., Montgomery, J. K., Greenwood, C. R., Kimbrough Oller, D., et al. (2017b). Mapping the early language environment using all-day recordings and automated analysis. *Am. J. Speech Lang. Pathol.* 26, 248–265. doi: 10.1044/2016_AJSLP-15-0169

Hale, L., and Guan, S. (2015). Screen time and sleep among school-aged children and adolescents: a systematic literature review. *Sleep Med. Rev*. 21, 50–58. doi: 10.1016/j.smrv.2014.07.007

Hart, B., and Risley, T. R. (2003). The early catastrophe: The 30 million word gap by age 3. *Ame. Educ*. 27, 4–9.

Hill, D., Ameenuddin, N., Reid Chassiakos, Y. L., Cross, C., Hutchinson, J., Levine, A., et al. (2016). Media and young minds. *Pediatrics* 138:e20162591. doi: 10.1542/peds.2016-2591

Hirsh-Pasek, K., Adamson, L. B., Bakeman, R., Owen, M. T., Golinkoff, R. M., Pace, A., et al. (2015). The contribution of early communication quality to low-income children's language success. *Psychol. Sci*. 26, 1071–1083. doi: 10.1177/0956797615581493

Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Dev*. 74, 1368–1378. doi: 10.1111/1467-8624.00612

Hoff, E., and Hoff, E. (2009). *Language Development*. Belmont, CA: Wadsworth Cengage Learning.

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., and Lyons, T. (1991). Early vocabulary growth: relation to language input and gender. *Dev. Psychol*. 27:236. doi: 10.1037/0012-1649.27.2.236

Hutton, J. S., Huang, G., Sahay, R. D., DeWitt, T., and Ittenbach, R. F. (2020). A novel, composite measure of screen-based media use in young children (ScreenQ) and associations with parenting practices and cognitive abilities. *Pediatr. Res*. 87, 1211–1218. doi: 10.1038/s41390-020-0765-1

Hutton, J. S., Huang, G., Wiley, C., DeWitt, T., and Ittenbach, R. F. (2021). Randomized trial of a mobile app introduced during well-visits to enhance guidance for reading with young children. *Acad. Pediatr*. 21, 977–987. doi: 10.1016/j.acap.2021.05.005

Janssen, X., Martin, A., Hughes, A. R., Hill, C. M., Kotronoulas, G., Hesketh, K. R., et al. (2020). Associations of screen time, sedentary time and physical activity with sleep in under 5s: a systematic review and meta-analysis. *Sleep Med. Rev*. 49:101226. doi: 10.1016/j.smrv.2019.101226

Kirkorian, H. L., Pempek, T. A., Murphy, L. A., Schmidt, M. E., and Anderson, D. R. (2009). The impact of background television on parent–child interaction. *Child Dev*. 80, 1350–139. doi: 10.1111/j.1467-8624.2009.01337.x

Konrad, C., Hillmann, M., Rispler, J., Niehaus, L., Neuhoff, L., Barr, R., et al. (2021). Quality of mother-child interaction before, during, and after smartphone use. *Front. Psychol*. 12:616656. doi: 10.3389/fpsyg.2021.616656

Lew-Williams, C., and Weisleder, A. (2017). How do little kids learn language? *Front. Young Minds* 5:45. doi: 10.3389/frym.2017.00045

Li, C., Mendoza, M., and Milanaik, R. (2017). Touchscreen device usage in infants and toddlers and its correlations with cognitive development. *Pediatr. Health Res*. 2. doi: 10.21767/2574-2817.100013

Li, M., Zhao, R., Dang, X., Xu, X., Chen, R., Chen, Y., et al. (2024). Causal relationships between screen use, reading, and brain development in early adolescents. *Adv. Sci*. 11:2307540. doi: 10.1002/advs.202307540

Lin, Y., Zhang, X., Huang, Y., Jia, Z., Chen, J., Hou, W., et al. (2022). Relationships between screen viewing and sleep quality for infants and toddlers in China: a cross-sectional study. *Front Pediatr*. 10:987523. doi: 10.3389/fped.2022.987523

Madigan, S., McArthur, B. A., Anhorn, C., Eirich, R., and Christakis, D. A. (2020). Associations between screen use and child language skills: a systematic review and meta-analysis. *JAMA Pediatr*. 174, 665–675. doi: 10.1001/jamapediatrics.2020.0327

Massaroni, V., Delle Donne, V., Marra, C., Arcangeli, V., and Chieffo, D. P. R. (2023). The relationship between language and technology: how screen time affects language development in early life—a systematic review. *Brain Sci*. 14:27. doi: 10.3390/brainsci14010027

McDaniel, B. T., and Radesky, J. S. (2018). Technoference: longitudinal associations between parent technology use, parenting stress, and child behavior problems. *Pediatr. Res*. 84, 210–218. doi: 10.1038/s41390-018-0052-6

Merz, E. C., Maskus, E. A., Melvin, S. A., He, X., and Noble, K. G. (2020). Socioeconomic disparities in language input are associated with children's language-related brain structure and reading skills. *Child Dev*. 91, 8468–8460. doi: 10.1111/cdev.13239

Mindell, J. A., Gould, R. A., Tikotzy, L., Leichman, E. S., and Walters, R. M. (2019). Norm-referenced scoring system for the brief infant sleep questionnaire–revised (BISQ-R). *Sleep Med*. 63, 106–114. doi: 10.1016/j.sleep.2019.05.010

Nakshine, V. S., Thute, P., Khatib, M. N., and Sarkar, B. (2022). Increased screen time as a cause of declining physical, psychological health, and sleep patterns: a literary review. *Cureus* 14:e30051. doi: 10.7759/cureus.30051

Ramirez, N. F., Hippe, D. S., and Shapiro, N. T. (2021). Exposure to electronic media between 6 and 24 months of age: an exploratory study. *Infant Behav. Dev*. 63:101549. doi: 10.1016/j.infbeh.2021.101549

Ribner, A. D., McHarg, G. G., and Team, N. S. (2019). Why won't she sleep? Screen exposure and sleep patterns in young infants. *Infant Behav. Dev*. 57:101334. doi: 10.1016/j.infbeh.2019.101334

Rideout, V., and Robb, M. B. (2017). *The Common Sense census: Media Use by Kids Age Zero to Eight*. San Francisco, CA: Common Sense Media, 263–283.

Rowe, M. L., Pan, B. A., and Ayoub, C. (2005). Predictors of variation in maternal talk to children: a longitudinal study of low-income families. *Parent. Sci. Pract*. 5, 259–283. doi: 10.1207/s15327922par0503_3

Rowe, M. L. A. (2012). longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Dev*. 83, 1762–1774. doi: 10.1111/j.1467-8624.2012.01805.x

Sadeh, A. A. (2004). brief screening questionnaire for infant sleep problems: validation and findings for an Internet sample. *Pediatrics*. 113, e570–e577. doi: 10.1542/peds.113.6.e570

Sundqvist, A., Barr, R., Heimann, M., Birberg-Thornberg, U., and Koch, F. (2024). A longitudinal study of the relationship between children's exposure to screen media and vocabulary development. *Acta Paediatr*. 113, 517–522. doi: 10.1111/apa.17047

Tham, E. K. H., Schneider, N., and Broekman, B. F. P. (2017). Infant sleep and its relation with cognition and growth: a narrative review. *Nat. Sci. Sleep*. 135–149. doi: 10.2147/NSS.S125992

Tikotzky, L., De Marcas, G., Har-Toov, J., Dollberg, S., Bar-Haim, Y., and Sadeh, A. V. I. (2010). Sleep and physical growth in infants during the first 6 months. *J. Sleep Res*. 19(1–Part-I), 103–110. doi: 10.1111/j.1365-2869.2009.00772.x

Tomopoulos, S., Dreyer, B. P., Berkule, S., Fierman, A. H., Brockmeyer, C., Mendelsohn, A. L., et al. (2010). Infant media exposure and toddler development. *Arch. Pediatr. Adolesc. Med*. 164, 1105–1111. doi: 10.1001/archpediatrics.2010.235

Vijakkhana, N., Wilaisakditipakorn, T., Ruedeekhajorn, K., Pruksananonda, C., and Chonchaiya, W. (2015). Evening media exposure reduces night-time sleep. *Acta Paediatr*. 104, 306–312. doi: 10.1111/apa.12904

Weisleder, A., and Fernald, A. (2013). Talking to children matters: early language experience strengthens processing and builds vocabulary. *Psychol. Sci*. 24, 2143–2152. doi: 10.1177/0956797613488145

Weizman, Z. O., and Snow, C. E. (2001). Lexical output as related to children's vocabulary acquisition: effects of sophisticated exposure and support for meaning. *Dev. Psychol*. 37:265. doi: 10.1037/0012-1649.37.2.265

Wiltshire, C. A., Troller-Renfree, S. V., Giebler, M. A., and Noble, K. G. (2021). Associations among average parental educational attainment, maternal stress, and infant screen exposure at 6 months of age. *Infant Behav. Dev*. 65:101644. doi: 10.1016/j.infbeh.2021.101644

Xie, W., Lu, J., and Lin, X. (2024). Is screen exposure beneficial or detrimental to language development in infants and toddlers? A meta-analysis. *Early Child Dev. Care* 194, 606–623. doi: 10.1080/03004430.2024.2349622

Xu, D., Yapanel, U., and Gray, S. (2009). *Reliability of the LENA Language Environment Analysis System in Young Children's Natural Home Environment*. Boulder, CO: Lena Foundation, 1–16.

Zimmerman, F. J., Christakis, D. A., and Meltzoff, A. N. (2007). Associations between media viewing and language development in children under age 2 years. *J. Pediatr*. 151, 364–368. doi: 10.1016/j.jpeds.2007.04.071