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The home environment and its relation to vocalizations in the first year of life

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Abstract

Background: Prior data has shown that the home environment impacts child development; however, there remains a paucity of research on how the home environment relates to child and adult words. Therefore, the aim of this prospective and quantitative study was to examine the relationship between the home environment and the quantity of vocalizations or words, and conversational turns produced by infants and parents at 3 and 12 months of age.

Methods: Seventy-two (56% male) full-term infants were assessed at 3 and 12 months of age. The home environment was assessed in person via interview and observation of the child's home using the Infant-Toddler Home Observation for Measurement of the Environment (IT-HOME) Inventory subscales. Vocalizations were measured using the Language Environment Analysis (LENA) device, which measures the adult word count, child vocalization count and conversational turn count. These measures were then averaged for the most voluble, or vocal hour, in the recording period.

Results: At 3 months, IT-HOME Learning Materials scores were significantly associated with a decrease in adult words. We found a statistically significant difference in LENA outcomes between 3 and 12 months when stratified by sex. Specifically, male infants had significantly fewer

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. We used a prospective, quantitative design with self-report and objective measures. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional review board of Northeastern University (No. 17-08-19) and attained from all parents for themselves and their infants to participate.

vocalizations at 12 months when compared to 3 months, whereas females had more vocalizations. There was also a statistically significant difference in IT-HOME Learning Materials, Organization, Responsivity, and Total scores when comparing 3- and 12-month time points.

Conclusions: These findings reveal that the home environment changes significantly over the first year of life. At 3 months, Learning Materials in the home were related to adult words, while between 3 and 12 months, several aspects of the home significantly changed. Male children had reduced vocalizations between 3 and 12 months; whereas, female children had increased vocalizations during the same time points. Future research should focus on examining these outcomes with multiple measures, time points, and patient populations.

Keywords

Home; environment; vocalizations; infant; adult

Introduction

Vocalizations can be observed early in infancy and continue to develop throughout the first years of life (1). In fact, this development begins, *in utero*, where the fetus can discern and react to different sounds and languages (2,3). By 6 months, infants appear to understand that their vocalizations have social value and may be used to elicit interactive responses (4). These interactive responses are from caregivers and often take the form of infant directed speech, characterized by the utilization of short, simple phrases, slower speed of speaking, and varied pitch, among other traits, and maternal responsiveness which influence infant vocalizations (5–11). Parents and developmental specialists also participate in auditory bombardment in which they label items in their infant's environment repeatedly, to bolster receptive and expressive language and to increase vocalizations (12). In addition to labeling items in the child's environment, contingent adult feedback can rapidly restructure infant babbling due to infants' use of social feedback (13), and in this back and forth exchange infants learn new vocal forms by discovering patterns in their mothers' speech (14). This early exposure of language is important and has been found to peak early on in infancy at around 6 months of age (15), and, as a result, can be affected by stimuli in the infant's home environment.

One way in which researchers have measured the vocal exposure that a child has is by measuring adult word count, conversational turn count and infant/child vocalizations across various contexts. In a study with 36 preterm infants, adult word counts, infant vocalizations, and conversational turns were analyzed from recordings of the infant environment in the neonatal intensive care unit (16). This study found that exposure to parental talk was a significant predictor of infant vocalizations at 32 weeks and conversational turns at 32- and 36-week gestation. Further, Brookman and colleagues found recordings of mothers diagnosed with depression or anxiety and/or elevated symptoms contained fewer mother–infant conversational turns and infant vocalizations at 6 and 12 months of age in the home environment compared to a control group (17). Toys in the environment have also been shown to alter infants' vocalizations; Harold & Barlow [2013] showed that 6- to 8-month infants vocalized the least when they were watching videos or interacting with an adult, and vocalized the most when playing with large toys (18). A 2018 study examined both conversational turn count and adult word count and found significant correlation between conversational turn count at 18 to 24 months of age and IQ, verbal comprehension, and receptive/expressive vocabulary scores 10 years later. These speech and language inputs in the form of greater adult-child conversational experience is associated with more coherent white matter connectivity in the brain, suggesting that conversational turn count may influence cognitive developmental outcomes early on (19). Taken together, it is clear that caregiver interactions and the environment are essential for vocalization development (18).

Early environmental stimuli are the foundation for subsequent learning (20,21). Because of this, many researchers have examined the connections between early environmental stimuli (home, toys, materials) and developmental outcomes (22–26). More specifically, researchers have used the Affordances in the Home Environment for Motor Development – Infant Scale (AHEMD-IS), in relation to infants' motor and cognition (22,23). These studies found significant positive relationships between home environmental factors, such as the number of indoor and outdoor spaces, physical space, fine-motor toys, gross-motor toys, and play materials, and fine motor (22) and cognitive scores (23). Another widely used scale to assess the home environment is the Home Observation for Measurement of the Environment (HOME). The HOME measurement tool is used to assess the home environment as it pertains to toys, play materials, parental interaction with children as well as familial habits and patterns (27,28) and has been validated in several cultural contexts and internationally (27,29–33). This tool has been utilized to understand how the home environment relates to parental attachment, cognitive development, and educational performance (27,31,34,35). Further, Elardo, Bradley, and Caldwell [1977] used the HOME longitudinally between 6 months and 3 years to examine relations between the home environment and language development using the Illinois Test of Psycholinguistic Abilities. They found that the HOME subscales of Responsivity, Play Materials, and Maternal Involvement at 6 and 24 months all related to child's auditory reception, auditory association, visual association, and grammatical closure at age three (35).

Therefore, it is critical to further understand the role of the home environment in relation to vocal development. Specifically, the aims of the present study were to examine the relationship between the home environment, as measured by the Infant-Toddler Home Observation for Measurement of the Environment (IT-HOME) Inventory subscales, and the quantity of vocalizations produced by infants and parents, as measured by Language Environment Analysis (LENA) at 3 and at 12 months of age, respectively. Given the results of Elardo, Bradley, and Caldwell [1977] linking the IT-HOME subscales to communication outcomes, we hypothesized families with higher IT-HOME subscale and total scores would have increased quantities of vocalizations for infants and words for adults within the environment. We also aimed to determine how the IT-HOME and vocalizations change between 3 and 12 months, and if there were sex differences driving these changes. We hypothesized that the IT-HOME would significantly change over time as the infants develop and that there would be significant increases in vocalizations across time points. We also predicted that males would be less vocal than females at both time points. Lastly, for the relationship between the IT-HOME and vocalizations, we predicted that infants with higher scores on the IT-HOME subscales would have more child vocalization counts (CVC), adult word counts (AWC), and conversational turn counts (CTC) at each time point. We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/pm-21-53).

Methods

Design

We used a prospective, quantitative design with self-report and objective measures. This study was conducted in accordance with the Declaration of Helsinki. The study was approved by institutional review board at our institution (No. 17-08-19) and informed consent was attained from all parents for themselves and their infants to participate.

Sample

The data for the present study were collected as part of a larger study examining sucking, feeding and vocal development at 3 and 12 months of age in the Greater Boston Area. Participants were recruited through word of mouth, Facebook groups, and flyer distribution. Caregivers consented on behalf of their infants and were compensated with an Amazon gift card for their participation. The current study included only full-term infants at 3 months of age and 12 months of age. Infants who were preterm or had reported chromosomal and/or congenital anomalies were excluded.

This study consisted of 72 infants (55.6% male, 44.4% female) with a mean age of 91.6 days at 3 months (Table 1). Of the 72 infants, 55 (54.6% male, 45.5% female) completed the 12-month assessment with a mean age of 363 days. Parental education was originally categorized by six groups but was reduced to 2 categories to improve model fit [less than high school education (ed.): 0 individuals, high school ed.: 0, some undergraduate ed.: 6, undergraduate degree: 13, some graduate ed.: 1, graduate degree: 52]. The demographic comparison between infants with recorded measurements at 3 months were comparable to those infants with measurements recorded at 12 months. Descriptive statistics on the median and interquartile ranges for both child vocalizations and adult words, as well as conversational turns for participants enrolled in our study at 3 months and at 12 months are seen in Figures 1–3.

Study procedure

To conduct the study visit, researchers arrived at the infant's home approximately one hour before the infant's scheduled feed, as determined by the caregiver. Researchers completed the IT-HOME through both observation and interview. At the end of the study visit, the researchers set up the LENA system to stay with the child throughout the recording period. A few days after the study visit, the researcher returned to the participant's home to collect the LENA system.

Measurements

Infant/Toddler HOME inventory—The IT-HOME is a 45-item checklist that evaluates the home environment of infants and toddlers from birth to three years of age (36). The questionnaire requires the researcher to complete a combination of interview and observation-based questions with some questions having both interview and observation options for completion (29). The IT-HOME was conducted at both 3- and 12-month timepoints for the purposes of this study. There are six subscales included in the IT-HOME assessment: Responsivity, Acceptance, Organization, Learning Materials, Involvement, and Variety of Daily Stimulation. A total score is calculated by summing each domain score (29,36). Responsivity asks questions surrounding positive parental engagement and attachment to their infant as shown during the visit. Acceptance primarily includes questions around parental disciplinary approaches. Organization includes information about the infant or child's activities outside of the infant's home and parents, specifically discussing childcare and how often the infant leaves the home. Learning Materials focuses on the presence of certain toys and play materials in the home. Involvement describes the parents' interaction with the infant during play and while working in the home. Lastly, Variety involves questions of how often the infant or child is read to, as well as the interaction of the infant or child with both parents present in the home.

Language Environment Analysis (LENA) system—The LENA System enables the automated analysis of language recordings, collected from an infant wearing the LENA Digital Language Processor (DLP), and analyzed using LENA Pro Software (37,38). The LENA DLP is a small (~3×2 inches), light-weight recording device, worn by the infant in a specialized vest that records the infant's language environment for up to 16 hours (37,39) and can distinguish between the key child and other children as well as adults, competing sounds including TV and other electronic devices, and distant and overlapping speech (39,40). At the end of the study visit, a researcher powered on the LENA DLP and placed it in a specialized pocket at the front of the LENA vest, located on the infant's chest.

Parents had the option to start the LENA recording the day of the study or the next day. This was typically determined by their preference and the time that the study took place (e.g., 10 am *vs*. 4 pm). Parents who preferred to start the recording a different day powered on the LENA themselves on a day following the study visit. Researchers instructed parents to keep a time log denoting their actives during the study and that the LENA vest should be removed for particular activities (e.g., car seat, bath time, or sleep). A few days following the recording, the researchers retrieved the LENA device and vest at the infant's home and returned it to the laboratory where it was uploaded to LENA Pro software for analysis.

In the present study, only data from the hours in which the infant was awake were analyzed. To determine this, researchers referenced the time log provided to parents to complete during in-home visits and any hour containing only a sleeping activity (i.e., nap or sleep), was excluded. If parents noted both a sleeping and awake activity, infants had to have at least 5 vocalizations within the hour to count as an awake hour. In addition, any hour that contained less than 5 vocalizations was excluded from the analysis. After the child slept for the night, based on time log report, hours beyond that point were excluded from the analysis. Infants without data in their time log were excluded from the analysis along with infants who did not have at least 4 hours of awake activities recorded in their time logs. Each infant's recording varied in duration, and though most infant recordings took place from the morning through the afternoon until the infant slept for the night, activities that infants completed varied across recordings based on their family's preferred activities for the day. Therefore, while all infant recordings included feeding sessions, most recordings also included play sessions and likely included bath times and story times though the number of each varied between participants.

After determining the infant's waking hours, a full output of the infant's LENA data was exported in 5-min intervals using LENA Pro Software and the infant's most voluble hour, which is the hour the infant produced the most vocalizations, was identified by utilizing the composite view in LENA Pro Software. This measure has been utilized in past work from our lab (41) as well as in work by Iyer, Denson, Lazar, and Oller (42). The following averaged output measures were then calculated using data from the infant's most voluble hour: child vocalizations count, adult word counts, and conversational turn counts. Specifically, the raw counts exported from the LENA Pro software for CVC, AWC, and CTC that fell within the most voluble hour were summed and then averaged per minute by dividing the sum by 60 min. These values were then utilized for the present analysis. CVC is defined as the number of vocalizations by the infant in a given period of time, while AWC is the number of words spoken by an adult in a given period of time (9). CTC is the number of back-and-forth alternations between a child and an adult in a given period of time (9). Further, as recordings were performed for varied lengths of time, utilizing the most voluble hour enabled all infants to be compared while controlling for recording length differences as well as was the best representation of the child's most vocal period thereby assessing the most vocal time-period. This method was used in a prior study from our lab examining vocal outcomes (41). Prior studies have reported that LENA outcome measurements from shorter periods of time attained from longer LENA recordings is similar to automated LENA outputs for these periods (43,44). Average length of LENA recordings for the sample was 12.51 h at 3 months and 14.29 h at 12 months. Average length of LENA recording during which the infant was awake was 7.14 h at 3 months and 8.35 h at 12 months. The duration of each infant's LENA recordings can be found in Table S1.

Data analysis

Infant measurements were recorded at 3 months of age and then again at 12 months. All infants who met the inclusion criteria were included for analysis. Due to the COVID-19 pandemic, not all infants had measurements recorded at the 12-month time point. For this analysis we ran a series of multivariate multiple regressions where coefficients were selected based on multivariate test statistics. Reduced models were then compared to full models with linear hypothesis testing to verify there were no changes in model fit. Analyses were completed at both 3- and 12-month time points as well as a difference between the two. We then completed a series of multiple pairwise comparisons (with appropriate correction) to check for statistically significant differences in IT-HOME scoring materials for those infants who completed both 3- and 12-month visits.

Specifically, we first sought to understand the relationship between the home environment (as measured by the IT-HOME subscales) and quantity of vocalizations produced by infants and parents (as measured by LENA) at 3 and 12 months as well as the difference between these two time points. Four models were considered: 3-month HOME scores were used to predict 3-month LENA scores, 12-month HOME scores predicted 12-month LENA scores, the change (from 3 to 12 months) in HOME scores were used to predict the change in

LENA scores, and the change in HOME scores predicted 12-month LENA scores. All models controlled for possible confounding by sex and parental education as supported by prior studies (45–48). Other covariates including parental: ethnicity, employment, marital status, and primary language spoken at home were considered however were excluded from the analysis given the lack of diversity in participant responses; we address this limitation further in our discussion. Statistical analyses were completed using the software package R, version 4.0.2.

Results

At 3 months, there was a jointly statistically significant association between LENA scores and IT-HOME Learning Materials, $F_{(3, 52)}=3.16$, $P<0.05$ and IT-HOME Involvement measurements, $F_{(3, 52)}=4.12$, $P<0.05$. Linear hypothesis testing confirmed a model including only IT-HOME Learning Materials and IT-HOME Involvement fit just as well as a model including all IT-HOME measurements as well as with the inclusion of infant sex and parental education, Pillai's Trace =0.34, F=1.13, df = [18, 162], P=0.32. Statistically significant results from the multivariate regression model report a 1 unit increase in IT-HOME Learning Materials results on average in a 4.99 score decrease in Average Adult Word scores at 3 months while holding IT-HOME Involvement scores constant (Table 2). Further, emerging significant results from the multivariate regression model report a 1 unit increase in IT-HOME Involvement results in an 8.22 score increase on average in Average Adult Word scores at 3 months while holding IT-HOME Involvement scores constant (P=0.06). There were no statistically significant associations between LENA scores and IT-HOME measurements at 12 months while controlling for parental education and infant sex.

In total, 63 infants had one LENA measurement taken at 3 months of age while 48 infants had one LENA measurement taken at 12 months of age. At 3 months, during the most voluble hour, 30.16% of infants were reported as playing, 22.22% were reported as feeding or eating, 3.17% were reported as being outside of the home, 36.51% were reported as completing more than one activity, and 7.94% did not report an activity. At 12 months, 41.67% of infants were reported as playing, 14.58% were feeding or eating, 10.42% were out of the home, and 33.33% completed more than 1 activity. Between 3 and 12 months, the ratio of infant vocalizations to adult words at each timepoint was calculated. At 3 months, the average ratio of infant vocalizations to adult words was 0.13 (SD =0.10), while at 12 months, average ratio of infant vocalizations to adult words was 0.22 (SD =0.32). The ratio of each infant's vocalizations to adult words for each timepoint can be found in Table S2. For the difference between 12 and 3 months, there was a jointly statistically significant association between the change in LENA scores when comparing males to females, $F_{(3, 34)}=4.07$, $P<0.05$. Linear hypothesis testing confirmed a model including only infant sex fit just as well as including all IT-HOME measurements as well as parental education, Pillai's Trace =0.37, F=0.72, df = [21, 108], P=0.81. Statistically significant results from the multivariate regression model report on average, males have a 0.72-point decrease in vocalizations from 3 to 12 months and females have a 0.88-point increase; more specifically, the difference in Child vocalizations (from 12 to 3 months) is 1.60 lower for males when compared to females (Table 3, Figure 4). There were no statistically significant associations between LENA scores at 12 months and the change in IT-HOME measurements from 3 to 12 months while controlling for parental education and infant sex.

When examining differences in IT-HOME scoring materials between 12 and 3 months (for only those participants with both a 3- and 12-month visit), statistically significant differences were observed for: Learning Materials $t_{(54)}$=7.87, P<0.005, Organization $t_{(54)}$=3.94, P<0.005, Responsivity $t_{(54)}$=5.15, P<0.005, and Total $t_{(54)}$=7.45, P<0.005 scores (Table 4, Figure 5). There were no statistically significant differences in any change in IT-HOME scores between participants when classified by infant sex or parental education.

Discussion

This study aimed to determine the relationship between the home environment and the amount of infant and parent vocalizations within the first year of life. Results revealed that aspects of the home environment are only related to the quantity of vocalizations at 3 months while no associations were seen at 12 months. IT-HOME scores changed significantly between 3 and 12 months, but the quantity of vocalizations did not. However, there were sex differences evident in the association of the quantity of infant vocalizations between 3 and 12 months. This is the first time that the IT-HOME has been examined in relation to infant vocalizations.

IT-HOME and vocalizations at 3 months

Infants whose homes were rated with higher IT-HOME Learning Materials scores, had significantly fewer adult words, at the 3-month time point. The Learning Materials subsection includes items such as evaluating the presence of “Muscle activity toys or equipment” and the presence of “Complex eye-hand coordination toys”. These results might suggest that parents who provided a wider variety of toys for their infants spoke fewer words around their infant in the home environment. This was not consistent with our hypothesis as we predicted higher scores on the IT-HOME subscales would be related to more vocalizations. These findings may indicate that the more toy variety in the infant’s environment, the less parents may be vocalizing. This may be because the parents are more reliant on the toys in their environment for infant engagement or simply because of the nature of the toys themselves. In the present study, we collected data on several toy types (e.g., muscle activity toys, hand-eye coordination toys, etc.) included within the home environment through the IT-HOME; however, more data on the type and frequency of toy play would be beneficial in future studies. Prior literature suggests a link between toy type and parental engagement (49,50). For instance, Sosa [2016] found parents vocalized least with infants when utilizing electronic toys with infants and that parental vocalizations increased with the use of traditional toys and books. Another study of 9 and 12 month old infants examined parent-child interactions with toys and found that parents were more vocal in their interaction with infants when playing with traditional toys (e.g., no sounds, music, or electronic capability) compared to toys that offered those features (49). More data is needed to further explore the relation between specific toy types used in the home and the number of adult words, during several different time points in infancy.

There were emerging trends towards significance between scores on the IT-HOME involvement subscale and the quantity of adult words. Though these results did not achieve statistical significance, we acknowledge the practical importance of these findings in that we would expect a positive relationship between IT-HOME involvement and adult words. This notion is consistent with prior literature suggesting that increased parent-child involvement relates to increased adult words while decreased involvement results in decreased adult words (51). We did not find significant associations between the IT-HOME subscales and child vocalization and conversational turn counts at 3 months, which was not consistent with our hypothesis. However, these results may indicate that certain aspects of the home environment at 3 months relate to only adult behavior and not that of the child. At the 3-month time point, infants are beginning to produce more typical phonation and begin to articulate while vocalizing (52). At this early juncture though it is likely that infants are just beginning to develop the understanding of the social value of their vocalizations (4) and because of this, the home environment may not play as large of a role in infant vocalizations or conversational turn counts at this point in development.

No other comparisons were emerging or significant between the IT-HOME subscales and child vocalization, conversational turn counts, or adult word counts during the most voluble hour at 3 months.

IT-HOME and vocalizations at 12 months

There were no significant associations between the IT-HOME total or subscales and vocalizations at 12 months. This was not consistent with our hypothesis or with the prior research showing a relationship between HOME Responsivity, Play Materials, and Maternal Involvement subscales at 6 and 24 months and children’s auditory reception and association, visual association, and grammatical closure at age 3 (35). These differences in findings may be attributed to the older age of the children included, language evaluations utilized, and the prior study consisted of a more diverse cohort from the southern region of the United States, whereas the current study consisted of a more homogenous sample.

3 vs. 12-month comparisons of vocalizations

We also examined differences in LENA outcomes between the 3- and 12-month timepoints while controlling for sex. There were significant changes in the quantity of infant vocalizations between 3 and 12 months, though not for adult words or conversational turns. We speculate that during this time-period parents may have had increased non-verbal interactions with their infants at 3-months compared to 12-months, as is supported by prior literature (7,9–11). We examined activity type for participants during the most voluble hour at both time points and found that infants and parents engaged in a variety of activities, with play being the most widely reported activity. However, many parents reported two or more activities during the most voluble hour making it challenging to determine strong associations between the activity during the most voluble hour and vocalizations. When the most voluble hour was examined in more detail, we saw an increase in the average ratio of infant vocalizations to adult words at 12 months compared to 3 months. This increase likely reflects the child’s maturation between the 3- and 12-month timepoints as average adult words decreased between timepoints. These trends were also shown in Gilkerson and colleagues who found that raw child vocalizations increased from 2 to 12 months, while adult words decreased (9).

Additionally, for all infants, we found a statistically significant change in child vocalizations over time and this difference was further explained by infant sex (e.g., males tended to have a decrease in vocalizations over time and females tended to have an increase). Results for conversational turns were not significant but suggest a decrease over time, and this decrease was greater for female infants when compared to male infants. Findings for child vocalizations and conversational turns aligned with our hypothesis with prior literature showing that males have fewer vocalizations in infancy (46,53). Further, being male is a significant predictor for Late Language Emergence or other markers for language delay, which likely reduces early vocalizations (47). This sex difference is more pronounced earlier in childhood and then narrows with age (54). However, our results are also somewhat varied in comparison to prior literature as a study by Gilkerson and colleagues using the LENA device to record vocalizations in the home from 2 months to 4 years found that child vocalizations and conversational turns increased over time. This was not evident in our data. Further, Gilkerson and colleagues reported no significant differences in child vocalizations, adult words or conversational turns in relation to child sex. However, one of the main differences between this study and the current findings is that we used the infant's most voluble hour, while Gilkerson and colleagues utilized the entire 12-hour recording that likely incorporated a larger portion of the infant's activities across multiple days (9). Further, Gilkerson and colleagues had a larger study population (N=329) with LENA recordings taken across several days.

IT-HOME 3 vs. 12 months

When comparing the home environment at 3 and 12 months, results showed there were significant increases in IT-HOME scores for Learning Materials, Organization, and Responsivity subsections, as well as IT-HOME Total scores across the timepoints. We hypothesized that the infant home environment would change over time between the 3- and 12-month timepoints and would specifically increase across the total score and all subscales. Overall, it is clear that the home environment as a whole (e.g., IT-HOME Total scores) changes significantly between 3 and 12 months. More specifically, the subscales of Learning Materials, Organization, and Responsivity significantly changed across the first year of life. Considering that these subscales are focused on the toys in the home, experiences beyond the home environment and responsiveness to the child, it is reasonable that aspects would change between the two timepoints. As the infant develops, parents likely acquire a wider variety of toys and this follows recommendations by specialists to provide and select developmentally appropriate play materials (55). Similarly, as infants and children age, they become more social and likely require more responses and engagement from caregivers (56). Additionally, as infants and children develop, they spend more time interacting with other infants and families and are often cared for in groups (57), likely leading to more interactions outside of the home environment, potentially relating to the increased Organization subscale scores seen in the present study. We did not see significant differences over time in the Acceptance or Variety subscales that largely examines criticism/punishment of the child, family visits and meals with both parents, respectively. These items may not change overtime as parents in our study likely did not view their infants as behaving in a difficult manner or support physical punishment for infants at the 3- or 12-month timepoint. Though we did not evaluate punishment other than through use of the IT-HOME, previous study has shown younger mothers who do not support alternatives to physical punishment and who view infants as difficult are more likely to utilize physical punishment (58). Alternatively, parents may not have displayed physical punishment in front of researchers. Further, the family support surrounding the home may not change much in the first year. Prior work by Orri, Côté, Tremblay, and Doyle [2019] examined changes in the IT-HOME scale between 6, 18, and 36 months of age (59) and similarly found that across these time points scores for the IT-HOME Learning Materials, Responsivity, and Variability subscales increased, while scores for the Organization, Acceptance and Involvement subscales decreased over time. Differences in study findings may be attributed to potential cultural and socioeconomic differences between our cohort in the Northeastern United States compared to the United Kingdom where Côté and colleagues' study took place. Further, infants in our study had high socioeconomic status, with almost all parents being married and having a college degree, whereas a larger portion of participants in Côté, Tremblay, and Doyle were unemployed, unmarried, and had less education, potentially making it more difficult to access childcare, etc. and for improvement in Organization subscale items over time.

Limitations

There are several limitations to consider in relation to the present investigation. Specifically, as this is the first investigation of the association between the IT-HOME and infant vocalizations, adult words, and conversational turns, we could not consider other variables that may further impact the home environment, such as socioeconomic status, income, and parental ethnicity, employment, marital status, and primary language spoken at home as the participants in our study group consisted of a homogenous sample derived from the northeast of the United States. Likewise, we acknowledge a higher percentage of the parents in our sample hold a graduate degree or higher (74%) when compared to 12.6% of adults aged 18 and older in the United States (60). For these reasons, we cannot generalize our findings to that of the entire United States population. Moreover, though it impacts parent language input, we did not control for maternal emotional health including screening for depression and anxiety in the present study.

Additionally, the overall quantity of our data was affected by the COVID-19 pandemic which caused a decrease in data collection for the present study at the 12-month time point and resulted in less IT-HOME and LENA data at 12 months. For this reason, we assume our data to be missing completely at random, allowing us to estimate regression coefficients in the presence of missing data without the need to consider methods for imputation (61).

While some studies have shown the reliability and validity of the LENA system (37,39,62,63) even over short time periods (43,44), others have demonstrated a lack of reliability for certain LENA outcome measures, such as CTC and CVC (64–69). Therefore, we acknowledge that we did not utilize manual coding and that this may have affected the results of the present study. Further, while this was a longitudinal study; we did not utilize multiple LENA measurements or IT-HOME measurements per time point. Repeated measures at each time point would allow for a more representative sample of both vocalizations and the home environment. Further, adding additional measures beyond the IT-HOME would help us to derive more specifics about and be more beneficial to our understanding of the child's environment. Therefore, future studies should focus on repeated measures of the IT-HOME and LENA, with a larger sample size, across patient populations. Lastly, while parents recorded at different times of day for varying lengths of time depending on when they preferred to begin recording, all infants had at least 4 hours of data. Only hours during which the infant was awake were included in the analysis as determined by the LENA log that the parents completed for each hour the infant wore the device. Hours after the infant was asleep for the night were not included and therefore most recording occurred during the morning and afternoon. Though we did limit the analysis to awake hours, we acknowledge that we did not control for recording length in our analysis. While we have included information about parent-reported infant activities during the most voluble hour, in future analyses, we hope to continue to use and validate infants' most voluble hours with more specific information on the activities completed during them and to relate it to the infant home environment in a larger, more diverse sample with a range of SES.

Conclusions

The results of this study revealed that IT-HOME Learning Materials scores were associated with adult words at 3 months with no significant associations between these variables at 12 months. Between 3 and 12 months, we found that females had significantly more vocalizations compared to males. Results also showed that the IT-HOME Organization, Involvement, and Responsivity subscale scores significantly increased across time points. Overall, these findings indicate the importance of the home environment, particularly Learning Materials (e.g., toys), in influencing adult words offered to infants at 3 months. More research is needed to further investigate these associations with a larger sample size, repeated time points, and across patient populations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Conflicts of Interest:

All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/pm-21-53). The series "Neonatal Feeding and Developmental Issues" was commissioned by the editorial office without any funding or sponsorship. EZ, MH, and AI are employees of Northeastern University. AM and TC are doctoral students at Northeastern University. BA is a former master's student at Northeastern University. This

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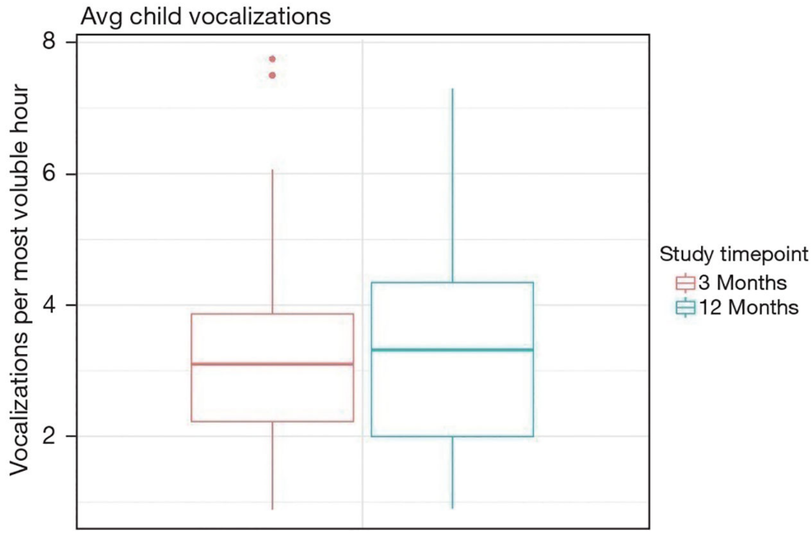

Figure 1.

Box and whisker plots of Language Environment Analysis (LENA) outcome average child vocalizations at 3 months of age (red) and 12 months of age (blue).

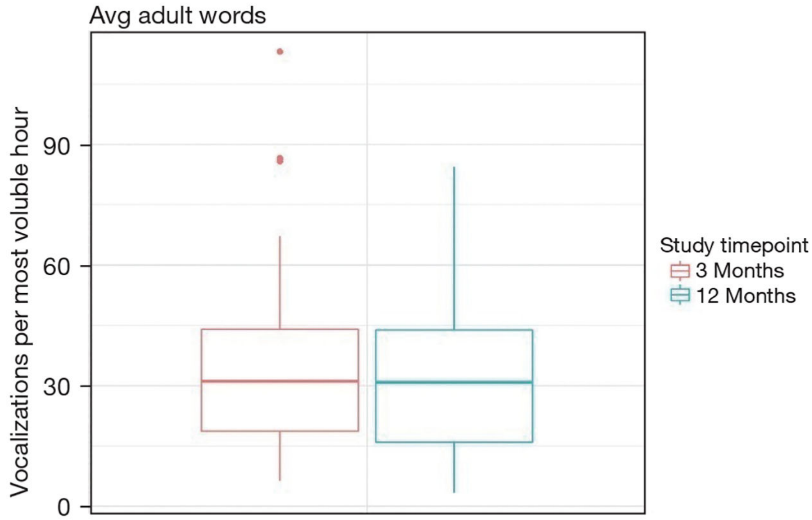

Figure 2.
Box and whisker plots of Language Environment Analysis (LENA) outcome average adult words at 3 months of age (red) and 12 months of age (blue).

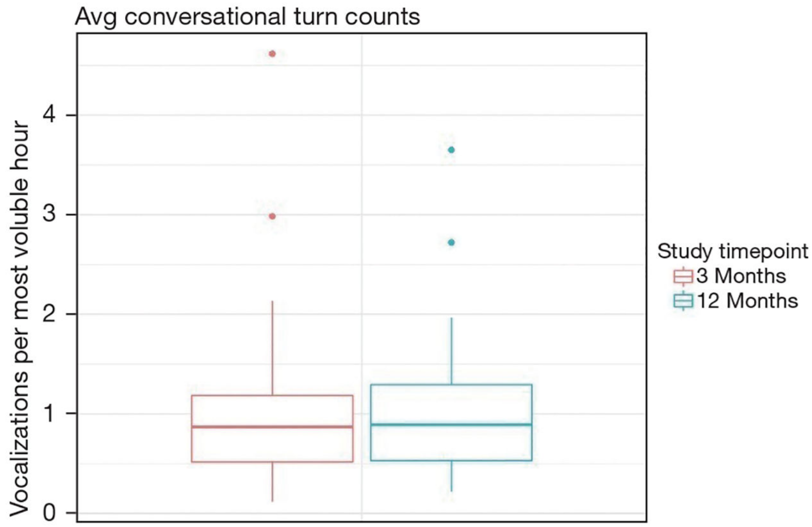

Figure 3.
Box and whisker plots of Language Environment Analysis (LENA) outcomes conversational turn at 3 months of age (red) and 12 months of age (blue).

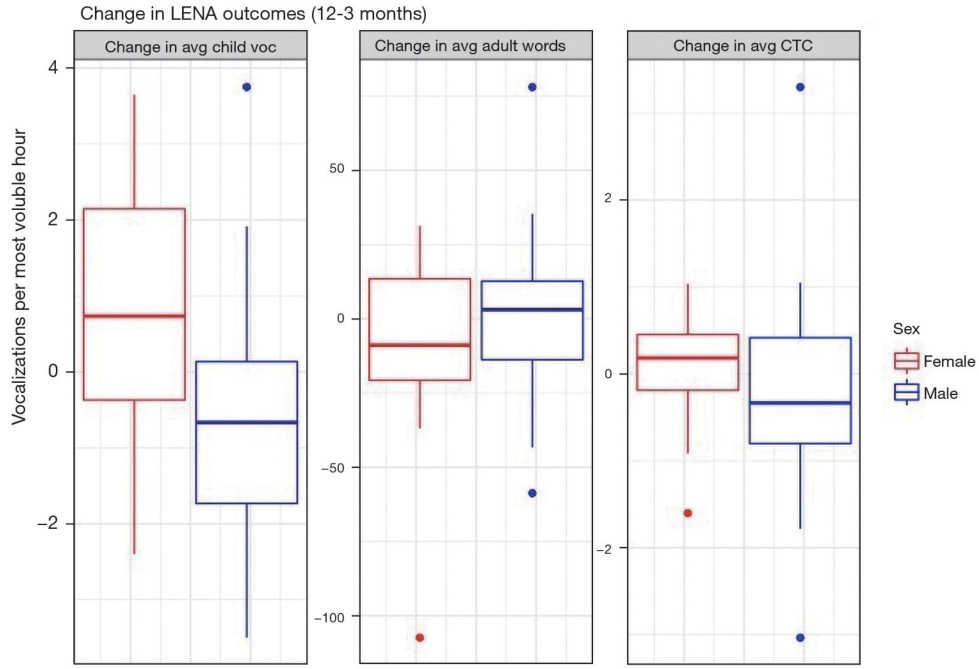

Figure 4.

Box and whisker plots of change in Language Environment Analysis (LENA) child vocalizations, adult words, and conversational turns per the most voluble hour for males (blue) and females (red) between 3 and 12 months.

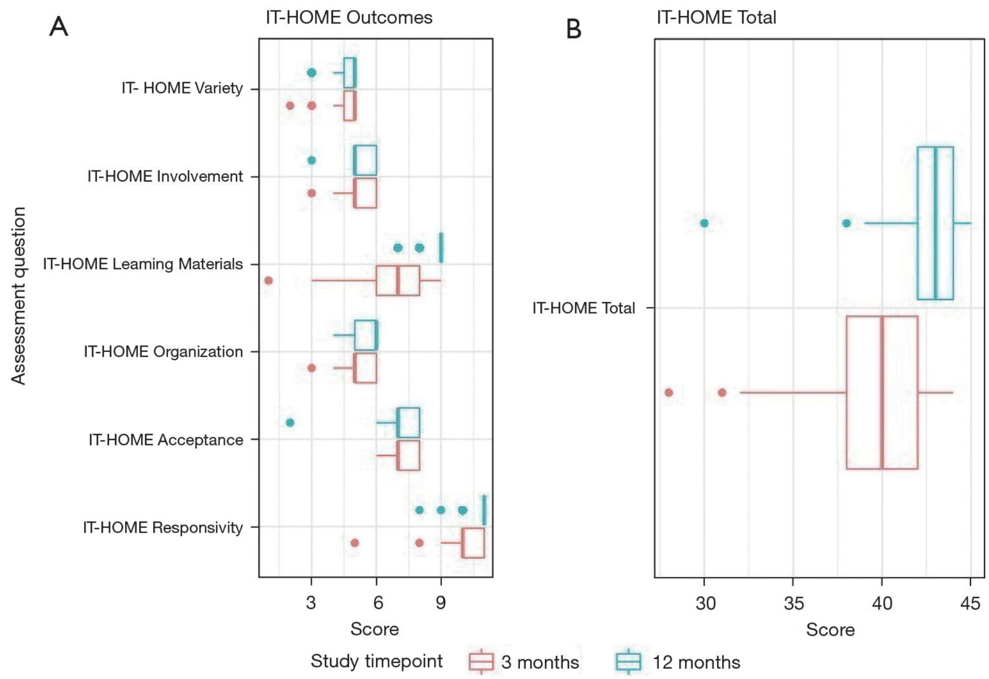

Figure 5.

Box and whisker plots for Variety, Involvement, Learning Materials, Organization, Acceptance, and Responsivity subscales (A) and Infant-Toddler Home Observation for Measurement of the Environment (IT-HOME) total scores (B) between 3 months (red) and 12 months (blue).

Table 1

Description of study participants

Variables	3 months	12 months
N (%)	72 (100.0)	55 (76.4)
Male/female, n (%)	40 (55.6)/32 (44.4)	30 (54.6)/25 (45.5)
At least one sibling (yes/no), n (%)	36 (50.0)/36 (50.0)	29 (52.7)/26 (47.3)
Parent has at least a graduate degree (yes/no), n (%)	53 (73.6)/19 (26.4)	42 (76.4)/13 (23.6)
Parent ethnicity (parent 1/parent 2), n (%)		
White	59 (81.9)/57 (79.2)	43 (78.2)/43 (78.2)
African American	1 (1.4)/2 (2.8)	1 (1.8)/2 (3.6)
Asian	10 (13.9)/9 (12.5)	10 (18.2)/9 (16.4)
Hispanic/Latino	1 (1.4)/2 (2.8)	1 (1.8)/1 (1.8)
Missing	1 (1.4)/2 (2.8)	–/–
Primary language at home is English (yes/no), n (%)	64 (88.9)/8 (11.1)	46 (83.6)/9 (16.4)
Parental marital status, n (%)		
Married	70 (97.2)	53 (96.4)
Partner	2 (2.8)	2 (3.6)
Other family members at home, n (%)		
None	68 (94.4)	50 (90.9)
Nanny/Au pair	1 (1.4)	–
More than one other adult	3 (4.2)	2 (3.6)
Missing	–	3 (5.5)
Average age at testing, days (SD)	91.6 (8.83)	363 (7.59)
Average HOME total (SD)	39.4 (3.18)	42.4 (2.35)
Average child voc. (SD)	3.25 (1.52)	3.37 (1.49)
Average adult words (SD)	34.2 (21.2)	31.8 (19.9)
Average CTC (SD)	0.98 (0.71)	0.99 (0.67)

CTC, conversational turn counts.

Table 2

Multivariate regression coefficients (95% CI) when regressing LENA scores at 3 months on IT-HOME Learning and IT-HOME Involvement at 3 months

Variables	Average child vocalizations	Average adult words	Average CTC
Intercept	4.71* (1.52, 7.89)	26.8 (−14.6, 68.2)	0.17 (−1.29, 1.64)
IT-HOME Learning	0.037 (−0.21, 0.28)	−4.99* (−8.2, −1.8)	−0.068 (−0.18, 0.04)
IT-HOME Involvement	−0.33 (−0.99, 0.33)	8.22 (−0.33, 16.8)	0.25 (−0.05, 0.55)

Asterisks denote regression coefficient is statistically significance at the 0.05 level. IT-HOME, Infant-Toddler Home Observation for Measurement of the Environment; LENA, Language Environment Analysis; CTC, conversational turn counts.

Table 3

Multivariate regression coefficients (95% CI) when regressing the change in LENA scores (from 12 to 3 months) months on infant sex

Variables	Change in average child vocalizations	Change in average adult words	Change in average CTC
Intercept	0.88* (0.11, 1.65)	−7.97 (−20.9, 4.93)	0.11 (−0.32, 0.54)
Sex	−1.60* (−2.63, −0.57)	7.50 (−9.81, 24.8)	−0.36 (−0.94, 0.22)

Asterisks denote regression coefficient are statistically significance at the 0.05 level. LENA, Language Environment Analysis; CTC, conversational turn counts.

Table 4

Average IT-HOME Learning Material scores (SD) at 3 and 12 months for those participants with both a 3- and 12-month visit IT-HOME score

Variables	3 months	12 months
N	55	55
IT-HOME Acceptance	7.29 (0.60)	7.31 (0.92)
IT-HOME Involvement	5.15 (0.65)	5.35 (0.58)
IT-HOME Learning Materials	6.89 (1.75) *	8.75 (0.58)
IT-HOME Organization	5.09 (0.78) *	5.51 (0.57)
IT-HOME Responsivity	10.2 (1.02) *	10.8 (0.56)
IT-HOME Variety	4.67 (0.64)	4.67 (0.61)
IT-HOME Total	39.3 (3.4) *	42.4 (2.35)

Statistical significance (at the 0.05 level, with multiple testing correction) denoted with an asterisk (*). IT-HOME, Infant-Toddler Home Observation for Measurement of the Environment.