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Consonant and syllable complexity of toddlers with Down syndrome and mixed-aetiology developmental delays

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Abstract

This study examines whether speech sound production of toddlers with Down syndrome (DS) is on par with or more severely impaired than that of mental age (MA) peers with developmental delay due to aetiologies other than Down syndrome at two points within an 18-month period near the onset of spoken word production. The utterances of 26 children with DS, aged 24–33 months, with a mean MA of 14.3 months, originally studied by Fey et al. (2006) and Warren et al. (2008) were compared to those of a group of 22 children with similar intellectual and communication delay but no DS (NDS). Phonological measures included the size of the consonant inventory, syllable shape complexity, and number of communication acts with canonical vocalizations. At Time 1, the DS group performed as well as or better than the NDS group on these measures of speech production. At Time 2, 18 months later, the DS group was behind the NDS group on the same measures. Results extended the pattern of more severe impairment in children with DS than NDS peers commonly noted in expressive language to measures of phonological development.

Keywords

phonology; speech development; Down syndrome

The classic language profile of children with Down syndrome (DS) is for language comprehension skills to be on par with mental age (MA) controls but for production skills to lag farther behind. The first and still most consistently observed delays in the development of communication in children with DS deal with grammar, especially morphosyntax (Chapman, Seung, Schwartz, & Kay-Raining Bird, 1998; Fowler, 1990; Mervis & Becerra, 2003; Miller, 1999). Fowler takes the view that morphosyntax provides a kind of wall that is especially difficult for children with DS, like those with specific language impairment, to scale. Intellectual disability cannot account for this difficulty. Rather, it is a fundamental characteristic of these children. Other evidence has suggested that the special difficulties in expressive language for these children do not arise at the onset of grammar but, rather, are present from the start of language production, with speech sound production and vocabulary (Cardoso-Martins, Mervis, & Mervis, 1985; Miller, 1999; Warren, Fey, Finestack, Brady, Bredin-Oja, & Fleming, 2008). Our interest was in following a group of children with DS

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who were at the earliest stages of lexical development to determine whether they were weaker in consonant production than could be expected by their cognitive abilities. Our control group was a group of children similar in age and intellectual ability to the children with DS, rather than the more commonly observed control group of younger children with typical development (TD) matched on MA.

Problems with speech production are among the most commonly reported difficulties for children, adolescents and even adults with DS (Kumin, 2006). Recent studies have indicated that, as is the case for grammar, at least from early school age, speech sound errors in children with DS are even more frequent than or qualitatively different from those of younger TD children or children with developmental delays not associated with DS, and deficits are greater than what would be predicted by MA alone (Cleland, Wood, Hardcastle, Wishart, & Timmins, 2010; Kumin, 2006; Roberts et al., 2005; Roberts, Stoel-Gammon, & Barnes, 2008; Rupela & Manjula, 2007). Additionally, children with DS often exhibit great inconsistency in production of established words and show impairment in vocal imitation skills (Rondal, 1980; Rosin, Swift, Bless, & Vetter, 1988).

In this population, the development of speech sound production skills may be adversely affected by intellectual disability, mild to moderate hearing loss, general hypotonia, and anatomical and physiological differences in skeletal, muscular, and nervous systems. Early in their speech sound development, however, there are indications that children with DS typically are not that far behind their TD age mates (see Stoel-Gammon, 2001a for a review). For example, several studies have demonstrated that development of sounds in speech-like vocalizations over the first year of life for children with DS is much like that of TD children at similar points of cognitive development (Dodd, 1972; Smith & Oller, 1981; Stoel-Gammon, 1997). The rate of vocalizations and the order of acquisition of consonants and vowels are similar to those produced by TD children during this prelinguistic period (Miller, 1999; Smith & Oller, 1981; Smith & Stoel-Gammon, 1996; Steffens, Oller, Lynch, & Urbano, 1992; Stoel-Gammon, 1998). Many researchers conclude that the order of acquisition of consonant sound types is similar in the DS population to the TD population (Bleile & Schwarz, 1984; Dodd, 1972; Smith & Stoel-Gammon, 1983; Stoel-Gammon, 1997, 2001a).

There are some notable exceptions to these relatively positive assessments, however. Some investigators have reported delayed onset and inconsistent use of canonical babbling and atypical vocalizations among children with DS at and before the first appearance of words (Kumin, Councill, & Goodman, 1994; Legerstee, Bowman, & Fels, 1992; Lynch, Oller, Steffens, Levine, et al., 1995). These differences may serve as clues that even at the earliest stages, vocal behaviour differs for this group of children.

Although much is known about vocal behaviour of older children and of infants with DS (Rondal, 2009; Stoel-Gammon, 2001a), much less is known about their phonological development during the period after they begin to exhibit intentional communication and before they acquire a vocabulary of approximately 50 words and start combining words into multiword utterances. This period, beginning late in the first and ending in the second year of life for TD children, extends through age 4 and well beyond for many children with DS

(Berglund, Eriksson, & Johansson, 2001; Gillham, 1990; Oliver & Buckley, 1994; Smith & Stoel-Gammon, 1983).

A restricted phonology may also be present at the earliest point of word production, or word production may be slow to develop despite an adequate repertoire of sounds and syllable shapes. The present study was undertaken to more closely examine the early speech sound output of 26 children with DS and compare it to that of a MA- and chronological age-similar group of 22 children with developmental delays but no DS (NDS). All the children were assessed longitudinally at two time points; at an average chronological age of approximately 26 months and average MA of approximately 15 months, after the onset of intentional communication but before they were regularly producing words, and 18 months later, when two thirds of the children were actively combining words in utterances. We were interested in assessing whether the children with DS exhibited the familiar profile found in other areas of language in their speech production at these early points in development (Miller, 1999); that is, did their early sound production skills lag behind those of similar-aged children with developmental delay but without DS? Based on reports that their development of speech-like sounds over the first year is relatively equivalent with MA-based expectations, combined with reports of especially weak speech skills by school age, we anticipated that the profile with expressive skills lagging behind MA expectations would be more observable on measures of consonant and syllable productions at our later than our earlier measurement point.

Method

Participants

The participants in this study were 48 of the 51 children with developmental disabilities between the ages of 24 and 33 months who participated in the studies reported by Fey et al., 2006 and Warren et al., 2008. Twenty-six children had DS. From the group of 25 children with no Down syndrome (NDS), one was excluded from the present investigation due to a diagnosis of Angelman syndrome. Children with this syndrome characteristically have severely impaired speech and frequently develop few or no spoken words (Williams, Peters, & Calculator, 2009). Another child was excluded because of a repaired cleft palate, which may have had a special influence on sound development. The Time 1 data from one child in the NDS group were lost due to a technical failure. This child was eliminated from all analyses. Thus, 22 of the original 25 children in the NDS group remained in the current study.

The 48 participants averaged 26 months of age and had: (a) developmental delays in the mild to moderate range, with Mental Development Indexes (MDIs) below 70 on the Bayley Scales of Infant Development, Mental Scales (BSID; Bayley, 1993); (b) no prior diagnosis of autism; (c) no more than 10 words or signs at the beginning of the study, as confirmed by the child's speech-language service provider on the MacArthur Communicative Development Index (CDI; Fenson et al., 1993); (d) vision and hearing skills within normal limits, with or without correction, as demonstrated by passing a hearing screening in both ears at 25 dB at 500, 1000, and 2000 Hz; and (e) sufficient upper body motor skills to perform basic gestures, such as reaching. One child with DS had a mild sensorineural hearing loss and passed the screening with bilateral hearing aids. All of the participants continued to receive community-based communication therapy outside of the study throughout the study period. Although the type of communication therapy varied among the participants, there were no statistically reliable differences in the number of hours of communication therapy received by the children outside of the current investigation ($t = .46$, $p = .28$).

Additionally, participants were required to be within the early communicative prelinguistic stage. In addition to having no more than 10 spontaneous words or signs, the children had to produce communication acts within a range determined suitable for prelinguistic milieu teaching (PMT; Yoder & Warren, 2002). Communication measures were generated from the Communication Temptations and Book Sharing components of the Communication and Symbolic Behavior Scales (CSBS, Wetherby & Prizant, 1993). Within these contexts, children were required to produce fewer than 2 communication acts or less than 1.25 canonical vocalizations per min to qualify (Fey et al., 2006).

In a telephone interview with each child's parent, it was confirmed that the child appeared to meet all entry criteria and that the family was willing to participate in the study. Four additional children with DS passed this telephone screening and were evaluated in a face-to-face examination, yet failed to meet study criteria for communication delay. Two of these children were excluded because they exceeded the criteria for communication acts or canonical vocalizations during the CSBS. Two more children exceeded the criterion of ten or fewer spontaneous words or signs on the CDI. In sum, slightly more than 10% of the children with DS who were evaluated for the study following the telephone screening were excluded because their communication and language skills were too advanced for study purposes and 26 were included.

Of the 22 children who did not have DS, 17 had developmental delays of unknown aetiology, one had Trisomy 8, one had a mitochondrial disorder, and one experienced a right cerebrovascular accident at birth. One participant with developmental delay of unknown origin had renal disease as a complicating factor. One child originally described as having delays of unknown aetiology later received a diagnosis of Fragile X syndrome.

Four additional children with developmental delay but not DS passed the telephone screening and took part in pre-experimental testing but were excluded from the NDS group because they exceeded the vocabulary criterion on the CDI. Thus, 4/26 (15%) of the children who were tested for inclusion in the NDS diagnostic group were later judged to be insufficiently communicatively delayed to participate.

The two groups, DS and NDS, were compared on 11 key pre-experimental variables, each of which is represented in table 1. There were three significant differences between groups on these variables, and a fourth variable nearly significantly distinguished the groups. First, although the group means differed by less than two months, children with DS were, on average, significantly younger than the children in the NDS group. Second, the children with DS had significantly more siblings in the home (an average of one more). Third, based on the total scores on the Parenting Stress Index (PSI; Abidin, 1995), the parents of children with DS were under significantly less stress than were parents of children without DS. This relatively low-stress pattern is common in families of children with DS, and this characteristic supports the representativeness of the samples included in this study (Fey et al., 2006; Hodapp, Ricci, Ly, & Fidler, 2003). Fourth, the DS group produced more utterances than the NDS group, and this difference narrowly missed being statistically reliable. This difference may have given the DS group a significant advantage, especially in the number of consonants produced, because their greater volubility gave them more opportunities to display the consonants at their disposal.

None of the first three of these variables (i.e., chronological age, siblings, and parental stress) at Time 1 correlated significantly with the growth in speech development from Time 1 to Time 2 with the exception of number of siblings correlating with SSL at Time 1 ($p = .03$). The other *r*s were < .30 and *p*s > .051. None of these variables was statistically significant when included in the statistical models we tested. Therefore, they are not included in our statistical analyses reported here. In contrast, the number of utterances produced in the 15 min parent-child interaction at Time 1 was correlated with both Time 1 and Time 2 speech measures. Therefore, we included this measure as a covariate in analyses of all three dependent measures.

The participating children were a part of a clinical trial that examined the effects of 6 months of parent responsivity education/prelinguistic milieu teaching (RE/PMT) communication intervention (Warren et al., 2008). Children were assigned at random to receive either RE/PMT in addition to their community-based services or to continue receiving only their existing community-based interventions. The children who received RE/PMT were evenly distributed throughout the DS and NDS groups. There were no significant main effects of treatment (RE/PMT vs. no RE/PMT) and no significant interactions between treatment and diagnostic group (DS vs. NDS) in three Treatment X Diagnostic Group ANOVAs with gain in speech skills as the dependent variable. Therefore, the treatment variable was not included in any statistical analyses in this study.

Procedure

Following the initial assessment, participants returned to the laboratory for ongoing assessment every 6 months. The assessment context in this study is a semi-structured parent-child communication interaction used at study onset (Time 1) and 18 months later (Time 2). Parent-child interactions have commonly served as the sampling context in studies of speech and communication behaviours at the early stages of lexical development (Paul & Jennings, 1992; Rescorla & Ratner, 1996; Stoel-Gammon, 1985; Whitehurst, Smith, Fischel, Arnold, & Lonigan, 1991). At Time 1, children had in their expressive lexicons at most 10 words, spoken or signed, but 11/48 (23%) had no spoken words; thus, most of the children's vocalizations comprised babbling rather than meaningful speech. Even at Time 2, only 28 of the 48 participants (58%) had more than 50 words in their spoken lexicons. Therefore, it was not possible to test the children's phonological skills based on a standard elicitation procedure, nor was it possible to include all children at either time in relational phonological analyses.

The sampling context—Both the child and the parent were seated at a table throughout the 15 min session. Each parent was instructed to select toys one at a time and to share a toy with the child only after the child indicated an interest in playing with it. After 5 minutes of play, parents were provided with a snack (Cheerios ® in a lidded container) and a cup or box of juice. Both the snack and the drink were out of reach of the child. When the child indicated a desire for the Cheerios ® or juice, the parent was instructed to allow the child to have only a small amount. Throughout the snack and the last 5 minutes of the session, an audiotape of various sounds (e.g., a cat meowing, a phone ringing) played intermittently and a hidden examiner performed actions to encourage the child to communicate (e.g., shook a slinky hanging from the ceiling, blew bubbles through a narrowly opened door).

Each sample was audio- and videotaped through a one-way mirror, using an analogue VHS camera and a high-fidelity VCR with two-channel audio capabilities. These videotape signals were digitized and saved to CD. All data coding was performed through ProcoderDV (Version 2.1.7, Tapp, 2006). This program identified the onset of all marked segments of the digital file by time in hundredths of a second. Measures were automatically tallied using Mooses (Multiple Option Observation System for Experimental Studies) software, Version 3.4.10 (Tapp, 2006).

Observations for all samples in this study ended at 15 minutes. Ten out of the 96 samples ended one to 11 seconds prematurely. No corrections were made to accommodate these slight differences in session length.

Identifying and segmenting utterances—Conventions of other researchers (Fasolo, Majorano, & D'Odorico, 2008; Nathani & Oller, 2001; Paul & Jennings, 1992; Stoel-Gammon, 1985, 1989, 2001b; Thal et al., 1995; Whitehurst et al., 1991) were followed in identifying and segmenting the children's words and prelinguistic vocalizations, with some adaptations. Minimally, a child utterance had to contain normal phonation. Child utterance boundaries were determined by at least one second of silence, a breath, an interruption by an adult, or extraneous noise that interfered with transcription of the sounds. Utterances that were judged too faint to hear were excluded from analysis, along with vegetative sounds such as coughing and crying or laughing. Grunts were included as long as phonation was audible. Utterances associated with strongly negative affect (i.e., `fussiness') were systematically excluded as were utterances produced while the child was chewing or had fingers or objects in or over the mouth. Small amounts of background noise were tolerated, as long as the noise did not interfere with the identification of syllables and sounds. However, any child utterance completely overlapping with adult speech, singing, or music was systematically excluded, even if the utterance was intelligible.

Determining canonical vocalizations—Following segmentation of the utterances, each child utterance was judged to be canonical or noncanonical. If phonation was present, with no consonant other than the quasi-vocalic glides [h, w, j] or glottal stop, or if the utterance contained only syllabic consonants, it was judged to be noncanonical. Utterances containing consonant-vowel (CV) or vowel-consonant (VC) sequences with one or more clearly produced consonants were coded as canonical vocalizations.

Dependent variables

Number of different English consonants—For each unintelligible canonical vocalization and each true word, coders used up to four listening opportunities to identify the initial and final English consonants, if any were present. Coders identified each consonant singleton, cluster, or glide by utterance position (initial or final) using broad phonemic transcription of English consonants. Final oral stops had to be released to count in the inventory. Occasionally, the children produced clear examples of a sound not native to English (e.g., a velar fricative) or an indeterminate sound that shared features of two English consonants, making it impossible for coders to choose between them (e.g., initial [d] or [g] for what seemed to be a voiced palatal stop). Such cases were not counted in the child's inventory of English consonants, but they were identified with a dummy canonical consonant, [*], to maintain an accurate count of utterances containing canonical syllables.

For a consonant to count in a child's inventory, it had to be (a) a good or distorted production of an English phoneme, and (b) produced at least two times in initial or final position. The metric used for all analyses was the total number of different consonants across initial and final positions.

We identified only the initial and final consonants of each unintelligible vocalization or word in this measure because of the finding that TD children from ages 6 to 24 months and children with phonological delays represent individual consonant types frequently in initial and intervocalic but not final position and sometimes in only intervocalic and final positions but not initial position; but it is unusual to find any consonant type appear in intervocalic position only (Bernhardt & Stemberger, 2002; Davis, 1998; Stoel-Gammon, 2002). Thus, we determined that we could get better reliability with little risk of underestimating the total number of different consonants in each child's inventory by identifying only the initial and final consonant types.

Syllable Structure Level (SSL)—We were interested in the change in syllable and word shape over time during this transitional period of early word production. At Time 1, the children were producing few, if any, words in the speech samples. Thus, at Time 1 we were actually measuring Mean Babbling Level (MBL; Stoel-Gammon, 1989). At Time 2, some of the children were still producing mostly babbled utterances and others were producing multi-word utterances. Because we were interested in the change in syllable shape over time, regardless of the type of vocalization produced, we combined unintelligible and intelligible utterances under the rubric SSL (Paul & Jennings, 1992).

In scoring SSL, each utterance is given a complexity score. Utterances with no true canonical consonants (e.g., glides or [h] but no stops, affricatives, fricatives, or liquids) have an SSL of 1. Utterances with only one unique consonant are assigned an SSL of 2, whether the consonant appears once or more than once in the utterance. Consonants differing only in voicing are treated as if they are the same. Utterances with two or more consonants differing in place or manner of articulation have an SSL of 3. Expanding the concept, utterances with a sequence of true consonants (e.g., [gl] but not [gw]) in one syllable position were also assigned an SSL of 3.

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Unlike our calculation of the number of different English consonants, in which consonants in intelligible vocalizations were counted as initial or final consonants on a word-byword basis, we applied SSL uniformly on the utterance, not the word, level. Thus, for SSL, the multiword utterance, *my baby*, would receive an SSL of 3 under our procedure, because the entire utterance contains [m] and [b], rather than an SSL of 2, with *my* and *baby* each receiving an SSL of 2. Similarly, in determining SSL, coders took intervocalic consonants into consideration, noting whether or not the entire utterance contained at least two different, noncognate consonants.

Canonical vocal communication acts (CVCAs)—The CVCA variable is the only speech measure also containing criteria for communicative intent. CVCAs included all words and prelinguistic utterances that were (a) judged by a pair of coders in the larger studies (Fey et al., 2006; Warren et al., 2008) to be intentionally communicative by virtue of the child's attention to a referential object/event and the adult; and (b) judged by coders in the present study to contain a canonical vocalization. The variable for CVCAs was reflected as the number of CVCAs per 15 min sample.

Coding reliability

The primary (SBS) and the reliability coder (a graduate student in speech-language pathology) worked together for approximately 48 hours over 8 weeks to establish coding procedures. The training included joint and independent coding of child speech samples not included in the present study.

To evaluate reliability, the reliability coder independently coded a randomly selected 21% of the 101 samples after the primary coder had coded the entire set. Although the reliability coder could usually determine which children had DS from watching the media files that served as the data source and whether the samples came from the initial or final assessment, she was blind to the study questions and any hypotheses of the study regarding diagnostic groups.

Reliability was determined by the coders' independent database entries on average SSL, the number of different consonants, and CVCAs. Single rater intraclass correlation coefficients (ICCs) were computed to determine the proportion of variance in scores that was related to actual participant differences rather than to the coders or interactions between coders and participants (McGraw & Wong, 1996). ICCs for CVCAs and SSL were .95 and .98 (95% *CI* = .88 – .99). The ICC for initial consonants was .94 (95% *CI* = .86 – .98). The ICC for final consonants was .74 (95% *CI* = .46 – .88). Because of lower inter-judge reliability on final consonants, hypothesis testing was first done on results from initial consonants separately from final consonants. Because the pattern of results was consistent for both initial and final consonants, these consonants were analysed together in this report.

Results

For the primary question in this study, we asked whether the children with DS differed in the complexity of their speech output from that of children with developmental delay but without DS at two different time points early in development. We predicted an advantage for the NDS group that would be more notable at Time 2 and that there may be few or no significant differences at Time 1.

Even though the experimental groups were not statistically different in MA, a key issue in our study was the extent to which the speech acquisition characteristics of children with DS can be attributed to their cognitive abilities. Because of this, we examined correlations between MA and Time 2 speech variables. Each of these correlations was significant or nearly so (rs > .27, ps < .07). Consequently, we tested each variable for its suitability as a covariate in our analyses. The data violated the assumption of parallelism of slopes for SSL and Number of Consonants (ps < .05) and nearly did so for CVCAs ($p < .12$). Closer examination of these analyses revealed significant correlations between MA at Time 1 and the speech variables at Time 2 for Number of Consonants ($r = .55$, $p < .01$), SSL ($r = .45$, $p < .05$), and nearly significant correlations for CVCAs ($r = .41$, $p = .061$) for the NDS group. In contrast, none of the correlations approached the level of significance for the DS group (rs < −.28, ps > .16). Thus, for the NDS group only, children with higher MAs at Time 1 tended to have higher performance on the speech variables at Time 2. Because of these differences in the relationship between MA and speech outcomes at Time 2, MA was not included as a covariate in our analysis of covariance.

To control for the Time 1 difference between groups in number of utterances produced, we ran a Group (DS vs. NDS) by Time (Time 1 vs. Time 2) analysis of covariance (ANCOVA) for each of our dependent variables (i.e., total number of consonant types, SSL, and CVCAs). The covariate was number of utterances produced by each child, or volubility. Given our experimental questions and predictions, our most significant interest in these analyses was in the interaction between time and diagnostic group.

For each analysis, the data met the assumption of parallelism of slopes, but the variances of the dependent measures were not homogeneous and one of the measures, number of CVCAs, clearly was not normally distributed. Therefore, we confirmed our post-hoc comparisons of means with the results of Mann-Whitney *U* tests, which are nonparametric, and therefore, distribution-free.

The results of the Time X Diagnostic Category interaction are provided in tables 2 and 3. A common pattern was found across measures. First, with the volubility of the children at Time 1 controlled, the Time X Diagnostic Category interaction was statistically significant for all variables, indicating that the observed differences in rates of growth were significant for all three measures. Second, post hoc analyses of these interactions displayed in table 3 indicated that (a) at Time 1, the DS group had higher means than did the NDS group, although this advantage was statistically significant only for SSL, and (b) at Time 2, the reverse was true. That is, the NDS group significantly outperformed the DS group on all three measures. The group means and mean differences between the groups on each variable at Times 1 and 2 are displayed in table 3.

These patterns of interaction favouring the DS group at Time 1 and the NDS group at Time 2 were supported by our Mann-Whitney U analyses. Using this nonparametric test, which did not enable us to control for the association between Time 1 volubility and our three measures, all differences between groups at Time 1 and Time 2 were statistically reliable. In these tests, all *U*s ≥ 380.5, all *Z*s ≥ ± 1.95, and all *p*s ≤ .05.

Figure 1 depicts the sounds of the DS and NDS groups' consonant inventories at Times 1 and 2. As in children with TD and in previous reports on the speech of children with DS (Cleland et al., 2010; Roberts et al., 2008), nasals and oral stops were more prevalent than the later developing consonant types (i.e., fricatives, affricates, and liquids) at the testing periods for both groups of children. All later developing consonant sounds were more common at the second sampling session than the first, for both groups of children. At Time 1, more children in the DS group were producing more consonant sounds, and, especially, more later developing consonants, but by Time 2, the children in the NDS group had caught up with or surpassed the DS group in the number of children producing earlier developing sounds. Furthermore, at Time 2, more children in the NDS group than the DS group produced later developing consonants.

Discussion

Our longitudinal comparison of the development of speech and speech-like sounds for children with and without DS revealed a change in profile over the period from approximately 25 to 43 months chronological age (CA). Specifically, the children with DS began the study with consonant production abilities similar to or greater than those of the children without DS. Eighteen months later, the same children with DS were well behind their NDS peers on the same speech measures.

Although our study was not designed to and did not identify features of speech production unique to children with DS, we did discern a pattern of extremely slow development from Time 1 to Time 2 that clearly distinguished the DS from the NDS children at Time 2, at a mean CA of 44 months. In addition, we observed that MA was associated with measures of speech development for children in the NDS but not the DS group. These two findings converge upon the conclusion that early phonological development for children with DS cannot be attributed to general developmental delay. Cleland et al. (2010), Miller (1999), Roberts et al. (2008) and many others point to the likelihood that physiologic factors, such as frequent otitis media and related hearing issues, general hypotonicity, and variations in oral anatomy and function are responsible for slow growth in speech production in children with DS. Our findings are consistent with this view.

The most unpredicted outcome of our study was that the DS group, which was slightly younger than the children in the NDS group, not only performed as well as the NDS group on our measures of consonant inventory and syllable complexity at Time 1; they performed significantly better on at least on one measure, SSL. Our findings confirm the impression that the order of emergence of consonants is broadly similar to that of TD children, with nasals and oral stops predominating over early consonant productions. Several more children in the DS group than the NDS group produced fricatives and liquids at the earliest observation point in the study. Thus, relative to a mixed group of children with developmental delays who did not have DS, the children with DS produced a greater number and variety of consonant types at approximately 2 years of age.

A firm conclusion that children with DS have an early advantage in speech sound production over children with other forms of developmental delay awaits replication of our Time 1 results. In the meantime, it is tempting to conclude that, if sounds and syllable structures were available to our sample of children with DS at a relatively early point in development, weak speech production skills must have played, at most, a limited role in these children's slow vocabulary growth (Warren et al., 2008). This is what Schoen, Paul, and Chawarska (2011) concluded after observing relatively intact speech production skills for children with autism who were communicating at a level similar to the children in our study. From this perspective, observed vocabulary delays of the children with DS in our sample would more likely be attributed principally to weaknesses in *other* processes of lexical development, such as the establishment and mental representation of stable sound-meaning relationships. These processes draw heavily on the well-documented weak auditory-verbal memory skills of children with DS (Conners, 2003). Such developmental weaknesses and resulting slow lexical growth may then have constrained the further development of speech skills (but see Mosse & Jarrold, 2011, for evidence on preserved mechanisms for word-learning in individuals with DS).

Although it may be that problems with speech output did not contribute appreciably to the late onset of words and to the slow early vocabulary growth among our participants with DS (Warren et al., 2008), there are at least three reasons for caution before accepting our participants' relative speech production strengths as evidence that speech production is not a major factor in the slow lexical development of children with DS. First, although the group with DS had larger consonant inventories than the NDS group at Time 1, it would be a mistake to conclude that the children with DS were especially strong in this area. For example, both the DS and NDS groups had very restricted consonant inventories at 25 months of age, averaging just 4 and 2 consonants in their consonant inventories, respectively, even if we include glides, as is common in other early investigations of consonant production. By comparison, the 8-month-old TD participants of Robb and Bleile (1994) averaged over 5 different consonants, and the 11- to 13-month old TD group of Schoen et al. (2011) averaged 7.5 unique consonants, based on a 15-minute sample, as in the present study. Similarly, at expressive communication ages of approximately 14 months, children with autism spectrum disorder in the Schoen et al. study averaged nearly 6.5 sounds and the late talkers of Paul and Jennings (1992) averaged 6 sounds between the ages of 18 and 23 months. Thus, despite the statistical advantage over the NDS group at Time 1, when they are compared with children from other studies with similar MAs or communication ages, children in our DS group must be considered to have significant restrictions in speech sound development.

This general finding of restricted consonant production at Time 1 may reflect our sampling procedures to some extent. The children with developmental delay in our study all met criteria for limited word use and infrequent intentional communication at approximately age 2. Higher functioning children who exceeded the entry criteria were systematically excluded. Others likely were screened out in a telephone interview and many others may not even have been referred to our study. Thus, the children who participated in either of our groups may have had somewhat lower communication performance than is characteristic of the larger populations from which they came.

In sum, when differences in sampling methods, length of samples, and participant MAs are taken into account, both groups in our study appear to have been quite limited in the number of consonants they produced, even at Time 1. The limited output of our participants with DS may have been sufficient to begin a rudimentary lexicon of a few words by Time 1, but not enough to support additional lexical and phonological growth between Time 1 and Time 2.

The second reason for caution in interpreting our findings as an indication that early sound production limitations do not play a major role in the late onset and slow development of vocabulary is that our study examined only the sounds and syllable shapes found in the children's early inventories using perceptual methods and broad phonemic transcription of words and babble. Although we did not get the impression that the children in our study produced many non-English sounds, it is possible that our procedure missed at least some production differences that would have clearly distinguished the groups and shown the children with DS at a disadvantage (see Schoen et al., 2011; Oller et al., 2010).

Thus, we did not evaluate the participants' ability to *control* their production of the sounds in their inventories. Despite their early superiority over the NDS group in numbers of sounds and syllable structures, the children in the DS group may have had less reliable access to available oral motor programs or poorer articulatory control over the sounds and syllables that were in their repertoires. This lack of control would be expected to place special constraints on the use of early words and could be responsible for slow growth in speech sound and vocabulary development. Commonly reported speech production problems in children with DS include decreased intelligibility with increased length of utterance; inconsistent speech errors; difficulty in sequencing oral movements and sounds; use of atypical phonological error patterns; and superior receptive to expressive language skills. All these are symptoms of childhood apraxia of speech, which is sometimes diagnosed in children with DS, and is associated with delayed onset of vocabulary (Kumin, 2006; Rupela & Manjula, 2007).

Our third reason for restraint in concluding that weak phonological skills do not play a major role in constraining early vocabulary development is that the Time 1 production superiority of the children with DS in the present study did not last long. These children's growth in the complexity of vocalizations over the 18-month study period was slower than that of the NDS group on each of our dependent measures. Unfortunately, we did not include measurements between Times 1 and 2. We cannot determine whether either group experienced a short burst of growth in phonology at an early or intermediate point in the observation interval, or if the growth was slow and steady. Nor can we determine the point at which the NDS group caught up with and eventually overtook the DS group on our sound production measures. The earlier this point occurred, the more likely it is that slow speech sound development played a significant role in the slow growth in vocabulary.

Study Limitations

We have already raised some of the study limitations that complicate interpretation of the study, such as our focus on points in time separated by 18 months and our use of a broad transcription method, which may have been insensitive to certain sound distinctions. We further acknowledge several other limitations. First, most of our participants with DS were not producing words at Time 1 and about a third were still not using words at Time 2. The average number of words produced by the DS group at Time 2 was 61.73 (*SD* = 43.91), according to parent report on the CDI. Therefore, meaningful relational analyses were not possible for most children with DS, and our focus on measures stemming from independent analyses was a necessity rather than a choice. Second, although they were as long as those used in many studies observing speech sound development over time, our 15-minute samples were fairly small, yielding on average only 50 to 60 codable utterances. Much larger samples can now be collected efficiently and analysed automatically using systems, such as the LENA Digital Language Processor (Oller et al., 2010). Third, we did not evaluate the children's hearing levels or cognitive abilities beyond Time 1. It also would have been useful to have information on the children's oral motor abilities. In general, these young children were not sufficiently mature to participate reliably in typical oral motor tasks. We can only speculate about the role of these variables in the slow speech sound and lexical acquisition among children with DS.

Summary and directions for further study

The present study confirmed that despite having phonological skills comparable to or better than those of a similar group of children with intellectual disability but without DS at an average of 25 months CA and 14 months MA, children with DS exhibit slower gains in speech over the third and fourth years of life. By age 3-1/2 and possibly much earlier, these children exhibit deficits in speech production relative to children similar in MA with developmental disabilities other than DS. So, even if their earliest lexical development is not adversely affected by their limitations in speech production, it seems likely that at least by some time between 2 and 3-1/2 years, weak phonological skills are at least partially responsible for slow progress in the use of spoken words. In fact, delayed phonological development may be both the product and a cause of problems with vocabulary acquisition. Future studies of children with DS should focus on the relationship between speech, speech perception, motor skills, and word-learning to determine the ways in which these processes interact in early development (e.g., Werker & Curtin, 2005) in children from this population (Cleland et al., 2010) and the extent to which these interactions differ substantially from those among children with TD or with developmental delays not associated with DS.

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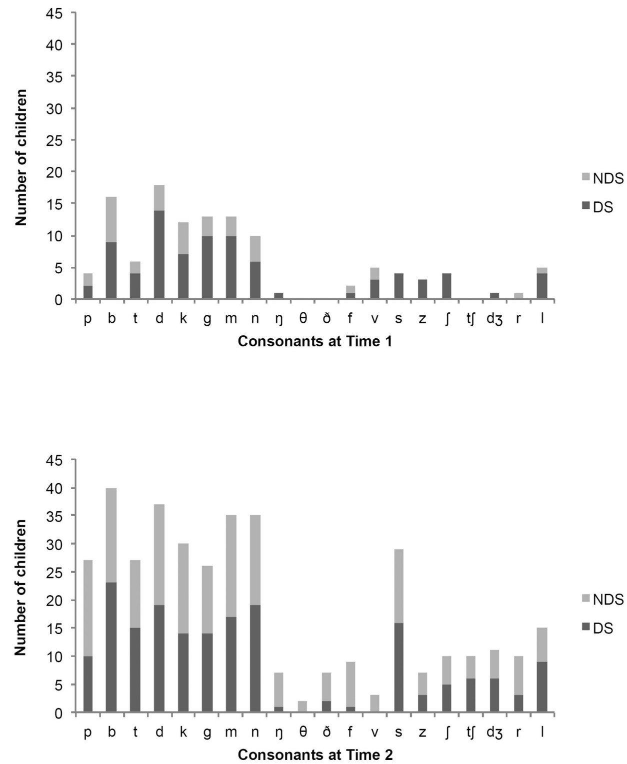

Figure 1.

Singleton consonants in the phonemic inventories of children in the DS (*n* = 26) and NDS (*n* = 22) groups at Times 1 and 2. Only consonants that were produced at least two times per participant during a 15-min communication sample appear in the figure.

Table 1

Participant Characteristics at Time 1

	NDS Group		DS Gtoud		
Measure	***M***	***SD***	***M***	***SD***	***P***
Bayley-MA	15.23	2.74	14.31	1.49	.17
Age in months at study onset	26.64	2.87	25.12	1.93	.04
CDI-receptive	118.91	108.95	86.04	52.59	.21
CDI-spoken words	1.91	2.37	2.88	2.22	.16
Number of utterances/15 min	51.30	28.91	68.96	36.24	.06
Communication acts/15 min	12.48	9.18	15.54	10.37	.28
Monthly hrs speech/lang tx	4.34	2.04	3.92	1.83	.46
Monthly hrs all services	11.91	5.47	13.79	5.60	.25
Years maternal education	14.95	2.70	14.81	2.42	.85
Siblings in home	1.00	1.11	1.92	1.29	.01
PSI-total stress score	231.30	36.14	198.13	36.02	.00

Note. NDS = no Down syndrome; DS = Down syndrome; Bayley-MA= Bayley Scales of Infant Development-Mental Age; CDI = MacArthur Communicative Development Index; PSI = Parenting Stress Index.

Table 2

Time x Group Interaction Effects for the Experimental Variables

Variable	*F(l, 45)*	*P*	Covariate *F*	Covariate *p*
Consonants	10.85	.002**	17.80	.001***
SSL	19.77	.001***	1.66	.204
CVCA	20.61	.000***	11.11	.002**

Note. SSL = syllable structure level; CVCA = canonical vocal communication act.

The covariate in the model was volubility = 60.23.

* $p < .05$, two-tailed.

** $p < .01$, two-tailed.

*** $p < .001$, two-tailed.

Table 3

Post Hoc Analyses of Time x Group Differences at Times 1 & 2

Variable	Time	Group	*M* [a]	*SD*	Mean Group Difference[b]	Cohen's *d*	95% *CI* for *d*	
							LL	UL
Number of Consonants	1	DS	2.78	1.73	0.66	.0.37	−0.20	0.95
		NDS	2.12	1.74				
	2	DS	6.62	4.23	−3.43[b]	−0.79	−1.38	0.20
		NDS	10.04	4.25				
SSL	1	DS	1.44	0.21	0.23[b]	1.08	0.47	1.68
		NDS	1.21	0.21				
	2	DS	1.68	0.34	−0.27[b]	−0.78	−1.37	−0.19
		NDS	1.95	0.34				
CVCA	1	DS	6.60	5.61	3.12	0.55	−0.03	1.12
		NDS	3.48	5.63				
	2	DS	23.66	26.68	−32.35[b]	−1.18	−1.80	−0.57
		NDS	55.90	26.77				

Note. *CI* = confidence interval; *LL* = lower limit; *UL* = upper limit.

SSL = syllable structure level; CVCA = canonical vocal communication act.

[a]Estimated marginal means are adjusted with the covariate of volubility at 60.23.

[b]Superscripted differences, based on comparisons of estimated marginal means, are statistically significant using the Sidak adjustment. Using direct Mann-Whitney tests, all comparisons were statistically reliable.