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Vocal Interaction between Children with Down syndrome and their Parents

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Abstract

Purpose—The purpose of this study was to describe differences in parent input and child vocal behaviors of children with Down syndrome (DS) compared to typically developing (TD) children. The goals were to describe the language learning environments at distinctly different ages in early childhood.

Method—Nine children with DS and 9 age-matched TD children participated; four children in each group were ages 9–11 months and five were between 25–54 months. Measures were derived from automated vocal analysis. A digital language processer measured the richness of the child's language environment, including number of adult words, conversational turns, and child vocalizations.

Results—Analyses indicated no significant differences in words spoken by parents of younger vs. older children with DS, and significantly more words spoken by parents of TD children than parents of children with DS. Differences between the DS and TD groups were observed in rates of all vocal behaviors; with no differences noted between the younger vs. older children with DS, and the younger TD children did not vocalize significantly more than the younger DS children.

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Conclusions—Parents of children with DS continue to provide consistent levels of input across the early language learning years; however, child vocal behaviors remain low after the age of 24 months suggesting the need for additional and alternative intervention approaches.

Keywords

Down syndrome; speech development; parent-child communication; vocalizations; automated vocal analysis

Delayed and disordered speech is among the hallmark features of Down syndrome (DS) (Abbeduto, Warren & Conners, 2007). These delays and disorders are usually apparent early in development. Because DS is a common developmental disorder and is typically identified before or at birth, the research literature on the maturation of these children is relatively robust. It is known, for example, that oral-motor problems in infants with DS often result in problems with the precise production of early speech sounds (Spender et al., 1995; 1996). Nevertheless, the age of onset of canonical babbling with a minimum of a single consonant/vowel speech-like production (e.g., ba) is only about 2 months behind typically developing (TD) infants on average (Lynch, Oller, Steffens, & Levine, 1995; Nathani, Oller & Cobo-Lewis, 2003); and the onset of reduplicated babbling (e.g., "dadada") in infants with DS has been reported to develop at the same time as for TD infants (Smith & Oller, 1981). Furthermore, the overlapping emergence of nonverbal communication skills (e.g., use of gestures) is only marginally delayed (Mundy, Sigman, Kasari, & Yirmiya, 1988). In short, research suggests that early communication of infants with DS, in relation to babbling and nonverbal skills, develops comparably to that of typical language learners at the same developmental stage (Sterling & Warren, 2008).

Unfortunately, the early success of children with DS slows considerably when they begin the transition to linguistic development. There is a consensus in the literature that the subsequent onset of meaningful speech (e.g., first words) is delayed and proceeds at a much slower pace than typically developing children (Abbeduto et al., 2007; Kumin, Councill, & Goodman, 1999; Ypsilanti, Grouios, Alevriadou, & Tsapkini, 2005). Furthermore, expressive development appears to significantly lag behind the use of gestures and receptive development, and is typically delayed relative to developmental age, not just chronological age (Caselli et al, 1998; Miller, 1992). These linguistic delays are chronic and difficult to ameliorate through intervention (Abbeduto et al., 2007). Thus, the picture that emerges as children with DS progress through the later period of early childhood (ages 2–5 yrs) is of a language developmental trajectory that appears to level out after age 2 years.

Little is known about the trajectories of vocalizations themselves. That is, although it is well documented that children with DS are significantly delayed in transitioning to spoken words, what happens to their rates of vocalizations? One might hypothesize that a child's rate of vocalizations stays constant over a longer period of time, despite a lack of speech development. Alternatively, vocalizations could accelerate or decline based on environmental feedback (e.g., parent input or responsiveness). To the extent that child vocalizations continue to serve a communicative role in early interactions, it is important to also consider developmental trends in rates of vocalizations (inclusive of both speech and nonspeech vocalizations).

A change in how a child vocalizes and communicates may lead to changes in parent responsiveness; and conversely, highly responsive parents who follow their child's lead and model language based on child interests may lead to positive changes in intentional child communication (Yoder & Warren, 1998; 2002). For example, when children begin to use gestures and vocalize, parents tend to interpret these behaviors as communicative, imitate the child, and may assign meaning to the vocalizations using words. These responsive strategies support more advanced language and vocabulary development in the child, with concomitant and more complex changes in parent language input (Warren et al., 2008). Several randomized controlled studies have documented differential effects of language intervention approaches for young children with DD that focus on both child and parent training to ensure high levels of responsiveness (Yoder & Warren, 2002; 2006; Yoder, Woynaroski, Fey & Warren, in press). Thus, the language learning process is bi-directional with the parent's behavior affecting the child and the child's behaviors affecting the parent, with both moving in unison to lay a foundation for subsequent language acquisition. This same basic process is at work for both typically developing children and for children with intellectual and developmental delays and disorders (Warren & Brady, 2007).

The presence of DS is known to impact parenting style. Several studies suggest that parents with young children with DS tend to use a more directive interaction style that involves more verbal requests, prompts, and topic control (e.g., Roach, Barratt, Miller, & Leavitt, 1998; Tannock, 1988). Other studies have documented increases in parent communication behaviors and vocalizations during interactions with their infant child with DS compared to TD infants. For example, Slonims et al. (2006) reported that 2-month old infants with DS received lower communicative behavior ratings (e.g., attentive versus avoidant) with their mothers compared to parent-child interactions of typically developing infants; however, at 5 months of age, these communicative ratings increased within interactions between infants with DS and their parents. In contrast, this change was not noted in child-parent interactions for the TD infants. In a study comparing early vocalizations and turn-taking between mother-infant pairs with DS to typically developing children, Berger and Cunningham (1983) audiotaped once weekly interactions for 16 weeks starting at age 6 months. The recordings were collected at 20 and 24 weeks (or 11 and 12 months of age). Results revealed significant differences between mother's vocalizations during the two follow-up recordings, with the mothers of infants with DS showing increased vocalizations at 12 months compared to 6 months. The opposite trend was found for TD children in that mother's rates of vocalizations decreased slightly from 6 months to 12 months.

Despite a modest amount of research on style adaptations that parents make to children with DS, we lack a clear picture of how the language delays observed in these children, influences the richness of their language learning environment (or amount of parent input). A breakdown in the transactional, bi-directional process of parent-child interactions at this critical stage may further impede language development, given the reported weaknesses in expressive speech and language development for this population. That is, if the child does not communicate effectively, the natural interactive processes that enhance language development and acquisition may be compromised and thus less effective (Vilaseca & Del Rio, 2004). When parents of children with DS modify their communication behaviors by increasing their language input, perhaps this adaptation as a language intervention strategy is not sufficient to impact the child's expressive vocabulary and language skills. Additional language acquisition and parent training strategies may be necessary.

The objective of the present study was to determine differences in parent-child verbal interactions, including adult words spoken near the child, adult-child conversational turns, and child vocalizations of young children with DS across two age periods (9–11 months and 25–54 months), compared to that of TD language learners at the same chronological ages. Automated vocal analysis using Language Environment Analysis (LENA) technology (Oller et al., 2010; Xu, Yapanel, & Gray, 2009; Xu, Yapanel, Gray & Baer, 2008) was employed to quantify these behaviors in the home environment, and outcomes were compared to those of typically developing children drawn from a large normative sample (Gilkerson & Richards, 2008). This technology has been used to quantify similar behaviors of young children with autism (Warren et al., 2010); however, this is the first study that will describe these outcomes for young children with DS. The method of data collection (automated vocal analysis) allowed us to summarize a large amount of language data in a short period of time, and the age range of participants allowed for an analysis of differences in parent and child behaviors across the early childhood years. Specific research questions addressed were:

1. Are there differences in the richness of the language environment in terms of amount of parent words spoken near the child for children with DS across the two age periods, compared to that of age-matched typically developing children?

2. Do child vocalizations and parent-child conversational turns of children with DS differ over the two age periods investigated?

Method

Overview

The specific focus of this study is on three types of data generated from automated analysis – adult words (could be one or both parents) spoken near the child, child vocalization frequency, and conversational turns (back and forth interactions) between the child and parent(s). We compared these parent-child behaviors of 9 children with DS to those of 9 same-age typically developing children and their parents drawn from a normative database that includes over 32,000 hours of vocal recordings contributed by 329 families (Gilkerson & Richards, 2008).

Participants

Children with Down syndrome—Participants were families with children between the ages of 9 months and 54 months who had been diagnosed with DS. They were recruited between May and August 2008 through flyers sent to a local DS support group, advertisements in parenting magazines, and direct mailings to early intervention service providers. Interested parents were instructed to contact research staff who conducted a 10-minute phone interview. Inclusionary criteria used to enroll families in the study included

(a) English as the primary language spoken in the home, (b) primary parent was at least 18 years old, and (c) parents were able to be at home with the child for two full days, over one weekend. In total, 9 children (3 male; 6 female) with DS ranging in age from 9- to 54-months (M: 24; SD: 17) were recruited. Seven of the mothers had completed a 4-year or higher university degree, and the other two had a high school degree. Table 1 details the age, gender, and maternal attained education of each of the 9 families.

Typically Developing Normative Sample—We compared data from the children with DS to a sample of chronologically matched children. Chronological matches (as opposed to developmental matches) were desirable because this allowed us to examine the fine-tuning hypothesis as related to differences in vocalizations, and to date little is known about the trajectory of vocalizations as children with DS mature through the early years. Including a chronological match provides information on what we should expect based on typical language learners, and allowed us to administer consistent, age-appropriate standardized measure of language development across the two groups. Furthermore, parent input can be compared between children having a similar time history for interacting with significant others in their language learning environments.

Typically developing (TD) language learners for a matched comparison sample were randomly selected from a larger sample of children who participated in the LENA Research Foundation Natural Language Study (NLS) (see detailed description in Gilkerson & Richards, 2008). In the LENA Research Foundation NLS, approximately 3,800 recordings were obtained from a total of 329 TD children from monolingual English-speaking households, and selected to match the U.S. Census with respect to mother's attained education. The matched sample of same-age peers for the current study had expressive and receptive language at or above normal limits as determined by the Preschool Language Scale-4 (PLS-4; Zimmerman, Lee, Steiner, & Pond, 2002) administered by a certified speech-language pathologist. Demographics for the TD sample are provided in Table 1.

Matching to the DS sample: For the intended comparison of TD children to those with DS, we matched each child with DS to one TD child with respect to key demographic variables. TD children drawn from the original NLS were matched to the DS sample on gender and mother's attained education. Their mean age at recording was matched within one month to that of the DS sample as well. As noted in Table 1, three of the matched TD children had above average language scores on either the Expressive Communication subtest (i.e., C1) or the Auditory Comprehension subtest (i.e., C3; C6). In order to match participants on both gender and mother's education, and to ensure recordings for each matched pair of children were collected within one month of each other, these three children were included in the study as they met all of the matching criteria.

In the NLS design, recordings were collected for each TD child once per month for 38 months, during naturalistic settings (e.g., home and community). Two of these full day recordings (one weekday, one weekend day) were selected for each TD child for the current study based on chronological age, to compare to two day long recordings for each child with DS (i.e., a total of two 12-hour recordings per child, or 24 hours of recordings over two days). Recordings for the DS sample were collected on successive days; and recordings for the TD sample were collected on average one month apart (M=28, SD=8.3 days). Although the current version of the DLP is able to record up to 16-hours, previous versions recorded up to 12-hours. Thus, for the current study all recordings were truncated then data summarized based on only the first 12 hours of data to standardize recording durations across the two populations of children. A description of language performance just prior to the first recording for the 9 children with DS is provided in Table 2, based on results from the PLS- 4 (Zimmerman et al., 2002). TD participants were evaluated from 16 weeks prior to 1 week post recording (M=5.3, SD=6.6 weeks). Characteristics of the number of recording sessions across both samples are provided in Table 3.

Hardware and Software—The LENA system comprises a digital language processor (DLP) and language analysis software. The DLP is a recorder that weighs approximately 2.5 ounces. It fits into the front pocket of children's clothing specially designed to hold the device, and it records the child's vocalizations and adult talk near the child within an approximate 6–10 foot radius. When a recording is complete, the digital audio file is transferred from the DLP to a computer via USB connection for detailed analyses of the acoustic data. The acoustical analysis separates speech-related sounds from environmental sounds, and segments are identified as adult male, adult female, or key child (i.e., the child wearing the DLP), and other child (i.e., child in the room, not wearing the DLP). The analysis does not differentiate information regarding specific linguistic content. More detailed information on software processing is provided in Xu et al. (2008).

LENA Automated Language Measures—The LENA software generates automated measures of three major components of the child's language environment: adult word counts, child vocalization frequency, and conversational turn counts.

Adult word counts (AWC): After adult speech segments are identified, acoustic features in the speech signal are further analyzed to estimate the number of adult words in each segment. The processing algorithms do not identify specific words but only estimate the frequency of words spoken near the child (i.e., within 6 to 10 feet) wearing the DLP.

Child vocalizations (CV): The child vocalization measure estimates the number of times the child vocalized as well as the duration of each vocalization. Following Oller (2000), child vocalizations are defined as speech-related child utterances of any length separated by 300ms of any other type of sound (i.e., vocalizations of other individuals, media sounds, silence or noise). Fixed signals (e.g., cries, screams) and vegetative sounds (e.g., burping) are excluded from the automated child vocalization measures described here. Note that the CV is an estimated frequency of events of widely variable duration, consisting sometimes of one syllable or of many syllables produced as a single utterance. For example, if a child simply says "ba", the utterance is counted as one vocalization, and if a child says "bababababa", or "Mommy I want a cookie" (without significant pauses between the words) each utterance is also counted as only one vocalization. Thus, CVs do not provide a direct measure of utterance complexity.

Conversational turns (CT): A conversational turn is defined as a sequence of speech-related sound segments in which the first is identified as adult female or male and the second as the key child (wearing the device), or vice versa. To qualify as a CT there can be (between the two speech-related segments) no more than five seconds of intervening non speech-related segments (e.g., silence, noise, media sounds) and no intervening vocalizations from a different adult or child. Thus, the CTs are measures of adult-child vocal interactions.

Reliability and validity: The reliability and validity of the LENA automated measures included in the present study have been tested extensively and are reported in detail in Xu et al. (2009), Xu et al. (2008), and in a published study of the effects of the relation of audible television to adult words, child vocalizations and conversational turns (Christakis et al., 2009). Eight professionally trained transcribers listened to and transcribed 70 hours of audio from 70 children in the NLS (total sample of 329), two children per age 2 months – 36 months (see detailed procedures in Gilkerson, Coulter & Richards, 2008). Inter-rate reliability was assessed and Cohen's kappas were reported as ranging from .62 –.75 on average. Transcribers identified segments (i.e., units of sound originating from the human vocal tract) for the key child (child wearing the DLP) and adult speech in the environment, since these are the two variables that ultimately contribute to the three measures: adult word counts, child vocalizations, and conversational turns. Other sounds were identified (e.g., other children, overlapping speech/sounds, TV/electronic media, noise, unclear sounds, silence) and lumped into a single "Other" category for analyses. Setting the transcribers' labeling as the 'gold standard', Xu et al. (2009) reported that the automated system correctly identified 82% of adult segments or speaker type (i.e., sounds originating from the vocal tract of an adult) and 76% of child vocalization segments. Agreement for 'Other" segments was at 83%. An additional analysis was conducted on the 70 test files to determine accuracy of adult word counts between what the DLP recorded and what the trained transcribers counted. The Pearson product-moment correlation between DLP and the transcribers word counts was $r = .92$, $p<.01$, with an average 2% undercount bias in the LENA adult word count output.

Procedure

DS Sample—At the onset of the study, parents completed a background questionnaire including items related to family demographics (e.g., sibling ages and gender) and household characteristics (e.g., parental occupation and education level, etc.). In accordance with the study protocol, participants were asked to complete a total of two day-long recording sessions (total of 24 hours). Target recording dates were scheduled with the parents prior to data collection. To help balance out differences related to amount of time spent with the child during the recording day, parents were asked to collect the recordings during days they would be spending the majority of time at home with their child. Four families recorded over two weekend days, three recorded over the weekdays, and two recorded over one weekend and one weekday.

Participants received a recording packet at least one day prior to each scheduled recording date. The recording packet contained the DLP, two items of clothing, parent questionnaires, and instructional documents. Parents were instructed to turn on the DLP when the child woke up in the morning, insert it into the pocket of the clothing, and dress the child.

Thereafter, they were to go about their normal daily activities. During the recording day, the recorder stayed on the child at all times except during car rides, baths and sleep periods. Parents were instructed to take the recorder off during car rides due to safety concerns, as the pocket that holds the DLP is on the child's chest at the same place a seat belt would be. If the recorder was not on the child, parents were instructed to place it nearby within 6-feet and continue to record. Parents were asked not to turn off the recorder, but to leave it running continuously all day long at which time it would shut off automatically at the end of each day of recording. The DLPs were picked up by a research assistant and brought to the lab. Audio recording data from the DLP were then uploaded and automatically processed using LENA software.

On completion of the study, each family was compensated $50.00 for their time and provided with summary data in a report for their child.

Typically Developing Sample—Recording procedures were similar to those described for the DS sample, in that the parents were asked to place the DLP on their child at the beginning of the day and go about their normal daily activities; differences in the procedures for the two groups are noted here. For the TD sample, recording durations varied between 12 to16 hours based on different versions or updates to the DLP. During the first phase, participants recorded once per month for 6 months. A subset of the original 329 participants (N=80) continued recording monthly during the second phase. Thus, most of the original 329 participants in the normative sample recorded between 5–6 recordings over as many months, while some provided many more. As described above, each TD child selected for comparison to the DS group in this study contributed exactly two 12-hour recordings. Thus, the amount of recorded hours for analysis across the two samples was the same (i.e., total of 24 hours of language sampling per child in each group).

Results

For each of the three LENA language measures collected, comparisons were made by diagnostic-based grouping (DS and TD), age-based grouping (younger DS and TD; older DS and TD), and diagnostic-by-age interaction. When the interaction was significant, Scheffe post-hoc comparisons were conducted to examine differences within diagnostic groups, and based on ages. Dichotomous age-based grouping was defined as participant age less than 12 months versus over 24 months. All statistical analyses were generated using IBM SPSS Statistics version 21. Figures 1–3 depict participant-level scores (counts) across the three language measures for the children with DS and TD children; participants are sorted by age (youngest to oldest - C1 to C9) to highlight developmental trends. Means and standard deviations for age-standardized LENA language measures for children with DS and typically TD children are provided in Table 4, and depicted in an error bar graph in Figure 4.

Based on the LENA Research Foundations original normative study (NLS), there is minimal variability in adult words counts after age 5 months; however, both child vocalizations and conversational turn counts can be expected to rise with age (Gilkerson & Richards, 2008). So, in addition to comparing raw counts we also utilized normative values computed from the original sample of 329 children in the LENA Research Foundation Natural Language

Study to generate age-standardized values for each LENA outcome variable. This allows comparison of outcome values (AWC, CV, and CT) across different ages using the same metric, and to facilitate comparison with traditional standardized measures. They were computed by comparing the 12-hour recording counts for a given child against the mean and SD for the 329 normative TD sample at that same age, resulting in a Z-score that could be rescaled to M=100, SD=15. The When we age reference them, it is not to the other 9 kids in this sample, it's with the larger 329 kids in the NLS corpus. We then conducted additional analysis of variance tests on these data comparing Diagnostic Group, Age Group, plus Diagnosis × Age interaction. Table 5 summarizes 2 × 2 ANOVA comparisons using both count-based and age-adjusted values.

Adult Word Count Group Comparisons

The average daily number of adult words spoken in the home environment in proximity to the sample of children with DS was compared to words spoken near the children in the typically developing sample. Overall, as a group the TD children heard more adult words per day (mean difference = 3357 across the two recordings); and, this difference was statistically significant ($F(1,14) = 5.55$, $p = .03$). That is, overall the children with DS in this sample heard an estimated 22% fewer words in their environments than did their typically developing peers. These families' average daily adult word count corresponds to the 46th percentile based on the LENA normative language study (50th percentile = 12, 297 words per 12-hr day), compared to the 75th percentile for the TD sample (Gilkerson & Richards, 2008). There was no significant main effect by age and there was no interaction effect. Within the DS group, parents of the younger children with DS used a comparable number of words in their environments (mean = 10,668) as did parents of the older children with DS (mean = 12,525). The post-hoc Scheffe test confirmed that this difference was not statistically significant ($p = .83$).

Child Vocalization Group Comparisons

In relation to child vocalizations, as a group the children with DS produced significantly fewer vocalizations (mean = 968; SD = 369) than all 9 children in the TD group (mean 2149; SD = 667) ($F(1,14) = 35.82$; $p < .01$). This corresponds overall to an average of 54% fewer vocalizations per day for the DS sample than the TD sample. Given the significant diagnosis by age group interaction, we conducted the post-hoc Scheffe test to examine difference between groups by diagnosis (TD and DS) and by age (younger and older). Results revealed that the younger TD children were not vocalizing significantly more than the younger DS children ($p=.583$). Further, the older TD children were vocalizing significantly more than all three other groups - the younger TD children ($p=.02$), the older DS children ($p=.00$), and the younger DS children ($p=.001$). Post-hoc analyses also showed that vocalizations by the younger and older children with DS were not significantly different ($p=.407$). Although not significant, mean differences between the younger and older children with DS revealed that the older children produced fewer vocalizations (mean = 765; SD = 291) compared to the younger children with DS (mean = 1223; SD = 309) for a mean difference of 459 vocalizations across the two recordings.

Conversational Turn Group Comparisons

Conversational turn counts, drawn from vocal activity blocks that included alternations within five seconds between adult speech and child vocalizations, were significantly lower for all nine children with DS (mean=220; SD=34) relative to the sample of nine TD children (mean=522; SD=187). Thus, overall, the children with DS participated in 137% fewer conversational turns than their age-matched counterparts. This difference was statistically significant ($F(1,14) = 60.13$; $p < .01$) Scheffe post-hoc comparisons between groups revealed that conversational turns between the younger children with DS and their parent(s) was not significantly different than turns engaged in by the younger TD children and their parent(s) (p=.182). Similar to child vocalizations, the older TD group engaged in more conversational turns than all other three groups (p=.000 for younger TD, younger DS, and older DS children). Within the DS sample, conversational turns did not significantly differ (p=1.00) between the older children (mean = 217; SD=36) and the younger children (mean = 223; SD=37), with a mean difference of 6 conversational turns.

Discussion

The present study is the first to use an all-day naturalistic recording system to describe parent-child communication behaviors and interactions in natural environments for children with Down syndrome. Although early babbling and nonverbal skills of infants with DS develops comparably to that of typical language learners at the same developmental stage (Sterling & Warren, 2008); the subsequent onset of meaningful speech is delayed and proceeds at a slower pace for this population compared to typically developing children. However, we have limited data on the trajectory of vocalizations, and the potential impact of environmental input on vocalizations. The aim of this study was to describe differences in parent language input and child vocal behaviors of infants and young children with Down syndrome and typical language learners across the early language learning years, as measured by automated vocal analysis. We described differences in these behaviors for children with DS to those of TD language learners less than 12 months and older than 24 months of age (up to 54 months).

The comparison of recordings from the nine children with DS and the nine children in the age-matched typically developing sample revealed some similarities and differences in relation to the language learning environment each child experienced. Summaries of the amount of adult talk between the two groups revealed that overall, the caregivers of young children with Down syndrome expressed fewer words in their environments; however, these differences were not significant. There was some variability observed across children in that some parents talked more to their child with Down syndrome than parents of typically developing children (i.e., Child 1, Child 3 and Child 7). Nevertheless, it is important to consider potential long-term outcomes of the mean differences in amount of parent words recorded for the children with DS; if the average daily difference children with Down syndrome hear are 3357 fewer words than typically developing children – that amounts to a relative deficit per year of over 1.2 million words. Whether such cumulative differences in adult input affect acquisition of different language components such as expressive vocabulary or morphology for young children with Down syndrome awaits further research.

In relation to child vocalizations, prior to two years of age, two of the four infants with DS produced similar or higher rates of vocalizations than their age-matched counterpart, but after two years of age all five of the children with DS produced markedly fewer vocalizations than their TD age-matched peers. This finding was the same for conversational turns for the children with DS, in that the same two infants had similar rates of turns with parents as their TD counterparts, and all children over two years participated in markedly fewer turns as compared to the typical language learners. Assuming these outcomes are representative of the children's vocal behaviors in their natural environments, there is an average daily difference of 1815 vocal productions between the older children with DS and the older typical language learners. This difference would translate into differences of more than 12,500 vocalizations per week and 650,000 vocalizations per year for the children with DS compared to children with typical language development. If we were to project similar differences for conversational turns, the older children with DS would engage in an average of 301 fewer turns per day, or 2107 turns per week, and over 109,000 fewer turns per year than turns exchanged between typical language learners and parents or adults in the environment. Thus, cumulative daily differences in vocalizations and conversational turn-taking with adults may start to play a considerable role with children with DS, especially after the age of two years.

At the transition point when children typically begin to combine words, vocalization rates of the older TD language learners were markedly higher, whereas they stayed the same or decreased for the older DS children, providing preliminary evidence of possible delayed trajectories in vocalizations across the early language learning years. Researchers have confirmed weaknesses in morphology and syntax (Ypsilanti et al., 2005), slower vocabulary growth (Kumin et al., 1999), and strengths in gestures to compensate for limited expressive language (Caselli et al., 1998). We know less about trajectories or trends in the development of vocalizations themselves - and the data here suggest these behaviors may lag behind for this population. Furthermore, if the children were communicating using more gestures, including sign language, these pre-speech behaviors would not be detected by the digital language processor.

Based on the three LENA measures together, the outcomes suggest that although some parents continue to provide input that can positively influence the child's language learning environment, the transactional process of learning language may not occur between some children and their parents. Less participation in conversational interactions was observed for 78% (or 7 of 9) of the children with DS - implying that many words spoken by parents were not responded to by their children. Thus, talking ‘more’ as a responsive strategy may not be enough or sufficient to increase the rate of vocabulary and syntactic growth for young children with DS. Diminishing the cumulative differences in vocalizations and conversational turns that may further negatively impact spoken language acquisition at the pre-linguistic stage would require more intensive intervention and longitudinal analysis of child progress.

Another clinical implication of the study outcomes for children with DS is considering steps to thoroughly identify and assess turn-taking behaviors within child-parent interactions. Given that amount of parent talk stayed constant for the older children with DS, clearer descriptions and counts of child turn-taking behaviors may be necessary. Although parent training programs such as “It Takes Two to Talk” have been reported to lead to more active child engagement in and control of conversations when conversing with their mothers (Girolametto, & Weitzman, 2007; Pennington, Thomson, James, Martin, & McNally, 2009), current assessment measures do not provide immediate feedback. Changing turn-taking behaviors may require intensive and ongoing feedback. The digitized recording device used in this study could be used as an intervention tool to provide parents with a visual representation of evidence of the amount of input and changes or progress in child vocalizations and child turns.

Children with DS have been reported to have a distinctly difficult time making progress in expressive language (e.g., Yoder & Warren, 2002; Warren et al., 2008), despite different interventions developed to target vocalizations and vocal communication (see Brady, Bredin-Oja, & Warren for a review). However, a recent study by Romski and colleagues (2010) presented encouraging results with the use of augmented language intervention (e.g., speech-generating devices, or picture exchange systems) and suggests this approach may be more effective in teaching expressive vocabulary than vocal language only interventions. Perhaps combining augmentative and alternative communication (AAC) approaches such as these, along with direct teaching of vocal behaviors, would lead to more intentional child communication – and hence more communication in general for the parent to take turns and respond to.

Although there are a number of limitations inherent to the present study, there are strengths to be noted. Even though the sample size was small, overall, the results are based on 432 hours of audio recordings (or 24 hours of observation per child). Data of this magnitude has not previously been feasible due to the significant cost and time involved in human transcription of recorded speech samples. For example, in the longitudinal work by Hart and Risley (1992; 1995), transcription of each 1-hour audio recording collected in the home environment required 8 to 10 hours to transcribe. Further, measuring parent-child vocal interactions using automated vocal analysis allowed for sampling in naturalistic settings, unconstrained from the potential effects of the feasibility of and participant reactions to videotape methods. Finally, the approach utilized to match the sample of children with Down syndrome to typically developing children was notable. The children were able to be matched on chronological age, gender, and parent education based on an extensive collection of 329 normative participants and recordings available from the LENA Research Foundation’s prior research.

In terms of limitations, the number of families of children with Down syndrome represents a small, cross-sectional sample of convenience. Thus, we need to be careful about generalizing results to larger populations of parents and children with Down syndrome. Within this sample, the majority of parents had completed a bachelor’s degree or higher, creating a sample of higher educated families. Thus, the results should be interpreted cautiously to homes of families with lower education levels. However, it should be noted that given the well documented tendency of families with lower education levels to actually interact less with their children on average (Hart & Risley, 1992; 1995), results for lower SES families could reflect even more substantive differences. Further, the vocal measures were collected over two different days, raising the question of how representative this communication sample is in the lives of each family. Our procedures did not include an attempt to determine parent's perceptions of the 'typical nature' of the recording days, and if they believed their interactions with their child and the child's vocalizations or 'language' used were representative of what they typically observe.

An additional limitation is that adult word count may not be the best measure to capture frequency of adult vocalizations, given that it also may reflect more complex adult input to typically developing children with higher language levels. A stronger way to characterize the frequency of adult vocalizations might be the number of adult utterances rather than total word count or another estimate of contingency. Furthermore, the LENA system cannot measure gestures or sign language. In one of the largest descriptive studies of expressive vocabulary in young children with DS, 130 parents of children with DS reported that their children primarily used signs, and speech-sign combinations instead of just speech (Kumin et al., 1999). Consequently, the communication development of the children with Down syndrome in this study might have appeared somewhat better if these behaviors were measured. Use of the LENA system in combination with other measures (e.g., parent questionnaires and home videos), could in part circumvent this problem and provide a richer assessment of the dynamics of parent-child interactions and how these may impact language learning for children with DS.

One final limitation is the extent to which the between group differences can be interpreted based on the average to superior language skills of the TD sample. In addition to gender and mother's attained education, we chose to match the children based on chronological age to capture information on differences in rates of vocalizations themselves, and to describe parent input and parent-child turns at distinctly different chronological ages. This allowed examination of parent-child vocal behaviors and interactions based on a similar time frame for experience in that language learning environment, in comparison to behaviors of same-age children and parents. That said, it is still important to note that the differences reported are among children of the same age who have expressive and receptive language skill differences.

Exploring and describing differences in the language learning environment experienced by children with delayed or disordered language and those with typical language development allows us to better understand the developmental progression of pre-linguistic skills such as vocalizations, and patterns of child-parent communication behaviors. Although the data is cross-sectional and not longitudinal, a picture emerged revealing that vocalizations by children with DS may fall increasingly behind rates of typically developing peers. Recording these behaviors in the home environment provides much needed information on all-day naturalistic interactions, and the possibility of providing families with immediate feedback on child progress across these early skills. Additional research is needed to document whether combined intervention approaches can increase child vocalizations and concomitant conversational turns.

In conclusion, the present study demonstrates the persistence of expressive language delays beginning at or soon after age two years in children with DS despite consistent parental input. To be effective, parent training programs and interventions must do more to alter the course of these substantial speech delays. In concordance with recent studies, interventions that employ augmented language approaches to facilitate symbolic communication through signs and similar methods may be more effective. Longitudinal studies investigating changes in parent input, child communication, and parent-child communication patterns over the critical language transition period from prelinguistic to linguistic communication, and how to best assist children to meet this milestone are greatly needed.

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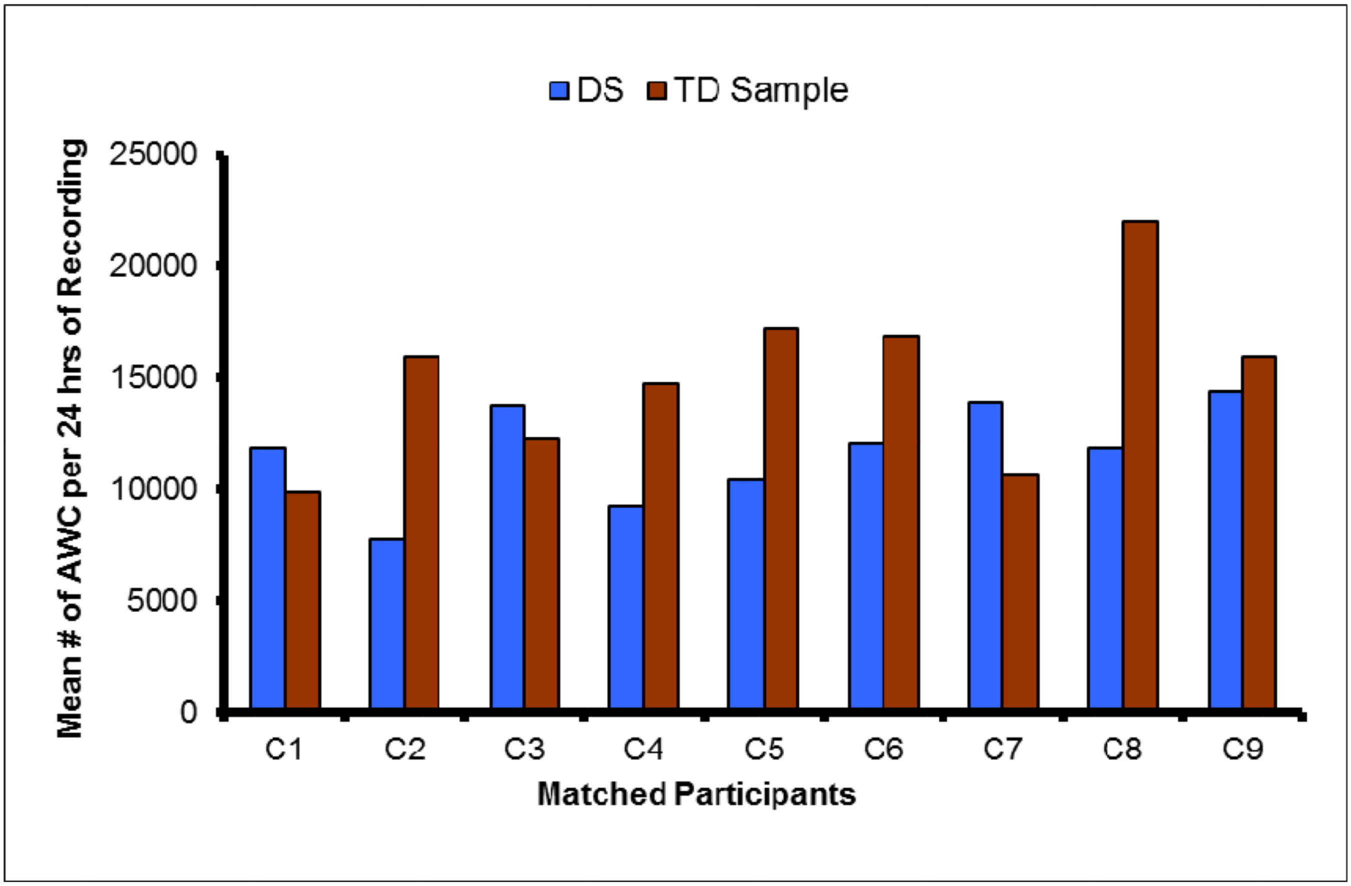

Figure 1.
Adult word count (AWC) means for 24-hours of recordings for children with Down syndrome (DS) and typically developing (TD) children.

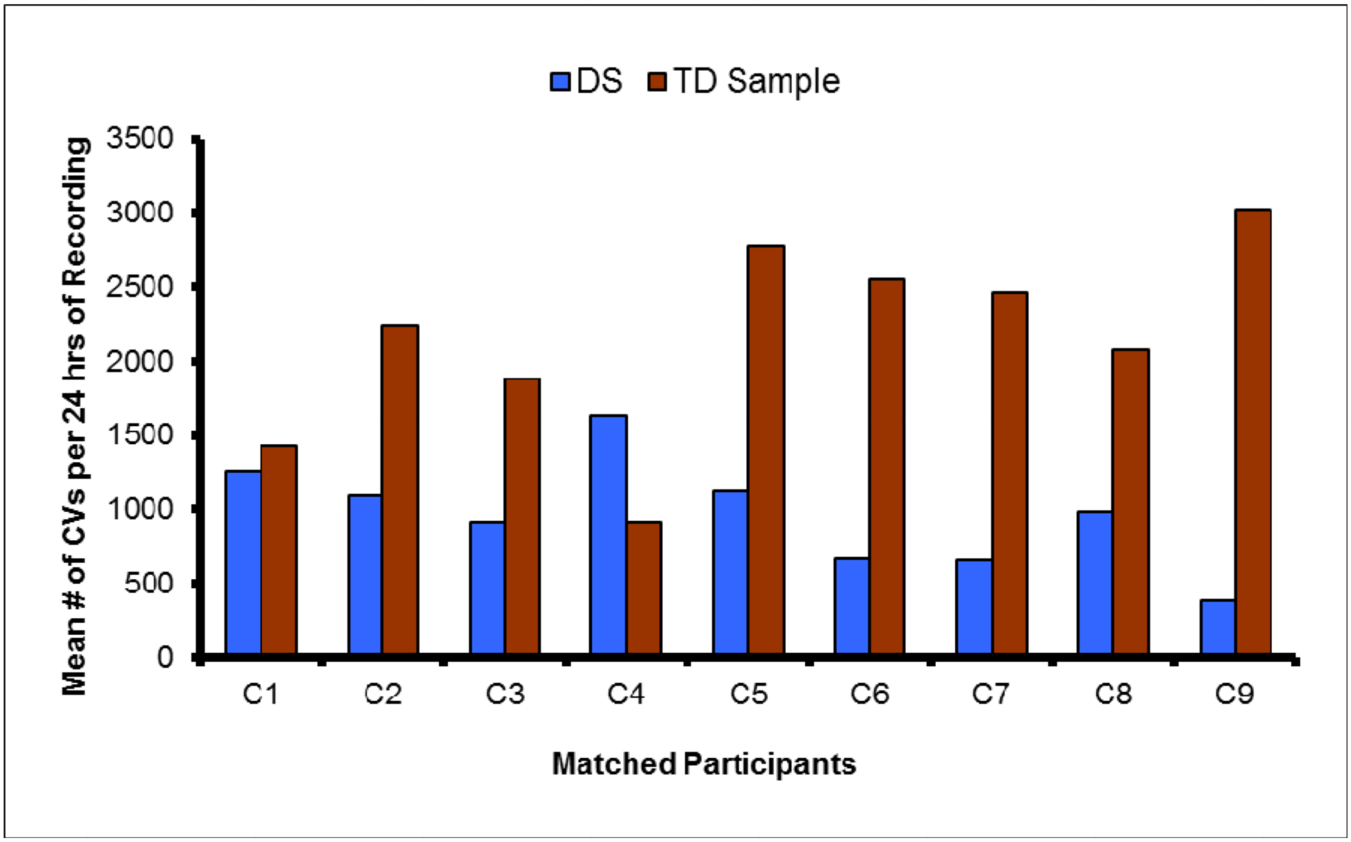

Figure 2.

Child vocalization means for 24-hours of recordings for children with Down syndrome (DS) and typically developing (TD) children.

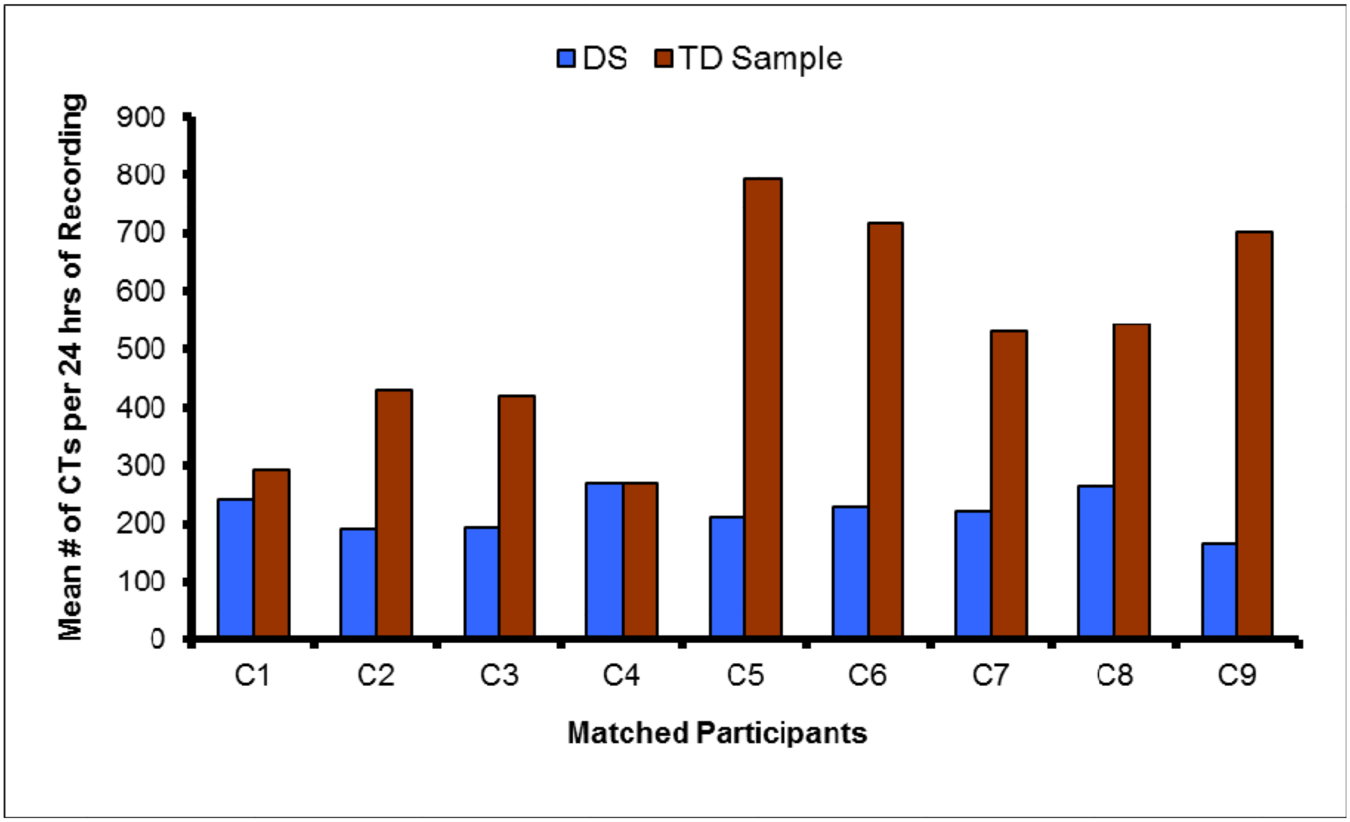

Figure 3.

Conversational turn (CT) means for 24-hours of recordings for children with Down syndrome (DS) and typically developing (TD) children.

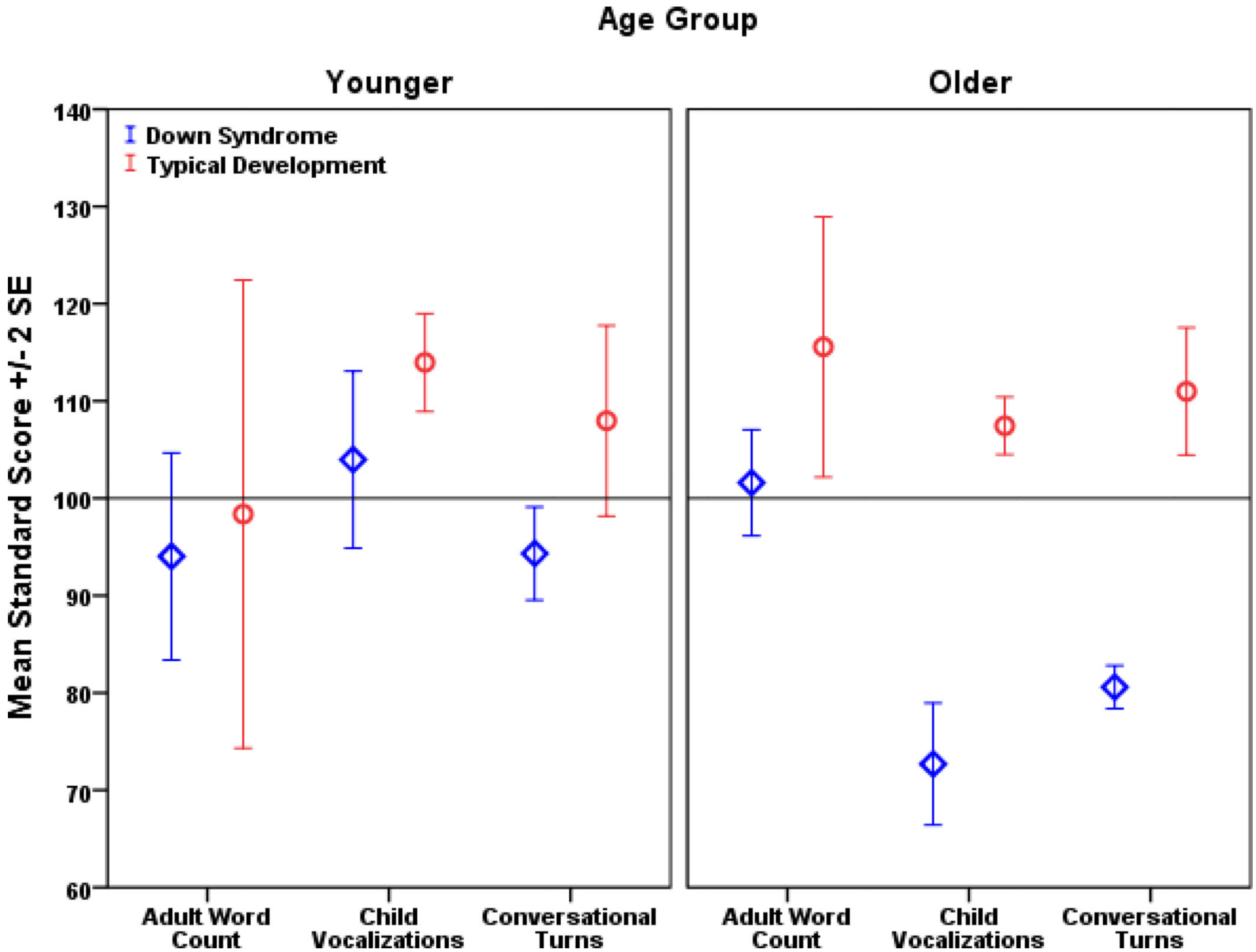

Figure 4.

Age-standardized LENA values for adult word counts, child vocalizations, and conversational turns in younger and older age groups for children with Down syndrome and typically-developing children.

Note. SE = Standard Error; Mean = 100, Standard Deviation = 15.

Table 1

Key demographic variables for Down syndrome and typically developing participants

					PLS-4 Standard Scores		
Child	**Sample**	**Age**	**Gender**	**Mother's Education**	**Total Language**	**AC**	**EC**
C1	DS	9	F	BA+	81	88	77
	TD	10			115	107	121
C2	DS	9	M	BA+	79	69	93
	TD	8			113	111	112
C3	DS	10	M	BA+	73	79	72
	TD	10			119	120	114
C4	DS	11	F	HS	83	86	83
	TD	10			102	97	107
C5	DS	25	F	BA+	67	75	66
	TD	26			103	105	100
C6	DS	26	M	BA+	75	75	79
	TD	27			116	118	111
C7	DS	31	F	BA+	71	77	70
	TD	31			97	105	89
C8	DS	47	F	BA+	50	57	51
	TD	46			106	102	109
C9	DS	54	F	HS	50	50	50
	TD	54			115	112	114

Note: C1, C2, etc. = Child Pairing 1, 2, etc.; DS = Down syndrome; TD = Typically Developing; F = Female; M = Male; BA+ = Bachelor's degree or higher; HS = High School degree; PLS-4 = Preschool Language Scale-4 (Zimmerman, Lee, Steiner, & Pond, 2002); AC = Auditory Comprehension; EC = Expressive Communication.

Table 2

Speech and language performance of children with Down syndrome

Child	Age (mon)		PLS-4 Standard Scores		
			Total Language Score	AC Score	EC Score
C1	9		81	88	77
Speech: Vocalizing using vowels and one consonant; beginning to babble in CV combinations (ma); no words heard yet.					
C2	9		79	69	93
Speech: Vocalizing using vowels and at least 2 consonants; plays with sounds; combines two sounds into CV combination (ba); no words heard yet.					
C3	10		73	79	72
Speech: Vocalizing using vowels and at least 2 consonants; plays with sounds; combines sounds to babble in CV combination (da); no words heard yet.					
C4	11		83	86	83
Speech: Vocalizing using vowels and 3 different consonants; combines sounds to form two-syllable CVCV combinations (mama, baba, dada); no words heard yet.					
C5	25		66	75	64
Speech: Combines at least 2 consonant sounds to form two-syllable CVCV combinations (mama, baba, dada); no words heard yet; using 5–10 signs to communicate intent.					
C6	26		75	75	79
Speech: Can produce 5 different consonant sounds; expressing 5 to 10 words; producing different types of CV, VC, and CVCV combinations; babbles short syllable strings with inflection similar to adult speech; combines words and gestures to communicate.					
C7	31		71	77	70
Speech: Can produce 5 different consonant sounds; expressing 5 to 10 words; names objects; producing different types of CV, CVC, and CVCV combinations; combines Words and gestures to communicate.					
C8	47	Female	50	53	51
Speech: Vocalizing using different vowels and consonants; babbles using two-syllable combinations (mama, baba, dada); has vocabulary of one word; not yet able to imitate words.					
C9	54	Female	50	50	50
Speech: Can produce 5 different consonant sounds; expressing 5 to 10 words; babbles short syllable strings with inflection similar to adult speech; using words and signs for a variety of pragmatic functions (e.g., requests, labels, ask for recurrence, asks for help); not yet combining words together.					

Note: PLS-4 = Preschool Language Scale-4 (Zimmerman, Lee, Steiner, & Pond, 2002); SS = Standard Score; Speech and language description based on performance during PLS-4 administration, including parent report; CV = Consonant-Vowel.

Table 3

Recording session characteristics for children with Down syndrome and typically-developing matched participants.

	DS Sample	TD Sample	Total Sample
Total number of participants	9	9	18
Total number of recordings	18	18	36
Total recording hours	216	216	432
Total days of recordings	18	18	36
Number of recordings per child	2	2	36
Mean hours of recordings per child	24	24	24
Mean (SD) month of age of child at recording	24.7 (16.9)	24.7 (16.9)	24.7 (16.4)

Note. DS = Down syndrome; TD = Typically Developing; SD = Standard Deviation.

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Table 4

Age-standardized LENA language measure outcomes for children with Down syndrome and typically developing children by diagnosis, age, and diagnosis by age groupings

		AWC		Conv Turns		Child Vocs	
Group	**n**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Diagnosis							
DS	9	98	9	87	8	86	18
TD	9	110	12	108	7	109	12
Age							
< 12mon	8	99	11	101	10	109	13
> 24mon	10	108	12	94	15	88	18
[illegible]							
DS < 12mon	4	94	11	94	5	104	9
DS > 24mon	5	101	6	81	2	73	7
TD < 12mon	4	104	10	109	9	114	16
TD > 24mon	5	115	13	107	5	104	5

Note. DS = Down syndrome; TD = Typically Developing; SD = Standard Deviation; mon = months; AWC = Adult Word Count; Conv Turns = Conversational Turns; Child Vocs = Child Vocalizations.

Table 5

ANOVA outcomes comparing diagnostic group, age group, and diagnosis-by-age interaction for LENA count-based and age-standardized language measures

			Count-based			Age-adjusted		
Measure	**Effect**	**df**	**F**	**p**	**P-η^2**	**F**	**p**	**P-η^2**
AWC	Dx Group	1	5.55	.03	.28	5.48	.04	.28
	Age Group	1	3.48	.08	.20	3.62	.08	.21
	Dx × Age	1	0.28	.60	.02	0.13	.73	.01
CV	Dx Group	1	35.82	<.01	.72	20.64	<.01	.60
	Age Group	1	1.89	.19	.12	19.81	<.01	.59
	Dx × Age	1	14.97	<.01	.52	5.20	.04	.27
[illegible]	[illegible]	1	60.13	<.01	.81	62.36	<.01	.82
	Age Group	1	16.55	<.01	.54	8.14	.01	.37
	Dx × Age	1	17.91	<.01	.56	5.23	.04	.27

Note: P-η^2 represents partial η^2 value; AWC = Adult Word Count; CV = Child Vocalizations t; Turns = Conversational Turns; Dx = Diagnostic.