Developmental Psychology

ISSN: 0012-1649

2024, Vol. 60, No. 12, 2274–2289
https://doi.org/10.1037/dev0001762

Infants' Home Auditory Environment: Background Sounds Shape Language Interactions

Catalina Suarez-Rivera[1, 2], Katelyn K. Fletcher[3], and Catherine S. Tamis-LeMonda[1]
[1] Department of Applied Psychology, New York University
[2] Department of Population, Policy and Practice Research and Teaching, University College London
[3] Department of Psychology, Temple University

Background sounds at home—namely those from television, communication devices, music, appliances, transportation, and construction—can support or impede infant language interactions and learning. Yet real-time connections at home between background sound and infant–caregiver language interactions remain unexamined. We quantified background sounds in the home environment, from 1- to 2-hr video recordings of infant–mother everyday activities (infants aged 8–26 months, 36 female) in two samples: European-American, English-speaking, middle-socioeconomic status (SES) families ($N = 36$) and Latine, Spanish-speaking, low-SES families ($N = 40$). From videos, we identified and coded five types of background sound: television/screens, communication devices, music, appliances, and transportation/construction. Exposure to background sounds varied enormously among homes and was stable across a week, with television/screens and music being the most dominant type of background sounds. Infants' vocalizations and mothers' speech to infants were reduced in the presence of background sound (although effect sizes were small), highlighting real-time processes that affect everyday language exchanges. Over the course of a day, infants in homes with high amounts of background sounds may hear and produce less language than infants in homes with less background sounds, highlighting potential cascading influences from environmental features to everyday interactions to language learning.

Public Significance Statement
Numerous features of the home environment affect infants' learning. In two samples, we video-recorded infants and mothers during everyday activities and examined associations between background sounds and language interactions. Infants experienced a variety of background sounds, including sounds from music, television, and appliances. Mothers and infants were less likely to talk in the presence than in the absence of background sounds, suggesting reduced opportunities for infants to hear and learn from language in "noisy" environments.

Keywords: background sounds, noise, auditory environment, mother–infant interactions, language development

This article was published Online First September 26, 2024.
Diana Leyva served as action editor.
Catalina Suarez-Rivera https://orcid.org/0000-0002-5900-9670
Catherine S. Tamis-LeMonda https://orcid.org/0000-0002-9071-4028
Catalina Suarez-Rivera and Katelyn K. Fletcher share joint authorship. All data have been made publicly available at Databrary and can be accessed at https://nyu.databrary.org/volume/1504 and https://nyu.databrary.org/volume/563. This study's design and its analysis were not preregistered. The authors have no conflicts of interest to disclose.

This work was funded by the Eunice Kennedy Shriver National Institute of Child Health and Human Development Grant R01HD094830 and the LEGO Foundation awarded to Catherine S. Tamis-LeMonda. The authors thank the National Science Foundation (Award 2314963), which was awarded to Catherine S. Tamis-LeMonda and Catalina Suarez Rivera titled "Collaborative Research: The Temporal Structure of Infants' Everyday Behaviors: Language and Play Interactions in the Home Environment."

The authors thank participating families for letting them into their homes to learn about infant language development. The authors are grateful to Jacob Schatz, Orit Herzberg, Shimeng Weng, Aria Xiao, and Kelsey West for help with data collection, data coding, and transcription.

Catalina Suarez-Rivera played a lead role in formal analysis, methodology, software, validation, visualization, writing–original draft, and writing–review and editing and a supporting role in project administration, resources, and supervision. Katelyn K. Fletcher played a lead role in conceptualization, data curation, formal analysis, investigation, project administration, resources, software, validation, visualization, writing–original draft, and writing–review and editing and an equal role in methodology. Catherine S. Tamis-LeMonda played a lead role in funding acquisition, methodology, and supervision, a supporting role in project administration, resources, software, validation, and visualization, and an equal role in conceptualization, data curation, formal analysis, investigation, writing–original draft, and writing–review and editing.

Correspondence concerning this article should be addressed to Catherine S. Tamis-LeMonda, Department of Applied Psychology, New York University, 246 Greene Street, New York, NY 10003, United States. Email: catherine.tamis-lemonda@nyu.edu

The auditory environment constitutes a key feature of infants' home experiences—particularly those that pave the way for language learning. Caregiver speech to infants supports vocabulary development (Rowe, 2012) and extends bouts of joint engagement (Schatz et al., 2022; Suarez-Rivera et al., 2019), thus setting the stage for continued language exchanges. Infants also learn from their own vocalizations. They refine the sounds they produce to be phonologically similar to those of adult speech based on auditory feedback (Goldstein & Schwade, 2008; Long et al., 2022).

In contrast to the importance of caregiver speech and infant vocalizations for language learning, background sounds—those not produced by the mother or infant—may support *or* impede infant language interactions and learning. Background sounds may disrupt language interactions if caregivers stop talking to infants while watching television/screens (for example) or enhance interactions if caregivers sing to music or talk about television programs. Thus, documenting the nature of infants' home auditory environment and how background sounds relate to moment-to-moment fluctuations in caregiver speech and infant vocal productions requires observing infants in their everyday home environments.

Background Sounds and Home Language Interactions

Background sounds can come from many sources (e.g., television, construction, and appliances). Researchers have studied specific types of background sounds in isolation (e.g., television, Courage & Howe, 2010; music, Mendoza & Fausey, 2021; Soderstrom & Wittebolle, 2013) but have not studied multiple sounds jointly. Furthermore, missing from the literature is an ecologically valid portrayal of the various types of background sounds that infants experience in the natural home environment and how such sounds may inhibit or enhance ongoing language interactions.

The rare studies of background sounds mostly reveal negative associations between "noise" exposure (i.e., overly high levels of sound) and attention, language, and cognition (Courage & Howe, 2010; Erickson & Newman, 2017; Fisch, 1981; McMillan & Saffran, 2016; Selnow & Bettinghaus, 1982). Noisy environments may interfere with infant language processing and development by reducing infants' vocalizations and/or caregiver speech to infants. Disruptions to social interactions due to frequent television/screen and phone use are so prevalent that the term "technoference" was coined to refer to media's harmful impact on everyday family interactions (McDaniel & Radesky, 2018). Parents' use of cell phones during play with infants interferes with word learning (Reed et al., 2017), and lab studies show that background television reduces parent–child language interactions (e.g., Kirkorian et al., 2009; Pempek et al., 2014). Indeed, infants learn from live interactions with people rather than from television or screens (e.g., Kuhl et al., 2003). Similarly, music may disrupt attention and therefore interfere with learning target actions from others (Barr et al., 2010). Older 9- to 10-year-olds repeat utterances containing novel words with less accuracy in the presence than in the absence of broadband white noise (Riley & McGregor, 2012).

Nonetheless, whether and how background sounds interfere with infant learning depends on several factors (Courage & Howe, 2010; Kostyrka-Allchorne et al., 2017). For example, active coviewing of television by caregivers and infants supports infants' abilities to model action sequences (Barr & Wyss, 2008; Barr et al., 2007; Strouse & Troseth, 2008). In addition, programs centered on target words with explicit prompting, such as those that encourage infants to respond to direct questions, enhance infant attention to target objects (Cleveland & Striano, 2008) and learning of target words (Krcmar et al., 2007; Linebarger & Walker, 2005). Similarly, music offers opportunities for mothers and infants to sing and thus may encourage language interactions (Mendoza & Fausey, 2021) or increase task enjoyment (Kang & Williamson, 2014). Relatedly, the Yerkes–Dodson law suggests that a small amount of noise may heighten arousal and benefit performance (Yerkes & Dodson, 1908).

Scientific Replication

A key question in developmental science is the extent to which findings generalize from one sample to an entirely different sample (Jensen, 2012). Developmental phenomena may not replicate because of differences in methods, small sample sizes, or sample characteristics across studies (Gennetian et al., 2020). Alternatively, sociocultural groups may differ in baseline characteristics but demonstrate similar patterns of associations between variables of interest (Prevoo & Tamis-LeMonda, 2017); thus, a specific study finding may not generalize across samples whereas another may. In the case of the home auditory environment, infants from low-income households may be exposed to more background sounds (on average) than infants from middle-income households (e.g., Evans, 2004) at the same time that both groups show similar variability in their experiences (Sperry et al., 2019). Furthermore, patterns of associations may not generalize across samples because of inherent differences between sociocultural groups. High levels of background sounds may be particularly detrimental to the language development of dual-language-learning infants who have been found to experience greater difficulty perceiving speech in noise than monolinguals (Mayo et al., 1997; Takata & Nábělek, 1990). Such an effect has been observed in children (Bovo et al., 2018) and even adults (Morini & Newman, 2020; Rogers et al., 2006; Tabri et al., 2011).

Thus, we embarked on the first study of infants' auditory home environment and language interactions across samples that differed in ethnicity, language, mothers' education, and socioeconomic status (SES)—namely, infants in English-speaking, middle-SES households and infants in Spanish-speaking low-SES households. Our two-sample approach sought to increase confidence in inferences about the nature of infants' exposure to background sounds (including stability of background sounds) and real-time associations with infant vocal productions and caregiver speech.

The Present Study

In two samples, we described infants' exposure to background sounds in home environments and tested moment-to-moment connections to infant vocalizations and mother speech. We observed infants and mothers for 1 to 2 hr during natural home activities, generating unprecedented data on multiple types of background sounds and vocalizations/speech of infants and mothers. Notably, we examined how mother speech, infant vocalizations, and backgrounds sounds were distributed over time. This approach yielded hundreds of data points per dyad, which allowed us to compare the likelihoods of mothers talking to their infants and of infants vocalizing in the presence versus absence of background sounds.

Analysis of moment-to-moment behaviors captures the dynamic ebb and flow of language interactions, which is not possible with summary statistics such as averages and rates.

Our first exploratory goal was to characterize variation among infants in their exposure to background sounds, thus moving beyond parent reports and the brief experimental manipulations of lab studies. We expected unique patterns of background sounds in the auditory environment of individual infants, with the frequency and types of background sounds varying widely from home to home. Importantly, we tested whether infants' exposure to background sounds was stable across a 1-week period, an important consideration for the validity of data on infants' exposure to background sounds.

Second, we examined real-time associations between background sounds and infant and mother vocalizations. To our knowledge, moment-to-moment connections between background sounds and caregiver speech and infant vocalizations in a naturalistic setting remain unspecified. We considered two alternative hypotheses. The presence of background sounds may interfere with concurrent infant vocalizations and maternal speech, which aligns with prior findings on noise–outcome associations. Alternatively, infants and mothers may habituate to frequently occurring background sounds, tuning out noise that might otherwise interfere with their interactions. In terms of background sound types, we anticipated that reductions in infant vocalizations and maternal talk to infants would be pronounced for television/screens, communication devices, transportation, appliances, and construction relative to music. We further explored whether dyads jointly attended to the television/screen (i.e., the source of television/screen sounds) and whether background music involved adult or child-directed lyrics.

We expected associations between background sounds and language interactions to replicate in English-speaking and Spanish-speaking samples, perhaps with larger effect sizes being seen for infants from Spanish-speaking homes than those from monolingual homes given prior studies of dual-language learners (e.g., Bovo et al., 2018; Rogers et al., 2006).

Sample 1: Infants From English-Speaking, Middle-SES Families

Method

Transparency and Openness

Sample, materials, and data collection procedures were described in detail in this article. Furthermore, Datavyu sample coding spreadsheets, coding manuals, and processed data are shared with authorized investigators on Databrary at https://nyu.databrary.org/volume/1504. Furthermore, with participants' permission, videos are shared with authorized investigators at https://nyu.databrary.org/volume/563. Analyses were conducted in SPSS software (Version 28) and R (Version 4.2.1). Study design and analyses were not preregistered.

Participants

Thirty-six infants (19 female) and their mothers were recruited from hospitals in a large urban Northeast City. Infants were seen ±1 week of turning 13 months (n = 15), 18 months (n = 13), or 23 months (n = 8). All infants were firstborn, term at birth, had no disabilities, and had not experienced complications at birth. Mothers' age ranged from 28 to 43 years (M = 34.4, SD = 3.3); all mothers had earned college or higher degrees; 69% worked part- or full-time; 83% were White, 5% Asian, and 12% Other; 88% were non-Hispanic. Families received a gift card for participation.

Procedure

A female researcher visited dyads in their homes twice a week (M days between visits = 5.41), with 31 of the 36 dyads being seen a second time. Infants and mothers were video-recorded for 2 hr each day during their spontaneous activities. Visits were scheduled when infants were alert and between main meals on a weekday, typically between 8 a.m.–5 p.m. When possible, the second visit was scheduled at the same time of day as the first. The second visit allowed us to assess the short-term stability of background sounds. Mothers were instructed to ignore the experimenter and go about their typical routines.

Measures and Coding of Background Sound

Types of Background Sounds. Based on a review of several videos, researchers identified five types of background sounds: traffic/construction, appliances, music, communication devices, and television/screen. A primary researcher coded types of background sounds from the video-recorded interactions using Datavyu (https://datavyu.org/), a video-based annotation tool that allows for user-defined codes. Using a time sampling approach, we segmented each video into 720 10-s intervals during which coders noted the presence or absence of five types of sounds: television/screen, communication devices, music, appliances, and transportation/construction. Each separate sound received a score of 1 if it occurred at any time during the interval and 0 if it did not.

Television/screen sounds were coded if the program was audible in the recording, regardless of whether the infant was watching. Television/screen sounds were prerecorded programs (that could also be played on tablets or cell phones). Communication devices included live sounds (not prerecorded programming) produced from cell phones including video chat, phones on speaker phone, and smart speakers (e.g., Alexa or Google Home). Music could be from the radio, computer, speaker, and other sources. Appliances included electrical/mechanical machines that serve household functions like cooking or cleaning (e.g., blender, vacuum cleaner, microwave, and so on). Sounds from transportation/construction included those from cars, vehicle sirens, subway trains, and construction such as jackhammers.

We did not include muted television/screen or interactive toys that make sounds/play songs. Sounds generated by the infant (banging a toy, pressing buttons on the phone) were not coded as background sounds. A reliability coder independently scored 33% of each participant's 10-s intervals, and Cohen's kappas were computed to assess interrater reliability. Interobserver reliability kappa for television/screen was κ = .95, communication devices κ = .81, music κ = .93, appliances κ = .78, and transportation/construction κ = .70.

Types of Television/Screen and Music and Dyad Participation. In a follow-up pass for intervals that included sounds from television/screens, we coded whether infants and mothers looked at the television/screen at any point during the interval. We also identified whether the show was child-directed (e.g., animated shows and children's movies), adult-directed (e.g., reality television, cooking shows), or other (e.g., commercials). We also coded whether the mother talked about the show at any point during the interval. Reliability kappas were strong for infant watching television/screen $\kappa = .89$, mother watching $\kappa = .89$, show type $\kappa = .84$, and mother talking about the show $\kappa = .85$.

Finally, we followed up with a coding pass on intervals that contained music to determine whether mothers sang along or played the music on an instrument. We also coded whether the song was child-directed (e.g., nursery rhymes, lullabies) or adult-directed (e.g., pop music, jazz music) and whether the song had lyrics during the interval. Kappa for mother singing was .84, instrument use was .98, song type was .94, and lyrics was .93.

Infant Vocalizations and Mothers' Infant-Directed Speech. Coders transcribed videos and recorded mothers' speech to infants in Datavyu (https://datavyu.org/) at the utterance level, following guidelines developed in our lab in consultation with language experts on a national project of child play (https://www.play-project.org/coding.html#Transcription). Infant nondistress vocalizations were also annotated. Scripts exported time-locked data on sound types, infant vocalizations, and mother language input for analyses, thereby aligning behavioral data with background sound coding. Thus, data for each 10-s interval included information on the background sound types during the interval, whether the infant vocalized, and whether the mother spoke to her infant.

Amplitude of Sounds. A decibel meter application on a tablet (Lenovo 8 Tablet) and microphone (Dayton Audio iMM-6) recorded sound levels (amplitude) at 30s intervals during the 2-hr observations. The tablet was placed in a central location in the home out of the infant's reach so that it remained in the same place for the duration of the recording without any disruptions to the application that recorded sound levels. We also chose to leave the tablet out of the infant's reach to not draw the infant's interest to the tablet. Dyads were not asked to stay near the tablet to not compromise the ecological validity of the natural recording. Thus, the decibel meter did not quantify sound exposure from the infant's first-person perspective because it was left in the same place throughout the visit. We computed average amplitudes in each home and related them to infant and mother vocalizations. Notably, amplitudes captured all sounds in the environment and did not distinguish between different sound sources. In line with the limitations of the decibel data collected, we reported those data for full transparency but did not draw strong conclusions about them.

Data Analysis Plan

We begin with descriptive statistics on overall and subtypes of background sound in infants' environments (e.g., the proportion of 10-s intervals in which infants experienced specific background sounds) and report stability in infants' sound exposure across a 1-week period. Real-time associations between background sounds and infant vocalizations/mother speech were quantified using contingency tables that classified each 10-s interval into one of four cells representing possible combinations of speech and background sounds at home (Figure 1). α was set to 0.05 for all significance tests. Chi-squared tests were based on aggregated group-level data, and paired t tests compared the percentage of intervals with sound containing infant vocalizations/mother speech to the percentage of intervals without sound containing infant vocalizations/mother speech.

Figure 1

The Four Cells (A–D) Forming the Contingency Table for 10-s Intervals Crossing Speech and Background Sounds Used for Analyses

	sound present	no sound
speech present	A sound present speech present	B no sound speech present
no speech	C sound present no speech	D no sound no speech

Results

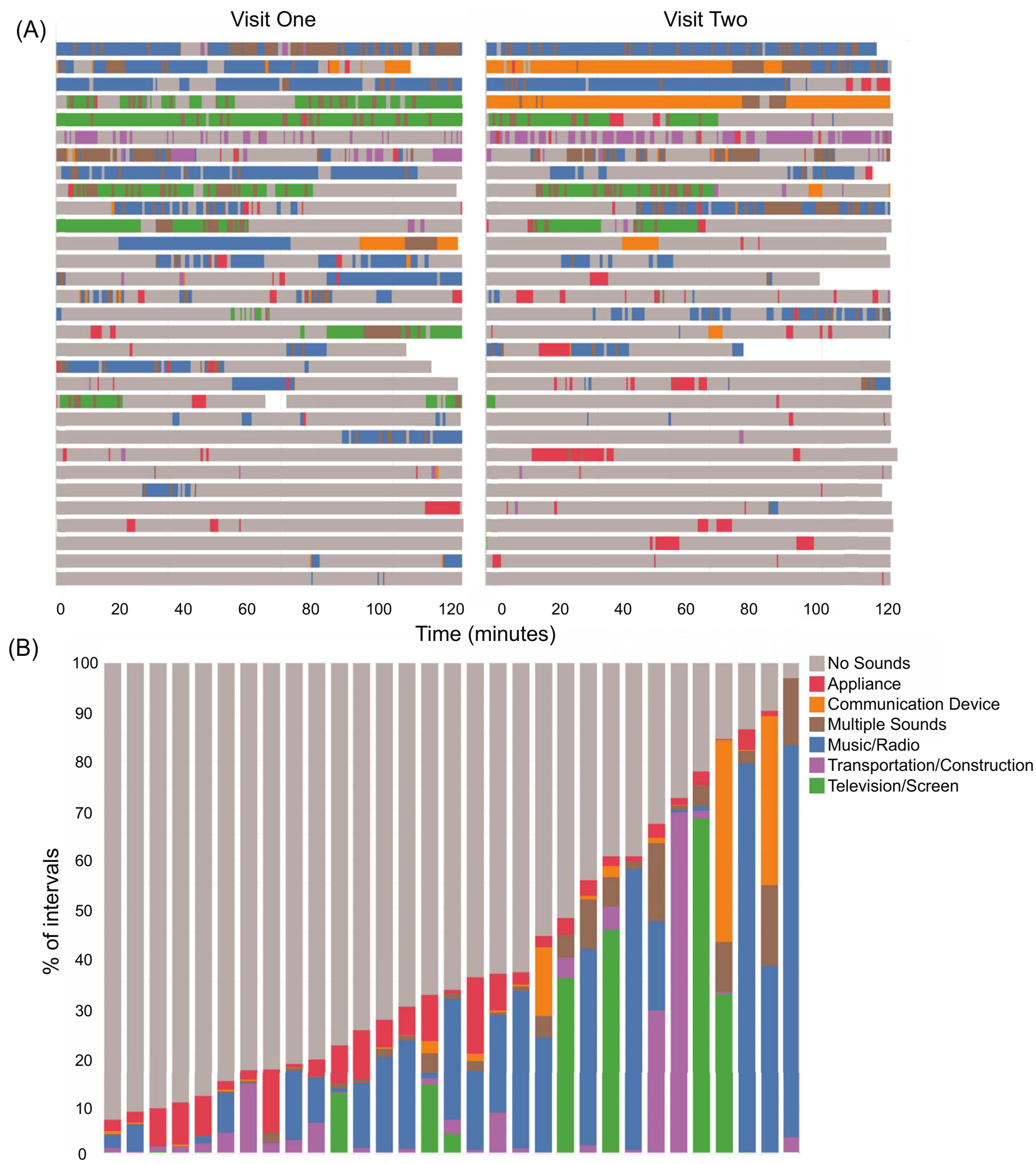
Frequency and Types of Background Sounds

Infants were exposed to background sounds about half of intervals ($M = 45\%$; $SD = 29\%$) across the 4 hr (2 visits). However, the "average" exposure to background sounds does not capture the unique background sounds experienced by individual infants. Homes differed in frequencies, types, and amplitudes of background sounds. Figure 2A presents timelines of each infant's background sound exposure across the two visits, ordered from the infant exposed to the most background sounds (97% of intervals) to the infant exposed to the least (7% of intervals). The overall frequency of background sounds was stable between visit one and visit two, $r = .669$, $p < .001$ (Figure 3A), with stability magnified at extremes. Infants at the high end were exposed to background sounds 90% or more intervals on both visits. Infants at the low end were exposed to background sounds around 10% of intervals on both visits.

In terms of types of background sounds, music was the most prevalent when aggregating across infants and visits (Figure 2B). Most infants (83%) were exposed to music, averaging 25% ($SD = 28\%$) of intervals. All infants were exposed to sounds from appliances, but only for an average of 5% ($SD = 4\%$) of intervals. Thirty-two infants (89%) were exposed to transportation and construction sounds, but only for an average of 8% ($SD = 14\%$) of intervals. Twenty-four were exposed to communication devices (67%), although such sounds were brief (M intervals $= 2\%$; $SD = 5\%$). The fewest number of infants ($n = 9$, 25%) were exposed to television/screen sounds for an average of 10% ($SD = 23\%$) of intervals. Thirty-two infants (89%) were exposed to multiple sounds for an average of 4% of intervals ($SD = 6\%$), ranging from 0% to 23% of intervals. All but four infants experienced multiple background sounds, at least some of the time.

Figure 2

Background Sound Types in Infants' Homes From Sample 1 Across Two Visits (A–B)



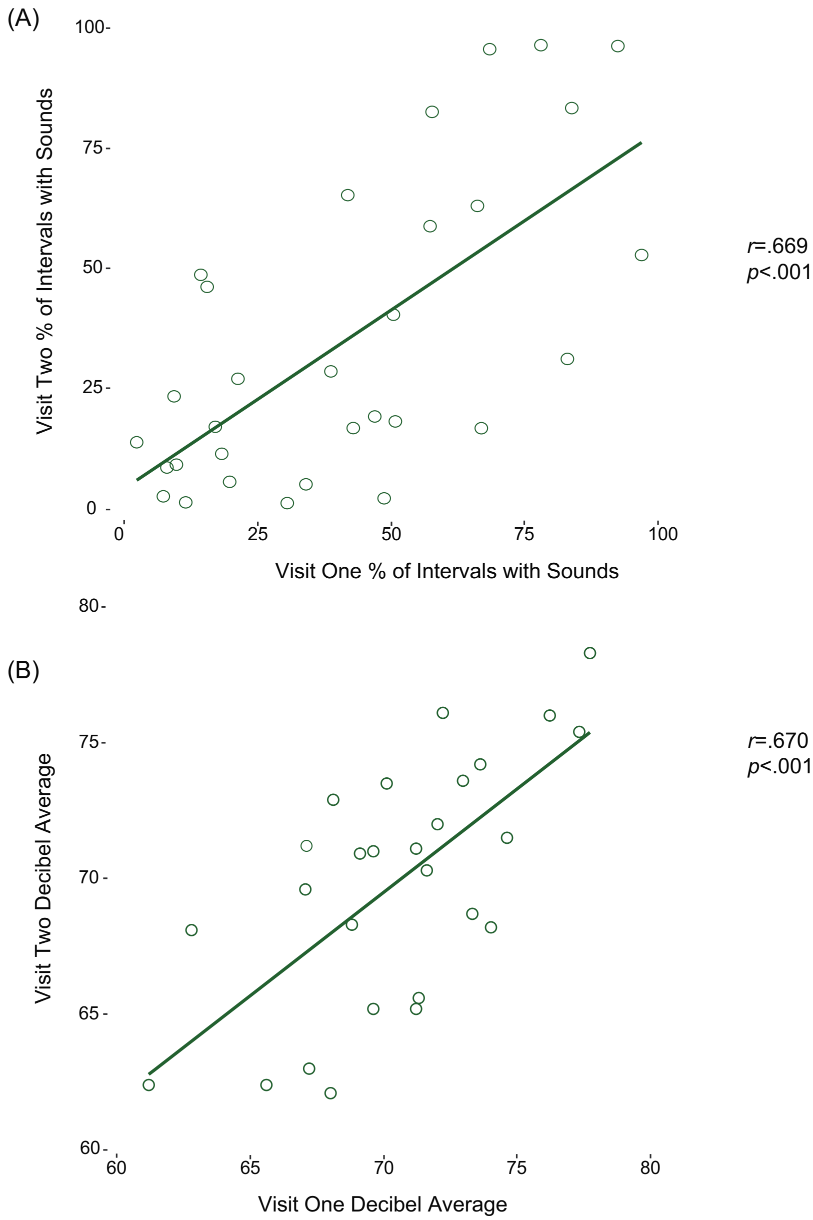
Note. Sample 1: Panel A distribution of background sound types in infants' homes across two visits for the 31 twice-visited English-speaking participants. Each row represents one infant. Bars on the left represent background sounds on visit 1 and bars on the right represent background sounds on visit 2. Red represents appliance sounds, orange represents communication device sounds, brown represents multiple sounds, blue represents music, purple represents transportation and construction sounds, and green represents television/screen sounds. The white spaces represent times when the video was stopped. Panel B shows the percentage of intervals that contained background sounds across the full 4 hr of video for each infant. Each bar is one infant. Figures are ordered from the least to the greatest amount of background sounds. See the online article for the color version of this figure.

Like overall background sound, infants' experiences with specific types of background sounds were stable across the two visits for television/screens, $r = .84$ $p < .001$; music, $r = .69$ $p < .001$; transportation and construction $r = .89$, $p < .001$; and communication devices, $r = .36$, $p = .045$. The stability of sounds from appliances was marginally significant, $r = .32$, $p = .083$, as was the stability of multiple background sounds, $r = .34$, $p = .063$.

Decibel data were available for 27 participants (due to technical failure in the remaining participants), and averaged 71.08 dB (SD = 4.05), ranging from 61.2 dB to 77.7 dB. Sixty to 70 dB is generally considered the standard volume of normal conversation. Decibel

Figure 3

Scatterplots Where Each Dot Represents One English-Speaking Infant–Mother Dyad (Sample 1)



Note. Panel A *x*-axis shows the total number of 10-s intervals of the home visit video-recording that contained background sounds on visit one; the *y*-axis shows the total number of 10-s intervals that contained background sounds on visit two. Panel B shows the average decibel meter levels on visit one (*x*-axis) and visit two (*y*-axis). See the online article for the color version of this figure.

levels above 85 dB are considered harmful to human hearing. Decibel readings were stable across visits, $r = .670$, $p < .001$ (Figure 3B).

Exploratory Breakdown of Television/Screen and Music Sounds

Across visits, television/screens primarily involved children's shows ($M = 58\%$ of intervals with television/screens, $SD = 47\%$), followed by adult-directed shows ($M = 25\%$ of intervals, $SD = 41\%$), and commercials ($M = 17\%$ of intervals, $SD = 38\%$). For dyads who had television/screens present at some point during the visit, mothers watched television/screens about half of the intervals in which television/screen sounds were coded ($M = 48\%$ of TV intervals, $SD = 42\%$). Infants watched just over half the time ($M = 58\%$ of intervals, $SD = 45\%$). Dyads watched 38% of intervals with television/screens together ($SD = 41\%$).

Music across visits was generally child-directed (M = 62% of intervals with music, SD = 40%), with lyrics (M = 67% of music intervals, SD = 29%). Mothers sang along occasionally (M = 10% of music intervals, SD = 14%) and rarely played instruments or musical toys (M = 12% of music intervals, SD = 29%).

Effects of Background Sounds on Language Interactions

Background Sounds in Relation to Infant Vocalizations. We next examined whether background sounds related to infant vocalizations in real time—that is, whether infants vocalized more during intervals that contained no background sounds compared to intervals with background sound. Overall, infants averaged 421.89 vocalizations per hour (SD = 195.34, range = 71.50–820.50). Figure 4A depicts a 2 × 2 contingency table crossing the number of 10-s intervals without/with background sound and the number of 10-s intervals containing infant vocalizations (yes–no) summed across infants. Chi-square analyses using the aggregated data (i.e., a single matrix summing intervals from participants) revealed that background sounds were associated with reductions in infant vocalizations ($p < .001$). Specifically, infants vocalized, on average, in 55% of intervals without background sound compared to 46% of intervals with background sound, a small but significant difference of 9%, 95% CI [5%, 14%], $t(35) = 4.57$, $p < .001$, Cohen's $d = 0.76$. Figure 5A depicts the difference in percentages for individual infants (i.e., the proportion of intervals without background sound that had infant vocalizations minus the proportion of intervals with background sound that had infant vocalizations). Bars above the ordinate value of 0 represent increased vocalizations in the absence of background sounds; bars below 0 represent increased vocalizations in the presence of background sounds; and bars hovering at 0 show no difference between the percentage of intervals without and with sound. As shown, 28 of 36 infants (i.e., 78%) vocalized more in the absence versus presence of background sounds.

Breakdowns of background sound types revealed significant reductions in infant vocalizations for most categories, as indicated by pooled χ^2 values for multiple sounds, television/screens, music/radio, and appliances. Infants vocalized to the same degree during intervals of silence and intervals with transportation/construction and communication devices (Table 1).

We further explored if the reduction of infant vocalizations in the presence of television/screens differed when the mother, infant, or both were watching versus not watching. This was not the case. The percentage of intervals with television/screen sounds in which the infant vocalized was lower than the percentage of silence intervals with infant vocalizations (i.e., 55%) whether or not a mother (46%) or the infant (35%) or both (34%) were watching.

Likewise, we explored whether the reduction of infant vocalizations in the presence of music attenuated if the mother sang or played an instrument. This was not the case. The percentage of intervals with music in which the infant vocalized was lower than the percentage of silence intervals with infant vocalizations (i.e., 55%), whether the mother sang/played an instrument (29%) or not (42%).

Figure 4

Contingency Tables of Background Sounds and Speech Co-Occurrence at Home for Sample 1 (A–B) and Sample 2 (C–D)

(A)

Sample 1

Infant speech	Sound: yes	Sound: no
yes	5277	7675
no	6259	6391

$\chi^2 = 197.27$, df = 1, $p < .001$

(C)

Sample 2

Infant speech	Sound: yes	Sound: no
yes	2574	2150
no	6116	3576

$\chi^2 = 98.47$, df = 1, $p < .001$

(B)

Sample 1

Mother speech	Sound: yes	Sound: no
yes	7665	11183
no	3871	2883

$\chi^2 = 556.59$, df = 1, $p < .001$

(D)

Sample 2

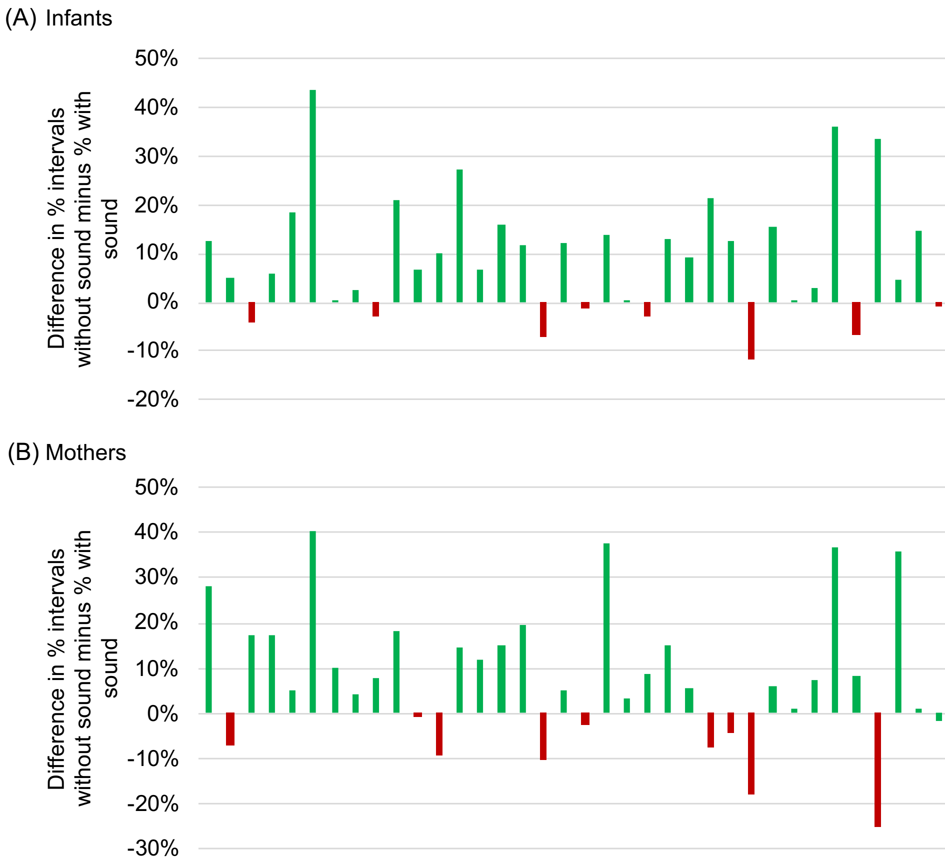
Mother speech	Sound: yes	Sound: no
yes	4266	3132
no	4424	2594

$\chi^2 = 43.44$, df = 1, $p < .001$

Note. Sample 1 and 2: Total number of 10-s intervals in which background sounds occurred or did not occur with infant and mother speech pooled across participants in Sample 1 (i.e., English-speaking) and Sample 2 (i.e., Spanish-speaking). See the online article for the color version of this figure.

Figure 5

Difference in the Percentage of Intervals With Speech/Vocalizations for Individual English-Speaking Infants (A) and Mothers (B)



Note. The percentage difference on the *y*-axis was calculated by subtracting the percentage of intervals with vocalizations in the absence of background sounds minus the percentage of intervals with vocalizations in the presence of background sounds. Each bar represents one mother or infant. Infants and mothers were more likely to vocalize or talk during intervals without sound, as indicated by bars with positive values. See the online article for the color version of this figure.

Background Sounds in Relation to Mothers' Speech to Infants. On average, mothers produced 874.10 utterances per hour (*SD* = 357.47, range = 256–1540.50). Notably, real-time associations between overall background sounds and mother speech paralleled findings for infants. Figure 4B depicts a 2 × 2 contingency table crossing the total number of intervals without and with background sound and the total number of intervals containing mother speech. Chi-square analyses using aggregated data revealed that background sounds were associated with reductions in mother speech ($p < .001$). Specifically, mothers vocalized, on average, in 76% of intervals without background sound compared to 68% of intervals with background sound, a small but significant difference of 8%, 95% CI [3%, 13%], $t(35) = 3.28$, $p = .002$, Cohen's $d = 0.55$. Figure 5B depicts the difference in percentages for individual mothers. Bars above the ordinate represent increased mother speech in the absence of background sounds; bars below 0 represent increased mother speech in the presence of background sounds; and bars hovering at 0 show no difference between the percentage of intervals without and with background sounds. As shown, 26 of 36 mothers (72%) spoke more to their infants in the absence than in the presence of background sounds.

Breakdowns of background sound types revealed significant reductions to mother speech for most categories, as indicated by pooled χ^2 values for multiple sounds, television/screens, music/radio, appliances, and transportation/construction sounds. Mothers vocalized to the same extent during intervals with communication devices and silence (Table 2). We explored whether the reduction of mothers' speech in the presence of television/screens would differ based on whether mother, infant or both were watching. This was not the case. The percentage of intervals with television/screen sounds in which the mother talked was lower than the percentage of silence intervals with mother speech (i.e., 76%) whether or not mother (58%), or the infant (32%), or both were watching (51%).

Decibel Readings in Relation to Infant Vocalizations and Mothers' Speech. Decibel readings did not relate to the frequency of infant vocalizations ($r = .08$, $p = .761$) or mother utterances ($r = .27$, $p = .267$). Further exploration of decibel readings using analysis

Table 1
Real-Time Analyses of Background Sounds and Infant Vocalizations (Sample 1)

Type of 10-s interval	% of interval	% with infant vocalization	χ^2 *p*
No Background Sounds	55	55	NA
Any Background Sounds	45	46	<.001
Multiple Sounds	7	43	<.001
TV/Screens	15	47	<.001
Music	32	42	<.001
Appliances	8	43	<.001
Transportation	13	56	0.270
Communication devices	1	51	0.324

Note. The percentage of intervals was calculated based on pooled data. Chi-square tests used pooled data for each background sound category. NA = not applicable.

of variance—comparing the effect of sound amplitude on mother and infant speech in high decibel (80 dB and above) and low decibel (less than 80 dB) intervals (compared to speech during intervals without nonspeech sound)—was not significant, $F(1, 2) = 105.87$, $p = .395$. Thus, counter to expectations, mother and infant utterances did not reduce under high decibel conditions ($M = 3.12$, $SD = 2.52$) compared to low decibel conditions ($M = 3.00$, $SD = 3.12$), perhaps because the decibel meter picked up on both speech/vocalizations and background sounds.

Discussion

Infants' exposure to background sounds varied enormously in this sample of middle-income, English-speaking families. In terms of background sound types, music sounds were common but rarely involved mothers singing along with music or playing instruments, whereas sounds from television/screen were rare. Sounds from appliances and transportation/construction were seen in most of the auditory home environments sampled, but they occurred for brief periods of time. Background sounds and sound types were stable across visits based on the comprehensive, moment-to-moment coding of background sounds. Decibel measures of sound amplitude were also correlated between visits. Still, they did not measure background sounds exclusively nor capture the infant's first-person sound exposure per se, limiting interpretation of findings.

In line with the hypothesis that background sound interferes with language interactions, infant vocalizations and maternal speech to infants were reduced during intervals with background sounds, a pattern that held for most dyads. However, although associations were consistent, effects were small and some background sound types and combinations showed larger associations with language interactions than did others. There was no association between infant vocalizations and mother speech with sounds from communication devices, perhaps because engagement with cell phones or smart speakers (e.g., Alexa or Google Home) sometimes occurred "live," as part of an ongoing conversation of the dyad with family members or friends. Likewise, infants did not reduce their vocalizations during transportation/construction sounds. Anecdotally, infants tended to imitate sound effects of vehicles when they heard them. Notably, reductions in infant vocalizations and mother speech in the case of television/screens occurred, although our measure of television did not classify television with/without characteristics that may benefit language interactions (e.g., linguistic input, prompting routines, and the intentional targeting of words). Still, the association between television and reduced language interactions maintained whether or not mother and infant were engaged (i.e., watching the television/screen together). Nonetheless, these behaviors were uncommon and so the natural activity of this sample may not capture moments in which screens and music provide a context for mothers to talk with their infants about the content of television/screens or sing (Kostyrka-Allchorne et al., 2017; Mendoza & Fausey, 2021). We next asked whether variability of background sound exposure and associations to infant vocalizations and mother language input replicated in a sample that differed in ethnicity, home language, mothers' education, and SES.

Table 2
Real-Time Analyses of Background Sounds and Mother Speech (Sample 1)

Type of 10-s interval	% of interval	% with mother speech	χ^2 *p*
No Background Sounds	55	76	NA
Any Background Sounds	45	68	<.001
Multiple Sounds	7	53	<.001
TV/Screens	15	58	<.001
Music	32	67	<.001
Appliances	8	51	<.001
Transportation	13	75	<.001
Communication devices	1	77	0.368

Note. The percent of intervals was calculated based on pooled data. Chi-square tests used pooled data for each background sound category. NA = not applicable.

Sample 2: Infants From Spanish-Speaking, Low-SES Families

Method

Participants

Participants were 40 mothers and their infants (23 boys) aged 8 to 25 months (±1 week) ($M = 14.91$, $SD = 3.14$). Mothers were recruited from community agencies in a large urban city serving primarily low-SES, Spanish-speaking Latine families. Participants were predominantly of Mexican descent (80%), with the remaining from Ecuador (6%), Guatemala (3%), United States (3%), Puerto Rico (3%), and other (5%). All mothers were Hispanic or Latine and spoke Spanish to their infants; most mothers (86%) spoke Spanish as the primary language at home. The remaining used English as the primary language. On average, mothers had 8.71 ($SD = 5.04$) years of formal schooling. Mothers resided an average of 11.86 years ($SD = 5.76$) in the United States. With participants' permission, videos are shared with authorized investigators of Databrary at https://nyu.databrary.org/volume/484. Families received a gift card for participation.

Procedure

We video-recorded infants and mothers during 1 to 2 hr of everyday activities at home, coded background sound types at

10-s intervals across the visit, transcribed speech from videos, and analyzed real-time associations between background sounds and infant and mother vocalizations for the first hour of video recording following the analytic approach of Sample 1.

Intercoder Agreement

Kappa reliabilities of types of background sounds, based on comparisons between two independent coders on 33% of each participant's video, were again strong: television/screen κ = .94, communication devices κ = .84, music/radio κ = .89, appliances κ = .73, and transportation/construction κ = .70. Kappa reliabilities for further coding of television/screen and music intervals were likewise strong: watching television/screen κ = .99, mothers watching κ = .98, show type κ = .96, and mothers talking about show κ = .99. Kappa for mother singing κ = .99, song type κ = .93, lyrics κ = .99, and instrument use κ = .99. Native Spanish speakers transcribed video recordings for mother and infant speech. Identified errors were corrected, and cleaned transcripts were used for further coding passes.

Results

Frequency and Types of Background Sounds

Background sounds were, on average, frequent but also differed substantially among families. Overall, infants were exposed to background sound at about 67% of intervals (*SD* = 47%). The most common types of background sound were television/screen sounds, which were present in 32 of the families (80%) for an average of 37% of intervals across the full sample (*SD* = 48%), and music/radio sounds, which were present in 34 homes (85%) for an average of 13% of intervals across the full sample (*SD* = 34%). Transportation/construction sounds were less prevalent, averaging 9% of all intervals (*SD* = 29%), and present in 37 homes (93%). All but six participants (85%) experienced sounds from appliances, averaging 8% of intervals (*SD* = 27%). Twenty-four participants (60%) were exposed to sounds from communication devices, which were rare (*M* = 1%, *SD* = 8%). Last, all but two participants experienced multiple sounds simultaneously (95%), encompassing 7% of intervals across the full sample (*SD* = 25%).

Individual infants experienced unique auditory environments. At the low end of the distribution, one infant experienced background sounds during only 14% of intervals, whereas an infant at the other extreme experienced background sounds during nearly all intervals (98%; see Figure 6). Figures 6A and 6B depict the variability from family to family in the prevalence of each type of background sound.

Exploratory Breakdown of Television/Screen and Music Sounds

Television/screens primarily involved children's shows (*M* = 81% of intervals with television/screen, *SD* = 33%), followed by adult-directed shows (*M* = 17% of intervals, *SD* = 34%), and commercials (*M* = 2%, *SD* = 5%). Of the intervals with sounds from television/screen, mothers watched about one-third of the time (*M* = 34% of intervals, *SD* = 40) and talked about what was happening in 6% (*SD* = 11%) of intervals. Infants watched about half the time (*M* = 41% of intervals, *SD* = 36%). Dyads watched together at 11% of intervals with television/screens (*SD* = 20%).

Music was generally child-directed (*M* = 87% of intervals with music, *SD* = 30%), with lyrics (*M* = 49% of intervals with music, *SD* = 35%). Mothers rarely sang along (*M* = 2% of intervals with music, *SD* = 5%) or played instruments (*M* = 5% of intervals with music, *SD* = 11%).

Effects of Background Sounds on Language Interactions

Background Sounds in Relation to Infant Vocalizations. Aggregating across participants, infants vocalized 198.58 times per hour (*SD* = 109.87), ranging from 35 vocalizations (the infant who vocalized least) to 369 vocalizations (the infant who vocalized most). Figure 4C depicts a 2 × 2 contingency table crossing the number of 10-s intervals without/with background sound and the number of 10-s intervals containing infant vocalizations (yes–no) summed across infants. Chi-square analyses using the aggregated data revealed that background sounds were associated with reductions in infant vocalizations ($p < .001$). Specifically, infants vocalized, on average, in 36% of intervals without background sound compared to 30% of intervals with background sound, a small but significant difference of 6%, 95% CI [1%, 11%], $t(36) = 2.10$, $p = .043$, Cohen's $d = 0.34$ (small). Figure 7A depicts the difference in percentages for individual infants. As shown, most bars are above the ordinate, indicating more vocalizations by 26 of 37 infants (70%) in the absence versus presence of background sounds.

Breakdowns of background sound types revealed significant reductions in infant vocalizations, as indicated by pooled χ^2 values, during multiple background sounds, television/screens, and music/radio. Infants vocalized to the same degree during intervals of silence and intervals with appliances, transportation/construction, and communication devices (Table 3).[1]

We explored whether the reduction of infant vocalizations in the presence of television/screens differed when the mother, infant, or both were watching. This was not the case. The percentage of intervals with television/screen sounds in which the infant vocalized was lower than the percentage of silence intervals with infant vocalizations (i.e., 36%) whether or not a mother (20%) or the infant (24%) or both were watching (15%).

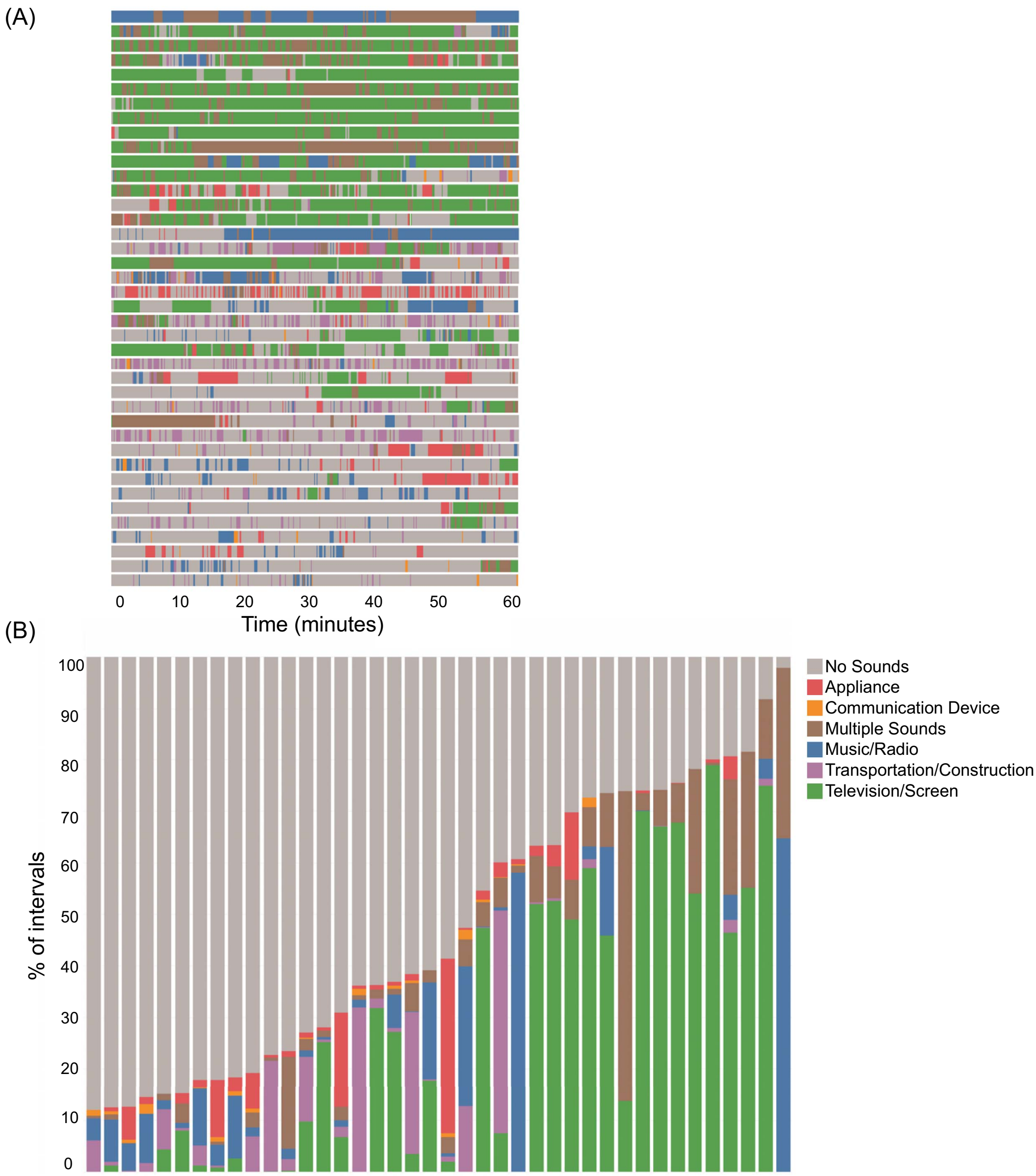
Likewise, we explored whether the reduction of infant vocalizations in the presence of music would differ depending on whether the mother sang or played an instrument. This was not the case. The percentage of intervals with music in which the infant vocalized was lower than the percentage of silence intervals with infant vocalizations (i.e., 36%) whether the mother sang/played an instrument (17%) or not (29%).

Background Sounds in Relation to Mothers' Speech to Infants. On average, mothers produced 507.05 utterances per hour (*SD* = 369.46), ranging from 26 to 1,584 utterances. Figure 4D depicts a 2 × 2 contingency table crossing the average number of intervals without/with background sound and the average number of intervals containing mother speech. Chi-square analyses using the aggregated data revealed that background sounds were associated with reductions in mother speech ($p < .001$). Because several

[1] Contingency tables for breakdowns of background sound types were pooled across participants to maintain power.

Figure 6

Background Sound Types in Infants' Homes From Sample 2



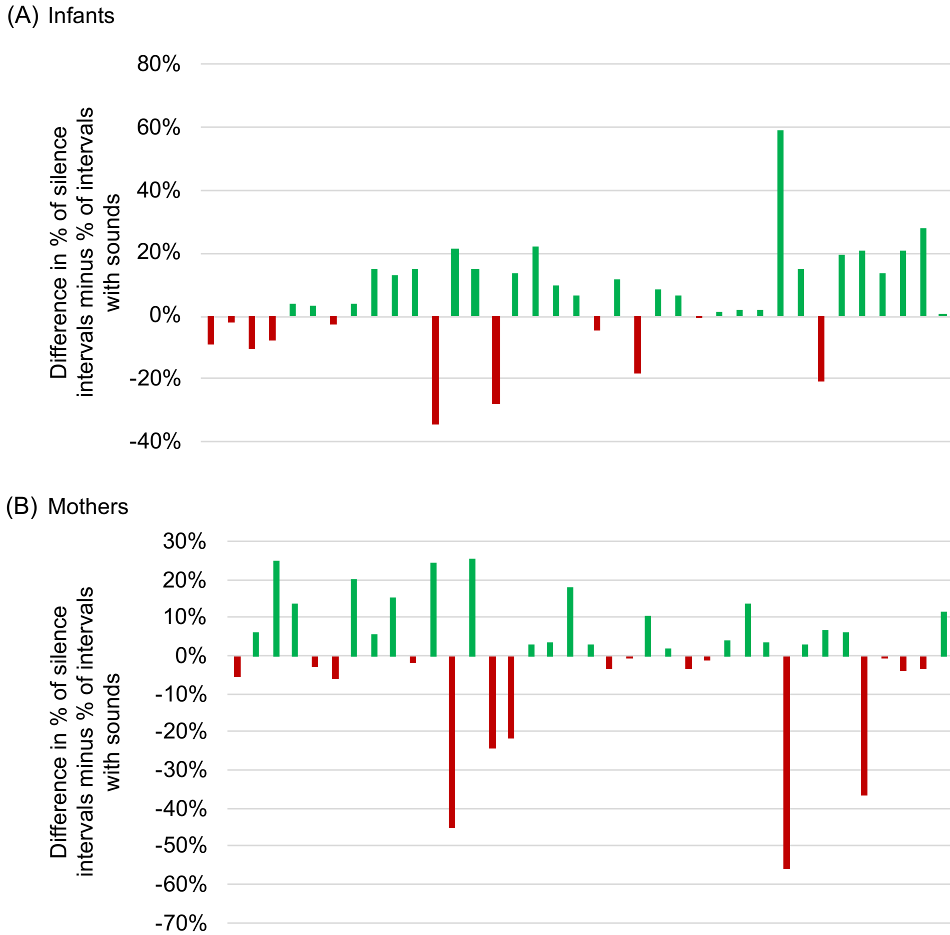
Note. Sample 2: Panel A is the distribution of background sound types in Spanish-speaking infants' homes across the 1-hr visit. Each row represents one infant. Red represents appliance sounds, orange represents communication device sounds, brown represents multiple sounds, blue represents music, purple represents transportation and construction sounds, and green represents television/screen sounds. The white spaces represent times when the video was stopped. Panel B shows the percentage of intervals that contained background sounds across the 1 hr of video for each infant. Each bar is one infant. Figures are ordered from least to greatest percentage of background sounds. See the online article for the color version of this figure.

mothers did not have any intervals without background sounds, we did not run *t* tests based on individual data (i.e., a dyad cannot be compared on infant vocalizations/mother speech on intervals with and without sounds if all intervals contain background sounds). Figure 7B depicts the difference in percentages for individual mothers. As shown, over half of the bars are above the ordinate, indicating increased speech by 21 of 37 mothers (57%) in the absence of background sounds.

Breakdowns of background sound types revealed significant reductions to mother speech for most sound categories, as indicated by pooled χ^2 values for multiple sounds, television/screens, music/radio, appliances, and transportation/construction sounds. Mothers

Figure 7

Difference in the Percentage of Intervals With Speech/Vocalizations for Individual Spanish-Speaking Infants (A) and Mothers (B)



Note. The percentage difference on the *y*-axis was calculated by subtracting the percentage of intervals with vocalizations in the absence of background sounds minus the percentage of intervals with vocalizations in the presence of background sounds. Each bar represents one mother or infant. Infants and mothers were more likely to vocalize or talk during intervals without sound, as indicated by bars with positive values. See the online article for the color version of this figure.

vocalized to the same extent during intervals with communication devices and silence (Table 4).[2]

We explored whether the reduction of mother speech in the presence of television/screens differed when the mother, infant, or both were watching. This was not the case. The percentage of intervals without background sound (silence) that contained mother speech (i.e., 51%) was greater than the percentage of intervals with television/screen sounds and mother speech, whether the mother alone was watching (31%) or both were watching (46%).

Discussion

We observed striking variability in the exposure to background sounds of infants from Hispanic, low-SES, and Spanish-speaking families. Overall, infants experienced background sound most of the time (67% of intervals on average). Television/screen and music sounds were common but rarely involved mothers talking to infants about the show or singing along with music. Sounds from transportation and construction (e.g., cars honking, subways) punctuated the hour of observation. In line with the hypothesized association between background sounds and language interactions, infants showed reduced vocalizations in the presence of overall background sounds (small effect size) and most sound types. Mothers showed reductions in speech in the presence of most sound types, but effect sizes were again small. Reductions during television/screen and music occurred regardless of the engagement of mothers and infants. However, we did not measure other properties of television that may moderate this association (e.g., Linebarger & Walker, 2005). Notably, sounds from communication devices did not relate to reductions of either infant vocalizations or mother speech in this Spanish-speaking sample, replicating findings in the English-speaking sample. Infants in Sample 2 did not experience reductions

[2] Contingency tables for breakdowns of sound types were pooled across participants to maintain power.

Table 3
Real-Time Analyses of Background Sounds and Infant Vocalizations (Sample 2)

Type of 10-s interval	% of interval	% with infant vocalization	χ^2 p
No Background Sounds	40	36	NA
Any Background Sounds	60	30	<.001
Multiple Sounds	21	31	<.001
TV/Screens	49	27	<.001
Music	23	29	<.001
Appliances	18	35	0.127
Transportation	22	35	0.122
Communication devices	2	29	0.080

Note. The percentage of intervals was calculated based on pooled data. Chi-square tests used pooled data for each background sound category. NA = not applicable.

in vocalizations during transportation/construction sounds as found with infants in Sample 1.

Pooled Analyses

Pooling across samples, chi-square analyses (i.e., a single matrix summing intervals across 76 infants) revealed that background sounds were associated with reductions in infant vocalizations ($p < .001$). On average, infants vocalized in 46% of intervals without background sound compared to 38% of intervals with background sound, a small but significant difference of 8%, 95% CI [4%, 11%], $t(72) = 4.36$, $p < .001$, Cohen's $d = 0.39$. Breakdowns of background sound types revealed significant reductions in infant speech for all sound categories, as indicated by pooled χ^2 values (Table 5). Notably, the pooled effect for transportation/construction sounds indicated a decrease in infant vocalizations not seen in either sample separately, possibly due to the increased power of pooled analyses.

Similarly, the aggregated two-sample data revealed that background sounds were associated with reductions in mother speech ($p < .001$). Furthermore, mothers vocalized, on average, in 64% of intervals without sound compared to 58% of intervals with sound, a significant difference of 6%, 95% CI [1%, 8%], $t(72) = 2.15$, $p = .035$, Cohen's $d = 0.22$. Breakdowns of background sound types revealed significant reductions in mother speech for all categories except communication devices, as indicated by pooled χ^2 values (Table 6).

Table 4
Real-Time Analyses of Background Sounds and Mother Speech (Sample 2)

Type of 10-s interval	% of interval	% with mother speech	χ^2 p
No Background Sounds	40	51	NA
Any Background Sounds	60	49	<.001
Multiple Sounds	21	43	<.001
TV/Screens	49	50	<.001
Music	23	51	0.007
Appliances	18	35	<.001
Transportation	22	47	<.001
Communication devices	2	53	0.702

Note. The percentage of intervals was calculated based on pooled data. Chi-square tests used pooled data for each background sound category. NA = not applicable.

General Discussion

We observed infant–mother dyads in the home environment to document infants' experiences with background sounds and associations to infants' vocalizations and mothers' speech to infants in two samples that differed in ethnicity, SES, and spoken language. Our novel, real-time approach to characterizing background sounds at home revealed tremendous variability in the frequency and types of background sounds that infants experienced. Moreover, background sounds at home were not transient: Strong stability characterized infants' exposure to different types of background sounds and overall background sound over two visits (Sample 1). Most centrally, background sounds were associated with reduced infant vocalizations and mother speech in distinct ethnocultural and socioeconomic contexts, with reductions to vocalizations/speech seen for certain types of background sounds.

The Unique "Sound Signatures" of Individual Homes

Infants experienced distinct "sound signatures," ranging from nearly constant background television/screens to the occasional phone ringing to the intermittent honking of vehicles. Most homes contained multiple co-occurring background sounds, at least some of the time, further cluttering the auditory environment. Variation in infants' experiences with background sounds, derived from natural home observations, extends the focus beyond television/screens and cell phones. Moreover, we visited homes when only the mother and infant were present; presumably, in everyday life, homes are filled with even more competing background sounds when other family members or visitors interact with sources of background sounds. Furthermore, the stability of background sounds in Sample 1 across visits indicates day-to-day regularity in infants' exposure to background sounds. Infants' varied and stable experiences with background sound at home highlight the unique characteristics of each infant's auditory developmental niche.

Variability Characterizes Background Sound Exposure Across Samples

Variability characterized infants' experiences with background sounds across both samples. Although infants from Hispanic, low-income families experienced background sounds in the majority of their time recorded at home on *average*, their range of total background sound exposure was as large as the range seen in the homes of infants from non-Hispanic, middle-SES households. In fact, some English-learning infants in middle-income homes experienced much more background sound than did Spanish-learning infants in low-income homes, and vice versa. Likewise, vocalization rates per hour differed widely among infants from both samples (range = 71–820 in sample one; range = 35–369 in sample two) and mothers (range = 256–1,540 in sample one; range = 26–1,584 in sample two). The tremendous variation within each sample underscores the risk of homogenizing samples, and the importance of describing within-group, not just between-group differences (Kuchirko & Tamis-LeMonda, 2019; Luo et al., 2020; Prevoo & Tamis-LeMonda, 2017).

Table 5
Pooled Real-Time Analyses of Background Sounds and Infant Vocalizations

Type of 10-s interval	% of interval	% with infant vocalization	χ^2 *p*
No Background Sounds	49	50	NA
Any Background Sounds	51	39	<.001
Multiple Sounds	7	36	<.001
TV/Screens	20	33	<.001
Music	21	39	<.001
Appliances	6	39	<.001
Transportation	9	47	0.004
Communication devices	1	44	0.047

Note. The percentage of intervals was calculated based on pooled data. Chi-square tests used pooled data for each background sound category. NA = not applicable.

Importantly, associations between background sound and language exchanges were virtually the same in Samples 1 and 2. English-learning infants were still affected by noise despite evidence suggesting that Spanish-learning infants—who presumably are dual-language learners—have difficulties with sound exposure. Indeed, the only difference in the pattern of results across samples pertains to an infrequent category (i.e., appliances were associated with a reduction of infant vocalizations in Sample 1 but not in Sample 2), so we refrained from making inferences about sample differences. Furthermore, any differences between samples could not be attributed to home language alone because samples also differed in terms of ethnicity, education, and SES. Instead, our approach focused on within-group variability and the extent to which patterns of associations between background sound and language interactions generalize across widely different populations.

Background Sounds May Interfere With Real-Time Language Interactions

In both samples, real-time speech reduction in the presence of background sounds was common. Across dyads from both samples, 74% showed fewer infant vocalizations and 66% fewer maternal utterances in the presence of background sound compared to the absence of background sound. Moreover, in both samples, infants and mothers vocalized less in the presence of nearly all types of background sounds (with a few exceptions such as communication devices). Although effects were weak in magnitude, the reduction to language interactions can add up. Extrapolating over the course of a day, infants in homes with high background sounds may hear far less speech and produce many fewer vocalizations than infants residing in homes with fewer background sounds.

Table 6
Pooled Real-Time Analyses of Background Sounds and Mother Speech

Type of 10-s interval	% of interval	% with mother speech	χ^2 *p*
No Background Sounds	49	72	NA
Any Background Sounds	51	59	<.001
Multiple Sounds	7	47	<.001
TV/Screens	20	52	<.001
Music	21	64	<.001
Appliances	6	43	<.001
Transportation	9	60	<.001
Communication devices	1	69	0.205

Note. The percentage of intervals was calculated based on pooled data. Chi-square tests used pooled data for each background sound category. NA = not applicable.

Nonetheless, our study may have underestimated the effects of background sounds on language interactions. The coding scheme implemented in this study produced the first but coarse documentation of background sounds at home. Specifically, we did not have the power to delve deeper into each type of background sound category and focus on characteristics that may be more beneficial for language interactions than others. For example, sounds from television/screens were not coded regarding linguistic input or the use of prompting routines or target words. Future work may focus on the features of background sounds that may moderate associations with language interactions at home.

The real-time connections documented here may potentially explain previous long-term associations between noise environments and language development. However, given the correlational nature of studies, we cannot infer causality from background sound to mother and infant language interactions. For example, mothers are likely to turn on music when occupied. Indeed, music was mostly child-directed and contained lyrics 48% to 67% of the time, and so mothers may be unlikely to also talk while playing music for their infants. Similarly, appliances (e.g., vacuums) are common during chores; these may be times when mothers are least likely to interact with their infants, and thus times when infants are less likely to vocalize. Mothers create background sounds for the most part (except outside noises) and may choose to be quiet at certain times, rather than background sounds causing mothers to talk less to their infants. Nonetheless, experimental manipulations of sound suggest that background sounds indeed reduce maternal speech (e.g., Kirkorian et al., 2009). Here we extend such work to the ecologically-valid home environment by showing that infants experience small reductions in language input in the presence of background sounds, and vocalize less themselves.

Limitations

Rather than a controlled, experimental investigation of the effects of background sounds and background sound types on language exchanges between mothers and infants, findings reveal real-time correlates of the background sounds during infant-mother natural activity at home. In particular, background sound types were not equally frequent. Some sound types, such as appliances and communication devices, were quite infrequent. We were thus hesitant to draw conclusions about the effects of infrequent background sound categories on language exchanges. Likewise, even though different types of background sounds may show different associations with language depending on the presence of key features, we did not have the power to examine further breakdowns of already infrequent sounds.

Finally, background sounds were characterized based on their source rather than their content and the degree of mother–infant engagement. For example, this study did not distinguish between background sounds with and without language. Specifically, infants may be actively listening to and learning from music if it contains linguistic input. Therefore, a reduction in vocalizations might be expected. Music that is infant-directed, in particular, elicits physical entrainment and thus contributes to synchronized social interactions (Lense et al., 2022). Likewise, television/screens may contain features that support infant learning in certain viewing contexts (Courage & Howe, 2010; Linebarger & Walker, 2005). Thus, background sounds may provide opportunities to learn language, just as overheard speech does. Even when speech is not directed at infants, infants can learn from overheard conversations (Gampe et al., 2012; Sperry et al., 2019).

Implications

If certain background sounds indeed disrupt real-time interactions, modifying infants' exposure to background sounds may be one path of intervention for promoting language interactions. Of course, background sounds at home may be more amenable to intervention than outside-of-home sources. High-quality interactions promote language, so it would be important to limit background sounds during parent–infant language exchanges (e.g., shared book reading). Furthermore, encouraging caregivers to carve out time in the day to limit background sounds may support infants' ability to extract meaning from language interactions without distraction or the dilution of speech. Of course, caregivers cannot and should not create a totally quiet and speech-filled environment all the time. It may be possible for caregivers to use existing background sounds to elicit infant vocalizations (e.g., when an ambulance is heard at home and the mother encourages the infant to imitate the sound). Thus, caregivers should be encouraged to be intentional about when to introduce background sounds in their homes based on their activities with infants.

Conclusions

Infants' auditory environments—from the speech of caregivers to the vocalizations of infants to the background sounds such as TV and appliances—influence infants' emerging language skills. Home observations revealed reductions to infant vocalizations and mother speech in the presence of background sounds, thereby highlighting the real-time processes involved in everyday language exchanges. A full appreciation of the socially- and contextually-embedded nature of infant language learning requires moving beyond laboratory-based tasks and a focus on speech alone. The study of environmental cascades from infants' auditory environments to infant vocal production and caregiver speech reveals processes that may be core to language learning, yet rarely considered.

References

Barr, R., Muentener, P., Garcia, A., Fujimoto, M., & Chávez, V. (2007). The effect of repetition on imitation from television during infancy. *Developmental Psychobiology*, *49*(2), 196–207. https://doi.org/10.1002/dev.20208

Barr, R., Shuck, L., Salerno, K., Atkinson, E., & Linebarger, D. L. (2010). Music interferes with learning from television during infancy. *Infant and Child Development*, *19*(3), 313–331. https://doi.org/10.1002/icd.666

Barr, R., & Wyss, N. (2008). Reenactment of televised content by 2-year olds: Toddlers use language learned from television to solve a difficult imitation problem. *Infant Behavior & Development*, *31*(4), 696–703. https://doi.org/10.1016/j.infbeh.2008.04.006

Bovo, R., Lovo, E., Astolfi, L., Montino, S., Franchella, S., Gallo, S., Prodi, N., Borsetto, D., & Trevisi, P. (2018). Speech perception in noise by young sequential bilingual children. *Acta Otorhinolaryngologica Italica*, *38*(6), 536–543. https://doi.org/10.14639/0392-100X-1846

Cleveland, A., & Striano, T. (2008). Televised social interaction and object learning in 14- and 18-month-old infants. *Infant Behavior & Development*, *31*(2), 326–331. https://doi.org/10.1016/j.infbeh.2007.12.019

Courage, M. L., & Howe, M. L. (2010). To watch or not to watch: Infants and toddlers in a brave new electronic world. *Developmental Review*, *30*(2), 101–115. https://doi.org/10.1016/j.dr.2010.03.002

Erickson, L. C., & Newman, R. S. (2017). Influences of background noise on infants and children. *Current Directions in Psychological Science*, *26*(5), 451–457. https://doi.org/10.1177/0963721417709087

Evans, G. W. (2004). The environment of childhood poverty. *American Psychologist*, *59*(2), 77–92. https://doi.org/10.1037/0003-066X.59.2.77

Fisch, L. (1981). Aircraft noise and hearing impairment in children. *British Journal of Audiology*, *15*(4), 231–240. https://doi.org/10.3109/03005368109081443

Gampe, A., Liebal, K., & Tomasello, M. (2012). Eighteen-month-olds learn novel words through overhearing. *First Language*, *32*(3), 385–397. https://doi.org/10.1177/0142723711433584

Gennetian, L. A., Tamis-LeMonda, C. S., & Frank, M. C. (2020). Advancing transparency and openness in child development research: Opportunities. *Child Development Perspectives*, *14*(1), 3–8. https://doi.org/10.1111/cdep.12356

Goldstein, M. H., & Schwade, J. A. (2008). Social feedback to infants' babbling facilitates rapid phonological learning. *Psychological Science*, *19*(5), 515–523. https://doi.org/10.1111/j.1467-9280.2008.02117.x

Jensen, L. A. (2012). Bridging universal and cultural perspectives: A vision for developmental psychology in a global world. *Child Development Perspectives*, *6*(1), 98–104. https://doi.org/10.1111/j.1750-8606.2011.00213.x

Kang, H. J., & Williamson, V. J. (2014). Background music can aid second language learning. *Psychology of Music*, *42*(5), 728–747. https://doi.org/10.1177/0305735613485152

Kirkorian, H. L., Pempek, T. A., Murphy, L. A., Schmidt, M. E., & Anderson, D. R. (2009). The impact of background television on parent–child interaction. *Child Development*, *80*(5), 1350–1359. https://doi.org/10.1111/j.1467-8624.2009.01337.x

Kostyrka-Allchorne, K., Cooper, N. R., & Simpson, A. (2017). The relationship between television exposure and children's cognition and behaviour: A systematic review. *Developmental Review*, *44*, 19–58. https://doi.org/10.1016/j.dr.2016.12.002

Krcmar, M., Grela, B., & Lin, K. (2007). Can toddlers learn vocabulary from television? An experimental approach. *Media Psychology*, *10*(1), 41–63. https://www.researchgate.net/publication/255659928_Can_Toddlers_Learn_Vocabulary_from_Television_An_Experimental_Approach

Kuchirko, Y. A., & Tamis-LeMonda, C. S. (2019). The cultural context of infant development: Variability, specificity, and universality. In D. A. Henry, E. Votruba-Drzal, & P. Miller (Eds.), *Advances in child development and behavior* (Vol. 57, pp. 27–63). JAI. https://doi.org/10.1016/bs.acdb.2019.04.004

Kuhl, P. K., Tsao, F. M., & Liu, H. M. (2003). Foreign-language experience in infancy: Effects of short-term exposure and social interaction on phonetic learning. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(15), 9096–9101. https://doi.org/10.1073/pnas.1532872100

Lense, M. D., Shultz, S., Astésano, C., & Jones, W. (2022). Music of infant-directed singing entrains infants' social visual behavior. *Proceedings of the National Academy of Sciences of the United States of America*, *119*(45), Article e2116967119. https://doi.org/10.1073/pnas.2116967119

Linebarger, D. L., & Walker, D. (2005). Infants' and toddlers' television viewing and language outcomes. *American Behavioral Scientist*, *48*(5), 624–645. https://doi.org/10.1177/0002764204271505

Long, H. L., Ramsay, G., Griebel, U., Bene, E. R., Bowman, D. D., Burkhardt-Reed, M. M., & Oller, D. K. (2022). Perspectives on the origin of language: Infants vocalize most during independent vocal play but produce their most speech-like vocalizations during turn taking. *PLOS ONE*, *17*(12), Article e0279395. https://doi.org/10.1371/journal.pone.0279395

Luo, R., Escobar, K., & Tamis-LeMonda, C. S. (2020). Heterogeneity in the trajectories of US Latine mothers' dual-language input from infancy to preschool. *First Language*, *40*(3), 275–299. https://doi.org/10.1177/0142723720915401

Mayo, L. H., Florentine, M., & Buus, S. (1997). Age of second-language acquisition and perception of speech in noise. *Journal of Speech, Language, and Hearing Research*, *40*(3), 686–693. https://doi.org/10.1044/jslhr.4003.686

McDaniel, B. T., & Radesky, J. S. (2018). Technoference: Parent distraction with technology and associations with child behavior problems. *Child Development*, *89*(1), 100–109. https://doi.org/10.1111/cdev.12822

McMillan, B. T., & Saffran, J. R. (2016). Learning in complex environments: The effects of background speech on early word learning. *Child Development*, *87*(6), 1841–1855. https://doi.org/10.1111/cdev.12559

Mendoza, J. K., & Fausey, C. M. (2021). Everyday music in infancy. *Developmental Science*, *24*(6), Article e13122. https://doi.org/10.1111/desc.13122

Morini, G., & Newman, R. S. (2020). Monolingual and bilingual word recognition and word learning in background noise. *Language and Speech*, *63*(2), 381–403. https://doi.org/10.1177/0023830919846158

Pempek, T. A., Kirkorian, H. L., & Anderson, D. R. (2014). The effects of background television on the quantity and quality of child-directed speech by parents. *Journal of Children and Media*, *8*(3), 211–222. https://doi.org/10.1080/17482798.2014.920715

Prevoo, M. J., & Tamis-LeMonda, C. S. (2017). Parenting and globalization in western countries: Explaining differences in parent–child interactions. *Current Opinion in Psychology*, *15*, 33–39. https://doi.org/10.1016/j.copsyc.2017.02.003

Reed, J., Hirsh-Pasek, K., & Golinkoff, R. M. (2017). Learning on hold: Cell phones sidetrack parent–child interactions. *Developmental Psychology*, *53*(8), 1428–1436. https://doi.org/10.1037/dev0000292

Riley, K. G., & McGregor, K. K. (2012). Noise hampers children's expressive word learning. *Language, Speech, and Hearing Services in Schools*, *43*(3), 325–337. https://doi.org/10.1044/0161-1461(2012/11-0053)

Rogers, C. L., Lister, J. J., Febo, D. M., Besing, J. M., & Abrams, H. B. (2006). Effects of bilingualism, noise, and reverberation on speech perception by listeners with normal hearing. *Applied Psycholinguistics*, *27*(3), 465–485. https://doi.org/10.1017/S014271640606036X

Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, *83*(5), 1762–1774. https://doi.org/10.1111/j.1467-8624.2012.01805.x

Schatz, J. L., Suarez-Rivera, C., Kaplan, B. E., & Tamis-LeMonda, C. S. (2022). Infants' object interactions are long and complex during everyday joint engagement. *Developmental Science*, *25*(4), Article e13239. https://doi.org/10.1111/desc.13239

Selnow, G. W., & Bettinghaus, E. P. (1982). Television exposure and language development. *Journal of Broadcasting*, *26*(1), 469–479. https://doi.org/10.1080/08838158209364014

Soderstrom, M., & Wittebolle, K. (2013). When do caregivers talk? The influences of activity and time of day on caregiver speech and child vocalizations in two childcare environments. *PLOS ONE*, *8*(11), Article e80646. https://doi.org/10.1371/journal.pone.0080646

Sperry, D. E., Sperry, L. L., & Miller, P. J. (2019). Reexamining the verbal environments of children from different socioeconomic backgrounds. *Child Development*, *90*(4), 1303–1318. https://doi.org/10.1111/cdev.13072

Strouse, G. A., & Troseth, G. L. (2008). "Don't try this at home": Toddlers' imitation of new skills from people on video. *Journal of Experimental Child Psychology*, *101*(4), 262–280. https://doi.org/10.1016/j.jecp.2008.05.010

Suarez-Rivera, C., Smith, L. B., & Yu, C. (2019). Multimodal parent behaviors within joint attention support sustained attention in infants. *Developmental Psychology*, *55*(1), 96–109. https://doi.org/10.1037/dev0000628

Tabri, D., Chacra, K. M. S. A., & Pring, T. (2011). Speech perception in noise by monolingual, bilingual and trilingual listeners. *International Journal of Language & Communication Disorders*, *46*(4), 411–422. https://doi.org/10.3109/13682822.2010.519372

Takata, Y., & Nábělek, A. K. (1990). English consonant recognition in noise and in reverberation by Japanese and American listeners. *Journal of the Acoustical Society of America*, *88*(2), 663–666. https://doi.org/10.1121/1.399769

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology & Psychology*, *18*(5), 459–482. https://doi.org/10.1002/cne.920180503

Received January 6, 2023
Revision received February 19, 2024
Accepted March 7, 2024 ■