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REPORT

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Infant placement and language exposure in daily life

Lauren G. Malachowski | **Virginia C. Salo** | **Amy Work Needham** | **Kathryn L. Humphreys**

Department of Psychology and Human Development, Vanderbilt University, Nashville, Tennessee, USA

Correspondence
Lauren G. Malachowski, Department of Psychology & Human Development, 230 Appleton Place, Nashville, TN 37203, USA.
Email: lauren.g.malachowski@vanderbilt.edu

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Abstract

Children's daily contexts shape their experiences. In this study, we assessed whether variations in infant placement (e.g., held, bouncy seat) are associated with infants' exposure to adult speech. Using repeated survey sampling of mothers and continuous audio recordings, we tested whether the use of independence-supporting placements was associated with adult speech exposure in a Southeastern U.S. sample of 60 4- to 6-month-old infants (38% male, predominately White, not Hispanic/Latinx, from higher socioeconomic status households). Within-subject analyses indicated that independence-supporting placements were associated with exposure to fewer adult words in the moment. Between-subjects analyses indicated that infants more frequently reported to be in independence-supporting placements that also provided posture support (i.e., an exersaucer) were exposed to relatively fewer adult words and less consistent adult speech across the day. These findings indicate that infants' opportunities for exposure to adult speech 'in the wild' may vary based on immediate physical context.

KEYWORDS

infant containers, infant placement, language exposure, seating devices

With advances in wearable technologies, we now have 'unprecedented access' to the day-to-day activities of infants' lives (de Barbaro, 2019). Developmental researchers are increasingly interested in characterizing these activities as a way to understand the rich and varied contexts in which development unfolds. Context is critical within the ecodevelopmental framework, an extension of Bronfenbrenner's model that explicitly incorporates developmental processes with children's contexts (Szapocznik & Coatsworth, 1999). Central to this framework are the *connections* or *interactions* between microsystems (i.e., components of the immediate environment), and characterizing these interactions is one way to understand everyday inputs to learning. For example, recent work has explored how the specific type of activity infants are engaged in (one component of the immediate environment) is linked to the content of adult language they experience during that activity (another component of the child's immediate environment; Tamis-LeMonda, Custode, et al., 2019).

One of the most basic—yet understudied—components of a child's immediate environment is where they spend time. For pre-mobile infants, this can be considered *infant placement*, as where they spend time is largely dependent on where they are placed by a caregiver. While awake, infants spend time in a variety of places, including on the floor, in a caregiver's arms, strapped to a caregiver's back, etc. In the United States, infants also spend considerable amounts of time in infant seating devices (e.g., bouncy seats, exersaucers, infant swings; Callahan & Sisler, 1997; Hallam et al., 2018). From an ecodevelopmental perspective, it is important to understand how infant placement may *interact with* other components of the immediate environment to shape infants' opportunities for learning.

Existing evidence indicates that infant placement shapes infants' exposure to adult speech. In one study, researchers audio-recorded 36 parents and their 7- to 11-month-old infants as they took a brief walk down the street (Mireault et al., 2018). Using a within-subject counterbalanced design, they found that parents and infants engaged in more back-and-forth vocal exchanges when the infant was strapped to the caregiver in an infant backpack compared to when the infant was being pushed in a stroller. In another within-subjects study of 20 mothers and their 5-month-old infants, infants experienced more verbal responsiveness to changes in their own behaviour when strapped to their mothers in infant carriers compared to when seated in an infant chair across from their mothers in a lab setting (Little et al., 2019). In both of these studies, manipulating infant placement altered patterns of verbal interaction with caregivers.

Mireault et al. (2018) suggest that, compared to a stroller, an infant backpack encourages infants to stay alert and attentive and promotes a greater degree of shared visual space with caregivers, thus prompting more ‘conversation’ between infant and caregiver. Little et al. (2019) suggest that the close physical contact afforded by the infant carrier allows caregivers to recognize, and respond to, infants' subtle cues. However, it remains unclear exactly which characteristics of these different placements contributed to differences in verbal interaction. The two placements being compared in each study differed in a number of ways, including physical contact, but also infant independence from their caregiver, posture support and vantage point. In the present study, we will investigate how two of these characteristics—infant independence and posture support—may be associated with language exposure in a Southeastern U.S. community.

We define *independence* as the infant's ability to play with objects or observe their surroundings without direct support from a caregiver. Strollers and infant chairs, but not backpacks and infant slings worn by a caregiver, promote infant independence because they allow infants to safely play or observe without being physically reliant on a caregiver. Other typical placements that support infant independence in this way include playmats, infant gyms, exersaucers and bouncy seats, all of which allow the infant to safely play or observe without necessary interaction with or physical support from a caregiver. When an infant is in one of these placements, caregivers may—intentionally or unintentionally—reduce verbal interaction with their infants to avoid interrupting their infant's play, or to focus their own attention elsewhere (e.g., cooking, showering, attending to a sibling). Thus, we propose that *infant independence* may be responsible for links between certain types of infant placement and infant–caregiver verbal interactions.

Seating devices, which provide a high level of artificial posture support (apart from a caregiver), may especially promote infant independence. Posture support has been found to promote manual object play in pre-sitting infants by freeing up the arms (Mlincek et al., 2022; Soska & Adolph, 2014). Posture support has also been found to expand the infant's visual field compared to lying prone or supine (Kretch et al., 2014). Thus, when an infant's posture is supported, they may be even more likely to engage in independent object play or observation of their surroundings.

As a result, placements supporting both independence and posture (independent + posture placements) represent a sub-category of independent placements that may be associated with even further-reduced verbal interaction.

Exposure to adult speech is an important form of input to consider in relation to infant placement because it serves as a ‘proxy’ for meaningful interactions with caregivers that provide rich opportunities for learning (Tamis-LeMonda, Kuchirko, et al., 2019). Importantly, adult speech is a critical contributor to infants' language development (e.g., Newport et al., 2001; Suanda et al., 2019; Tomasello, 2000; Waxman & Gelman, 2009). Exposure to a ‘language-rich’ environment is prospectively associated with skills in a number of language-relevant domains, including word knowledge, language processing and reading (Golinkoff et al., 2018; Hoff, 2003; Rowe, 2013; Wang et al., 2020; Weisleder & Fernald, 2013; Zauche et al., 2016). Quantity of language input even in the first months of life may shape brain activity presumed to support language development: five- to eight-month-old infants who engaged in more daily verbal exchanges with caregivers had lower connectivity in the posterior temporal language network (King, Camacho, et al., 2021). While the quantity of language input may contribute to the development of language-related skills, the *consistency* of language input may be of particular relevance to children's socio-emotional development. More consistent adult speech (i.e., a higher proportion of 5-min audio segments from daylong recordings containing adult speech) in infancy was associated with lower symptoms of psychopathology in toddlerhood (King, Querdasi, et al., 2021).

Importantly, from an ecodevelopmental perspective, children's exposure to language cannot exist apart from the influence of other ecosystems (i.e., immediate physical environment). In the present study, we explore interactions between infant placement and children's exposure to language in a Southeastern U.S. community. We hypothesized that placements supporting infant independence would be associated with exposure to fewer adult words. Given the importance of capturing naturalistic activity, we selected remote data collection methods to assess ‘real-life’ infant placement and language exposure. This study design also allowed us to assess both real-time links between placements and language exposure *and* differences in daily language exposure based on patterns of sampled infant placement. We collected data on infant placement and language exposure from a sample of 60 mother–infant dyads. Dyads were provided with infant-worn recording devices to capture three full days of the child's language environment. On those same days, mothers were prompted via text message to respond to survey questions regarding their infant's current placement. Study design, study methods, hypotheses and planned analyses were preregistered on OSF (https://osf.io/wm6fb/?view_only=9a065d575b744e2288e2c257fc862a5c).

Overall, we conducted two sets of analyses: one *within-subject* (i.e., are infants exposed to fewer adult words when spending time in independence-supporting placements compared to other placements?) and one *between-subject* (i.e., are children who spend more, vs. less, time in independence-supporting placements exposed to overall fewer adult words?). Within each set of analyses, we targeted placements supporting independence (pre-registered) as well as placements supporting both independence and posture support (exploratory).

1 | METHODS

1.1 | Participants

Sixty mothers and their 4- to 6-month-old infants ($M = 5.13$ months, $SD = 0.82$) in a metropolitan area in the Southeastern United States were recruited for participation via Facebook ads, flyers and emails (identified using names from state birth records and university address books). Data collection occurred between October 2019 and December 2020. Inclusion criteria were that mothers spoke primarily English at home and infants were singletons between 4 months, 0 days and 6 months, 0 days at the start of the study; born greater than 35 weeks gestation; and without major medical or developmental diagnoses (62% female, 38% male).

In order to assess links between infant placement and language exposure, we selected an age range in which caregivers often use a number of placement options. Between the ages of 4 and 6 months, infants are old enough to use devices that do not provide head/neck support (e.g., an exersaucer), but they still spend time in swings and bouncy seats designed for use starting at younger ages. Additionally, on average, six-month-olds are not able to locomote independently. The onset of independent locomotion marks a dramatic shift in infants' ability to choose where they spend time (Chen et al., 2022), adding additional complexity to the link between placement and language exposure. We chose to exclude the newborn period (0–3 months) because it would have required substantially more data collection to capture enough observations when infants were awake and alert for analysis.

Infants in the sample were primarily White (White: 85%; Black: 8%; Asian: 2%; More than 1 Race: 5%), which is roughly representative of the sampled region. Mothers were also primarily White (White: 90%; Black: 5%; Asian: 3%; More than 1: 2%). Four mothers (7%) identified themselves and their infants as Hispanic or Latinx. Household incomes ranged from \$20,000–29,000 to \$250,000+, with the median household income in the \$100,000 to \$149,999 category. The number of people living in each household ranged from 2 to 6 ($M = 3.63$, SD $= 0.96$). Income-to-needs ratios (INR) were calculated by dividing the median point in the reported income bin by the U.S. Department of Housing and Urban Development's low-income threshold for the number of people in the household for the county in which the University resides (2020). The INR ranged from 0.33 to 4.22 ($M = 1.82$, SD $= 0.89$), with ratios <1.0 ($n = 10$) considered low income based on local thresholds. Mothers were between 22 and 39 years old ($M = 32.04$ years, SD $= 3.69$) and tended to be highly educated; 90% of mothers had completed a bachelor's degree. Of the 60 mothers in the sample, 41 were actively employed (68%), 14 were homemakers (23%), 4 (7%) were students and 1 (2%) was out of work. Twenty-eight per cent of infants in our sample were in full-time childcare.

1.2 | Study procedures

1.2.1 | Consent

We received approval from the Vanderbilt University Institutional Review Board for all components of this study. After being screened and consented, participants completed an initial session, during which participants received instructions for the remainder of the study. Participants then completed three 'study days', in which infants' audio environments were captured using an audio recording device and mothers completed surveys about their infants' current placement (e.g., held, swing, car seat) and whether their infants were awake or asleep. We asked mothers to schedule their study days when they planned to be with their infant for the majority of the day in order to facilitate more accurate reports of the infant's current placement. All 3 days of data collection were completed within a 1-month period.

1.2.2 | Measuring infant placement

Using seating device listings from popular U.S. baby registry sites (e.g., Target.com) and naturalistic videos of infants in their homes (Bergelson, 2017), we created a list of possible infant placements. From this list, we highlighted placements likely to support infant independence. Independence-supporting placements included swings, exersaucers, car seats, strollers, walkers, infant chairs as well as infant gyms, the floor (e.g., infant lying on playmat) and furniture (e.g., infant propped up on a couch). All remaining placements were marked as 'other'.

We created a secondary categorization scheme focused on the combination of independence and posture support. Items in this category included bouncy seats, exersaucers, car seats, strollers, floor seats and swings (commonly called 'seating devices' or 'containment devices'; hereafter this category is referred to as seating devices). We also included high chairs in this category. High chairs can be used in highly-interactive mealtime contexts *or* as seating devices to promote independence. Here, we categorized highchairs as seating devices because they share many physical properties with the other items in this category.

Infant placement was assessed via Ecological Momentary Assessment (EMA), a survey technique used to sample naturalistic and real-time behaviour. On each study day, we used an integration of Twilio (2008) and REDCap (P. A. Harris et al., 2009, 2019) to deliver 12 text messages per day that prompted mothers to report on their infants' current placement. These were timed to be sent at semi-random intervals such that successive messages would be sent at least 30 min apart and between the infant's typical wake and night sleep times.

We asked mothers to select study days on days when they planned to care for their infants for the majority of the day. However, we did not expect or require that mothers would be the only ones caring for their infants on these days. To account for this possibility, the first question in our survey asked participants to report on whether they were aware of their infant's exact placement. The purpose of this question was to prevent participants from guessing their infant's placement or from changing their behaviour.

If mothers endorsed knowing their infants' placement, they were asked to select their infant's current placement from a pre-specified list. Selection of 'floor' or 'furniture' prompted a follow-up question about whether or not they were providing physical support to their infant, allowing us to more accurately assess whether a given placement promoted infant independence. We instructed participants to report on infant placement *as soon as they could safely do so*. See Table 3 for percentages of responses falling into each pre-specified category.

We chose this EMA technique to maximize the information gained (e.g., exact dates and times of infant placement) while minimizing the burden on participants (e.g., by avoiding the collection of video data or direct observation by an experimenter). Additionally, we made a number of methodological decisions to increase our chances of capturing behaviour that appropriately represents participants' everyday lives. First, we chose semi-random survey sampling to capture behaviour at various times throughout the day and to prevent participants from anticipating survey prompts. Second, we chose to average responses across three different days in order to minimize the impact of external variables that may have shaped behaviour on a given day (e.g., illness, high stress). Additionally, participants were able to cancel or reschedule their study days at any time in the event of illness or a family emergency. Last, we did not inform participants of our specific study hypotheses (see Consent Form in the Supplementary Materials), and thus it is unlikely that participants altered their behaviour or survey responses to meet experimenter expectations. Like all observational methods, it is possible that our EMA methodology altered participants' behaviour; however, EMA is generally less intrusive than direct observation or video-recording, which tend to be associated with high levels of participant reactivity (Haidet et al., 2009; F. C. Harris & Lahey, 1982).

1.2.3 | Measuring language exposure

Language exposure was measured via the LENA system (Gilkerson & Richards, 2009). The LENA algorithm is designed to identify and provide estimates of speech 'near and clear' to the infant (as opposed to distant and unclear speech). Evidence suggests that speech clarity is critical for language development (Liu et al., 2003). Additionally, clear speech may signify the proximity of caregivers. The primary reason for using LENA's Adult Word Count metric was that it allowed us to quickly analyse approximately 2880 h of naturalistic audio data without the need for human transcription. A recent review indicated that LENA-generated Adult Word Counts are strongly associated with word counts derived from human transcription ($r = 0.76$) and are a helpful tool for capturing differences in AWC across audio clips (Cristia et al., 2021). We completed our own validation of the LENA metrics by transcribing one randomly-selected 5-min segment of audio from each participant. The first author manually transcribed all audible speech from the recording, and the resulting word count was compared with the LENA-generated AWC from the same audio clip. In total, 59 5-min audio segments were transcribed (one participant did not consent to their raw audio recordings being saved or stored by our lab team after we obtained adult word count metrics from the LENA software). The overall ICC between LENA and human estimates of adult word counts was 0.85, indicating good reliability. Importantly, LENA-derived language metrics are consistently predictive of language outcomes, suggesting that they capture meaningful information about the early language environment

(Wang et al., 2020). Although LENA-estimated metrics are less accurate than human transcription, the increased efficiency of the LENA system offsets the drawback in relative accuracy.

Participants received portable recording devices and a set of custom-made LENA vests. On each study day, participants were instructed to power on a LENA recording device, place the device into a pocket on the chest of the infant vest and place the vest on their child for the remainder of the day. After being powered on, the LENA device continuously recorded for 16 h. After retrieving recording devices from participants, researchers used LENA software to obtain adult word counts (i.e., the number of distinct adult words spoken within range of the LENA device) at both the 5-min level (e.g., adult word counts for each 5-min segment in the recording) and the daylong level (e.g., a total adult word count for the entire 16-h recording). See the supplement for more details about study procedures.

To protect participant privacy and confidentiality, audio files and resulting summaries were never saved in conjunction with personal or identifying information (such as names or birthdates). Full audio files were stored on a secure, password-protected server. To follow the latest best practices on long-form audio recordings (see Cychosz et al., 2020), we edited our phone screen and consent form language mid-study (after 15 of 60 participants had completed the study) to include more explicit language about (1) what might be captured by recording devices (e.g., 'sensitive information' and 'unflattering interactions'), (2) participants' rights to request the silencing of audio segments or deletion of entire audio files, and (3) the possibility that researchers from our lab may listen to and transcribe segments of audio data.

1.3 | Specific measures

1.3.1 | Infant placement: independence support

Because we were interested in infants' language exposure while they are awake, we removed all survey responses ($n = 618$) in which the mother reported that the infant was sleeping. We also removed all responses where the mother entered 'other' ($n = 20$) as the infant's placement instead of selecting one of the response options because we did not have pre-determined hypotheses about the hand-entered items. Some of these items (e.g., bathtub, outdoor tent) were items that we did not pre-identify based on popular baby registry websites or pilot videos. Other responses were ambiguous (e.g., it was unclear whether a response of 'nursing pillow' meant that the infant was nursing or that the infant was alone on the floor on a nursing pillow). The remaining responses, selected from a set list of options, were then coded as either 'supporting independence' or 'other' based on our pre-registered list. In sum, there were 614 observations (46%) in the 'independence-supporting' category and 714 observations (54%) in the 'other' category. On average, 22.13 responses were analysed per participant (SD = 4.19, min = 11, max = 30).

For each participant, we also estimated the frequency of independence-supporting placements by taking the total number of 'awake' survey responses indicating use of one of these placements (across days of data collection) and dividing it by the total number of survey responses submitted while infants were awake. For example, a score of 0.5 indicated placement in independence-supporting placements (e.g., seating devices, floor without support) on 50% of survey responses when the infant was reported to be awake.

1.3.2 | Infant placement: seating devices

As above, survey responses indicating sleep were removed. Each infant placement survey response was coded as 'seating devices' or 'other'. Bouncy seats, exersaucers, swings, walkers, jumpers, high chairs, floor seats (e.g., Bumbo), car seats and strollers were included in this category. All other placements, including the 20 hand-entered responses (e.g., bath, nursing, outdoor blanket, outdoor tent), were coded as 'other' after confirming that none of these items would clearly fall into our seating device category (i.e., support both independence and posture support). In sum, 323 observations were placements in seating devices (24%) and 1024 observations of 'other' placements (76%) were analysed. On average, 22.45 responses were analysed per participant (SD = 4.15, min = 11, max = 30).

For each participant, we also estimated the frequency of seating device placement by taking the total number of 'awake' survey responses indicating placement in seating devices (across days of data collection) and dividing it by the total number of survey responses submitted while infants were awake. For example, a device use score of 0.5 indicated the use of seating devices on 50% of the total submitted survey responses when the infant was reported to be awake.

1.3.3 | Adult words per minute

LENA software uses sound frequency information to calculate adult words spoken near the LENA device (Gilkerson & Richards, 2020). Adult word counts can then be extracted in 5-min segments throughout each 16-h audio recording (e.g., 8:00 AM–8:05 AM, etc.). For ease of interpretation, we calculated words per minute values for each 5-min segment by dividing the total number of adult words within each 5-min segment by 5.

1.3.4 | Mean daily adult word count (AWC)

For each participant, we calculated an average daily adult word count by taking the mean of the LENA adult word count values across the 3 days of data collection. All but two recordings were 16 h long; one participant ended two recordings just after the infant's typical bedtime after 11.62 and 11.76 h of recording, respectively. Six participants in our sample were missing 1 day of audio data due to participant error (i.e., failing to record on the device; $n = 4$), technical errors (i.e., malfunction during audio offloading; $n = 1$), or loss of the device ($n = 1$). In these six cases, adult word count values were averaged across 2 days of data collection instead of three. Word count values were highly similar for those with 2 days ($M = 14{,}973.50$, SD = 2657.56) compared to 3 days of recording ($M = 14{,}916.33$, SD = 5562.64), $d = 0.01$.

1.3.5 | Consistency of language exposure

Given evidence linking higher levels of language input consistency (i.e., the proportion of recorded time segments containing at least one adult word) to toddler outcomes (King, Camacho, et al., 2021), we included a measure of language consistency as a metric of the early language environment. For each participant, we summed the total number of 5-min segments (across multiple days of data collection) containing an adult word count value ≥1 and divided this number by the total number of 5-min segments. For example, a value of 0.5 would indicate that at least one adult word was picked up by the LENA device in 50% of all 5-min segments present in the recordings.

1.3.6 | Additional variables

Basic demographic information was collected from mothers, including maternal age, infant age, race, ethnicity, household income range (reported in bins ranging from $0–10,000 to $250,000 or more), years of education completed, number of people living in the home and number of siblings.

1.4 | Data analysis

Prior to addressing our primary hypotheses, we explored potential family-level, parent-level and child-level covariates. Specifically, we ran correlations between our variables of interest and household size (i.e., number of people living in the home), income-to-needs ratio, infant age and years of maternal education. We did not find statistically significant correlations between measures of language exposure (AWC and Consistency) and demographics variables (income-to-needs ratio, number of people living in the home, infant age, years of maternal education). See Table S2 in the supplement for complete results. Given our findings, we did not include these variables in our primary analyses.

1.4.1 | Within-subject associations

We used R version 4.0.5 (R Core Team, 2020) for all analyses. To assess temporal links between infant placement and language exposure (*within-subject* approach), we matched each survey response indicating awake infant placement to the corresponding words per minute value. We used the *foverlaps* function in the 'data.table' package (Dowle & Srinivasan, 2019) to match the submission timestamp for each survey response to the 5-min LENA interval containing that timestamp. For example, if a participant submitted a survey indicating the use of a bouncy seat at 8:42:05 AM, this response was matched with the LENA recording interval 8:40:00 AM–8:45:00 AM. Our LENA devices (serial numbers 20,000 and above) were designed to control for internal clock drift during recordings, increasing our confidence that survey timestamps fell within the appropriate LENA intervals. As an extra precaution, we re-set any devices that had been sitting idle for long periods of time before sending them to participants.

We then constructed a two-level multilevel regression model with Adult Word Count as the outcome variable, allowing us to examine the fixed effect of placement while accounting for the clustering of observations within families:

$$\text{Adult Word Count}_{ij} = (b_0 + \mu_{0j}) + b_1\text{Placement}_{ij} + \varepsilon_{ij}$$

$$i = \text{observation}$$

$$j = \text{participant}$$

Before collecting data, we preregistered a random intercepts and random slopes model with a Poisson distribution, a common specification when modelling count data (Inouye et al., 2017). Results from our pre-registered model are included in the supplement. However, the dispersion of outcome data better fit a negative binomial distribution. Specifically, to account for overdispersion in our data, we used the *glmer.nb* function (R Core Team, 2020), which specifies a negative binomial distribution (an extension of the Poisson distribution). Infant placement was entered as a dichotomous predictor—with independence-supporting placements coded as 1 and all other placements coded as 0—and modelled as a fixed effect. Using a build-up strategy based on model fit indices, the final model included random intercepts but not random slopes for infant placement; random intercepts allowed words per minute values when infant placement was equal to 0 (i.e., 'other') to vary by family. These procedures were repeated with our second categorization of infant placement (seating devices vs. other).

1.4.2 | Between-subject associations

To assess *between-subject* links between frequency of use of independence-supporting placements and language exposure, we modelled (1) mean daily adult word count and (2) consistency of language exposure as a function of independence-supporting placement frequency using separate simple linear regressions. Frequency of independence-supporting placement ranged from 0.15 (i.e., 15% of submitted survey responses indicating an independence-supporting placement) to 0.76 ($M = 0.47$, SD = 0.13). Mean daily adult word count was winsorized such that one extreme value (33,235, more than 2.5 SDs above the mean) was replaced with the next highest observed value (27,573.67). After winsorizing, the mean daily adult word count ranged from 4613 to 27,573 words ($M = 14{,}873.68$ words, SD = 5357.46). We obtained highly similar results using raw values.

Regression analyses were repeated with placement in seating devices. Frequency of sampling in seating devices was winsorized such that two values more than 2.5 SDs from the mean (0.63 and 0.65) were replaced with the next-highest value (0.50). After winsorization, frequency ranged from 0 to 0.5 ($M = 0.23$, SD = 0.12). As above, we obtained highly similar results using raw values. Data and R code supporting our primary analyses have been made publicly available on OSF (https://osf.io/wm6fb/?view_only=9a065d575b744e2288e2c257fc862a5c).

2 | RESULTS

2.1 | Descriptive statistics

Consistent with a previous EMA study with parents of young children (Franchak, 2018), participants in the present study had a high response rate, completing an average of 33 of 36 possible text-message surveys across 3 days of data collection. Of these responses, only 33 total responses across participants indicated that mothers could not report on their infant's placement (an average of less than 1 'no' response per participant). The number of 'no' responses was not statistically significantly associated with daily AWC ($r = -0.19$, $t[59] = -1.46$, $p = 0.15$) or with the frequency of seating device use ($r = -0.13$, $t[58] = -0.98$, $p = 0.33$).

The average (as opposed to single rater) ICC between AWC values across the 3 days was 0.72, and the average ICC between our seating device use frequency variable across the 3 days was also 0.72. Together, these ICC values indicate moderate consistency in both adult word counts and the use of seating devices across study days.

2.2 | Independence-supporting placements

2.2.1 | Within-subject associations

Confirming our first preregistered hypothesis, infants were exposed to statistically significantly fewer words while in independence-supporting placements compared to other placements. As indicated by the Incidence Rate Ratio in Table 1, being in an independence-supporting placement, compared to another placement, was associated with fewer words by a factor of 0.57. Model-predicted means for words per minute values were 17.90 for independence-supporting placements and 31.48 for other placements.

2.2.2 | Between-subject associations

We did not observe a statistically significant difference in mean daily adult word count based on the frequency of time spent in independence-supporting placements, $B = -5545$ (SE = 4990), $p = 0.271$, $R^2 = 0.03$, $F(1,58) = 1.23$. We also did not observe a statistically significant difference in adult word count *consistency* based on time spent in independence-supporting placements, $B = -0.06$ (SE = 0.10), $p = 0.533$, $R^2 = 0.01$, $F(1,58) = 0.39$. Thus, these data did not support our second pre-registered hypothesis that overall time spent in independence-supporting placements would explain between-child differences in language exposure.

TABLE 1 Results from 2-level model with negative binomial distribution predicting adult words per minute.

Predictors	Incidence rate ratios	CI	*p*
(Intercept)	157.35	138.51–178.77	<0.001
Independence-supporting placement [1]	0.57	0.49–0.66	<0.001
Random effects			
σ^2	1.05		
$\tau_{00\ \text{Participant ID}}$	0.09		
ICC	0.08		
$N_{\text{Participant ID}}$	60		
Observations	1328		
Marginal R^2/Conditional R^2	0.07/0.14		

Note: Infant placement was entered as a dichotomous predictor, with 'independence-supporting' coded as 1 and 'other' coded as 0.

TABLE 2 Results from 2-level model with negative binomial distribution predicting adult words per minute.

Predictors	Incidence rate ratios	CI	*p*
(Intercept)	134.91	120.64–150.86	<0.001
Seating devices	0.74	0.62–0.89	<0.001
Random effects			
σ^2	1.06		
$\tau_{00\ \text{Participant ID}}$	0.07		
ICC	0.06		
$N_{\text{Participant ID}}$	60		
Observations	1347		
Marginal R^2/Conditional R^2	0.01/0.08		

Note: Infant placement was entered as a dichotomous predictor, with seating devices coded as 1 and 'other' coded as 0. Because 'other' responses indicated by participants could be clearly grouped into the 'other' category, we included 'other' responses in these analyses, resulting in a higher number of observations compared to our analyses with all independence-supporting placements.

2.3 | Seating devices

2.3.1 | Within-subject associations

Exploratory analyses indicated that infants were exposed to statistically significantly fewer words while in seating devices compared to other placements. As indicated by the Incidence Rate Ratio in Table 2, being in a seating device, compared to another placement, reduced the expected number of words by a factor of 0.74. Model-predicted means for words per minute values were 19.98 for seating devices and 27.58 for other placements.

2.3.2 | Between-child associations

Frequency of seating device placement was statistically significantly associated with mean daily adult word count, $F(1,58) = 6.47$, $p = 0.014$, $R^2 = 0.10$, such that infants who were more often reported to be in seating devices

TABLE 3 Frequency of non-sleep survey responses.

Placement	% of Total observations
Held	41.13%
Floor without physical support	9.21%
Exersaucer	5.49%
Car seat	5.35%
Crib	4.60%
Gym	4.31%
Furniture (e.g., couch) without physical support	4.23%
Stroller	3.34%
Highchair	3.04%
Furniture (e.g., couch) with physical support	3.04%
Changing	2.52%
Pillow	2.30%
Bouncer/Rocker	2.23%
Floor with physical support	1.86%
Swing	1.56%
Floor seat	1.41%
Worn	1.41%
Other	1.41%
Walker	1.19%
Doorway jumper	0.30%

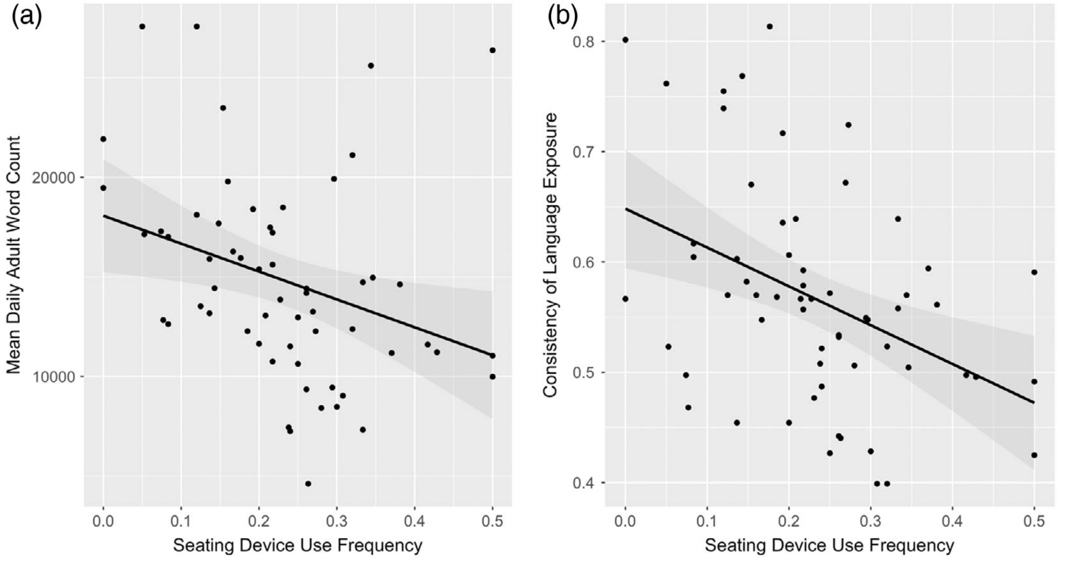

FIGURE 1 Daily adult word count and consistency of language exposure by frequency of placement in seating devices. The shaded area (in light grey) represents the confidence interval around the regression line.

tended to experience fewer words per day, $B = -13{,}950$ (SE = 5483), 95% CI [−24,925.19, −2974.43] (see Figure 1a). Estimates from the regression equation indicated a 6975 daily word difference between families on the extreme ends of the seating device-use continuum observed in the present study (i.e., families with no use of seating devices compared to infants sampled 50% of the time in seating devices). Note that two families reported even higher rates of seating device use (0.63 and 0.65), but these were replaced with values of 0.50 to prevent undue influence from outliers. Our approach to estimating word counts from the regression line is merely one method to represent and quantify the effect. Frequency of seating device placements was also associated with consistency of language exposure, $F(1,58) = 11.43$, $p = 0.001$, $R^2 = 0.16$, such that infants with higher rates of seating device use experienced less consistent language exposure, $B = -0.35$ (SE = 0.10), 95% CI [−0.56, −0.14].

3 | DISCUSSION

3.1 | Summary of findings

We aimed to test whether spontaneous infant placement, measured in families' everyday lives, was linked to language exposure. We used continuous audio recordings and repeated experience sampling to capture information about infant placement and language exposure across 3 days in a sample of 60 4-6-month-old infants. Consistent with our preregistered hypotheses, within-subject effects emerged such that placements supporting infant independence were associated with exposure to fewer adult words when compared to other placements. Placements supporting both independence and posture (i.e., seating devices) were also associated with fewer adult words compared to other placements. Contrary to our expectations, seating devices—but not all independence-supporting placements—explained individual differences in daily exposure to language. Specifically, infants more frequently sampled in seating devices tended to experience decreased quantity and consistency of adult words throughout the day, but this finding was not replicated when we assessed all independence-supporting placements.

3.2 | Compare and contrast categorizations

One possible explanation for this discrepancy is that seating devices lend themselves to more extended use compared to some of the items in the larger, independence-supporting category. For example, both exersaucers (in the seating devices category) and infant floor mats (in the independence support category, but not the seating device category) promote infant independence by allowing infants to play and observe without necessary caregiver involvement. However, the exersaucer—unlike the floor mat—provides upright posture support. With a wider view of their surroundings, infants may happily spend longer stretches of time in exersaucers than they would on the floor. Across a given day, extended time in placements associated with fewer in-the-moment adult words may accumulate to produce less *total* daily language exposure. In contrast, even if infants are exposed to relatively few words when spending time on a floor mat, they may not spend enough extended time on the floor for differences in in-the-moment language exposure to accumulate.

Our findings indicate that we can account for 10% of an infant's daily exposure to adult words and 16% of language consistency through intermittent assessment of infant placement in seating devices, a striking finding given the complex and multifaceted nature of language exposure. Our exploration of demographic characteristics (markers of socioeconomic status and family size) indicated that none of these variables accounted for the observed relation between placement and language exposure. One possible explanation for our findings is that infants spending time in seating devices are physically farther away from caregivers, and thus less likely to be exposed to clear speech. Given that we could not see our participants, our data prevent us from making direct claims about infant–caregiver proximity. However, it is likely that our findings can be explained in terms of proximity to caregivers. If an infant is playing or observing independently, caregivers may be more likely to spend time physically distanced from them, making 'near and clear' adult speech less likely. This question could be empirically addressed with the added use of mobile proximity sensors (e.g., TotTag, Salo et al., 2022) to indicate whether a caregiver is near to or far from a child.

The observed link between seating device use and language exposure—both in the moment and across the day—suggests that infant placement is a potentially important variable to consider when assessing infants' everyday verbal interactions with caregivers. Combined with findings from experimental work (Little et al., 2019; Mireault et al., 2018), our findings suggest that the use of certain placements (i.e., placements supporting both independence and posture, or 'seating devices') is associated with reduced exposure to adult speech. Time spent in these places (e.g., bouncy seats, car seats and exersaucers) may represent an opportunity cost for an infant in terms of language input.

Importantly, even if the use of seating devices is causally related to a reduction in language exposure, it would be premature to suggest that caregivers avoid the use of seating devices altogether. Although we were unable to locate any research examining why caregivers use seating devices, we suspect their popularity is a testament to their usefulness. Because seating devices provide posture support and keep infants contained and safe, caregivers may use seating devices while they attend to other activities (e.g., work, household tasks, self-care, or other children). Further, apart from language exposure, seating devices may afford valuable opportunities for *other forms* of learning (e.g., from object exploration; Soska & Adolph, 2014). Given that many seating devices are marketed to caregivers as generally beneficial to infant development (Alghamdi et al., 2022), it may be important to clarify the potential costs and benefits of their use (i.e., they may facilitate object exploration, but indirectly lessen exposure to language). Overall, the purpose of the present study is to carefully consider the interactions between different aspects of a child's environment and how these interactions shape children's experiences in their daily lives.

3.3 | Limitations and future directions

First, we note the potential limitations of relying on the LENA system. While the automated adult word count metric available through the LENA software is reasonably accurate, it is an imperfect measure of the amount of adult speech in a child's environment. The error rate for the LENA-automated AWC averages at 5% for a 16-h recording, as 'misses' and 'false alarms' tend to cancel each other out across time. Our regression line indicates a 6975 daily word difference between infants with no reported use of seating devices compared to infants sampled 50% of the time in seating devices. This estimated difference is substantially higher than the difference we might expect due to error (750 words, given a 5% error rate and our mean daily AWC of 14,921.07), but we caution against over-interpreting this value to be prescriptive.

Our secondary outcome was LENA-generated adult word count in 5-min segments. Evidence suggests that error rates in shorter clips are higher compared to longer clips, and thus our within-subject findings should be interpreted with some level of caution. However, our within-subject findings are consistent with existing findings that relied on human transcription of speech (Little et al., 2019; Mireault et al., 2018), increasing our confidence in the results.

Second, due to limitations associated with using EMA, we were not able to capture comprehensive information about infant placement. We relied on caregiver reports for information on infant placement and were limited to rough estimations (the 5 min surrounding a given survey response time) of the quantity of language exposure associated with a given placement category. However, our sampling method allowed us to capture useful information about infant placement without the use of video cameras or direct observation by an experimenter.

Third, despite evidence for a temporal link between seating device use and language exposure, our study design prevents us from making causal claims about seating device use and individual differences in daily language exposure. Future studies might address causality by encouraging caregivers to reduce their daily use of seating devices and measuring resulting changes in language exposure to infants.

Lastly, given the convenience sampling approach to recruitment and the geographically limited nature of our sample, the specific pattern of findings may not generalize to other groups. Cultural groups vary in their use of spoken language to communicate with infants. For example, caregivers in the United States engage in high levels of verbal interaction with infants and tend to use language ‘didactically’ (i.e., to teach infants about the world and elicit their participation; Tamis-LeMonda & Song, 2013). In contrast, caregivers in Botswana use language primarily as a way to ensure children's safety (i.e., in the form of short commands), rather than to elicit children's participation in a conversation (Geiger & Alant, 2005). Thus, if we want to understand how infant placement shapes opportunities for learning, more broadly, we might assess how infant placement shapes other forms of sensory inputs (e.g., visual, tactile) and non-verbal caregiver interactions.

There are also differences in the availability and use of different types of placements for infants. For example, infants in Tajikistan spend most of the day in a Gavorah cradle, where they are bound tightly head-to-toe and often covered with clothes that restrict their view of their surroundings (Karasik et al., 2018). No similar type of infant container is commonly used in the U.S., and this highlights the possibility that differences in infant placement may influence everyday experiences with caregivers. Thus, an important next step in better understanding the association between infant placement and language input would be to examine the availability and use of varied infant placements across cultures and how that might moderate the relation between placement and input.

4 | CONCLUSIONS

The present study was the first to examine whether spontaneous infant placement is associated with exposure to language in a naturalistic setting. Supporting pre-registered hypotheses and extending previous controlled experimental work, we found that infants were exposed to fewer words when spending time in placements supporting infant independence. Most notably, infants with more frequent use of seating devices experienced *fewer* daily adult words and *less consistent* exposure to adult speech throughout the day compared to infants with less frequent use. When an infant is physically supported and able to play without necessary intervention from a caregiver (e.g., in an exersaucer), caregivers may be more likely to attend to other tasks, thus reducing verbal input to the infant. Overall, our findings indicate that infant placement—especially placement in infant seating devices—may be relevant to our understanding of natural variation in children's everyday experiences of language.

AUTHOR CONTRIBUTIONS

Lauren G. Malachowski: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; visualization; writing – original draft; writing – review and editing. **Virginia C. Salo:** Conceptualization; formal analysis; funding acquisition; methodology; supervision; writing – original draft; writing – review and editing. **Amy Work Needham:** Supervision; writing – review and editing. **Kathryn L. Humphreys:** Conceptualization; funding acquisition; investigation; methodology; resources; supervision; writing – original draft; writing – review and editing.

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Our hypotheses, study design, study methods and planned analyses were preregistered on OSF at https://osf.io/wm6fb/?view_only=9a065d575b744e2288e2c257fc862a5c. doi: 10.17605/OSF.IO/WM6FB. The data that support the findings of this study are openly available on the same OSF page.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

Data and R code supporting our primary analyses have been made publicly available on OSF.

ORCID

Lauren G. Malachowski https://orcid.org/0000-0001-8344-0826
Virginia C. Salo https://orcid.org/0000-0002-4270-102X
Amy Work Needham https://orcid.org/0000-0001-9625-3595
Kathryn L. Humphreys https://orcid.org/0000-0002-5715-6597

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