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# Patterns of Infants' Digital Exposure in Disadvantaged Neighborhoods: Links to the Family Environment and Toddler-Age Language

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The present study examined patterns of digital exposure (frequency, duration, mothers' intentions for exposure, and co-viewing) of 7-month-old infants ($N$ = 221) from socioeconomically disadvantaged neighborhoods. One half heard another language at home, usually alongside German. Links to family variables were analyzed for the whole sample and to children's later toddler-age societal language vocabulary for a less linguistically diverse subsample ($n$ = 136). Latent mixture models identified three distinct digital exposure patterns: *zero dosage*, *moderate background TV dosage*, and *higher foreground and background dosage*. In the latter group, more mothers exposed their infants to media with specific intentions (e.g., distract or educate). Families in the *higher fore- and background dosage* group exhibited lower incomes, lower maternal education, less observed maternal sensitivity, and less frequent picture book reading. Infants in this group were more likely to hear a heritage language at home. Even after accounting for these family-related differences, infants with higher fore- and background dosage displayed smaller societal language vocabularies at age 1.5 years. Statistical interactions between digital exposure patterns, the quality of mother–child interaction (sensitivity, stimulation), and the frequency of picture book reading were nonsignificant. Findings indicate high fore- and background dosages may be detrimental, but moderate background TV poses less risk for very young children's societal language. This underscores the importance of a nuanced understanding of digital exposure in the context of family resources and risks. Recommendations should move beyond blanket prohibitions toward emphasizing the critical role of direct, language-rich interactions for language development, particularly in socioeconomically disadvantaged settings.

***Public Significance Statement***

This study shows that babies in socioeconomically disadvantaged German neighborhoods, many of which heard another language than German at home, had different experiences with digital devices: no contact, occasional background TV, or more frequent exposure to TV and smartphones for distraction and educational purposes (often paired with less support for German language learning). Whereas occasional background TV appeared harmless, babies whose mothers provided more frequent foreground exposure (e.g., to distract or educate their babies) knew fewer German words than other toddlers. Substantial, very early exposure to TV and smartphones could be slowing German language development already at this young age.

*Keywords:* digital media, receptive vocabulary, language, infant, sensitivity and stimulation

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*continued*

Babies and caregivers gazing at each other and at the surrounding world together, intensely focused and responding to one another's expressions, vocalizations, and talk—such contingent, dyadic interplay as well as language-rich stimulation have been theorized to represent a central route to early language development (e.g., Madigan et al., 2020; Tomasello, 2003). Consider another frequent current-day setting (McArthur et al., 2022): Babies experiencing TVs, smartphones, and other devices that accommodate one-sided interactions and are perhaps less tailored to emerging cognitive and attentional skills (Hipp et al., 2017). Such settings are more likely to be observed in socioeconomically disadvantaged families. Infants from socioeconomically disadvantaged families are more likely to spend substantial periods with digital devices (Brushe et al., 2023). Such extensive exposure has sparked concerns. However, past correlational research focusing mostly on hypothesized negative impacts of such a "dosage" of screen time on language development is far from conclusive (Xie et al., 2024). Mere screen time may not adequately capture the digital reality in infants' lives. Infants are exposed to multiple devices and applications in the fore- and background, with varying content and used for various purposes and in various social contexts (Barr, 2019; Linebarger & Vaala, 2010).

The Dynamic, Relational, Ecological Approach to Media Effects Research (DREAMER) framework highlights that the what, when, why, and with whom all contribute to different exposure patterns and effects. Effects are viewed as unfolding from such entire exposure patterns, including dosage, content, screen media features, and social context of exposure. Different exposure patterns are posited to be associated with different caregiver intentions. DREAMER further views exposure patterns as acting in conjunction with the family environment (Barr et al., 2024). Without any knowledge of what infants are experiencing outside of digital exposure, its effects remain obscure and muddled by confounders. In the family environment, key proximal factors include the caregiver interaction qualities that are deemed paramount for language development—and often neglected in prior work (Kostyrka-Allchorne et al., 2017). Further, everyday home activities such as shared reading elicit high-quality input from caregivers and thereby support language development (Hoff, 2006; Noble et al., 2019). Finally, particularly in socioeconomically disadvantaged neighborhoods, for many infants hearing a heritage language at home shapes the course of language development (Hoff, 2013). The DREAMER framework predicts that such key proximal factors, but also more distal family characteristics relevant to language development, are correlates or even moderators of digital exposure: what happens outside of digital exposure could either heighten or diminish digital exposure effects.

The present study expands on previous work by more comprehensively considering digital exposure of infants in their first year of life and its interplay with the family environment. We sought to identify multivariate patterns of several facets of infants' exposure: fore- and background dosages for various devices, the social context of viewing, and mothers' underlying intentions. Infants were from socioeconomically disadvantaged neighborhoods, a demographic for which information is scarce (Barr, 2019). We then examined how these patterns were distinguished by mothers' interaction quality (sensitivity, stimulation), language-rich activities such as picture book reading, exposure to a heritage language, and further proximal and distal family supports and challenges to societal language development, such as maternal depression, subjective strain, partnership satisfaction, absence of partnership conflicts, socioeconomic status (SES), and household structure. Last, for a subset of children for whom we had vocabulary reports, we tested relations between infant digital exposure patterns and toddler-age German societal language vocabulary while considering multiple confounders. In doing so, we considered possible modulation of effects by interaction quality and picture book reading.

## What Is Known About Infants' Digital Exposure

Findings for very young infants are rare, but prior work incorporating the infant stage (sometimes spanning into the second year) suggests that infants' digital experiences demonstrate substantial heterogeneity that deserves to be captured: With regard to dosage, many infants do spend considerable time with screen media. Daily average estimates for foreground screens span 20 min to close to an hour and for "background TV" up to many hours a day. Some infants are exposed to much greater than the average hours and other infants receive zero exposure (Barber et al., 2017; Brushe et al., 2023; Durham et al., 2021; Mendelsohn et al., 2011; Perrin et al., 2014; Taylor et al., 2018; Then et al., 2024). Watching TV or videos appears to be the predominant screen-based activity for under-2-year-olds (Rideout & Robb, 2020). As for the social context, infants may view alone or together with caregivers, a mediation style referred to as co-viewing or co-use (Zimmerman et al., 2007). Caregivers' beliefs and child-related intentions for exposure range from digital screen media being enjoyable, educational, or calming, to functioning as a "digital babysitter" (Cingel & Krcmar, 2013; Zimmerman et al., 2007). Such beliefs and intentions are linked to dosages of under-2-year-olds (Lauricella et al., 2015). In sum, condensing this heterogeneity in terms of dosage, social context, and intentions into a single overall "screen time" measure may be only modestly informative about infants' actual experiences.

Person-oriented approaches can break down such multivariate heterogeneity by identifying groups of children that experience similar patterns of digital exposure. Several facets of exposure, such as fore- and background dosages for various devices, co-viewing, and the intentions underlying exposure, can be considered simultaneously. Such person-oriented analyses of digital exposure have not yet been applied specifically for infants in their first year of life. For the toddler age, two studies surveying dosage indicators in socioeconomically advantaged families revealed distinct patterns of moderate and heavier dosage (McClure et al., 2015; Mol et al., 2014). These patterns were presumably related to specific caregiver

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intentions (e.g., moderate dosage caregivers viewed specific types of exposure as an exception, such as connecting with grandparents via videochat; McClure et al., 2015; Mol et al., 2014). Hence, we applied person-oriented analyses to gain first insight into young infants' patterns of digital exposure in families from disadvantaged neighborhoods. To account for linguistic diversity in such neighborhoods, we paid specific attention to whether infants heard a heritage language at home.

## Digital Exposure Covaries With the Family Environment

As proposed by the DREAMER framework, there are links between facets of infants' and toddlers' digital exposure and the proximal and distal features of family environments considered critical for language development (Barr et al., 2024; Hoff, 2006). Such covariation needs to be understood and accounted for when studying the effects of digital exposure patterns.

On the proximal level, one can distinguish between temporary family environment effects restricted to screen media exposure situations and likely more stable differences not limited to exposure situations. Exposure to background TV can temporarily reduce caregiver interaction quality and quantity (Kirkorian et al., 2009; Suarez-Rivera et al., 2024). Outside of or independent of exposure situations (and less temporarily), interaction quality and language-rich activities are sometimes inversely related to dosage. Greater fore- or background dosage have been shown to be related to less book reading, lower Home Observation Measurement of the Environment scores, and lower interaction quality in terms of conversational turns (Brushe et al., 2024; Detnakarintra et al., 2020; Masur et al., 2016; Medawar et al., 2023; Mendelsohn et al., 2011). Higher co-viewing dosages have also been found to be related to caregivers' lower language complexity outside of digital exposure situations (Lavigne et al., 2015). Yet, not all studies reveal such relations outside of exposure situations (Gago-Galvagno et al., 2023; Kucker et al., 2024; Taylor et al., 2018; Then et al., 2024). In addition, hearing a heritage language at home is also not consistently related to higher dosages (Duch et al., 2013). Inconsistencies could arise due to caregiving norms, beliefs, or other third variables underlying associations.

Among distal family characteristics, family structure (e.g., single-parent households, more and elder siblings) and lower SES, including lower parental education and lower income, relate to higher dosages (Brushe et al., 2023; Duch et al., 2013; Rideout & Robb, 2020; Then et al., 2024). In accord with the family stress model and the DREAMER framework, these links could reflect pressures of economic disadvantage and caregivers' coping attempts. That mothers may use media to cope is also supported by links between screen time and maternal depressive symptoms, distress, and lower partnership quality (Barr et al., 2024; Duch et al., 2013; Reich et al., 2023). Alternatively, the covariation between dosage and SES could reflect specific caregiver beliefs or child-related intentions regarding screen media. Relations between SES and co-viewing or co-use may be more complex; it may be an unintended byproduct of caregivers' own digital media use (Anderson & Hanson, 2017; Connell et al., 2015).

In sum, findings are mainly in relation to dosage and not always consistent. However, they provide reason to expect that patterns of digital exposure will be linked to proximal and distal supports and challenges to societal language development. We examined such links on the proximal level, including interaction quality as tapped by sensitivity and stimulating behavior in mother–infant interactions, the frequency of language-rich activities (picture book reading, rhyming, singing, pretend play), and whether the infant is exposed to a language other than the societal language at home. On the distal level, we considered links with mothers' education level and household income as indicators of SES, and single parenthood and first-born status as indicators of family structure. Links with maternal depression, subjective strain, (absence of) partnership conflict, and partnership satisfaction were also considered due to their potential role in connecting SES and digital exposure. The proximal and distal family environment factors that were significantly linked to exposure patterns were also included as potential confounders when studying the predictive associations with children's societal language development.

## Why Should Patterns of Digital Exposure Matter for Language Learning?

Several theoretical perspectives imply that digital exposure patterns could impact early language development, perhaps in interaction with the family environment. A framework by Linebarger and Vaala (2010) emphasizes the importance of child characteristics, the screen media stimulus, and the social context. According to this framework, even with a co-viewer orchestrating joint attention, learning new words from typical screen media is very challenging for young infants with emergent cognition and attentional control. Infants are unlikely to grasp that 2D-images represent real-life objects. Their attention may be bottom-up drawn to salient but not necessarily informative screen areas. Infants' difficulties in learning from 2D screen media compared to from human interaction have been termed the "video deficit" (Hipp et al., 2017). In addition, infants likely struggle with the visual clutter of digital scenes when not supported by social cues for word learning (Clerkin et al., 2017). Still, co-viewing could allow learning directly from caregiver interaction independently from what is occurring on the screen (Dore et al., 2020).

Negative effects of digital exposure patterns only follow once hypothetical counterfactuals more supportive of language development are introduced (Anderson & Hanson, 2017; Linebarger & Vaala, 2010). The *displacement* account implies a prominent role for dosage. Screen media are viewed as creating lost opportunities for interactions and activities. The *disruption* account refers to temporary reductions in caregiver–infant interactions and activities. Disruption could also be interpreted as supporting negative dosage effects (Barr, 2019; Christakis et al., 2009; Jing et al., 2023). It follows from both accounts that it is crucial to consider children's nondigital experiences to make predictions about effects. The DREAMER framework highlights interplay between digital exposure and the family environment. Instead of overall predictions as to whether effects are positive or negative, DREAMER emphasizes the potential for interaction effects (Barr et al., 2024). Theorizing on interaction effects has mostly focused on SES and "compensatory" pathways. Digital exposure has been hypothesized to be particularly detrimental for children of lower SES backgrounds whose, on average, less language-rich environments cannot "compensate" for time lost for more supportive experiences (Dynia et al., 2021; Hoff, 2006; Xie et al., 2024).

We focused on interactions with key features of the proximal family environment. For a subsample of children whose mothers

reported on their toddler's German vocabulary, we first examined associations with digital exposure, controlling for proximal and distal characteristics of family environment. Subsequently, we investigated whether effects of digital exposure patterns were moderated by key proximal family environment features: interaction quality and picture book reading.

## What Can Be Gleaned From Prior Research on Effects?

To our knowledge, there is no research on the effects of entire patterns of digital exposure on infants' language development. Some conclusions can be pieced together from correlational research on individual facets of exposure (foreground and background dosage, co-viewing, child-related intentions). Dosage is usually studied in the form of "screen time," but studies of infants before their first birthday are rare. For children aged three and under, meta-analytically, there is a negative bivariate association between screen time and language (Xie et al., 2024). The meta-association is greatest in low SES (e.g., Dynia et al., 2021; Tomopoulos et al., 2010) and nonsignificant in mid-/high-SES samples. This suggests compensatory effects. An additional meta-analysis for under 3-year-olds revealed a nonsignificant positive association between naturalistic screen media exposure and vocabulary. The discrepancy with Xie et al. (2024) may be due to the inclusion of educational content and only two studies of infants before their first birthday (Jing et al., 2023). For young children, studies of screen time are usually focused on linear relationships (Xie et al., 2024). For older children, two studies provide evidence of curvilinear associations with preschool- or elementary school-age language (reverse u-shape, Dore et al., 2020; Martinot et al., 2021). These imply that screen time only relates to slower language development when it exceeds a certain level. In these two studies, children with moderate screen time had the strongest language skills (Dore et al., 2020; Martinot et al., 2021). In terms of consideration of the family environment, screen time studies frequently control for activities such as shared reading (e.g., Alroqi et al., 2023; Taylor et al., 2018; Zimmerman et al., 2007). Interaction quality is rarely controlled for (Linebarger & Walker, 2005; Sundqvist et al., 2021; Tomopoulos et al., 2010), and statistical interactions between such proximal family environment variables and screen time are not tested.

There are fewer studies for other facets. For the duration of background TV, there is a similar mix of negative and null effects for under 3-year-olds (e.g., Gago-Galvagno et al., 2023; Masur et al., 2016). For co-viewing, a positive meta-association with language was significant only in lower SES samples (Xie et al., 2024). However, in one study, positive effects of co-viewing disappeared when interaction quality outside of media use was controlled for (Mendelsohn et al., 2010). For intentions, one study suggested that using media to calm was negatively related to language development. Other intentions were found to interact with screen time: Using media to educate or to connect appeared to compensate for negative effects of screen time (Kucker et al., 2024).

In sum, there is inconsistent evidence that fore- and background dosages are detrimental, that co-viewing is supportive of infants' language development, and some indication that intentions interact with other facets. Thus, there are both theoretical and empirical grounds to expect digital exposure patterns may affect societal language development. Due to patterns' constellation of numerous facets of exposure that may interact with each other, precise predictions regarding their effects are difficult. However, beneficial effects of substantial exposure during early infancy appear unlikely.

## The Present Study

Calls have been made to examine multiple intercorrelated facets of digital exposure, their covariance with the family environment, and interplay in relation to language outcomes (Barr et al., 2024; Linebarger & Vaala, 2010). Answering such calls challenges typical variable-oriented analyses. What is more, imposing overly simple, linear, universal dosage models may have contributed to the inconsistent state of evidence (Mannell et al., 2024). Past analyses also seldom controlled for interaction quality. Thus, the simple dosage measures could have been acting as rather unreliable indices of low interaction quality (Anderson & Hanson, 2017; Kostyrka-Allchorne et al., 2017; Linebarger & Vaala, 2010). Finally, simple dosage measures could have been differentially affecting children depending on their proximal family environment.

Therefore, in a sample from socioeconomically disadvantaged neighborhoods, we first applied person-oriented latent mixture models to the multifaceted digital exposure of infants during the second half of their first year of life. We considered patterns' links with crucial proximal supports for children's societal language development, namely interaction quality in terms of sensitivity and stimulating behavior, the frequency of stimulating language-rich activities (picture book reading, singing, rhyming, pretend play), and whether infants heard only the societal language at home. We also considered supports and challenges in the family background (mothers' education, household income), family structure (first-born status, single parenthood), and additional family stressors (e.g., maternal depression, subjective strain, indicators of partnership quality) to gain a fuller picture. Finally, we aimed to understand relations between digital exposure patterns and children's societal language receptive vocabulary at the age of 1.5 years in a subset of children for whom we had vocabulary reports. Key proximal supports were considered as moderators. Our sets of research questions were as follows:

1. What are patterns of infants' digital exposure in terms of fore- and background dosage (frequency and duration of contact with various devices), co-viewing, and mothers' intentions for exposure?
2. How do such patterns differ in terms of infants' proximal and distal family supports and challenges to language development?
3. How are such patterns associated with later societal language receptive vocabulary?
4. Are there "compensatory" effects involving (a) mothers' interaction quality (sensitivity and stimulating behavior in mother–child interactions) and (b) picture book reading? That is, are digital exposure patterns more closely associated with societal language receptive vocabulary for infants with (a) lower interaction quality or (b) less frequent picture book reading?

## Method

### Participants

This study utilizes data from the project Bremen Initiative to Foster Early Childhood Development (BRISE; Schütte et al., 2020). BRISE focuses on families from socioeconomically disadvantaged areas of the city of Bremen, Germany. Families were recruited from structurally disadvantaged neighborhoods and had to meet at least one of three criteria: (1) low educational attainment—at least one parent had not completed vocational training or had obtained, at most, a school-leaving certificate after 10 years of education; (2) immigrant roots—at least one parent or grandparent was born outside of Germany; and (3) low income—at least one parent was unemployed or a low-wage earner, or both parents worked part time. Data collection began during pregnancy or shortly after the child's birth and continued until the first year of primary school. The data for the present study were collected between 2018 and 2020. The bulk of present data was gathered before Germany's pandemic restrictions were in place. The ethics committee of the German Psychological Society approved BRISE, and all legal guardians gave informed consent.

Of $N = 300$ BRISE children, $n = 59$ have no data at the first measurement point due to withdrawal from the study or coronavirus-related restrictions. A further $n = 20$ children completed the initial measurement point (T1), but there is no data on media exposure for these children. Consequently, the final sample comprises $N = 221$ children (100 boys). At T1, the children were $M = 7.26$ months old ($SD = 0.82$, range = 5.81–11.07 months), and the mothers averaged 31.99 years of age ($SD = 5.65$, range = 18–48 years). Approximately 38% of mothers held at least a bachelor's degree. The monthly mean family net income was 2,739€ ($SD = 1,441$€, range = 200€ to 7,600€; note that in Germany, net income during infants' first year is usually lower, as parental leave may equal only two third of the leave takers' earnings). The sample could be described as mostly low to middle income (a family of three was at risk of poverty at 1,933€ in 2019; Statistische Ämter des Bundes und der Länder, 2022). In 35% of the families, both parents and all four grandparents were born in Germany; in 17% of the families, both parents were born in Germany and at least one grandparent was born abroad; in 20% of the families, one parent was born abroad; and in 28% of the families, both parents were born abroad. Of the infants, 47% heard only German at home. The remaining infants heard mostly German (15%), mostly a heritage language (17%), or only the heritage language (12%). In sum, 53% were exposed to a heritage language at home. The mother report on German societal language vocabulary was available for $n = 136$ children, of which 18% heard a language other than German at home. None of these $n = 136$ children heard mostly or only the heritage language at home. The lower share of children exposed to a heritage language in this subsample is due to (a) planned missings for children who heard only the heritage language at home and (b) as suggested by field reports, time constraints during home visits hindering mothers who spoke not only German from completing the entire questionnaire package. As not all mothers could report on their children's German vocabulary, we carefully conducted a series of robustness checks (see Results).

### Measures

Three different measurement time points were used for this study when children were on average 7, 12, and 17 months, respectively.

#### *Time 1 (7 Months)*

At the first measurement point, trained interviewers conducted home visits. Families completed paper–pencil questionnaires, and an 8-min semistandardized mother–child interaction situation was videotaped.

**Digital Exposure Facets.** Children's digital exposure was assessed using adapted items constructed for parents of infants and toddlers (Archer, 2017). These measured frequency, duration, intention, and co-viewing of media use. For frequency, three items asked how frequently an infant watched TV, watched TV in the background, and had direct contact with a smartphone (6-point scale from 1 = *never* to 6 = *several times a day*). For duration, three items asked how long during such a contact an infant watched TV, watched TV in the background, and had direct contact with a smartphone on average (6-point scale from 1 = *less than 5 min* to 6 = *61 min and more*). Separating frequency and duration of media exposure enables a more precise characterization of infants' exposure that may also relate to infants' development. For example, several short exposure "bursts" could either be particularly distracting or of little consequence because they do not add up to a high duration. For intentions, five binary items asked whether mothers used media for educational purposes, to distract the child to gain more time for other things, to distract the child to relax, to calm the child down, and to keep the child busy (0 = *never* vs. 1 = *at least once a week*). The intention items were developed by Archer (2017) from prior qualitative parent interviews and should have high face validity for parents. Co-viewing was measured by an item that asked whether the mother was right next to the infant when they were exposed to media devices (4-point scale from 1 = *does not apply at all* to 4 = *fully applies*).

**Mother–Child Interaction Quality.** We assessed mothers' sensitivity and stimulation behavior in a videotaped, semistandardized interaction situation between mother and child at the families' home. The standardization of the situation includes the location, the toys, and the context of the play session. The session took place on a blanket on the floor of the family's home, and the toys (rattle, squeaking book, duckling ball, stacking cups) demanded varying levels of effort from the child. Mothers were instructed to interact with their child as naturally as possible (for more information, see Linberg et al., 2019). A 5-min interaction was coded for maternal sensitivity to nondistress and maternal stimulation behavior using adapted National Institute of Child Health and Human Development Study of Early Child Care and Youth Development coding procedures (National Institute of Child Health and Human Development Early Child Care Research Network, 1991). *Sensitivity* captured prompt, contingent, and suitable replies to the infant's signals and needs. Mother's *stimulating behavior* captured stimulation of speech and play. Both variables were rated by trained coders using global ratings on a 5-point scale with qualitatively defined levels (1 = *not characteristic at all* to 5 = *very characteristic*). Coders underwent 50 hr of training to ensure high-quality ratings and comparability of the coding within and between coders (see Linberg et al., 2019). To determine interrater reliability, 15% of all available videos were double-coded and Cohen's kappa was calculated. Interrater reliability was estimated as moderate for maternal sensitivity ($\kappa = 0.55$) and maternal stimulation ($\kappa = 0.57$).

**Socioeconomic and Sociodemographic Family Characteristics.** Maternal education was coded dichotomously using the Standard International Classification of Education (United Nations Educational, Scientific, and Cultural Organization, 2012;

0 = lower education; maximum at Standard International Classification of Education Level 3—upper secondary education vs. 1 = higher education; at least Standard International Classification of Education Level 4—postsecondary nontertiary education). It is important to note that educational qualifications acquired abroad were assessed according to their official recognition in Germany. Household income was measured using the monthly net household income of all household members. Family language was classified dichotomously by differentiating between 0 = families in which only German was spoken and 1 = those in which German was not the exclusive language spoken at home. We also assessed single parenthood using a single dichotomous item (0 = no vs. 1 = yes). In addition, the status of the children as first borns was assessed (0 = first-born children vs. 1 = not first-born children).

**Maternal Depression.** The German version of the Edinburgh Postnatal Depression Scale (Cox et al., 1987), comprising 10 self-report items, was used to assess maternal depressive symptoms. This widely used questionnaire demonstrates good reliability and validity (Bergant et al., 1998). Our sum score showed good reliability (α = .85).

**Subjective Strain.** A shortened version of the Life Event Questionnaire by Thomson et al. (2014) assessed the occurrence of stressful life events in the last 3 months and the subjective impact on the mother. The list of stressors included child-related health problems (e.g., infection), child-related developmental issues (e.g., due to inadequate weight gain), financial problems, stress caused by the living situation (e.g., building a house, moving), stress caused by the workplace situation, partnership conflicts, separation from the partner, conflicts with the own family, death of a family member, illness of a family member, and a postpartum depression. For each stressor, the mother was asked to rate how stressful it was for her using a 4-point scale (1 = *did not affect me at all* to 4 = *affected me a lot*). A weighted sum score was calculated using these ratings for each stressor.

**Partnership Quality.** Two key aspects of partnership quality are (absence of) partnership conflicts and partnership satisfaction. Partnership conflicts were measured using nine items of the German short version of the Partnership Questionnaire (Kliem et al., 2012; 1 = *never/very rare* to 4 = *very often*). An inverted sum score (i.e., absence of) partnership conflicts showed good reliability (α = .81). Partnership satisfaction was measured by a single item, "How happy would you rate your marriage/partnership at the moment?" (1 = *unhappy* to 5 = *very happy*).

### *Time 2 (12 Months)*

**Language-Rich Activities.** We considered the frequency of four language-rich activities: picture book reading, singing together, playing nursery rhymes, and playing pretend games (e.g., pretending to eat). Mothers reported on a 5-point Likert scale (0 = *never* to 5 = *several times a day*) how often they engaged in these activities with their child.

### *Time 3 (17 Months)*

**Receptive German Vocabulary.** As a dependent variable, a standardized German receptive vocabulary checklist (parental report) comparable to the well-established MacArthur-Bates Communicative Development Inventories (Fenson et al., 2007) with 164 words (Parent Questionnaires for the early detection of children at risk; Grimm & Doil, 2006) was used (sum score). Children with no exposure to German at home were considered to have such minimal German vocabulary that it did not justify the use of this measure. Thus, it was only given to parents whose children were exposed to German at home. Note that for children exposed to both German and a heritage language, German vocabulary only represents a part of their total vocabulary, which is distributed over two languages (Oller et al., 2007).

### *Control Variables*

The gender of the infant, the age of the child when the Parent Questionnaires for the early detection of children at risk was conducted, and the age of the mother were additional control variables.

## Statistical Analyses

To address our first research question, we employed latent mixture models (Oberski, 2016) to identify latent patterns of infants' digital exposure. Models with varying numbers of latent groups were compared using the following fit indicators: Bayesian information criterion, sample-adjusted Bayesian information criterion, Lo–Mendell–Rubin Test, and entropy. It is important to note that we excluded families who responded "never" to the questions about the frequency of watching TV in the fore- or background and using smartphones ($n = 53$) from latent mixture modeling, as this group did not have any media exposure at all. These children with zero dosage had "missings" for all intentions and co-viewing, which distorted the identification of profiles. Therefore, the subsample for the latent mixture analyses contains $n = 168$ families. However, this zero-dosage group was included as a distinct group in all further analyses. To gain a deeper insight into the characteristics of the latent groups, mean values and proportions of the 12 media items were analyzed with *t* tests and chi-square tests for group differences. For the second research question, we analyzed how the infants' digital exposure was related to the family environment. Thus, we compared mean values of the family environment variables with *t* tests and chi-square tests to identify significant differences across the groups.

For our third research question, dummy-coded variables from the latent mixture models were used in regression analyses with Mplus 8.4 (Muthén & Muthén, 1998–2017) to investigate the association between the patterns of infants' digital exposure and later vocabulary. The final research question analyzed interactions between digital exposure groups and proximal variables (maternal sensitivity and stimulation behavior, and picture book reading) with child vocabulary as an outcome. Recall that children without receptive vocabulary scores ($n = 85$) were excluded, which is why the subsample for the third and fourth research questions was $n = 136$. Thus, we conducted various robustness checks to address the issue of the reduced sample for these analyses (see Results section).

More information on the justification of the sample size can be found in Supplemental A. All models were estimated utilizing the robust maximum likelihood method, which employs parameter estimates with standard errors and chi-square statistics that are robust to nonnormality and nonindependence of observations. Missing covariate data were considered missing at random because the broad set of proximal and distal variables was likely to capture the mechanisms

underlying missingness. Thus, it was managed with a full information maximum likelihood approach.

## Transparency and Openness

The raw data and most study materials are being progressively made available in a repository (BRISE-Konsortium, 2022, https://doi.org/10.5159/IQB_BRISE_MZP0-2_v2), although the specific version used in our analysis is not yet entirely accessible. Analyses code is available at https://osf.io/fj84m/?view_only=b5c44d354c4c43c6b000426110f701a2 (Möwisch & Willard, 2025). The study was not preregistered.

# Results

Descriptive statistics for all study measures are presented in Table 1 (see Supplemental Material for bivariate correlations of all study measures).

## Latent Patterns of Infants' Digital Exposure

The model fit indices of the latent mixture models (Table 2) showed that a two-group model explained significantly more variance than a one-group model. Given that the Lo–Mendell–Rubin Test in the three-group model did not yield a statistically significant $p$ value and the entropy also appeared to be higher in the two-group model, we preferred the latter model.

Comparisons of the 12 digital exposure items (see Table 3) revealed that in a *higher foreground and background dosage* group, children had greater exposure to watching TV, watching TV in the background, and smartphones both in frequency and duration. Mothers in this group also used media more often to educate their child, to distract their child to gain more time for other things, to distract their child to relax, to calm them down, and to keep their child busy. The rank order of intentions also differed, with the intent to educate featuring more prominently in the *higher foreground and background dosage* group. No significant differences were found

**Table 1**
*Descriptive Statistics of All Variables*

| Variable | *M*/% | *SD* | Minimum | Maximum | Missing (%) |
|---|---|---|---|---|---|
| | | Distal variables (Time 1) | | | |
| Education mother (BA or higher) | 37.5% | | | | 1.3 |
| Household net income | 2,739€ | 1,441€ | 200€ | 7,600€ | 19.4 |
| Single parenthood | 8.0% | | | | 2.3 |
| First-born children | 54.8% | | | | 0.0 |
| | | Proximal family variables (Time 1) | | | |
| Maternal depression | 5.83 | 5.14 | 0 | 27 | 8.1 |
| Subjective strain | 6.52 | 4.95 | 0 | 24 | 1.4 |
| Absence of partnership conflicts | 15.84 | 2.50 | 5 | 20 | 20.4 |
| Partnership satisfaction | 3.93 | 0.97 | 1 | 5 | 18.6 |
| Sensitivity | 3.99 | 0.73 | 2 | 5 | 36.7 |
| Stimulation | 3.21 | 0.96 | 1 | 5 | 36.7 |
| Other family language | 53.3% | | | | 5.0 |
| | | Digital exposure (Time 1) | | | |
| Frequency | | | | | |
| Watching TV | 1.48 | 2.20 | 0 | 6 | 0.0 |
| Watching TV (background) | 2.55 | 2.43 | 0 | 6 | 1.3 |
| Smartphone | 1.34 | 2.09 | 0 | 6 | 3.6 |
| Duration | | | | | |
| Watching TV | 2.15 | 1.72 | 1 | 6 | 28.1 |
| Watching TV (background) | 3.24 | 2.03 | 1 | 6 | 19.0 |
| Smartphone | 1.52 | 1.05 | 1 | 6 | 32.1 |
| Intention | | | | | |
| Education child | 47.2% | | | | 12.7 |
| Distraction child (to gain more time) | 53.1% | | | | 12.2 |
| Distraction child (to relax) | 31.9% | | | | 13.6 |
| To calm down the child | 38.7% | | | | 12.2 |
| To keep the child busy | 49.5% | | | | 12.2 |
| Co-viewing (right next to the baby) | 3.31 | 1.09 | 1 | 4 | 23.9 |
| | | Language-rich activities (Time 2) | | | |
| Picture book reading | 3.93 | 1.17 | 1 | 5 | 33.0 |
| Singing together | 4.27 | 0.98 | 1 | 5 | 33.0 |
| Nursery rhymes | 3.64 | 1.16 | 1 | 5 | 33.0 |
| Pretend games | 3.39 | 1.39 | 1 | 5 | 33.0 |
| | | Receptive vocabulary (Time 3) | | | |
| ELFRA-1 | 92.00 | 46.65 | 1 | 164 | 38.5 |
| | | Controls | | | |
| Age mother (years; Time 1) | 31.99 | 5.64 | 18 | 48 | 0.0 |
| Age infant (days; Time 3) | 539.56 | 46.28 | 466 | 725 | 38.00 |
| Female infant | 54.8% | | | | 10.8 |

*Note*. Intentions refer to use at least once a week. ELFRA-1 = Parent Questionnaires for the early detection of children at risk.

**Table 2**
*Model Fit Indices of the Latent Mixture Models for Infants' Media Exposure*

| Number of groups | LL | BIC | SABIC | LMRT (*p*) | Entropy |
|---|---|---|---|---|---|
| 1 | −2476.58 | 5076.13 | 5000.14 | | |
| 2 | −2277.70 | 4719.37 | 4618.05 | <.01 | .97 |
| 3 | −2223.16 | 4676.90 | 4534.42 | .27 | .93 |

*Note.* $N = 168$. LL = loglikelihood; BIC = Bayesian information criterion; SABIC = sample-adjusted BIC; LMRT = Lo–Mendell–Rubin Test.

for co-viewing. Within a larger *moderate background TV dosage* group, background TV dosage stood out, with higher frequency and duration compared to foreground TV and smartphone dosage.

To summarize, three distinct groups of families could be identified based on the digital exposure of their infants. The *zero dosage group* ($n = 53$) was not derived from the latent mixture models (see Statistical Analyses). The *moderate background TV dosage* group was larger and included infants for whom watching TV in the background was particularly prevalent ($n = 115$). The smaller *higher foreground and background dosage* group of infants had higher values for all dosage measures and featured frequent child-related intentions ($n = 53$). Note that for brevity, the group names do not cover all unique characteristics (e.g., nondifferences in co-viewing, differences in intentions).

## Infants' Digital Exposure and Family Environment

We compared the mean values and proportions of the family environment variables across all three groups to examine how the infants' digital exposure was related to the broader family environment (see Table 4).

**Table 3**
*Means and Frequency Comparisons on Digital Exposure Items for Latent Groups*

| Item | Moderate background TV dosage ($N = 115$) | High fore- and background dosage ($N = 53$) | *p* |
|---|---|---|---|
| Frequency | | | |
| Watching TV | 0.45 | 5.08 | <.01 |
| Watching TV (background) | 2.92 | 4.31 | <.01 |
| Smartphone | 1.43 | 2.56 | <.01 |
| Duration | | | |
| Watching TV | 1.37 | 3.91 | <.01 |
| Watching TV (background) | 3.32 | 4.72 | <.01 |
| Smartphone | 1.51 | 1.97 | <.01 |
| Intention | | | |
| Education child | 10.9% | 53.2% | <.01 |
| Distraction child (to gain more time) | 18.3% | 66.1% | <.01 |
| Distraction child (to relax) | 7.9% | 38.0% | <.01 |
| To calm down the child | 13.2% | 46% | <.01 |
| To keep the child busy | 15.3% | 52.1% | <.01 |
| Co-viewing (right next to the baby) | 3.51 | 3.25 | *ns* |

*Note.* $N = 168$. *ns* = not significant.

There were significant differences between the *zero dosage* and *higher foreground and background dosage* groups for several proximal variables. Mothers from the *higher foreground and background dosage* group demonstrated significantly lower levels of sensitivity and a lower frequency of joint picture book reading picture compared to mothers from the *zero dosage* group. The proportion of households where German was not the exclusive family language was significantly higher in the *high foreground and background dosage* group. However, no significant discrepancies were observed regarding maternal stimulating behavior. On a more distal level, mothers in the *higher foreground and background dosage* group were significantly younger, less educated, and reported a marginally higher prevalence of postnatal depressive symptoms. Income was significantly lower in the group of families with *higher foreground and background dosage*. No significant differences were observed with respect to single parenthood, first-born children, subjective strain, absence of partnership conflicts, and partnership satisfaction.

A similar pattern of results was also evident in the comparison between the *moderate background TV dosage* and the *higher foreground and background dosage* group (Supplemental Table S5): The *higher foreground and background dosage* group had significantly lower SES indicators and higher depressive symptoms. For the proximal family environment, the *higher foreground and background dosage* group demonstrated significantly lower sensitivity, less stimulating behavior, less frequent picture book reading, and lower proportions of exclusively German as a family language. In contrast, the comparison between *zero dosage* and *moderate background TV dosage* groups showed no significant differences for any other variables (Supplemental Table S4).

## Infants' Digital Exposure and Receptive Vocabulary

Descriptively, there was a great difference in children's receptive vocabulary between the *higher foreground and background dosage* group and both other groups. Children from the *higher foreground and background dosage* group demonstrated a significantly lower level of receptive vocabulary in the societal language at 17 months than children from the *zero dosage* or *moderate background TV dosage* groups.

Stepwise regression analyses revealed two main findings (see Table 5). First, there was a significant effect on receptive vocabulary when comparing the *higher foreground and background dosage* group with the *zero dosage* group. Notably, this effect was robust and persisted when controlling for multiple distal (e.g., SES) and proximal (e.g., maternal sensitivity) predictors (see Model 5). Second, no significant effect was evident when comparing the *moderate background TV dosage* with the *zero dosage* group (Model 5). Finally, the interaction analyses (see Table 6) revealed no significant interaction effects for maternal sensitivity, for stimulation, or picture book reading.

Robustness checks (Supplemental Tables S6 and S7) documented that the pattern of results of the stepwise regression analyses (i.e., ß values and significance levels) did not change substantially when using full information maximum likelihood to estimate missings in the outcome measure (particularly in the subgroup of children exposed to not only German in their family) for all $n = 221$ children (Supplemental Table S6) and for children exposed to only German at home ($n = 104$, Supplemental Table S7). In the latter case, the size of the *moderate background TV dosage* coefficient slightly increased and two family factors became additionally significant:

**Table 4**
*Comparisons of Means and Frequencies of Family Environment Variables Between Three Groups*

| Variables | Zero dosage ($N = 53$) | Moderate background TV dosage ($N = 115$) | High fore- and background dosage ($N = 53$) | Difference (zero dosage vs. high dosage) |
|---|---|---|---|---|
| Age mother (in years) | 33.4 | 32.1 | 29.8 | $p < .01$ |
| Maternal education | 52.8% | 39.6% | 21.6% | $p < .01$ |
| Household income | 3,294€ | 2,852€ | 1,827€ | $p < .01$ |
| Single parenthood | 9.8% | 7.1% | 11.7% | *ns* |
| First-born children | 62.2% | 50.4% | 53.6% | *ns* |
| Maternal depression (0–30) | 5.41 | 5.46 | 7.17 | $p < .10$ |
| Subjective strain (0–21) | 6.75 | 6.6 | 6.13 | *ns* |
| Absence of partnership conflicts (9–36) | 16.07 | 15.95 | 15.30 | *ns* |
| Partnership satisfaction | 4.05 | 3.91 | 3.86 | *ns* |
| Sensitivity | 4.14 | 4.10 | 3.56 | $p < .01$ |
| Stimulation | 3.16 | 3.37 | 2.83 | *ns* |
| Picture book reading | 4.27 | 4.01 | 3.44 | $p < .01$ |
| Singing together | 4.49 | 4.27 | 4.06 | $p < .10$ |
| Playing nursery rhyme | 3.84 | 3.66 | 3.42 | *ns* |
| Playing pretend games | 3.68 | 3.32 | 3.23 | *ns* |
| Other family language | 38.3% | 38.2% | 68.7% | $p < .01$ |
| Receptive vocabulary (ELFRA-1) | 100.29 | 99.8 | 60.11 | $p < .01$ |

*Note.* $N = 221$. *ns* = not significant; ELFRA-1 = Parent Questionnaires for the early detection of children at risk.

maternal education and household income. Note that the coefficient for maternal education was negative and significant for households where only German is spoken. Estimating unbiased marginal effects of the covarying indicators income and education in a sample selected for low income and/or low education of limited size may involve, for example, bias from overcontrol or collider effects (Elwert & Winship, 2014). As the bivariate correlation between maternal education and children's vocabulary is not significant in this subsample ($r = -.01$), the negative estimate in the regression should be interpreted with caution.

## Discussion

The present study explored patterns of digital exposure for infants in their first year of life, their links to the family environment, and later societal language skills. For infants from socioeconomically disadvantaged neighborhoods, three distinct patterns of fore- and background dosage and child-related intentions for digital media exposure were identified. These differed with respect to proximal and distal family factors crucial for language development. Compared to the zero dosage pattern, the higher fore- and background dosage pattern was predictive of lower receptive vocabulary almost a year later even when controlling for key family confounders. This indicates that the higher fore- and background dosage pattern captures consequential early experiences. Conversely, the moderate background TV dosage pattern was not predictive of lower vocabulary. There was no clear evidence in line with modulation of these (non) associations by interaction quality or picture book reading.

### Three Patterns of Digital Exposure

Infants' digital exposure was best described as one of three patterns. A quarter of infants experienced a pattern of zero dosage

**Table 5**
*Standardized Regression Coefficients (Standard Errors) for Receptive Vocabulary (Reference Category Is Zero Dosage)*

| Variable | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| Age child | .44 (.07)* | | | | .42 (.07)* |
| Female infant | .16 (.07)* | | | | .07 (.08) |
| Maternal education | | .02 (.09) | | | −.02 (.08) |
| Other family language | | .21 (.08)* | | | .14 (.08) |
| Household income | | .26 (.10)* | | | .16 (.09) |
| Maternal depression | | −.01 (.09) | | | .02 (.09) |
| Sensitivity | | | .14 (.11) | | −.03 (.11) |
| Stimulation | | | −.05 (.12) | | .04 (.10) |
| Picture book reading | | | .18 (.10) | | .08 (.09) |
| Moderate background TV dosage | | | | −.01 (08.) | −.03 (.09) |
| High fore- and background dosage | | | | −.34 (.10)* | −.25 (.09)* |
| $R^2$ | .21* | .13* | .05 | .12* | .35* |

*Note.* $N = 136$.
* $p < .05$.

**Table 6**
*Results of Interaction Analyses of Digital Exposure Patterns and Proximal Family Variables for Receptive Vocabulary (Reference Category Is Zero Dosage)*

| Variable | β | *SE* | *p* | 95% CI |
|---|---|---|---|---|
| Model 6 (sensitivity) | | | | |
| Moderate background TV dosage | −.16 | .90 | .86 | [−1.76, 0.98] |
| High fore- and background dosage | .04 | .85 | .86 | [−2.02, 1.50] |
| Sensitivity | .04 | .27 | .87 | [−0.40, 0.26] |
| Moderate Dosage × Sensitivity | .15 | .95 | .87 | [−1.00, 1.85] |
| High Dosage × Sensitivity | −.39 | .82 | .64 | [−1.92, 1.57] |
| Model 7 (stimulation) | | | | |
| Moderate background TV dosage | −.06 | .09 | .01 | [−0.23, 0.12] |
| High fore- and background dosage | −.31 | .12 | .01 | [−0.56, −0.08] |
| Stimulation | .10 | .16 | .51 | [−0.14, 0.36] |
| Moderate Dosage × Stimulation | −.00 | .14 | .99 | [−0.22, 0.21] |
| High Dosage × Stimulation | −.19 | .14 | .09 | [−0.45, 0.06] |
| Model 8 (picture book reading) | | | | |
| Moderate background TV dosage | −.02 | .09 | .81 | [−0.20, 0.16] |
| High fore- and background dosage | −.26 | .12 | .02 | [−0.49, −0.04] |
| Picture book reading | .21 | .19 | .26 | [−0.33, 0.57] |
| Moderate Dosage × Picture Book Reading | −.10 | .15 | .53 | [−0.44, 0.18] |
| High Dosage × Picture Book Reading | −.09 | .14 | .53 | [−0.36, 0.19] |

*Note*. $N = 136$. Model 6 and Model 7 controlled for the age of the child, gender of the child, maternal education, household income, family language, and picture book reading. Model 8 controlled for the age of the child, gender of the child, maternal education, household income, family language, and sensitivity and stimulation. Control variable coefficients are not shown. CI = confidence interval; *SE* = standard error.



of background or foreground TV or direct exposure to smartphones. Previous studies similarly suggest that some caregivers restrict early exposure to digital devices (e.g., Durham et al., 2021). Yet, note that zero direct exposure does not rule out indirect exposure to smartphones. Moreover, zero dosage might be a temporary phenomenon (Zimmerman et al., 2007).

Half of the infants experienced a pattern of moderate background TV dosage. These infants experienced shorter, more infrequent periods of foreground TV and direct exposure to smartphones. In this pattern, rare child-related instrumental intentions suggested that screen media may have been primarily serving mothers' entertainment, informational purposes, or to have the "company" of voices in the background, rather than being turned on for the child. Previous person-oriented analyses similarly demonstrated that lower dosage patterns can be characterized by caregivers allowing specific types of dosages with specific purposes (McClure et al., 2015). In our study of young infants, this specific type of dosage was mainly background TV. Given the infrequency of child-directed instrumental intentions in this group, in our study, the specific purpose was presumably related to the mother and not the child.

Another quarter of the infants experienced a pattern of higher fore- and background dosage with various child-related intentions. These infants received more frequent and longer exposure to TV, background TV, and direct contact with smartphones. Their mothers frequently endorsed several child-related intentions, particularly distracting infants to gain time and educating the infant. In this pattern, educational intentions were the second most commonly named, whereas they were one of the least commonly named intentions in the moderate background TV pattern. Educational intentions could be specifically targeting societal language learning: anecdotally, in this study, mothers with another family language mentioned to home visitors that they kept the TV on to support infants' societal language learning. Using digital media to educate or distract are prevalent intentions (Zimmerman et al., 2007). Such intentions could be motivating mothers' media decisions or could reflect mothers justifying their decisions (Cingel & Krcmar, 2013; Lauricella et al., 2015).

In the present study, co-viewing or co-use did not distinguish patterns. Most infants were usually in close physical proximity to mothers during exposure. That some mothers were using screen media to "gain time" indicates that solo-viewing does occur. However, at this age, co-viewing may be commonplace because young infants typically spend minimal periods without caregivers (Leyendecker et al., 1995). Mothers may also believe infants are incapable of handling smartphones alone (Archer, 2017). Another explanation for the similarly high shares of co-viewing is that the frequent co-viewing in the higher dosage pattern is a function of mothers' own device use instead of a deliberate attempt to support their infant (Anderson & Hanson, 2017).

In sum, well before infants' first birthday, distinct patterns captured more than just uniform level differences in dosage and the endorsement of child-related intentions of screen media exposure. For some facets, there were only more subtle level differences or none at all (e.g., background TV and co-viewing) and there were also shifts in the rank order of common intentions. Thus, the person-oriented approach revealed unique profiles of foreground- and background dosages and intentions. When simplistically measuring "screen time," prior work may have been implicitly capturing such differences in fore- and background dosages and caregiver intentions. Our person-oriented patterns make evident that dosage should not be viewed in isolation from other facets of exposure.

## Patterns Represent Accumulations of Resources and Risks to Societal Language Development

In accordance with the DREAMER framework, the three patterns differed regarding proximal and distal family environment features.

We first describe these differences for the socioeconomic factors, where they were particularly clear. Socioeconomic differences were in line with previous studies suggesting a "digital divide" in terms of dosage (Duch et al., 2013): The infants in the higher fore- and background dosage pattern were most and those in the zero dosage pattern least likely to have a mother without tertiary education or with a low household income. The higher fore- and background dosage pattern' mean household income was even situated in the vicinity of "poverty risk" (under 60% of the German median income, Statistische Ämter des Bundes und der Länder, 2022). Poverty indicates the presence of numerous additional biological (e.g., pre- and perinatal stress) and social risks (e.g., inadequate housing) for language development (Perkins et al., 2013). Pathways between low income and digital media exposure were not the focus of our study, but our findings provide clues on such. Among family stressors, only depressive symptoms distinguished the higher fore- and background dosage pattern. This suggests that depressive symptoms represent potential mediators between low income and digital exposure over and above more general strain or partnership discord. These findings generally align with a family stress model. They also correspond with previous work suggesting mothers use TV to cope with emotions (Bank et al., 2012; Reich et al., 2023). Moreover, findings support the DREAMER framework that posits the relevance of distal family characteristics for digital exposure (Barr et al., 2024).

In line with the previous findings, differences in the proximal family environment generally adhered to a similar gradient from zero to moderate to higher dosage (Detnakarintra et al., 2020; Gago-Galvagno et al., 2023). However, differences were more subtle and not always significant, particularly those between the zero and moderate background TV dosage patterns. Based on videos of mother–child interactions, mothers in the higher fore- and background dosage pattern were rated least sensitive. They also reported the lowest frequencies of picture book reading. Differences in early stimulation behavior and other activities were not significant. Yet, note that even though infants in the higher fore- and background dosage pattern were experiencing slightly less support for societal language development, on average their mothers were still rated as moderately sensitive and occasionally read, sang, and played with them.

The higher fore- and background dosage pattern also received the least support for the societal language in terms of their family language: this pattern included the highest shares of infants growing up with a heritage language (usually alongside German). This finding underscores the importance of understanding the specific impact of mothers' culturally shaped beliefs and acculturation-related stressors on infants' early digital exposure. Previous findings from the BRISE sample suggest that immigrant mothers were experiencing low social support during and after pregnancy (Samdan et al., 2022) that may have contributed to their infants' exposure pattern.

Overall, findings highlight how digital exposure patterns are embedded in a web of proximal and distal family resources and risks for societal language development. This includes differences in proximal family environment features assumed to be crucial for language development, as well as socioeconomic differences and certain family stressors. Specifically, a higher fore- and background dosage as well as using screen media not only to distract but also for educational purposes at a very young age coincide with an accumulation of risk factors for the societal language. It is of chief interest whether digital exposure patterns are independently impacting societal language development or are primarily a symptom of these associated risks and resources. Our findings underline that future studies need to consider a broad array of proximal and distal family factors as potential confounders.

## The Higher Dosage Pattern Predicts Lower Toddler-Age Vocabulary

The identified patterns of digital exposure were linked to societal language development. Compared to infants with zero dosage, only infants experiencing the higher fore- and background dosage pattern were reported to have what amounted to a quarter of a standard deviation smaller societal language receptive vocabulary at age 1.5. This disparity was evident even when important indicators of the proximal and distal family environment were controlled for, suggesting that it was not merely due to an absence of high interaction quality and language-rich activities. It also remained relatively stable in various robustness checks pertaining to language background, suggesting that the effect of digital exposure was not strongly biased by sample composition in terms of family language. The moderate background TV dosage pattern did not appear detrimental to societal language learning when compared to the zero dosage pattern. Several possible explanations for why only the higher fore- and background dosage pattern was linked to lower vocabulary focus on either dosage differences or patterns' specific combination of digital exposure facets.

If dosage was the key difference between patterns, it appeared to have a nonlinear or threshold effect. Such nonlinear relationships have been found in two previous studies (Dore et al., 2020; Martinot et al., 2021). Both for toddlers and first graders, a reverse u-shape suggested that children with "moderate" dosages had greater societal language skills or gains than those with low or high dosages. Those with the highest dosages had the lowest language skills or gains. Perhaps in those two studies and our study, moderate dosages were only displacing negligible amounts of interactions and language-rich activities (Dore et al., 2020; Martinot et al., 2021). Possibly only higher dosages of cluttered nonsocial 2D-input are sufficient to noticeably displace or disrupt interactions and word learning (Barr, 2019; Christakis et al., 2009; Clerkin et al., 2017; Jing et al., 2023). Alternatively, moderate digital exposure could occur during a time of day when children with zero dosage do not experience much support for language development (Dore et al., 2020; Martinot et al., 2021). Notably, there was a difference in the details: In our study, infants with moderate dosage did not outperform the zero dosage group on societal language vocabulary, they were equal. Unlike infants, older children may be able to learn some vocabulary from digital exposure (Dore et al., 2020; Martinot et al., 2021). Considering the "video deficit," cluttered visual input, and the displacement account, spending time with screen media is unlikely to benefit young infants' word learning (Barr, 2019; Christakis et al., 2009). Thus, beneficial effects of moderate dosage may only evolve sometime during the toddler age.

If the combination of facets in the patterns is key, at least two explanations are conceivable. Both are based on how the patterns relate to the social context of exposure and screen media characteristics (Linebarger & Vaala, 2010). First, background TV in the moderate dosage pattern could disrupt caregiver–infant interactions less severely than foreground TV in the higher dosage pattern. Even though laboratory studies demonstrate that foreground co-viewing of educational programs can elicit high-quality

interactions (Anderson & Hanson, 2017), infants' typical digital foreground fare may not (Henderson et al., 2024)—particularly several months before infants' first birthday. Second, if mothers in the moderate dosage pattern had the TV on for their own purposes, they may have been exposing infants to adult-directed content. Adult-directed content could resemble the speech stream of overheard speech on which infants can perform statistical learning (Linebarger & Vaala, 2010; Linebarger & Walker, 2005; Saffran, 2020). However, findings are inconclusive on whether adult-directed content is beneficial or particularly detrimental (Linebarger & Walker, 2005; Tomopoulos et al., 2010). Moreover, these explanations hinge on constructs that were not assessed. Future studies could incorporate verbal media interactions and program features into more comprehensive person-oriented analyses of digital exposure (see Holmgren et al., 2023 for toddlers).

## No Environmental Interplay?

This study was able to test the often-neglected interplay between digital exposure and the nondigital proximal family environment in relation to societal language outcomes (Barr et al., 2020). Previously found "compensatory" moderating effects of a higher SES (Xie et al., 2024) imply that interaction quality and language-rich activities could buffer negative dosage effects. However, in the present study, there was barely any evidence for a statistical interaction between digital exposure patterns and proximal features of the family environment. Digital exposure appeared to affect (or not affect) societal language independently from mothers' sensitivity and stimulating behavior toward their infants or shared picture book reading. Thus, our findings lend no support to the idea that high interaction quality and frequent picture book reading can "compensate" for any effects of infant digital exposure. Early interaction quality and picture book reading do predict toddler language, but associations are small (Attig & Weinert, 2020; National Institute of Child Health and Human Development Early Child Care Research Network, 2000). Therefore, such modest effects may not suffice to counteract strong negative effects of high fore- and background digital exposure. Moreover, interaction quality has many additional facets (e.g., warmth, scaffolding, joint attention, caregiver language quantity, and quality) that relate to early language development (Rowe & Snow, 2020). These additional facets could also modulate digital exposure effects and should be included in further studies.

What is more, due to power constraints, we were unable to test interactions between digital exposure patterns and family language. Various forms of environmental interplay are possible. On one hand, whether digital exposure represents a "lost resource" for a certain language depends on what languages are spoken in a household. Unlike compensatory effects, "lost resources" imply that negative effects of media exposure are strongest for children with the greatest "resources" for a certain language. If digital exposure displaces and disrupts interactions and language-rich activities—resources—for the heritage language, that might not affect societal language development. On the other hand, digital exposure could negatively affect societal language learning regardless of family language. For example, by impeding heritage language vocabulary acquisition, digital exposure could hinder transfer of conceptual vocabulary knowledge from the heritage to the societal language (Pavlenko, 2009). In sum, although we could not show evidence for statistical interactions, this should not be interpreted as the absence of environmental interplay.

## Limitations

To our knowledge, this is a first study of very early patterns of digital exposure and their interplay with the family environment in a socioeconomically disadvantaged context. Yet, several limitations related to measurement and unobserved confounders should be considered.

First, information on content, age-targeting, application interactivity, mobile versus stationary devices, socially contingent media use (e.g., video chat), joint media interactions beyond mothers' mere presence, as well as other family members' media usage are urgently needed to gain a full picture of infants' digital exposure. The Comprehensive Assessment of Family Media Exposure Consortium's set of measures generates such rich data. These include a media use survey that can enhance comparability between parent estimates by establishing a standard item format (our measure deviates from others by separating frequency and duration). They also include diaries and mobile sensing techniques that circumvent potential bias from caregivers over- or underestimating dosages (Barr et al., 2020). Second, caregiver reports of vocabulary are widely used. Still, early vocabulary is highly dynamic during the vocabulary spurt and expressive vocabulary or other language domains, such as grammar and phonology, could be differentially affected.

Third, for children exposed to a language other than German at home, a more complete assessment of the language of screen media exposure and activities, as well as overall family language environments (e.g., quantity and quality of heritage and societal language exposure) is essential. Omitting these factors could have biased the higher dosage pattern's negative effect on societal language vocabulary. Toddlers exposed to another language at home may also have had large receptive vocabularies in their heritage language. Neglecting these prohibits conclusions on "language development." Fourth, our latent mixture models are conducted on a highly linguistically diverse sample including infants who were exposed only to a heritage language. Our findings on societal language are limited to a smaller group of children who heard mostly or solely German at home. Robustness checks suggest that our results are not severely biased. Yet, future studies need to consider impacts of digital exposure for all subgroups of children from immigrant families in sizeable samples.

Fifth, due to current data availability, this investigation was restricted to using single-wave predictors and outcomes (even though the digital exposure measure preceded the language outcome by nearly 1 year). Future publications using forthcoming scientific use files of BRISE data will be able to make use of more sophisticated modeling techniques, such as relating change in exposure to change in multiple developmental domains up into the elementary school years.

## Research Implications

We have shown that even within socioeconomically disadvantaged neighborhoods, heterogeneity in infants' digital exposure occurs in the form of distinct subgroups, is entwined with further variation in the family environment, and relates nonlinearly to children's societal language. Thus, our findings support the call to finally move beyond imposing simplified linear dosage models (Mannell et al., 2024) and understand the reality of digital exposure (Barr, 2019). Other subfields of developmental science show that dosage as a concept subsuming frequency, intensity and durational aspects of children's experiences

is useful (Wasik & Snell, 2019). Yet, isolating the effects of such is a challenge as they often interact with other facets of the same experiences. Intervention studies can be of aid.

In addition, refining the theory of digital exposure (e.g., understanding the merit of the "displacement" concept), dosage effects (e.g., confirming nonlinear effects), and fleshing out the differential effects suggested by the DREAMER framework (e.g., identifying family moderators) requires gathering rich longitudinal information on digital exposure and family processes. This includes naturalistic observations during and outside of digital exposure (Anderson & Hanson, 2017; Barr et al., 2020; Christakis et al., 2009). Longitudinal measurements over the course of early childhood could identify how effects of digital exposure change over time. For example, it is conceivable that even moderate dosage accumulates over the years and unfolds negative effects later on. It is also possible that there are sensitive periods during which digital exposure is particularly detrimental to word learning. Longitudinal designs would enable tracing cascading effects of digital exposure via early word learning to later language and other domains (e.g., socioemotional development, Huang et al., 2024). Such designs should be repeated in various macro contexts and time periods as, for example, different social welfare systems or a pandemic could affect caregivers' need and willingness to heavily rely on digital screen media. Person-oriented analyses and other data-driven techniques are tools to make such complex data manageable.

## Practice Implications

The World Health Organization (2019) recommends total screen abstinence for babies that many caregivers are not heeding (McArthur et al., 2022). Our study suggests not all screen exposure is detrimental to societal language of infants growing up in socioeconomically disadvantaged neighborhoods. Yet, the most socioeconomically disadvantaged caregivers are hoping for benefits. For the early infant stage, beneficial uses are not yet well enough understood to make recommendations. Instead of futile prohibitions, clear messaging via social media can communicate that total digital abstinence is not necessary, but baby learns much better from enjoying interactions with expert speakers of a language—mom, dad, siblings, neighbors—than from spending extended periods with digital screen media.

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