PHONOLOGICAL DEVELOPMENT IN TODDLERS WITH DOWN SYNDROME AND MIXED-ETIOLOGY DEVELOPMENTAL DELAYS

BY

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Abstract

Purpose: Young children with Down syndrome (DS) usually have special difficulty acquiring expressive vocabulary and grammar, and recent studies have indicated that at least from early school ages, their speech production skills also are weaker than can be predicted by their intelligence scores. During the babbling stages, however, children with DS have often been found to produce canonical syllables roughly within a typical timeframe. The first purpose of this dissertation is to determine whether early phonological development in children with DS can best be characterized as delayed but predictable based on mental age, as is the case for early comprehension of vocabulary and syntax, or whether, like vocabulary and grammatical production, speech production is more severely impaired than could be anticipated by the children's cognitive abilities alone. The second purpose of this dissertation is to examine the extent to which early vocabulary delays are associated with deficits in speech sound production.

Method: Measures of consonant inventory and syllable structure level were taken at two points from 50 of the children studied by Warren et al. (2008). Canonical and noncanonical words and utterances, and the initial- and final-consonant inventory were coded during two15-minute videotaped semi-structured conversational samples with a parent at two points in time, 18 months apart.

Results: For all measures at Time 1 (age ~25 months), the children with DS performed equally well or better than their peers without DS (NDS). The reverse was true for all measures at Time 2 (~ 43 months). Consonant inventory size at Time 1 predicted lexical growth at Time 2 only for the children with DS. For the NDS group of children, 60% of whom began the study with fewer than 2 productive consonants, only Time 1 cognitive scores predicted later lexical growth.

Conclusion: A clear relationship between slow phonological growth and slow lexical growth at the period of “first word” acquisition was established for children with DS. The results of this study indicate that the phonological skills in young children with DS are delayed beyond the level predictable by mental age at the period of early lexical development.

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Chapter 1: Introduction

Until the late 1980s and early 1990s, it was common to assume that children with intellectual disabilities had similar developmental profiles, with language skills following a more or less typical pattern constrained by cognitive abilities and reflected in mental age (MA). That is, it was assumed that these children would have deficits in language comprehension and production that would make their performance like that of younger typically-developing (TD) children.

At that time, it became apparent that certain profiles of development were etiology-specific. This was most noticeably true for children with Down syndrome (DS). Children in this group were shown to have comprehension skills that were reasonably well-predicted based on their MA but production skills that lagged farther behind, and increasingly so with advancing age. At first, these special lags in development of language production skills for children with DS appeared to show up as the children were developing syntax and grammatical morphology, and were strikingly evident by 5-6 years of age (Chapman, Seung, Schwartz, & Kay-Raining Bird, 1998; Fowler, 1990; Mervis & Becerra, 2003; Miller, 1988). Thus, the communication profile of children with DS appeared similar to those of children with specific language impairment, or SLI (Chapman & Hesketh, 2000; Miller, 1999).

Later, it became clear that special deficits in language production were notable much earlier, at MAs of 24 months and younger (Miller, 1999; Warren, et al., 2008).

Warren et al. found that their group of children with developmental delays not due to DS outperformed same-age MA-similar children with DS in vocabulary measured at 3-1/2 years of age. This finding held for vocabulary measured both by total (spoken and signed) word counts in adult-child communication samples and by the MacArthur Communicative Development Index (CDI; Fenson et al., 1993), a vocabulary checklist filled out by the child's parent. Thus, from the very outset of vocabulary development, the majority of toddlers with DS have language production problems that are greater than would be anticipated by their measured cognitive abilities (Mervis & Becerra, 2003; Miller, 1999; Yoder & Warren, 2004).

The causes of these early delays in language production are unclear, but several candidates have been considered. For example, children with DS have high rates of hearing impairment, and older children with DS have been shown to be especially weak in phonological memory skills, which are likely to be especially important in word learning. (Baddeley, Gathercole, & Papagno, 1998; Baddeley & Jarrold, 2007; Conners, Rosenquist, Arnett, Moore, & Hume, 2008). Miller (1999) noted that problems with muscular tone and motor speech control and intelligibility could explain at least part of the significant vocabulary and grammatical deficits that characterize development in DS. Problems in motor speech control affect intelligibility, and intelligibility, in turn, affects language-facilitating interactions with caregivers. For example, children who are not understood may talk less frequently, thus limiting the social interaction that forms the context for early language learning. Furthermore, if these children are largely unintelligible, parents have little opportunity to phonetically recast utterances (Velleman, Mangipudi, & Locke, 1989). Once children gain the capacity for grammar, they may limit output to simple forms more likely to be understood, thus getting less practice at retrieving and producing developmentally complex grammatical forms within their control in comprehension.

As shown later in this chapter, there is a clear relationship between early phonological development and early lexical development. This is particularly true with TD children, but it also holds for late-talking children and children who have developmental delays without DS. The frequency of canonical vocalizations (consisting minimally of a well-formed consonant and vowel combination) is critically linked to vocabulary development. For example, Yoder and Warren (2004) found that the number of canonical vocal communication acts (CVCAs) predicted lexical density six months later in a group of 30-month old children with developmental delays not attributable to DS.

Therefore, another possible complicating factor that could lead to special difficulties in language production at the earliest stages of development of children with DS involves their preverbal speech sound production skills. In this area, however, there are indications that children with DS typically are not that far behind their typical age mates. For example, many studies have demonstrated that for the most part, development of sounds in nonverbal vocalizations over the first year of life is like that of typical children (Chapman & Hesketh, 2000; Dodd, 1972; Legerstee, Bowman, & Fels, 1992; Smith & Oller, 1981; Stoel-Gammon, 1997). This should not be taken to mean that speech production is typical in children with DS. To the contrary, later in development, many studies document phonological differences in children with DS and typically-developing (TD) children using measures such as percent consonants correct (PCC, Shriberg, 1993) or extent of use of phonological processes (Smith & Stoel-Gammon, 1983). These studies have established that both developmental and uncommon phonological processes persist for a longer time in children with DS than in TD children.

Phonology is clearly an area of particular difficulty for individuals with DS. What is largely unknown is the phonological profile of children with DS during the "first words" period of speech production and how it relates to early development of vocabulary, before children obtain a vocabulary of approximately 50 words and begin combining words into multiword constructions. This period, occurring in the second year of life for TD children, extends through the third year of life and beyond in the population of children with DS. The developmental relationship between prelinguistic vocalizations and early vocabulary development among TD children is well documented (Cruttenden, 1994; Ferguson & Farwell, 1975; Locke, 1989; McCune & Vihman, 2001; Oller, 2000; Oller, Levine, Cobo-Lewis, Eilers, & Pearson, 1998; Oller, Wieman, Doyle, & Ross, 1976; Stark, Bernstein, & Demorest, 1993; Stoel-Gammon & Cooper, 1984; Vihman, Ferguson, & Elbert, 1986). We know much less about this relationship in children with DS. Yoder and Warren's (2004) finding that CVCAs predicted later lexical performance applied only to children without DS, but not to a mental age (MA) and chronological age (CA)-similar group of children with DS. Their sample included thirty-nine 30-month-old children, 17 of whom had DS, and related their CVCAs to lexical density (a measure of number of different words per unit of time) measured 6 months later. Yoder and Warren did not measure any other phonetic/phonological variables, however, such as sound inventory and syllable shape complexity. It is possible that a finer-grained analysis of speech sound production can better explain the relationship between prelinguistic vocalizations and early lexical development in children with DS.

There are two primary purposes of this dissertation. The first is to determine whether early phonological development in children with DS can best be characterized as delayed but predictable based on MA, as is the case for early comprehension of vocabulary and syntax, or whether, like vocabulary and grammatical production, speech production is more severely impaired than could be anticipated by the children's cognitive abilities alone. The second purpose of this dissertation is to examine the extent to which early vocabulary delays are associated with deficits in speech sound production at the onset of word production, and to determine whether measures of vocal development predict the significant early vocabulary acquisition delays in this group of children.

This dissertation will address these purposes by comparing the vocal output of a group of children with DS to those of MA- and CA-peers with non-Down syndrome-related cognitive and linguistic delays over an 18-month period from the age of approximately 2 years to 3-1/2 years. In the rest of this chapter, I develop and provide additional evidence that motivates the questions addressed in this study and the predicted outcomes by reviewing the literature on: (a) the phonological profile of individuals with DS; (b) the relationship between phonology and the lexicon in TD and developmentally delayed populations, (c) early vocabulary development of children with DS, and; (d) results of recent investigations into the relationship of phonological and lexical development of children with DS.

Later phonological development in DS

Phonology is one component of language that is significantly impaired in children and adults with DS, as evidenced by difficulties in articulation and intelligibility. For many individuals with DS, speech intelligibility is a life-long problem (Kumin, 1994; Rosin, Swift, Bless, & Vetter, 1988). For example, in Kumin's study, over 95% of parents of children with DS ranging from infancy to adulthood (N = 937) reported intelligibility as a problem for their children. Eighty percent of the respondents cited articulation as a primary area of difficulty for their children.

Speech sound deficits are usually apparent once children with DS have a productive vocabulary large enough for relational analyses, using tools such as phonological process analysis & single-word articulation tests. Early-appearing phonological processes such as final consonant deletion, cluster reduction, and stopping, which are common in 2-year-old, TD children, persist through adolescence and beyond in individuals with DS (Bleile and Schwarz, 1984, Dodd, 1976; Smith and Stoel-Gammon, 1983). These children also display atypical speech sound errors, such as lateralization of fricatives and unusual voice quality, and difficulties in prosody. Additionally, children with DS often exhibit great inconsistency in production of established words and show impairment in vocal imitation skills (Rondal, 1980).

Because of these unusual and inconsistent errors, some children with DS have been diagnosed with childhood apraxia of speech (CAS; Kumin & Adams, 2000; Rupela & Manjula, 2007). Kumin and Adams examined motor planning problems in 7 children with DS, ranging from ages 5-13 years. All of their participants showed characteristics of CAS, as observed in decreasing intelligibility with increased utterance length, inconsistent speech errors, difficulty in performing voluntary acts, difficulty with oral movement sequencing, and a discrepancy between receptive and productive language. Along these lines, Rosin, Swift, Bless, and Vetter (1988) reported evidence of motor sequencing problems in a study of 10 male adolescents with DS. These individuals had lower PCC scores on the GFTA than younger, TD children and a control group of cognitively impaired peers without DS. The DS group had more difficulty with repeating consonant-vowel sequences as length of the target increased. They needed more cueing in order to complete syllable repetition tasks and produced these with greater variance in intraoral air pressure.

As noted, deficits in speech production are a characteristic of individuals with DS. There is recent evidence that these speech production deficits are worse than what would be predicted by MA alone. Roberts, Long, Malkin, Barnes, Skinner, Hennon, and Anderson (2005) identified a particular weakness in phonological skills in children with DS compared not only to MA-matched, younger TD children, but also to children with Fragile X syndrome (FXS). Children with FXS have developmental delay, but a communication profile distinct from DS. Children with DS tend to have better language comprehension and pragmatic skills than spoken vocabulary and, especially, morphologic and syntactic skills. In contrast, as a group, children with Fragile X Syndrome (FXS) are more developed in vocabulary and syntax than pragmatics. Roberts and her colleagues compared phonological accuracy of 50 boys aged 3-14 with FXS, 32 MA-matched boys aged 4-13 with DS, and 33 TD MA-matched boys aged 2- 6 on the Goldman Fristoe Test of Articulation—Second Edition (GFTA-2; Goldman & Fristoe, 2000). They found that although the boys with Fragile X were delayed compared to TD controls, they resembled the younger TD boys in percent consonants correct (PCC, Shriberg, 1993), use of phonological processes, and whole-word proximity scores. In contrast, the boys with DS produced more consonant errors, more phonological processes, and lower whole-word proximity scores than did both the boys with FXS and the younger TD boys. The researchers tested children using a standardized articulation test, so they only measured performance in isolated words. These participants were obviously past the period of early word acquisition, and do not overlap in age with the children who are the focus of the present study. Still, these results beg the question of when these etiology-related differences in phonology first become apparent.

To summarize, individuals with DS evidence problems in productive phonology that are greater than what would be predicted by MA alone. Sound production appears less stable, resulting in atypical errors and decreased intelligibility later in development. As a group, they acquire sounds in the typical order, but at a much slower rate than TD children and children with other etiologies resulting in communicative delay. Given these serious problems in phonological development, it is surprising that so little attention has been paid to the point at which the delay in phonological development first becomes apparent in children with DS.

Early phonological development in DS

Very early in development, children with DS do not differ dramatically from their TD age peers in the onset of canonical babble. Canonical babble is defined as an utterance containing at least one combination of a supraglottal consonant and a vowel with rapid consonant-vowel transitions (Oller, 2000; Smith & Oller, 1981). The onset of canonical babbling typically occurs in the second half of the first year, around 7-8 months of age (Davis & MacNeilage, 1995; Oller, 1980; Smith & Oller, 1981; Stark, 1981). Nearly all TD infants have entered the canonical stage by 10 months of age, the cutoff age for indicating risk for vocal and hearing disorders (Nathani, Ertmer, & Stark, 2006; Oller, 2000). Some studies have found no significant differences in the age of onset of canonical babbling between infants with TD and those with DS (Dodd, 1972; Smith & Oller, 1981). Both groups began babbling by 8- 8 ½ months of age. One study did report a delay of 2 months in the onset of canonical babbling in infants with DS, however, and less stable canonical babbling once they began using canonical syllables (Lynch, Oller, Steffens, Levine, & et al., 1995). Nevertheless, this delay is only slightly behind that of infants with TD, and at an average age of onset of 9 months, it is still before the cutoff age for likely vocal or hearing disorders. Furthermore, children with DS are not as delayed in the onset of canonical vocalizations as they are in other motor tasks, such as sitting and crawling. Clearly, the capacity to make such vocalizations is a robust human trait. In a real way, we are "born to babble," and only the most severe disruptions will limit this capacity.

Other prelinguistic vocal behaviors in children with DS also do not differ from those of TD children. Unaffected behaviors include amount of vocalization, developmental timetable of vocalizations, and characteristics of consonants and vowels produced in the babbling stage in the first 12 to 18 months of life (Fidler, 2005; Miller, 1999, Smith & Oller, 1981; Smith & Stoel-Gammon, 1996; Steffens, Oller, Lynch, & Urbano, 1992). In typical development, glides, nasals, and bilabial and alveolar oral stops predominate in early vocal productions (McCune & Vihman, 2001). Fricatives, affricates, and liquids appear later. The CV syllable shape of babbling is also the most frequent syllable shape of TD children's early words (Stoel-Gammon, 1985). The early canonical vocalizations of children with DS resemble those of TD children. Consonants appear to emerge in the same order, although the period of onset of consonants can be particularly protracted (Kumin, Councill, & Goodman, 1994).

Despite these similarities to the TD population, various researchers have observed differences in prelinguistic vocalizations in children with DS. These may serve as "clues" that even at the earliest stages, vocal behavior differs for this group of children. Lynch, Oller, Steffens, and Buder (1995) described "atypical vocalizing" in a group of children with DS from the period of 2 to 12 months. In the first six months of life, infants with DS produce more nonspeech-like sounds than speech-like sounds (Legerstee, Bowman, & Fels, 1992). Perhaps even the somewhat delayed onset of canonical vocalizations in this group of children presages later difficulties in speech development (Girolametto, Pearch, & Weitzman, 1997; Paul & Jennings, 1992; Whitehurst, Smith, Fischel, Arnold, & et. al., 1991).

The phonology-lexicon relationship in children without cognitive delays

For TD children and late-talking children (children with slow expressive language development, or SELD; Paul & Jennings, 1992), there is a close phonology-lexicon relationship. The sounds and syllable shapes of complex babble are carried over into children's earliest words, and "better babblers" (i.e., children with a rich consonant inventory and a variety of syllable shapes) tend to have earlier-emerging lexicons. Although some early-appearing and highly functional words do not consist of canonical syllables (e.g., *uh-oh*, *hi*, *"uh-uh"*, *yeah,* and "*mhm"*), it is impossible to create a large vocabulary without canonical syllables (Oller, Levine, Cobo-Lewis, Eilers, & Pearson, 1998). For this reason, canonical vocalizations are known as the "building blocks" of the emergent lexicon (Stoel-Gammon, 1998a, 1998b). For TD children, words emerge around the time of the first birthday, following a few months of canonical babbling. During those months, children produce CVCAs, a precursor to true words. Such communication acts may also be termed "meaningful babble," because they are produced with attention to the conversational partner and express intentionality (e.g., regulating behavior, social interaction, and joint attention). Both language-specific differences and individual children's sound preferences influence the distribution of sounds and syllable shapes in later babbling and early word inventories (Halle, de Boysson-Bardies, & Vihman, 1991; Schwartz & Leonard, 1982; Vihman & de Boysson-Bardies, 1994; Vihman, et al., 1986).

Several studies have shown that an earlier onset of babble and a more diverse inventory of sounds and syllable shapes are associated with earlier lexical development in TD children (McCune & Vihman, 2001; Stoel-Gammon, 1989; Vihman & Greenlee, 1987). Wetherby, Cain, Yonclas, and Walker (1988) found an increase in the rate of communication acts with multisyllabic canonical vocalizations from ages 12 months to 16 months in their longitudinal study of 15 TD children. They also found that the percentage of multisyllabic canonical vocalizations at these younger ages correlated positively with measures of communication rate, MLU and size of the lexicon made at 24 months of age. A similarly close relationship exists between mature babble and lexical development in late-talking children. Whitehurst, Smith, Fischel, Arnold, & et al. (1991) found that the proportion of canonical babble to all babble in a parent-child communication sample was correlated with later lexical use in a group of late-talking 2-year-olds.

One reason for the close relationship between canonical babble and the emergence of true words is physiological, reflecting maturation of the vocal tract and neural control (Davis & MacNeilage, 1995; Goffman & Smith, 1999; Kent, 1984). Sufficient oral motor skills are a prerequisite for oral language. Children who are poor at oral movements are also poor at productive language, whereas children with better oral movement skills are more variable in their language scores (Alcock, 2006).

Another reason for the close association between canonical babbling and early speech is social-interactional. Canonical babble, which resembles well-formed speech, may lead to greater caregiver responsiveness, which also contributes to child communication outcomes (Yoder & Warren, 2001). Adult caregivers respond differentially to canonical versus precanonical babbling (Oller, Eilers, Neal, & Schwartz, 1999). When a child produces a well-formed canonical syllable, adults are likely to attribute meaning to the child's output. They may respond in a phonetically contingent way, by imitating or expanding the child's utterances. This helps reinforce the child's canonical vocalizations. These vocalizations become phonetically consistent forms (McCune & Vihman, 2001), and are likely to become part of the child's early lexicon. Thus, the realization that the child is developing speech by producing canonical syllables influences the responding style of the caregiver, which in turn influences the child's output form.

The phonology-lexicon relationship in children with cognitive delay not related to DS

Researchers have reported similar results in studies of the phonology-lexicon relationship in children with mixed-etiology developmental delays. As is true for TD and late-talking children, canonical babbling is correlated with language level in children with developmental delay (Oller & Seibert, 1988). The specific vocal predictors may vary among groups of children with differing conditions, however. This may be due to etiology, to characteristics of the sample of children, or methodological differences among studies. For example, Whitehurst et al. (1991) found that for late talkers, only the proportion of canonical to total utterances was correlated with later expressive vocabulary gains. Whether or not the utterance was part of a communication act made no difference. In contrast, McCathren, Yoder, and Warren (1999) observed that the rate of vocalizations was positively correlated with later expressive vocabulary for children with mixed-etiology developmental delays regardless of whether the vocalizations were canonical or noncanonical. In their sample of children, sheer volubility was correlated with expressive language.

The number of communication acts with canonical vocalizations in a parent-child sample is another phonological predictor of later lexical growth in children with mixed-etiology communication delays (Yoder, Warren, & McCathren, 1998). These researchers divided a group of 58 prelinguistic toddlers (4 of whom had DS) into “functional” and “prefunctional” speakers. A functional speaker was defined as a child who used at least 5 different words non-imitatively in either a structured or unstructured communication sample with an unfamiliar adult. The median value of the number of CVCAs in a 15-minute caregiver-child communication sample was 3.8 for prefunctional speakers, and 10.5 for functional speakers. According to these results, toddlers with developmental delay who are not yet using words and who produce less than 1 CVCA every 4 minutes are at high risk to persist as prefunctional speakers one year later.

Lexical development in children with DS

Receptive vocabulary is a relative strength for children with DS, but productive language is another matter. For children with DS, the average age of vocabulary onset is 21 months (Stoel-Gammon, 2001a), although this can range between 1 and 5 years (Gillham, 1990; Kumin, 2003). Prelinguistic intentional vocal communication (i.e., meaningful babble) also appears delayed in children with DS. Smith (1984) observed a dramatic difference in the development of intentional oral communication in 10 infants with DS and 8 TD age peers. For the TD children, 13% of their utterances were judged meaningful at 14 months of age, and 50% of their utterances were judged meaningful at 18 months of age, just four months later. In contrast, for children with DS, only 2% of their utterances were judged meaningful at 21 months of age, and at 30 months, a full nine months later, less than 5% of their utterances were judged meaningful.

Once children with DS develop words, their rate of lexical development is very slow. Compared to TD children matched on MA and socioeconomic status (SES), children with DS acquire significantly fewer words at MAs of 15-30 months (Mervis & Becerra, 2003). On average, TD children produce 297 words at 24 months and 548 words at 30 months, as measured by the MacArthur-Bates Communicative Developmental Inventory: Words and Gestures (CDI; Fenson et al., 2007). In contrast, children with DS attain the first 50 word milestone between 3 ½ to 6 years of age (Gillham, 1990).

Children with DS acquire vocabulary at a slower rate compared not only to TD children, but to NDS children as well. A recent investigation that generated the data base used in the present study delineates this striking difference at the earliest stages of vocabulary development (Warren et al., 2008). This study included 51 two-year-olds with developmental delay, 26 of whom had DS. At study onset (Time 1), all children had fewer than 10 spoken words or signs. Children in the DS group increased their lexicons over the 18 months of this study but at a much slower rate than the children in the NDS group. Eighteen months later, the NDS group averaged vocabularies of approximately 250 words compared to fewer than 100 words for the DS group, as measured by the MacArthur CDI (Fenson et al., 1993). The results were quite similar when lexical values were measured observationally from communication samples with a parent or unfamiliar adult. Although the Warren et al. 2008 study reported data for both spoken and signed vocabulary, subsequent independent analyses of the data set prior to conducting this dissertation study revealed the same relationship when measuring spoken vocabulary only. Counting only unique, spontaneous oral words in a 15-minute parent-child communication sample (PCX), the analysis revealed an average of 57.17 unique, spontaneous words (*SD* = 44.90) for NDS children, compared to only 21.19 unique, spontaneous words (*SD* = 18.95) for children with DS, *d* = 1.15, *95% CI* = -16.82 - +8.43.

Figure 1 depicts the mean proportions of words in spoken and signed modalities produced by diagnostic group during the PCX at testing time 1 (mean age: 25 months) and testing time 4 (mean age: 43 months) in the Warren et al. (2008) study.

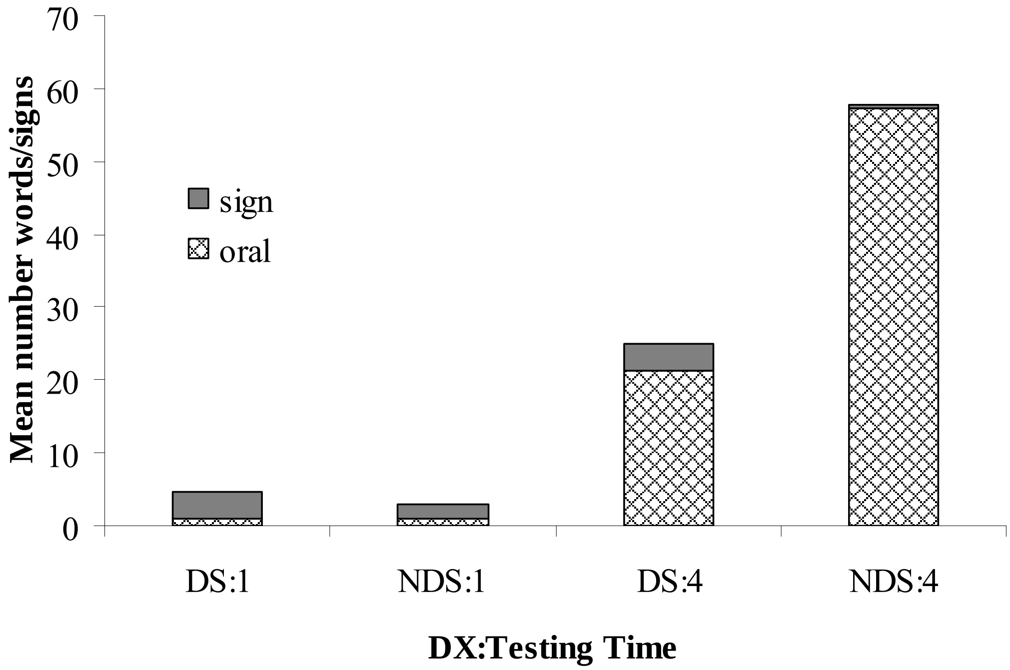

Figure 1. Warren et al. (2008) spontaneous words from the PCX sample, arranged by diagnostic group and test time.

Note. Reduced dataset with data from one child with Angelman's syndrome removed from analysis.

There is further longitudinal evidence that delays in expressive language in children with DS are beyond that which could be attributed to cognitive delay alone. Miller (1999) found that 64% of children with DS from ages 0 to 5 showed a profile of receptive language commensurate with MA but with expressive language delays greater than expected based on MA. Some of the children studied had delays from the outset of meaningful words, and others gained vocabulary but showed expressive delays when combining words together. Miller (1999) described two language development profiles accurately described 95% of the children with DS in a cross-sectional study. Language production was below levels predicted by MA for 60-75% of these children. Twenty to thirty-five percent showed language comprehension and production on a par with cognitive status. The remaining 5% had both impaired language production and comprehension skills. The older children appeared to have increasing difficulty in expressive vocabulary and especially syntax.

Profiles of language development do not remain static over time. For children with DS, as MA increases, productive language lags further behind language comprehension (Miller, 1999). Below an MA of 24 months, some 50-60% of Miller's sample of children exhibited delays in productive language. At an MA of 37 months, over 90% of the sample of children displayed significant delays in language production. Miller confirmed an increasing gap in productive vocabulary with increasing MA between children with DS and TD children in both cross-sectional and longitudinal studies. Children with DS do increase vocabulary size, but at a much slower rate than TD children. Furthermore, their rate of progress in vocabulary development is outpaced by their rate of acquisition of other cognitive skills.

The phonology-lexicon relationship in young children with DS

It is currently unknown to what extent phonological factors are related to early vocabulary delay in children with DS. However, there is reason to believe that phonological delay plays a significant role in the difficulty children with DS have in acquiring vocabulary. Yoder and Warren (2004) related a delay in canonical communication acts to a delay in the earliest stages of lexical development. They found that CVCAs predicted lexical development in 30-month- old children without DS 6 months after initial assessment. However, CVCAs did not predict later lexical development in children with DS in the same time frame.

The most important general conclusion from this research is that prelinguistic canonical vocalizations may predict later language development better for some groups of children than others. It is currently unknown whether this finding is due to variables that these investigators did not measure, or whether the results were sample-specific. Yoder and Warren alluded to weak verbal short-term memory (Marcell & Weeks, 1988) in children with DS as an explanation for these discrepant results for the groups of children in their study. If deficits in auditory memory explain poorer performance in expressive language, they may also affect speech sound performance. Yoder and Warren did not examine phonetic/phonological variables other than canonicity of utterances. This level of measurement does not differentiate between a child with a restricted sound inventory (such as the homorganic and early-developing sounds [b] and [m] in utterances like “ba,” “ma,” or “bam”) and a child with a more diverse and later-developing range of consonant sounds, such as [k], [l], and [s]. We also do not know if children whose utterances are more complex in terms of combining different sounds together in multisyllables (i.e., variegated babble) have better lexical outcomes than children who produce primarily simple, monosyllabic canonical babble. It is possible that either the diversity of the phonetic inventory, the complexity of utterances or both these factors together could also account for the differences found in Yoder and Warren’s sample of children.

Therefore, this dissertation will also determine if these phonetic/phonological variables (i.e., diversity of speech sounds and syllable shapes) are associated more strongly with lexical outcomes in one group of children than the other. For the purposes of this dissertation, it will be important to track not only canonicity, but also the complexity of the vocalizations to see if this phonology-lexicon relationship holds for the population of children with DS. Specifically, this dissertation will examine consonant inventory size and utterance complexity and relate these factors to lexical growth in children with DS and a control group of children without DS who are similar in age and cognitive development.

Questions posed in the study

This dissertation examines two primary questions:

1) Is phonological development of children with DS early in the first words period best described as delayed but predictable based on MA, or is it delayed beyond MA predictions, as is the case with lexical development?

2) Do early phonetic/phonological measures predict lexical development in children with and without DS?

This dissertation explores these issues by examining the productive phonological and lexical development of a group of 26 children with DS at the cusp of first word use in a longitudinal investigation. As noted, these children participated in a larger study of the efficacy of a communication intervention, referred to as Responsivity Education/ Prelinguistic Milieu Teaching or RE/PMT (Fey et al., 2006; Warren et al., 2008). At the outset of the study, the children were 24 to 33 months of age, had intellectual disabilities, and produced fewer than 10 spontaneous words or signs. Although the participants all produced fewer than 2 intentional communication acts per minute, they were all producing some intentional communication, using gestures, vocalizations, and coordinated attention between an adult and objects of interest. The longitudinal nature of this study makes it possible to examine phonetic and lexical skills from an essentially prelinguistic period to a period of frequent word production, for most of these children with DS. Importantly, the study also makes it possible to compare the speech sound-vocabulary relationship of the children with DS with that of a group of 24 children with similar cognitive and communication characteristics at the outset of the investigation.

Predictions

Question 1 is addressed by comparing differences in the number of canonical communication acts, average Syllable Structure Level (SSL, a measure of different consonants per utterance, Paul & Jennings, 1992; Stoel-Gammon, 1989) and consonant inventory size in the two groups of children at Time 1, just as the study began. No significant differences in phonological skills between the DS and NDS groups at Time 1 were anticipated, when the children had low levels of intentional communication and were expected to have relatively limited canonical vocalizations.

At Time 2, two outcomes were possible. One is that the DS group would show a similar or superior phonological profile to the NDS group at Time 2. This would reflect a true dissociation between phonological and lexical growth in the DS population. This outcome seemed unlikely, however, given that significant delays in phonology have been noted at somewhat later points in development.

A more likely outcome was that the DS group would show a slowdown in phonological skills, as compared to the NDS group. This outcome is in keeping with the general pattern of substantial delays in all aspects of speech and language production among children with DS. If phonological skills of children with DS progress at a similarly slowed-down rate, then the notion of a close relationship between phonological and lexical factors can be extended to include this population of children.

For question 2, one potential predictor of later lexical growth is the size of the phonetic inventory. This has been shown to predict later lexical development in late talkers (Paul & Jennings, 1992), and this variable may also predict lexical growth for both the NDS and DS groups of children in this study. Based on the findings of Yoder and Warren (2004), however, there should be a stronger correlation between the lexicon and phonological complexity for the NDS group of children than for the DS group. Given that no studies have indicated that there is an early-appearing *restriction* in the diversity or size of the consonant inventory in children with DS, and that their lexicon develops late and slowly, it was hypothesized that the phonetic growth variables would be more closely linked to lexical outcomes in NDS children than in children with DS. Stated another way, based on Yoder and Warren (2004), phonetic/phonological variables should predict later lexical outcomes better in children without DS than children with DS.

Chapter 2: Method

Participants

The participants in this study were 50 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. One child who took part in the earlier studies was excluded from the present investigation due to a diagnosis of Angelman syndrome. Children with Angelman syndrome characteristically have severely impaired speech and frequently develop few or no spoken words (Angelman Syndrome Foundation, n.d.). Thus, this child appeared fundamentally different from the other children in the study and was excluded.

The other participants averaged 26 months of age and had: (a) developmental delays in the mild to moderate range, with Mental Development Indexes (MDIs) ranging from 25 to 71 on the Bayley Scales of Infant Development, Mental Scales (BSID; Bayley, 1993); (b) no diagnosis of autism; (c) no more than 10 words or signs at the beginning of the study, as measured by the Infant Scale of the MacArthur Communicative Developmental Inventory: Words and Gestures (CDI; Fenson et al., 1993) completed by the primary caregiver and verified by the child's speech-language-pathologist; (d) vision and hearing skills within normal limits, with or without correction; and (e) sufficient upper body motor skills to perform basic gestures such as reaching (Fey et al., 2006, p. 59). Twenty-six participants had DS. Of the remaining 24 children, seventeen had developmental delays of unknown etiology, one had Trisomy 8, one had a mitochondrial disorder, one had microcephaly, and one experienced a right cerebrovascular accident at birth. One participant with developmental delay of unknown origin had renal disease as a complicating factor, and another had a repaired cleft palate. One child originally described as having delays of unknown etiology later received a diagnosis of Fragile X syndrome. One NDS child's Time 1 data were lost due to a technical failure. In addition, 4 children had no information from the Parent Stress Index. (PSI), and analyses involving this variable for Time 1 were carried out with casewise deletion of missing data. All of the children received community-based communication therapy outside of the study throughout the study period.

The Communication Temptations and Book Sharing components of the Communication and Symbolic Behavior Scales (CSBS, Wetherby & Prizant, 1993) were administered to each potential participant in the study. All children enrolled in the study produced fewer than 1.16 imperative acts per minute, 1.17 declaratives acts per minute,1.28 canonical vocalizations per minute, and 2.12 total communication acts per minute (Fey et al., 2006). It is especially important to note that in the group of children who met the basic criteria for the study, those who had strong communication and vocalization skills were excluded from the study. Twenty-six children with DS qualified for the study. An additional 4 children with DS were excluded from the study because 2 of them exceeded the criteria for communication acts in the CSBS and 2 of them exceeded the criterion of ten or fewer spontaneous words or signs on the CDI. In other words, 26/30 (87%) of the children with DS who were evaluated for the study eventually qualified and enrolled. Twenty-five children with developmental delays not attributable to DS qualified for the study. Eight additional children from this NDS diagnostic group were excluded from the study for the following reasons: 4 exceeded the vocabulary criterion on the CDI, 2 had Bayley scores exceeding the criterion, 1 had a Bayley score below the criterion, and 1 child was in the process of moving away. Thus, 25/33 (76%) of the children in NDS diagnostic group who were evaluated for the study eventually qualified and enrolled. These children included those with known diagnoses and those without a specific diagnosis other than developmental delay. An additional 23 children were also excluded from the study for the following reasons: 8 had too many communication acts in the CSBS, 3 displayed characteristics of autism, 2 had Bayley scores above criterion, 2 had Bayley scores below criterion, 2 had more than 10 words or signs on the CDI, and 8 were excluded for other, unspecified reasons. There was no diagnostic information recorded on these 23 children.

Group Characteristics. The two groups, DS and NDS, were compared on eight key pre-experimental variables, each of which is represented in Table 1. As shown in Table 1, at the outset of the study, there were three significant differences between groups on these variables. First, although the group means differed by less than two months, children with DS were, on average, younger than the children in the NDS group. Second, the children with DS had approximately one more sibling in the home. Finally, based on the total scores on the PSI, the parents of children with DS were under less stress than were parents of children without DS. Thus, although these groups have much in common, they clearly were not equivalent on a few potentially significant measures. None of these variables (i.e., age, siblings, and parental stress) at Time 1 correlated significantly with the growth in speech production or lexical measures from Time 1 to Time 2, however (*r*s < .26 , *p*s >.07).

Table 1

Entry Characteristics of the Participants, with and without DS (DS & NDS)

Pre-experimental variable	Group	*M*	*SD*	*p*
Bayley raw score	NDS	100.58	11.19	.12
	DS	96.62	5.75	
Age at Bayley	NDS	26.79	3.09	.02
	DS	25.12	1.93	
CDI-understood	NDS	120.08	104.27	.15
	DS	86.04	52.59	
CDI-spoken words	NDS	1.83	2.35	.12
	DS	2.88	2.22	
Monthly hours speech/language tx	NDS	4.56	2.27	.28
	DS	3.92	1.83	
Monthly hours all services	NDS	12.42	5.53	.39
	DS	13.79	5.60	
Years maternal education	NDS	14.83	2.65	.97
	DS	14.81	2.42	
Siblings in home	NDS	1.04	1.08	.01
	DS	1.92	1.29	
PSI-total stress score	NDS	235.73	38.45	.01
	DS	198.13	36.02	

Procedure

Following initial assessment, children returned to the laboratory for ongoing assessment every 6 months. The assessment context in this study is the parent-child communication session (PCX), which was one of two semi-structured communication interactions used at each data collection session over the 18-month study. Another non-structured communication interaction, the examiner-child communication session (ECX) was not chosen as the assessment context for this study because several of the children appeared reluctant to interact with an unfamiliar partner in free play. Furthermore, one of the preferred toys for many of the children was a set of sticks, and several ECX sessions were dominated by the noise of banging sticks. The variety of toys available for play at one time may have shifted the focus for some of the children on interacting with the objects more than with the examiner, although the examiner made efforts to engage the child in communication and to encourage vocalizations. The PCX was thus chosen because it provided the most stable context for the sampling and analysis of the children's speech sound development over time. Furthermore, this context allowed comparison of results with those from other studies of early phonological and lexical development. Parent-child interactions are the sampling context for many studies of early lexical and phonological development in different populations. This includes children with mixed-etiology developmental delay (Fey et al., 2006; Warren et al., 2008; Yoder et al., 1998), late-talking children (Fasolo, Majorano, & D'Odorico, 2008; Girolametto, Pearce, & Weitzman, 1997;

Paul & Jennings, 1992; Rescorla & Ratner, 1996; Whitehurst, et al., 1991), and typically-developing children (Stoel-Gammon, 1985).

The PCX sampling context. The 15-minute parent-child interaction session (PCX) was divided into three parts of five minutes' duration. Both the child and the parent were seated at a table throughout the session. For the first five minutes, each parent was instructed to select one of three toys enclosed in a sealed plastic or mesh bag and begin playing with it. The parent was allowed to share the toy with the child only after the child indicated an interest in playing with it. At this time, the parent enclosed the toy in the bag and put it within the child's reach. The parent was allowed to help the child open the bag and retrieve the toy after the child attempted to do so or requested assistance. Toys were rotated if the child lost interest, but the same procedure occurred with the presentation of each new toy. Following this five-minute play interval, 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. Small amounts of food or drink were provided throughout this five-minute session as long as the child requested them. At the same time, an audiotape of three different sounds (e.g., a bird chirping, a telephone ringing, a snippet from a children's song) played intermittently, and a slinky suspended from the ceiling moved unexpectedly. The sounds occurred for approximately 30 seconds, and were separated by at least a minute of silence. Parents were instructed to ignore the sounds and the slinky unless the child attended to them.

Then the parent was free to comment on them. The third and final segment of the PCX had components of both the first two segments. During this final segment, the parent again chose one of three different toys in bags and began to play with it. This time, when the child indicated interest in the toy, the parent was allowed to give the toy to the child without the bag. At the same time, an audiotape of various other sounds (e.g., a cat meowing, a phone ringing) played intermittently. The slinky moved between sound sequences. During the final minute of the PCX, bubbles were blown in the testing room through a partially-opened door. As before, parents were instructed to ignore such unusual events until the child took notice of them.

Each PCX sample was audio- and videotaped through a one-way mirror, using an analog VHS camera and a high-fidelity VCR with two-channel audio capabilities. These high-quality videotape signals were digitized and then saved to high-quality audio-and-video CDs. All data coding was performed through ProcoderDV (Version 2.1.7). This program identified the onset of all marked segments of the digital file by time in hundredths of a second. Observations for all samples in this study ended at 15 minutes. Eleven out of the 101 samples ended 1 to 11 seconds prematurely. No corrections were made to accommodate these slight differences in session length.

Dependent variables

Six phonetic/phonological variables and one lexical variable were generated for analysis. Two of these variables (proportion of canonical utterances and SSL) measured syllable complexity and four variables (initial consonants, advanced initial consonants final consonants, and advanced final consonants) measured speech sound complexity. Thus, both the shape of utterances and the size of the phonetic inventory were measured. Conventions of prior researchers (Paul & Jennings, 1992; Stoel-Gammon, 1989) were followed in coding the children's prelinguistic utterances, with some adaptations. Throughout this study, coders were instructed to code conservatively so as not to overestimate the child's phonetic skills. Details on collection and coding of child utterances for each of the dependent variables are provided below.

Coding

Definition and segmentation of child utterances. Minimally, a child utterance had to contain normal phonation. As noted by other researchers (Paul & Jennings, 1992; Stoel-Gammon, 1989), determining utterance boundaries was not always simple. Stoel-Gammon's (1989) procedures were adopted. In these studies, child utterances were bounded by silence one second or longer, a breath, interruption by an adult, or extraneous noise that interfered with transcription of the sounds. When segmenting utterances, coders were instructed to leave enough initial lag time so as not to clip off the onset of the child utterance and were allowed to adjust marking the start of the utterance until this criterion was met. A new child utterance began when the child next began to vocalize.

Utterances excluded from analysis. Whispered utterances were excluded from analysis because they lack phonation. Utterances that were too faint to hear clearly were also excluded from analysis, along with vegetative sounds such as coughing and frank crying or laughing. Grunts were included as long as phonation was audible. Negative utterances, such as protesting, were included in the analysis, as long as they were discrete and appeared under the child's control. It was important not to over-exclude such utterances, because many children use these types of utterances in their early communication (Nathani & Oller, 2001; Stark, 1989). Utterances associated with strongly negative affect (i.e., "fussiness") present special difficulties and frequently appeared to be reactive indications of the child's mood rather than examples of their playful or potentially intentionally communicative sound-making capabilities. Such utterances were systematically excluded.

Utterances produced while the child was chewing or had fingers or objects in or over the mouth were also excluded from the analysis because of the resulting distortion of the sounds. Minimal background noise was tolerated, as long as it 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. This is because the overlapping speech sounds from the adult or the continuous signal from the music made reliable identification of the child's sounds excessively difficult.

Partially overlapped utterances. Utterances with beginnings or endings that were obscured by noise were included in the analysis, with only the distinct syllables counting in the analysis. For example, if a parent interrupted a child, the child's utterance consisting of the syllables prior to the interruption were preserved and coded. Other researchers (Paul & Jennings, 1992) systematically excluded partially-obscured utterances; however, their goal was to obtain a corpus of a certain size for phonetic analysis, not to measure total number of vocalizations. Excluding partially-obscured utterances would have severely limited and distorted the actual number of vocalizations the children produced. Thus, all initial and final consonants from non-overlapped syllables were included in the analyses.

Identifying sounds. Following segmentation of the utterance, the coders had up to 4 opportunities to identify the initial consonant and 4 opportunities to identify the final consonant. This was a compromise between Paul and Jennings's (1992) rule allowing coders a maximum of 4 exposures to an utterance in order to transcribe it or discard it as uncodable and Rescorla and Ratner's (1996) rule allowing coders as many opportunities as necessary to listen to each utterance during transcription. Only clear exemplars of English initial and final phones were included in the inventory. The coder identified each consonant singleton, cluster, or glide by utterance position. This was particularly important in the coding of final sounds. Nasalized vowels were not taken as sufficient evidence of the presence of a final nasal consonant, and final oral stops had to be released to count in the inventory. Unreleased final stops were excluded from the inventory because it was often impossible to identify the specific stop with certainty.

If a coder had difficulty deciding between two distinct English phones for an otherwise clear production, either the developmentally less-advanced sound (e.g., a nonconsonantal glide favored over a consonantal liquid) and/or the least marked member of closely-related sounds (e.g., voiced cognates in initial position and voiceless ones in final position) was chosen. Occasionally, the children produced clear examples of a sound that is not native to English (e.g., velar fricative) or an indeterminate sound that shared features of two non-cognate sounds, making it impossible for the coder to choose between them (e.g., initial [d] or [g]). In such cases, the coder identified the sound with a “dummy” consonant “(x).” This was done in order to maintain an accurate SSL count without inflating the consonant inventory. The coder was allowed to orthographically transcribe hard-to-code utterances in a separate notes column to aid in transcription decisions and for future discussions on reliability coding.

Stretches of unintelligible vocalizations, or babble, were coded only for initial and final consonants. This procedure was modified slightly for stretches of vocalizations containing words. True words were extracted from each utterance and coded for initial and final sounds within each word. The initial and final consonants of the identified word counted in the inventory, despite being utterance-medial. This is because the child was clearly producing a discrete word, and not just a string of syllables. Thus, utterances containing words could have several initial and final consonant sounds, demarcated by word boundaries.

Intervocalic sounds. Intervocalic consonants in both babble and words were identified in transcribers’ notes and used to determine SSL, but were not included in the consonant inventory. Because intervocalic consonants pattern most like initial consonants in the typical population from 6 months through 24 months, covering the period from emergence of canonical babble through first words and beyond (Stoel-Gammon, 2002), only initial and final consonants were included in the phonetic inventory in this study. This is in keeping with several other studies on early consonant inventories. Typically, intercoder reliability is highest with initial consonants (Shriberg & Lof, 1991).

Distorted sounds. One of the most difficult aspects of transcribing young children's speech is that their productions are often "fuzzy," (Stoel-Gammon, 2001b), with imprecisely articulated consonants. Certainly, there is a question of what the intended target sound is with indeterminate consonants, especially if the utterance is unintelligible. In the present study, sounds were considered distortions in meaningful words if they were identifiable, common, and consistent productions of a particular English phoneme (Stoel-Gammon, 1989). For example, if a child consistently produced a lateralized [s] in recognizable words, the child was credited with [s]. However, in babble, this sound would be coded as (x), because, although "s-like," it does not meet the criteria for producing a "good" [s] phone. Such distorted sounds occurred infrequently, and in only the most lexically advanced children.

Prevocalic voicing. Prevocalic voicing of initial consonants was an accepted distortion in both babbling and word production. This was often perceived as a slight "[m]-ness" before a [b], a slight "[n]-ness before a [d], or a slight "[ŋ]-ness" before a [g]. Although these forms may have had some functionality in helping the child to begin stretches of vocalization with voiced consonants, especially voiced stops, they did not appear to represent nasal + oral stop clusters. Therefore, these pre-nasalized segments were categorized as the oral segment that followed the nasalization. If the initial nasal component was followed by a vowel, it was accepted into the inventory as a nasal segment. If no vowel followed a prolonged nasal segment, then the utterance was considered a syllabic nasal, and thus was nonconsonantal.

Determining canonicity. Following identification of sounds, each utterance was judged to be canonical or noncanonical. Nathani and Oller (2001) define canonical syllables as “mature, adultlike syllables that contain a vowel-like nucleus and consonant-like margin, have rapid formant transitions between the margin and the nucleus, and are produced with normal phonation” (pp. 324-325). This definition includes some non-English sounds as well as many of the sounds that occur in English. Early-appearing quasi-consonantal sounds such as the glides [h, w, j] and the glottal stop [ʔ] are not considered canonical consonants because they lack the articulatory precision and supralaryngeal vocal tract closure characteristic of other consonants. Thus, if phonation was present, with no consonant other than the quasi-vocalic glides [h, w, j] or glottal stop [ʔ] and no true CV (or VC) sequences, or if the utterance contained only syllabic consonants (such as “mm”), the utterance was judged noncanonical.

Dummy-coded consonants “(x)” were considered canonical, and any normally phonated utterance with at least an identified initial or final true consonant was considered canonical. It is important to note that dummy-coded consonants representing non-English sounds occurred in very few utterances overall. This is consistent with Stoel-Gammon's (1985) study of 34 younger TD toddlers, who heard such sounds "only sporadically" (p. 510). None of the children in her sample had an inventory with the same non-English phone at two consecutive data points. This implies that the production of non-English phones in children learning English and functioning beyond the age range of 15-24 months typically is infrequent and short-lived. Other studies detailing the growth of the phonetic inventory in English-learning children with speech delay do not document sounds other than those found in English (Kumin, Councill, & Goodman, 1994; Paul & Jennings, 1992; Rescorla & Ratner, 1996).

Syllable Structure Level (SSL). The SSL of each included child utterance (not word) was determined following a slight but significant modification of the conventions of Stoel-Gammon (1989) and Paul & Jennings (1992). Utterances with no true consonants have an SSL of 1. Utterances with only one true consonant, whether it appeared once or more than once in the utterance, have an SSL of 2. Also, utterances with two consonants that differ only in voicing (e.g., p/b) have an SSL of 2. Utterances with more than one consonant differing in place or manner of articulation in different syllable positions have an SSL of 3. Neither Stoel-Gammon nor Paul and Jennings mentioned the SSL category of consonant clusters. Following the logic of SSL, for the present study, utterances with a blend of true consonants (e.g., [gl] but not [gw]) in one syllable position were assigned an SSL of 3. Basically, SSL serves as a shorthand for the structure of young children's utterances, ranging from mostly noncanonical utterances (SSL near 1.0); to mostly simple or reduplicated

CV canonical utterances (or VC or VCV), with a SSL near 2.0; and finally to advanced syllable shapes, with at least 2 different consonants (SSL near 3.0). It is thus more informative than the commonly-used canonical/noncanonical distinction.

It is important to note that all conversational samples included at least some noncanonical utterances (such as "*uh-huh*" or "*yeah*"), even from the most verbal children at Time 2, so that high SSLs approached 2.5 rather than 3.0. This shows that SSL has limited utility once children are producing a variety of words. To determine SSL on a word-by-word basis would have severely distorted the complexity level of more verbal children's utterances. For example, a child who babbled [maba] would receive an SSL of 3. A verbal child who produced 'my baby' would receive an average SSL of 2 if SSL were judged on words, not utterances, because each word had only one unique consonant. Thus, to measure average syllable shape complexity across all the children, SSL was uniformly applied on the utterance, not the word, level. A flowchart for the coding procedure is included in the Appendix.

Frequencies of canonical and noncanonical utterances, SSL by level (1, 2, and 3) and initial and final consonant phones were tallied using Mooses (Multiple Option Observation System for Experimental Studies) software, Version 3.4.10 (Tapp, 2006). A description of each dependent measure follows below.

Syllable shape complexity. Two measures of syllable shape complexity were considered. First, the proportion of utterances in a sample that were canonical was calculated by dividing the number of canonical utterances by the sum total of canonical and noncanonical utterances. This measure was found to be a significant correlate to language development in late-talking 2-year-olds (Whitehurst et al., 1991). The second measure was average SSL. Average SSL was determined by summing the SSLs of each utterance and dividing by the total number of utterances. Both the proportion of canonical utterances and SSL were based on similar information, and they were highly correlated at both observation points for each diagnostic group ($r > .95$, $p < .01$ for all correlations). Because SSL is more informative than propcan and has been used in more studies (Fasolo, Majorano, & D'Odorico, 2008; Paul & Jennings, 1992; Stoel-Gammon, 1989; Thal, Oroz, & McCaw, 1995), it was the measure used in all subsequent analyses of syllable shape complexity.

Phonetic inventory. Two measures of phonetic complexity were generated from the data. First, a phonetic inventory of all "true" initial and final consonant sounds was completed. For a phone to count in the inventory, it had to be produced in at least two different utterances or words in the same utterance or word position to be included in the inventory. For example, a child's inventory could include initial [t], final [t], or both. Glides were not included as part of the true consonant inventory. The second measure, "advanced consonants," separated the inventory of true consonants into two groups based on order of emergence in the typical population and tallied the number of later-emerging consonants, namely, fricatives, affricates, liquids, and clusters. Stoel-Gammon (1985) noted that stops, nasals, and glides, which appear frequently in babble, are the sounds that occur most frequently in early speech, and that fricatives, affricates, and liquids appear later. Interestingly, these earlier-developing sounds are the ones produced most accurately by children with DS in later speech, whereas fricatives, affricates, and liquids are frequently in error (Bleile & Schwarz, 1984; Smith & Stoel-Gammon, 1983).

Lexical and communicative outcome measures

Canonical vocalization communication acts. Canonical vocalization communication acts (CVCAs) included all vocalizations judged by a pair of coders in the larger study (Warren et al., 2008) to be intentional and judged by the coder in the present study to contain a canonical vocalization. This measure included both words and babble. Importantly, this measure was found to predict later lexicon size in NDS children with developmental delay but not children with DS who were just slightly older than the children in the present study (Yoder & Warren, 2004).

Words. Spontaneous words were identified from the word glosses provided by prior coders (Warren et al., 2008). Because the focus is on the relationship between phonological factors and the lexicon, the present study excluded words that were overlapped with speech or noise, even if they were intelligible and had been glossed. Therefore, the present study contained only a subset of the prior study's corpus of spontaneous words.

There was a concern that excluding previously glossed words that met all of the other criteria for inclusion in the present study could negatively influence measurement of lexical size among the participants, particularly at Time 2, when many of the children were producing words during the parent-child sample. Therefore, spontaneous word counts for the participants in the present study were compared with those from Warren et al. (2008) at Time 1 and at the study endpoint (i.e., Time 2 for the present study, and Time 4 for the Warren et al. study). The means and standard deviations for the unique, spontaneous words measured by prior coders at study onset (Time 1) were 1.0 (*SD* = 2.28) for the DS group and 0.88 (*SD* = 2.36) for the NDS group, compared to the present coders' Time 1 means of 0.31 (*SD* = 0.62) for the DS group and 0.48 (*SD* = 0.99) for the NDS group. At study endpoint (Time 4 for the prior study and Time 2 for the current study), the prior coders measured a mean score of 22.35 (*SD* = 19.89) spontaneous words for the DS group and 49.25 (*SD* = 44.76) for the NDS group, compared to the present coders' measurements of 7.73 mean spontaneous words (*SD* = 5.44) for the DS group and 30.22 mean spontaneous words (*SD* =28.09) for the NDS group.

At Time 1, the correlation between the current and prior studies' word counts was significant at the $p < .05$ level for the participants as a whole ($r = .83$) and for the groups measured separately ($r = .70$ for the DS group, and $r = .90$ for the NDS group). The correlation between the word count and the CDI for spoken words was significant only for the prior coders' count, however ($r = .30$) for the children as a whole. Neither the prior coders' word count nor the word count from the current study significantly correlated with the spoken word count for the CDI for either group measured separately at Time 1, probably due to low scores at this measurement point. Most children produced no spontaneous words at Time 1, with a range of 0 - 4 words in the current study's tally, and a range of 0 - 11 words in the prior coders' tally.

Study endpoint correlations between the current and prior studies' spontaneous word counts were significant and substantial, for the participants as a whole ($r = .82$) and also by diagnostic group ($r = .70$ for DS; $r = .82$ for NDS). Furthermore, the word corpus from the present study significantly and substantially correlated with CDI spoken word measures for all participants, both as a whole ($r = .92$) and by diagnostic group ($r = .63$) for DS; ($r = .91$) for NDS at Time 2. The correlations between the CDI at Time 2 and the spontaneous word measures were larger for the word measures in the current study ($r = .92$) than for the spontaneous word measures in the prior study ($r = .73$) for the groups measured together and by each diagnostic group measured separately ($r = .44$ for DS, $r = .72$ for NDS) at Time 2. All correlations were significant at the $p < .01$ level. Figure 2 shows the means and 95% confidence intervals for the number of different words (NDW) produced by each group during the PCX at study onset (Time 1) and study endpoint (Time 2 for the present study, Time 4 for the Warren et al. (2008) study).

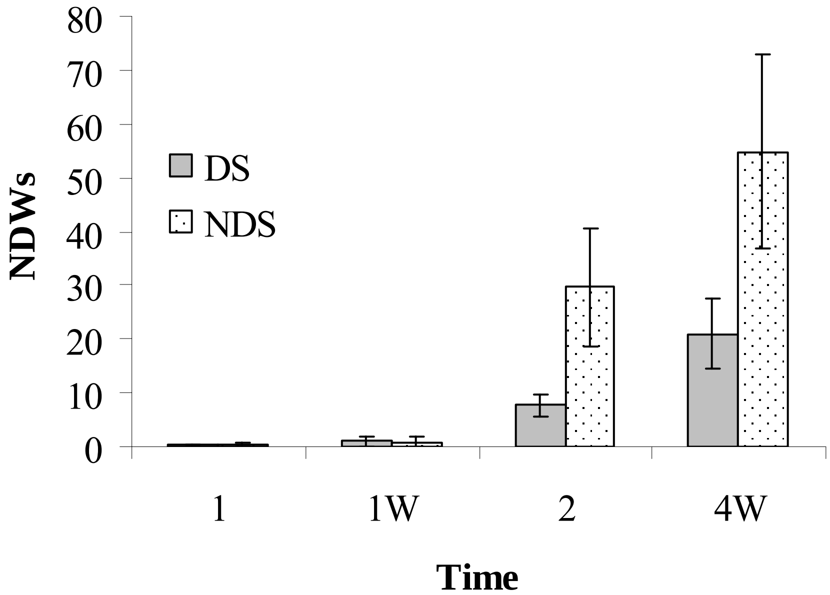

Figure 2. Means and 95% confidence intervals for number of different words (NDW, spontaneous only) produced during the PCX by each group at each testing point. W = Warren et al. (2008) study. Study endpoint = Time 2 = Time 4W.

As an extra precaution, a 2 (Group: DS vs. NDS) by 2 (Time 1 vs. Time 2) ANOVA was also performed on the lexical variable, the average number of different words (NDW) produced spontaneously during the PCX, to ascertain whether the relationships among the lexical outcomes in the DS and NDS groups over time in the Warren et al. study also held for this reduced data set. The overall ANOVA for the NDW yielded significant effects for Time, $F(1, 47) = 44.51$, $p < .01$, and for Group, $F(1, 47) = 15.96$, $p < .01$. There was also a significant Group by Time interaction, $F(1, 47) = 16.05$, $p < .01$. Planned comparisons revealed that the DS group's Time 1 mean of .31 NDW (SD = 0.62) was no different from the NDS average of 0.48 (SD = 0.99), $F(1, 47) = .53$, $p = .47$. It is important to remember that the children who were selected for the study produced fewer than 10 spontaneous words or signs, so this finding is expected. At Time 2, the groups differed significantly, $F(1, 47) = 16.03$, $p < .01$. The children with DS produced an average of 7.7 different words (SD = 5.44), whereas the NDS children produced an average of 30.22 different words (SD = 28.09) at Time 2, $d = -1.40$, *95% CI* = -3.49 - +10.08. These results are consistent with those found in the Warren et al. (2008) study.

Coding Reliability

Twenty-one percent of the 101 PCX samples were coded separately by a reliability coder, following an extensive training period, totaling approximately 48 hours over 8 weeks. The training included joint and independent coding of child speech samples not included in the present study. The primary coder (SBS) and the reliability coder (KJI) then reviewed all coding discrepancies after each independent coding. During these review sessions, the coding criteria were made more explicit when necessary and the coding manual was revised. Training was complete when overall agreement reached approximately 75% over 3 consecutive samples or when no coding adjustments were made during the review of the coded sample. Although the reliability coder could usually determine which children had DS from watching the videotaped samples, the reliability coder was blind to the hypotheses of the study regarding diagnostic groups. The samples for the reliability coder were selected randomly, and the children were not identified by diagnostic or treatment group. The reliability coder was aware of whether a sample came from the initial or final assessment time, however, because that information was included in the child's identification code, and it was generally easy to determine from just observing the videotape whether the sample came from a child who was 2 years old or 3 ½ years old.

Reliability was determined by comparing the coders' database entries on the number of canonical and noncanonical utterances, average SSL, the number of true and advanced consonants in both initial and final positions at Times 1 and 4. In other words, it was the number of sounds or utterances of each type that counted, not the specific identity of each sound or whether the same utterances were coded the same way at each observation point. Stoel-Gammon (2001b) recommended comparing inventories as opposed to point-by-point transcriptions because focus is on the reliability of the inventories, not on how similarly each individual utterance is transcribed. Acceptable point-by-point agreement generally ranges from only 60-80% in children's speech (Shriberg & Lof, 1991; Stoel-Gammon, 1991).

The primary coder and the reliability coder reviewed but did not modify each reliability sample after data were entered into the database in order to maintain interjudge consistency in coding. This ongoing training included approximately 40 additional hours. Single rater intraclass correlation coefficients (ICCs) were computed to determine the proportion of variance in scores that was related to actual sample differences rather than to the coders, interactions between coders and samples, or other unknown factors (McGraw & Wong, 1996). ICCs approach 1.0 when judges give nearly identical scores on each measure for each subject, indicating that the total variation in measurements is due solely to differences in the subjects on the target variables and residual variance, not to differences in the coders' scores. Typically, inter-transcriber reliability is lowest for final consonants and highest for initial consonants (Shriberg & Lof, 1991). In the present study, the reliability scores for final consonants were transcribed with the lowest inter-rater agreement. For this reason, hypothesis testing was first done on results from initial consonants separately from final consonants. Because the interjudge reliability is somewhat lower with final consonants than with the other measures, results concerning final consonants should be interpreted with caution. Table 2 displays the ICCs for each phonetic measure.

Table 2

Intraclass Correlations (Single Measures; 2-way Random Effects Model) and 95% Confidence Intervals for all Measurements in the PCX

Child measure	ICC	95% confidence interval	
		Lower Bound	Upper Bound
Canonical utterances	.97	.93	.99
Noncanonical utterances	.95	.88	.98
Syllable structure level (SSL)	.98	.94	.99
Initial consonants (word/utterance onsets)	.95	.88	.98
True initial consonants (no glides)	.94	.86	.98
Advanced initial consonants (fricatives, affricates, liquids, clusters)	.92	.82	.97
Final consonants (word/utterance codas)	.74	.46	.88
Advanced final consonants (fricatives, affricates, liquids, clusters)	.88	.73	.95

Statistical design

The principal statistical analyses involved analyses of variance (ANOVA) and multiple regression. The planned ANOVAs were 2 (Group: DS vs. NDS) by 2 (Time 1 vs. Time 2) repeated measures analyses. As noted earlier, the pre-experimental scores for participant age, number of siblings in the home, and total Parental Stress Index did not correlate significantly with Time 2 outcome measures, so they were not included as covariates in the analysis. Table 3 depicts the relationship between the participant age, number of siblings, and total PSI scores and the phonetic outcome variables.

Table 3

Correlation Coefficients (r) and p-values of Potential Covariates and Time 2 Outcome Variables

	AGE	PSI	SIBS
Number of different words (NDW)	0.07 $p = .67$	0.27 $p = .07$	-0.16 $p = .29$
Canonical vocal communication acts (CVCAs)	0.21 $p = .16$	0.25 $p = .09$	-0.11 $p = .45$
Syllable Structure Level (SSL)	0.03 $p = .87$	0.19 $p = .20$	-0.12 $p = .32$
Initial consonant inventory	0.13 $p = .41$	0.17 $p = .26$	0.03 $p = .84$
Advanced initial consonants	0.21 $p = .17$	0.04 $p = .78$	0.06 $p = .71$
Final consonant inventory	0.05 $p = .73$	0.17 $p = .27$	-0.12 $p = .42$
Advanced final consonants	0.00 $p = .98$	0.16 $p = .29$	-0.12 $p = .41$
Non-advanced consonants (nasals, oral stops)	0.00 $p = .98$	0.16 $p = .29$	-0.12 $p = .41$
Advanced consonants (fricatives, affricates, liquids, clusters)	0.14 $p = .36$	0.12 $p = .43$	-0.04 $p = .77$

Note. $N = 46$ (Casewise deletion of missing data).

Dependent measures for the planned group comparisons were number of initial consonants in the inventory, number of advanced initial consonants, number of final consonants in the inventory, number of advanced final consonants, SSL, and the number of canonical vocalization communication acts (CVCAs) in the sample. Because the ICCs were lower for final consonants than for initial consonants, group comparisons were first made on initial and final consonants separately. The lexical measure consisted of the word count from the PCX sample.

For the multiple regression analyses, the primary purpose was to assess the unique contributions of early phonetic/phonological variables toward the prediction of lexical performance. Therefore, the most important planned analyses utilized Time 1 phonetic/phonological variables as predictors of Time 2 lexical abilities after controlling for Time 1 cognitive ability (Bayley MDI) and vocabulary comprehension (CDI-understood), two non-phonetic variables predicted to be related to later word production. The original plan was to run separate regressions with each phonetic/phonological variable to be added to the model after controlling for mental age and vocabulary comprehension. To limit the number of analyses performed, three variables representing conceptually different aspects of the children's developing phonetic/phonological abilities were planned as dependent variables. These included the number of canonical vocalization communication acts (CVCAs), a key variable found by Yoder and Warren (2004) to be associated with later lexical production only for children without DS, total number of consonants in the phonetic inventory, and SSL.

Chapter 3: Results

The first question asked whether the DS and NDS groups of children differed in phonological skills at the two points of measurement. At Time 1, the children were approximately 25 months old and had fewer than 10 productive words or signs in their repertoires. At Time 2, the children were 3 ½ years old and the groups differed significantly in lexical size. Phonological skills were measured in terms of consonant inventory size and average complexity of utterances. Utterances were classified as noncanonical vocalizations, simple canonical vocalizations (having only 1 true consonant), and advanced canonical vocalizations (having at least 2 consonants differing in place or manner of articulation). The primary questions were addressed through analyses of variance (ANOVA).

As noted in the Introduction and Method, the children in this study were part of a larger trial investigating the efficacy of Prelinguistic Milieu Teaching (PMT). It is possible that this treatment had a direct effect on the children's phonological development or interacted with other variables, including the presence or absence of DS, to influence speech sound development. To examine this possibility, preliminary ANOVAs were conducted to see if there were any significant main effect or interaction effects involving treatment group (tx: early and late). There were no significant main or interaction effects involving treatment for any of the dependent variables, $0.24 < F < 2.86$, $.10 < p < .63$ for main effects; $0.00 < F < 3.85$, $.06 < p < .96$ for all interaction effects. Consequently, the tx variable was dropped from the analysis. Thus, the planned ANOVAs were 2 (Group: DS vs. NDS, between-subjects variable) by 2 (Time: 1 vs. 2, a within-subjects variable) analyses. This univariate design was used four times; once for each dependent variable. This allowed examination of not only phonological differences at two discrete points in time, but also an examination of differences in the rate of growth for the two groups of children in the same time period. Both Time 1 and Time 2 results will be discussed together for each measure so that interaction effects are made clear.

Phonetic repertoire

True initial consonants. The overall ANOVA for the number of true (supraglottal, non-glide) initial consonants yielded a significant effect for Time, $F(1, 47) = 72.00$, $p < .01$, but no main effect for Group, $F(1, 47) = 0.27$, $p = .60$. Figure 3, which provides the means and 95% confidence intervals for each group at each time shows this pattern as well as a significant Group by Time interaction, $F(1, 47) = 4.92$, $p = .03$. Planned comparisons revealed that the DS group's Time 1 mean of 2.4 true consonants ($SD = 2.08$) was not reliably different from the NDS average of 1.48 true consonants ($SD = 1.9$), $F(1, 47) = 2.51$, $p = .12$, $d = 0.46$, *95% CI* = -0.34 - + 1.24. At Time 2, the mean number of true consonants for the DS group ($M = 6.0$, $SD = 3.33$), also did not differ reliably from the mean for the NDS group ($M = 7.65$, $SD = 4.75$), $F(1, 47) = 2.02$, $p = .16$, $d = -0.41$, *95% CI* = -1.69 - +1.49 . As the figure illustrates, the children in the DS group started out slightly (but not reliably) more advanced in consonant production at Time 1. After an 18-month period of comparatively slower growth of speech sound skills, however, the children with DS were slightly, but not reliably, behind the children in the group without DS by Time 2. This means that the children from the NDS group had an increased rate of initial consonant acquisition over the same time period as compared to the children with DS, accounting for the significant interaction effect.

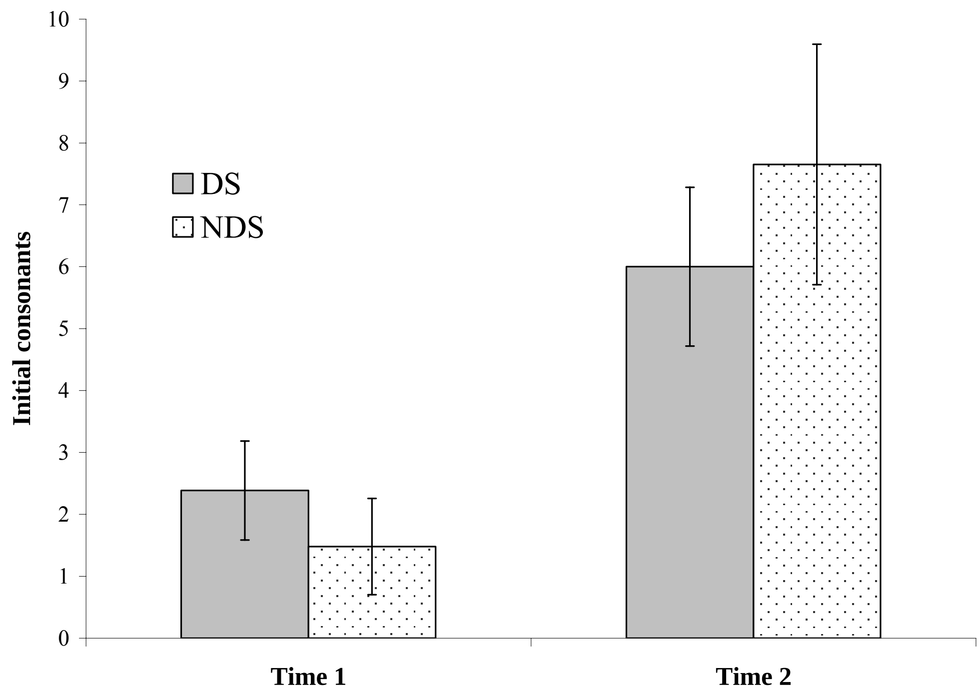

Figure 3. Means and 95% confidence intervals for true initial consonants for each group at each testing point.

Advanced initial consonants. Initial-position fricatives, affricates, liquids, and consonant clusters were identified as a subset of all initial consonants. These sounds tend to be acquired later in development than oral and nasal stops (Shriberg, 1993; Stoel-Gammon & Dunn, 1985). The overall ANOVA for the number of advanced initial consonants yielded a significant effect for Time, $F(1, 47) = 26.02$, $p < .01$, but no main effect for Group, $F(1, 47) = 2.10$, $p = .15$. Figure 4, which provides the means and 95% confidence intervals for each group at each time shows a significant Group by Time interaction, $F(1, 47) = 5.60$, $p = .02$. Very few children produced any advanced consonants at Time 1. Planned comparisons revealed that the DS group's Time 1 mean of 0.5 advanced initial consonants ($SD = .95$) was not reliably different from the NDS average of 0.17 advanced initial consonants ($SD = .49$), $F(1, 47) = 2.19$, $p = .15$, $d = -1.69$, *95% CI* = -2.05 - -1.49. The groups were significantly different at Time 2, however. At this point in time, the mean number of advanced initial consonants for the DS group ($M = 1.42$, $SD = 1.77$), was significantly lower than the mean for the NDS group ($M = 2.70$, $SD = 2.58$), $F(1,47) = 4.12$, $p < .05$, $d = -0.62$, *95% CI* = -1.30 - +0.68. Figure 4 illustrates a significant interaction effect, $F(1, 47) = 4.12$, $p < .05$ ($p = .048$). After an 18-month period of comparatively slower growth of speech sound skills, the children with DS had, on average, significantly fewer advanced consonants than the children in the NDS group at Time 2. As a group, the children in the NDS group increased their rate of production of advanced initial consonants to a greater degree than children with DS, resulting in this significant interaction effect.

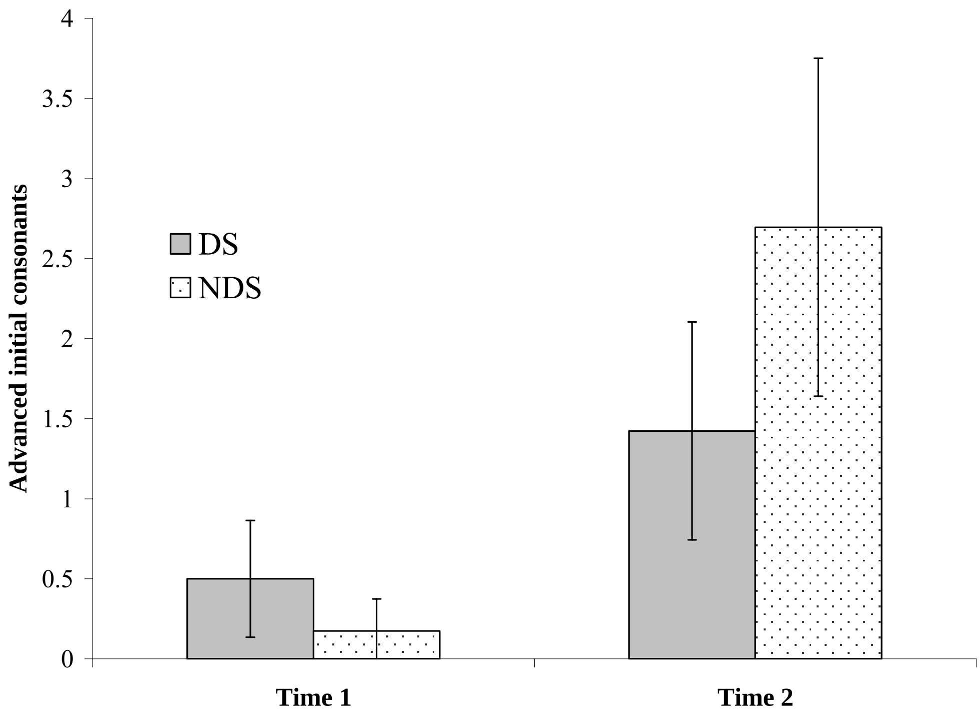

Figure 4. Means and 95% confidence intervals for advanced initial consonants for each group at each testing point.

Final consonants. The overall ANOVA for the number of final consonants yielded a significant effect for Time, $F(1, 47) = 51.10$, $p < .00$, but not for Group, $F(1, 47) = 3.09$, $p = .09$. Figure 5, which provides the means and 95% confidence intervals for each group at each time shows a significant Group by Time interaction, $F(1, 47) = 12.34$, $p < .01$. Planned comparisons showed that the DS group's Time 1 mean of 0.88 final consonants ($SD = 1.34$) was not reliably different from the NDS average of 0.35 final consonants ($SD = 0.65$), $F(1, 47) = 3.07$, $p = .09$, $d = 0.52$, *95% CI* = 0.01 - +0.79. However, the groups differed significantly at Time 2. At this point, the mean number of final consonants for the DS group ($M = 2.31$, $SD = 1.98$), was significantly lower than the mean for the NDS group ($M = 4.52$, $SD = 3.60$), $F(1,47) = 7.54$, $p = .01$, $d = -.81$, *95% CI* = -1.57 - +0.66. Figure 5 illustrates the significant interaction effect, $F(1, 47) = 12.34$, $p < .01$.

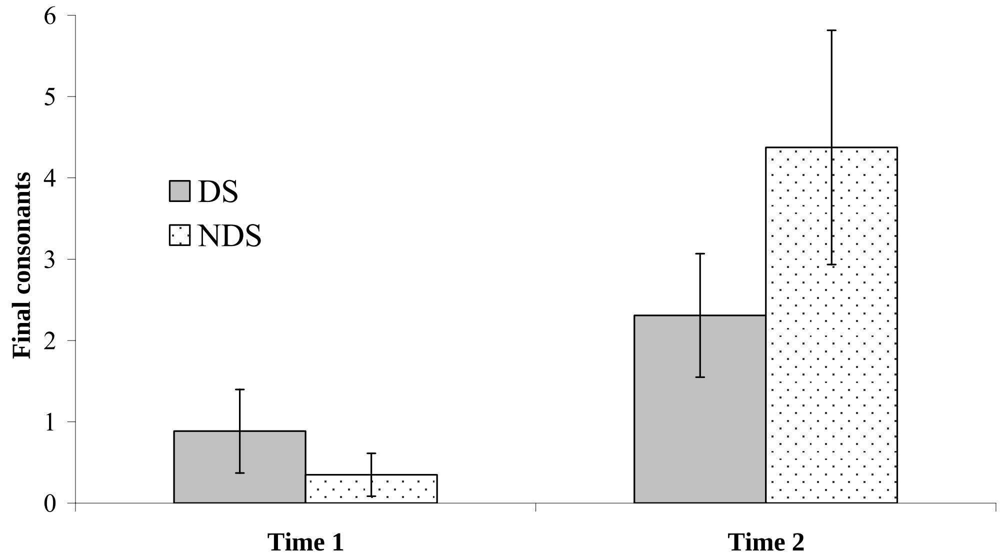

Figure 5. Means and 95% confidence intervals for final consonants for each group at each testing point.

Advanced final consonants. There was a significant main effect for Time in the overall ANOVA for the number of advanced final consonants, $F(1, 47) = 28.65$, $p < .01$. The main effect for Group was nonsignificant, $F(1, 47) = 1.60$, $p = .21$. Figure 6, which provides the means and 95% confidence intervals for each group at each time, depicts the significant Group by Time interaction, $F(1, 47) = 7.55$, $p = .01$. Planned comparisons showed that the DS group's higher Time 1 mean of 0.39 advanced final consonants ($SD = 0.80$) just missed significance ($p = .054$) when compared to the lower NDS average of .04 final consonants ($SD = 0.21$), $F(1, 47) = 3.90$, $p = .054$, $d = 0.67$, *95% CI* = +0.36 - +0.75. At Time 2, the groups were significantly different on this variable. At this point, the mean number of advanced final consonants for the DS group ($M = 1.00$, $SD = 0.89$), was significantly lower than the mean for the NDS group ($M = 1.96$, $SD = 2.08$), $F(1,47) = 4.57$, $p = .04$, $d = -0.66$, *95% CI* = -1.00 - +0.17. Figure 6 illustrates the significant interaction effect, $F(1, 47) = 7.55$, $p = .01$.

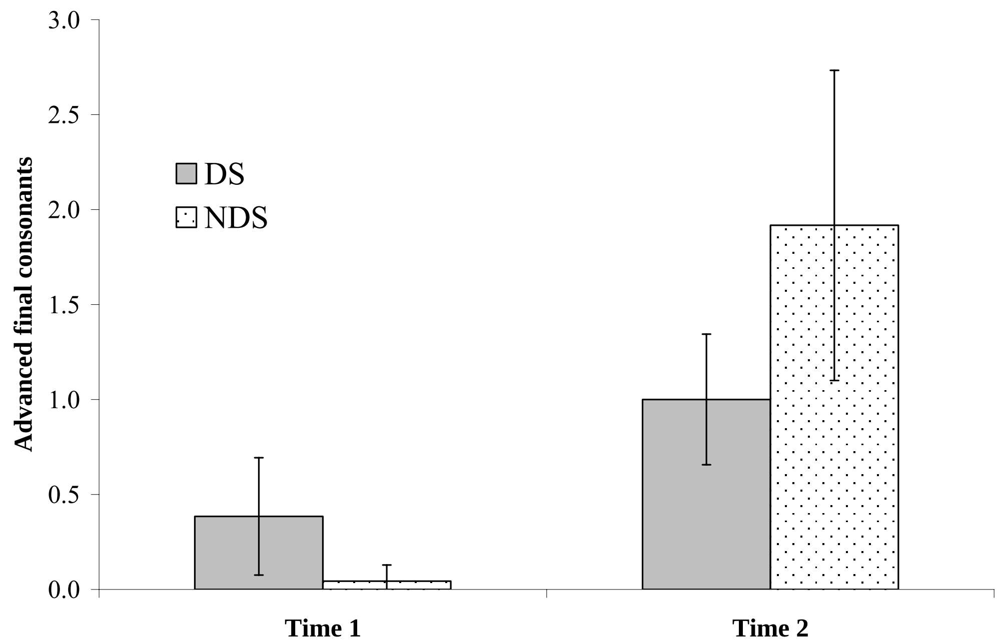

Figure 6. Means and 95% confidence intervals for advanced final consonants for each group at each testing point.

Complete consonant inventory

Because the analyses of the final consonants followed the same pattern as that of other phonetic measures, the initial and final consonants were combined together for analysis. In this analysis, all initial consonants and final consonants that were not also present in the initial consonant inventory were included. In other words, all unique consonants, regardless of utterance position, were combined. Consonants were added to the count if they reached criterion in either initial or final position. This procedure was extended for advanced consonants also. Fricatives, affricates, liquids, and consonant clusters were added to the inventory if they occurred in initial position or final position.

Unique consonants in the inventory. The overall ANOVA for the number of unique consonants yielded a significant effect for Time, $F(1, 47) = 91.00$, $p < .001$, but not for Group, $F(1, 47) = 0.31$, $p = .58$. Figure 7, which provides the means and 95% confidence intervals for each group at each time shows a significant Group by Time interaction, $F(1, 47) = 10.09$, $p < .01$. Planned comparisons showed that the DS group's Time 1 mean of 3.19 unique consonants ($SD = 2.50$) was significantly higher than the NDS average of 1.74 unique consonants ($SD = 2.03$), $F(1, 47) = 4.91$, $p = .03$, $d = 0.64$, *95% CI* = -0.32 - +1.47. At time 2, the NDS group had a greater number of overall consonants in the inventory ($M = 9.35$, $SD = 5.18$) than the DS group ($M = 7.00$, $SD = 3.54$), but this difference did not reach statistical significance, $F(1,47) = 3.50$, $p = .07$, $d = -0.55$, *95% CI* = -1.91 - +.1.57.

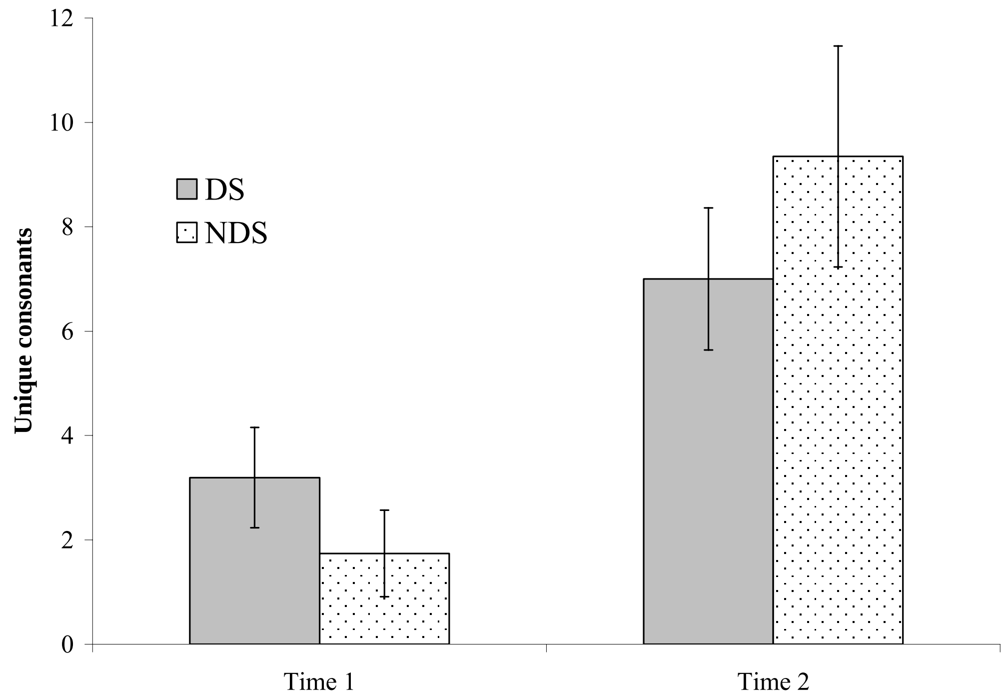

Figure 7. Means and 95% confidence intervals for all unique consonants for each group at each testing point.

Unique advanced consonants in the inventory. The overall ANOVA for the number of unique advanced consonants yielded a significant effect for Time, $F(1, 47) = 36.80$, $p < .01$, but not for Group, $F(1, 47) = 1.35$, $p = .25$. Figure 8, which provides the means and 95% confidence intervals for each group at each time, shows a significant Group by Time interaction, $F(1, 47) = 8.38$, $p = .01$. Planned comparisons showed that the DS group's Time 1 mean of 0.85 unique advanced consonants ($SD = 1.12$) was significantly higher than the NDS average of 0.26 unique advanced consonants ($SD = 0.54$), $F(1, 47) = 5.20$, $p = .03$, $d = 0.70$, *95% CI* = 0.26 - +0.92. At Time 2, the opposite result prevailed. The NDS group's average number of advanced consonants ($M = 3.52$, $SD = 3.10$) was significantly greater than that of the DS group ($M = 2.00$, $SD = 1.88$), $F(1,47) = 4.43$, $p = .01$, $d = -0.62$, *95% CI* = -1.34 - +0.65.

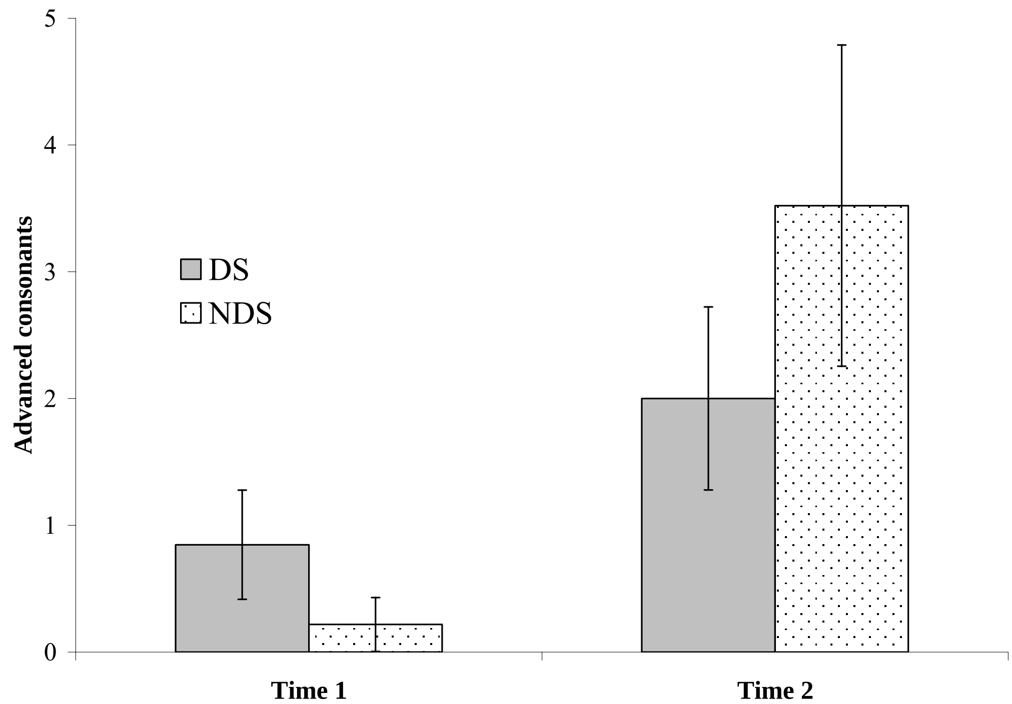

Figure 8. Means and 95% confidence intervals for unique advanced consonants for each group at each testing point.

Synthesis: Consonant inventory

Taken together, the results of all consonants and advanced consonants only suggests that advanced consonants may distinguish the groups better than the overall consonant inventory, despite very restricted variance in scores at Time 1. Figure 9 shows the group means for the entire consonant inventory of both groups broken down by “non-advanced” and “advanced” categories at both observation points. The non-advanced group of consonants consists of the nasal and oral stop consonants (NOS) and the “advanced” consonants consist of fricatives, affricates, liquids, and clusters (FALC). The figure also displays the significant interaction effects for both advanced consonants, $F(1, 47) = 8.38$, $p = .01$, as described above, and also for non-advanced nasals and oral stops, $F(1, 47) = 5.77$, $p = .02$. These interaction effects are characteristic of all the phonetic variables examined in this study. This effect shows a flatter rate of growth on all the phonetic variables in the DS group over time, despite having no disadvantage (and in many cases, a statistically reliable advantage) in performance compared to the NDS group at Time 1. The NDS group, in contrast, shows a steeper growth rate in the variables examined, with no disadvantage (and in many cases, a statistically reliable advantage) in performance by comparison with the DS group 18 months later. Furthermore, there were significant differences by diagnostic group in the mean number of exemplars of advanced consonants at each testing period. This was true for the NOS consonants at Time 2. The group differences in the number of NOS consonants at Time 1 just missed significance, $F(1, 47) = 3.90$, $p = .054$, $d = 0.47$, *95% CI* = -0.20 - +1.27.

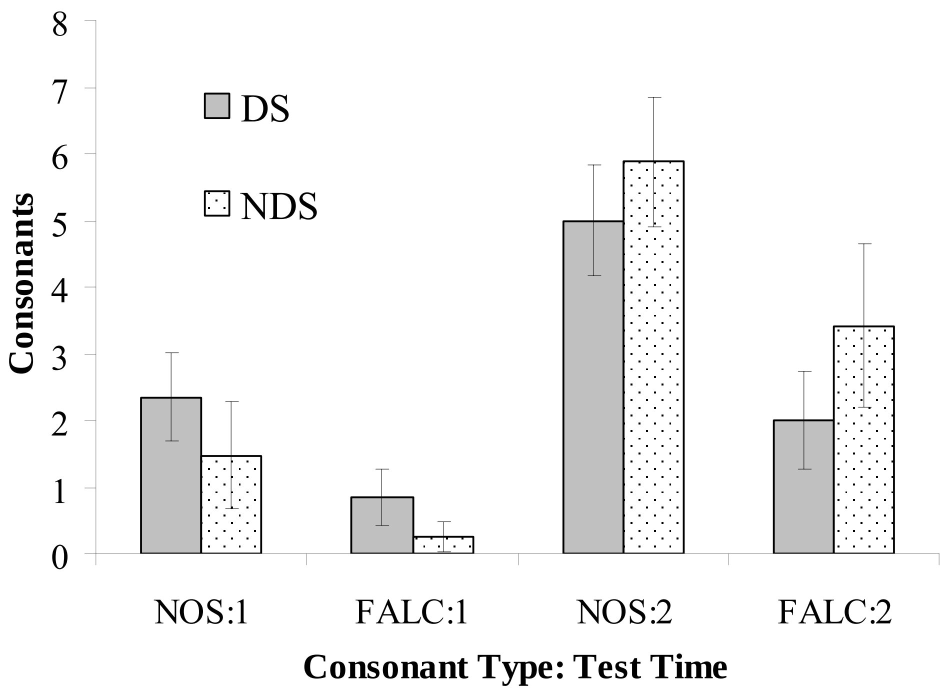

Figure 9. Means and 95% confidence intervals for consonant types by diagnostic group and testing time. NOS = nasals and oral stops; FALC = fricatives, affricates, liquids, and clusters.

Syllable shape

Average SSL. As noted earlier, the Syllable Structure Level (SSL) is shorthand for determining the syllable shape complexity of an utterance. This number may range from the extremes of 1.0 (no canonical utterances) to 3.0 (all utterances containing at least 2 supraglottal consonants differing in place and/or manner of articulation). Because speakers generally produce at least *some* noncanonical utterances in communication exchanges, (e.g., *uh-huh, mhm, uh-uh, oh*), a "high" average SSL might approach 2.5, rather than 3.0, however.

The overall ANOVA for SSL revealed a significant effect for Time, $F(1, 47) = 77.14$, $p < .01$, but no main effect for Group, $F(1, 47) = .01$, $p = .92$. Figure 10, which provides the means and 95% confidence intervals for each group at each time shows a significant Group by Time interaction, $F(1, 47) = 17.30$, $p < .01$. Planned comparisons revealed that the DS group's Time 1 mean SSL of 1.45 ($SD = 0.23$) was significantly higher than the NDS average SSL of 1.22 ($SD = 0.18$), $F(1, 47) = 15.24$, $p < .01$, $d = 1.13$, *95% CI* = +1.04 - +1.20. The groups were also significantly different at Time 2, but in the opposite direction. At Time 2, the mean SSL for the DS group ($M = 1.70$, $SD = 0.25$), was significantly lower than the mean SSL for the NDS group ($M = 1.92$, $SD = 0.42$), $F(1, 47) = 5.10$, $p = .03$, $d = -0.67$, *95% CI* = -0.76 - -0.50. The children in the DS group started out reliably higher, on average, in SSL at Time 1, but were significantly lower, on average, than the children in the NDS group by Time 2, resulting in the significant interaction effect over the 18-month period of development, $F(1, 47) = 17.30$, $p < .01$. Figure 10 depicts average SSL for the two groups of children at Time 1 and Time 2.

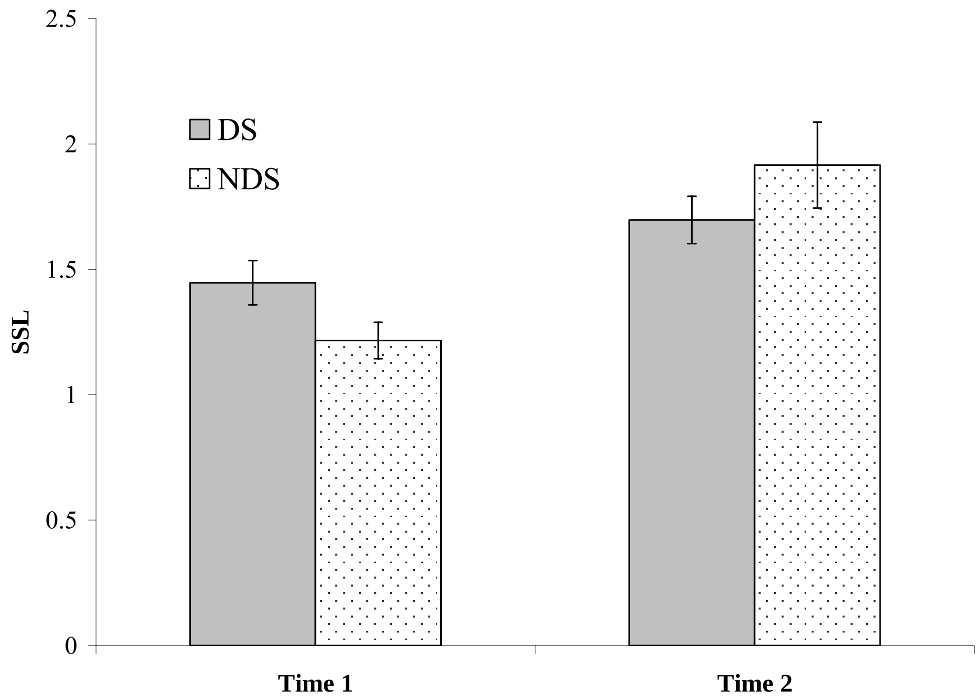

Figure 10. Means and 95% confidence intervals for average SSL for each group at each testing point.

Communication acts: all utterances and words

Up to this point, analyses were conducted on a strictly output form basis, without regard to communicative intent. The next two analyses address the communicative intent of the children's utterances, based on diagnostic group, at the two observation points in the study. One analysis assesses group differences in CVCAs (inclusive of unintelligible, partially intelligible, and completely intelligible utterances). In other words, this analysis measures communication acts with canonical vocalizations, including both babble and identifiable words. The second analysis assesses group differences in unique spontaneous word production (number of different words, or NDW) at Time 1 and Time 2, a subset of all CVCAs.

Canonical vocal communication acts. The overall ANOVA for the number of communication acts that contained canonical vocalizations (CVCAs) yielded significant effects for Time, $F(1, 47) = 76.19$, $p < .01$, and for Group, $F(1, 47) = 5.26$, $p = .03$. Figure 11, which provides the means and 95% confidence intervals for each group at each time shows clearly, however, that these significant main effects were mitigated by a significant Group by Time interaction, $F(1, 47) = 13.91$, $p < .01$. Planned comparisons revealed that the DS group's Time 1 mean of 7.23 CVCAs ($SD = 7.24$) was significantly greater than the NDS average of 2.78 CVCAs ($SD = 3.80$), $F(1, 47) = 6.97$, $p = .01$, $d = 0.74$, *95% CI* = +0.16 - +1.32. At Time 2, however, the mean number of CVCAs for the DS group ($M = 26.62$, $SD = 16.29$), was reliably lower than the mean for the NDS group ($M = 51.09$, $SD = 37.43$), $F(1, 47) = 9.17$, $p < .01$, $d = -0.93$, *95% CI* = -7.19 - +14.05. Thus, as was the case for the other variables, the children in the DS group started with a slight advantage at Time 1. After an 18-month period of comparatively slower growth of speech sound skills, however, they lagged significantly behind the children in the group without DS by Time 2.

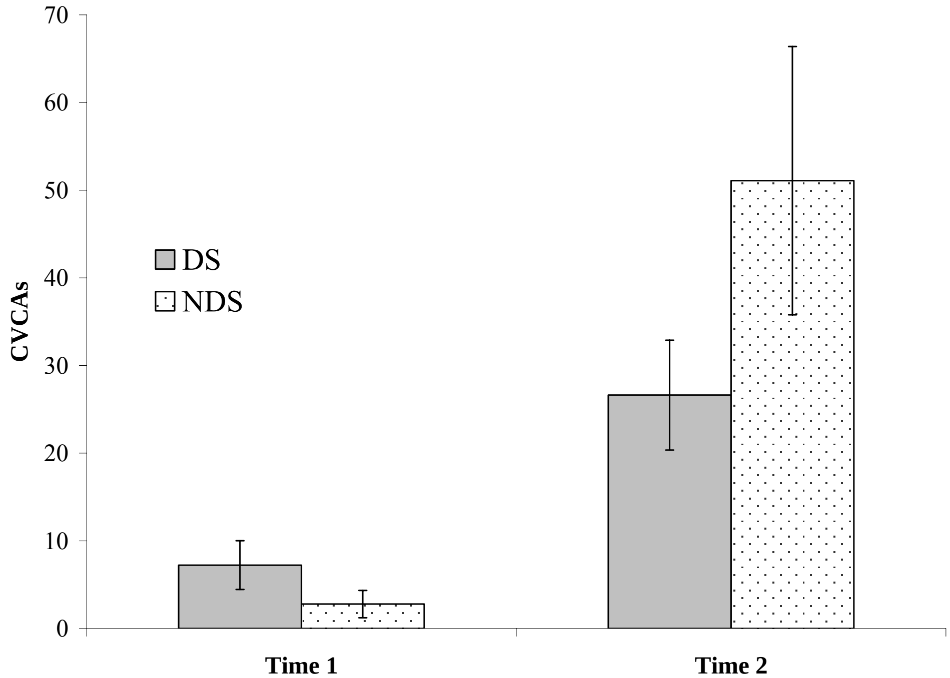

Figure 11. Means and 95% confidence intervals for canonical vocal communication acts (CVCAs) for each group at each testing point.

Comparison of phonetic/phonological measures to lexical use

The second major question of this dissertation involves an evaluation of the relationships between lexical outcomes and the phonetic/phonological variables used in the study. This question was intended to be a partial replication and extension of Yoder and Warren's (2004) study on predictors of lexical density in thirty-nine 30- to 36-month-old children with cognitive delay, 17 of whom had DS. The hypothesis to be evaluated in this study is that phonetic/phonological variables should predict later lexical outcomes better in children without DS than children with DS. The plan to address this question was to control for cognitive ability and language comprehension by first entering Bayley MDI and CDI-understood simultaneously. After controlling these variables, number of CVCAs, number of unique consonants, and SSL were selected as dependent variables to be added in separate regression analyses run for each of the two subgroups.

Table 4 presents the correlation matrix for these measures at Time 1.There is a trend for the Bayley score and the CDI-understood score to be moderately correlated with each other but not to be correlated with the phonetic/phonological variables. Those latter variables were somewhat more strongly related to each other at Time 1.

Table 4

Intercorrelations among Time 1 Predictor Variables for Later Vocabulary

Predictors	1	2	3	4	5
			DS only (n = 26)		
1. Bayley	----	.42* p = .03	.06 p = .78	-.07 p = .74	-.16 p = .44
2. CDI-U		----	.00 p = .98	.08 p = .71	-.21 p = .30
3. CVCAs			----	.73** p = .00	.53** p = .01
4. Unique Consonants				----	.51** p = .01
5. SSL					----

Predictors	1	2	3	4	5
			NDS only (n =23)		
1. Bayley	----	.49* p = .02	.48* p = .02	.32 p = .14	.04 p = .87
2. CDI-U		----	.221 p = .311	.134 p = .542	.139 p = .528
3. CVCAs			----	.67** p = .00	.59** p = .00
4. Unique Consonants				----	.78** p = .00
5. SSL					----

Table 5 provides the zero-order correlations between the selected predictor variables and the outcome variable, NDW, at Time 2.

Table 5

Zero-order Correlations of Time 1 Variables with Number of Different Words (NDW) produced at Time 2.

Time 1 predictor variables of later NDW	DS only (*n* = 26)	NDS only (*n* = 23)
CDI receptive	.07 p = .74	.35 p = .09
Bayley raw score	.09 p = .65	.55** p = .01
CVCAs	.50** p = .01	.24 p = .27
Unique consonants	.61** p = .01	.26 p = .23
SSL	.21 p = .29	.07 p = .76

Note. Correlations marked with * were significant at the p $\leq$ .05 level. Correlations marked with ** were significant at the $p \leq .01$ level.

There are two noteworthy aspects of this table. First, the Bayley is predictive in one group (NDS) and not the other. Second, the pattern of correlations runs directly counter to the predictions based on the results of Yoder and Warren (2004). That is, significant correlations were observed between both CVCAs and number of consonants at Time 1 and NDW at Time 2, but only for the DS group. To further investigate these data, the scatterplots shown in Figures 12 and 13 were examined.

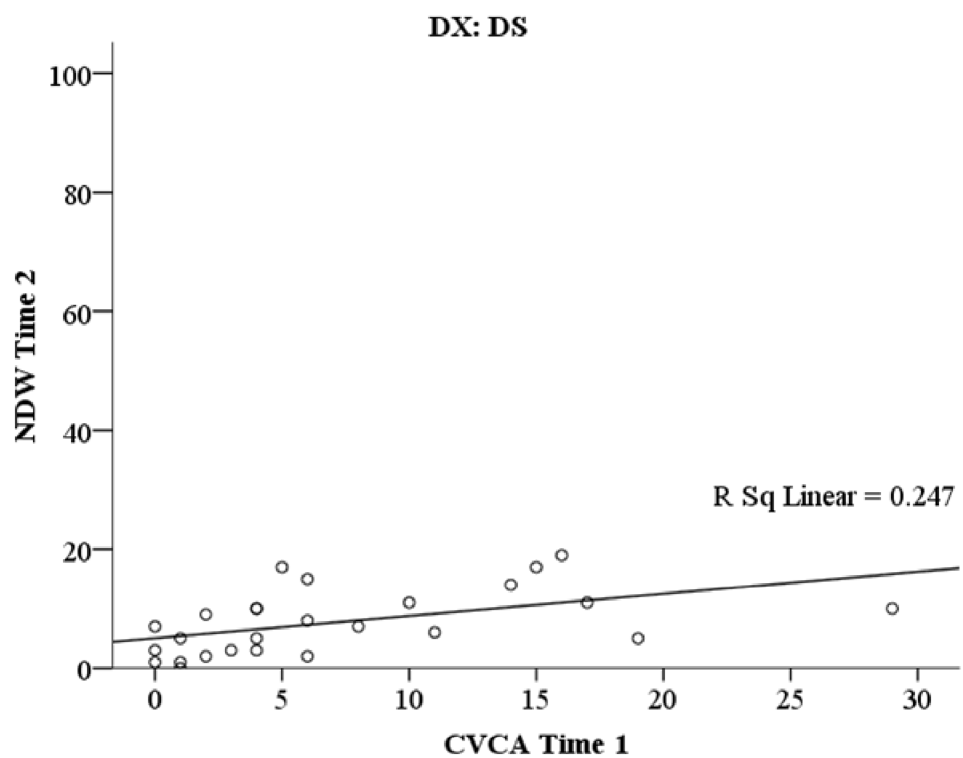

Figure 12. Correlation between canonical vocal communication acts (CVCAs) at Time 1 and number of different words (NDW) at Time 2 for the NDS group.

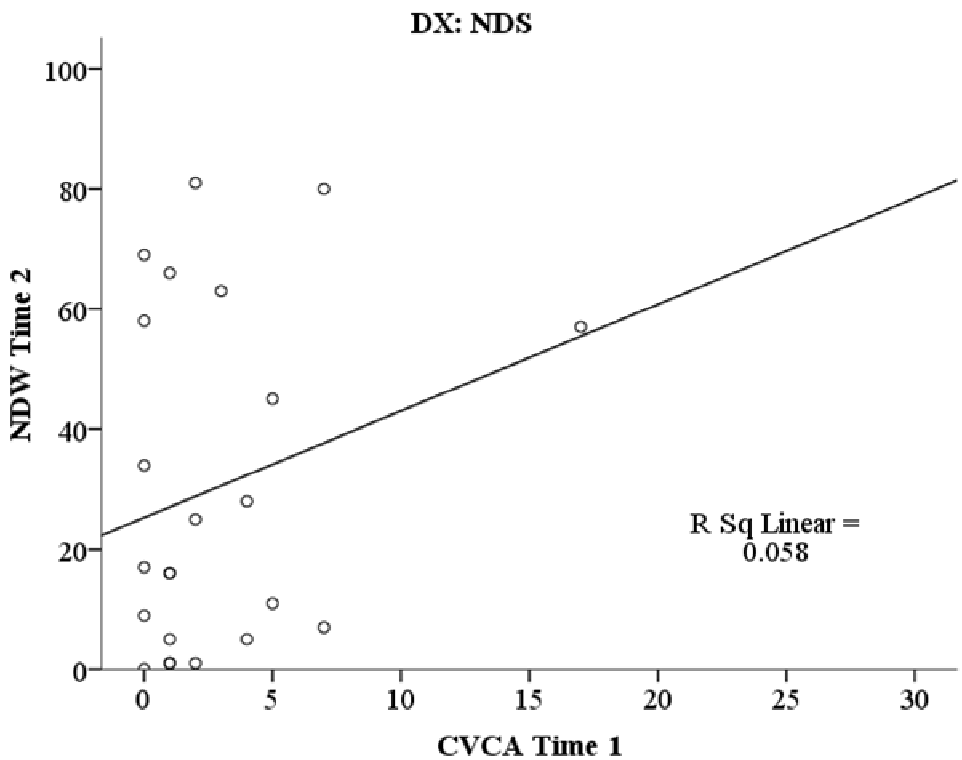

Figure 13. Correlation between canonical vocal communication acts (CVCAs) at Time 1 and number of different words (NDW) at Time 2 for the NDS group.

These scatterplots as well as those associated with the other correlations displayed in Table 5 indicate that the correlation between CVCA at Time 1 and NDW at Time 2 is limited for the NDS group by the positively skewed distribution. There are not enough children in this group who are using significant numbers of CVCAs at Time 1 to make it possible to have a strong correlation, given the amount of variability in NDS scores at Time 2. From the DS group plot, it appears that at least 5 or 6 CVCAs are necessary for predicting strong later word usage. About half of the DS group produced more than 5 CVCAs at Time 1, making a correlation more possible. There is simply more variability in CVCA usage with which to predict variability in later NDW in the DS group at Time 1.

The pattern illustrated in Figures 12 and 13 is even stronger for unique consonants ($r^2 = .376$ for the DS group; $r^2 = .067$ for the NDS group). Therefore, the proposed regression analysis was not performed on the NDS group of children. Given the dramatically limited variability among the NDS group on Time 1 phonetic/phonologic variables, the planned regression analyses for this subgroup were not carried out. A stepwise regression analysis was performed within the DS group alone, using all three phonetic/phonological variables as predictors. The regression model was significant, but only one variable, the number of unique consonants in the child's inventory, contributed significantly to the prediction. Results showed that 35% of the variance in NDW at Time 2 was accounted for by the Time 1 consonant inventory alone.

To examine the developmental relationship between phonetic/phonological and lexical abilities comprehensively, Time 2 phonetic/phonological variables were also correlated with Time 2 lexical abilities. These correlations also provide a weak test of the claim that the lack of relationship between Time 1 phonetic/phonologic measures and Time 2 word usage for the NDS group was due to restricted variability in their Time 1 phonetic abilities. If any meaningful developmental relationship between phonetic/phonologic and lexical abilities exists for this group of children, it should be expressed in correlations between these variables at Time 2. These correlations are shown in Table 6.

Table 6

Correlations between NDW at Time 2 and Time 2 phonetic/phonological variables

Time 2 variables	DS only (n = 26)	NDS only (n = 24)
CVCA	.86** $p < .01$	.85** $p < .01$
Unique consonants (initial or final)	.72** $p < .01$	.92** $p < .01$
SSL	.57** $p = .29$	.79** $p < .01$

Note. Correlations marked with * were significant at the p ≤ .05 level.

Correlations marked with ** were significant at the $p \leq .01$ level.

The correlations are moderate to very large for each of the selected variables for each group. The very strong correlations between CVCAs and NDW for both groups are expected, because CVCAs consisted of all canonical vocal output that was deemed communicative, not only babble. Thus, true words were counted in this measure every time they occurred in the sample. As the most advanced children grew more lexically, CVCAs became increasingly similar to words. Many children transitioned to frequent word use by the end of the study. Therefore, for these children, the CVCA at Time 2 looked increasingly like a proxy for a word count. On the other hand, moderate to very strong correlations were also observed between Time 2 consonant production and NDW. This indicates that the relationship between phonetic/phonological development and lexical development is not artifactual, but real and strong. In short, at least by age 3-1/2, children with developmental delay who are good sound producers, judged either by number of sounds in the inventory or by syllable complexity, are also good word users (and vice versa). This relationship is depicted in the scatterplots in Figures 14 and 15.

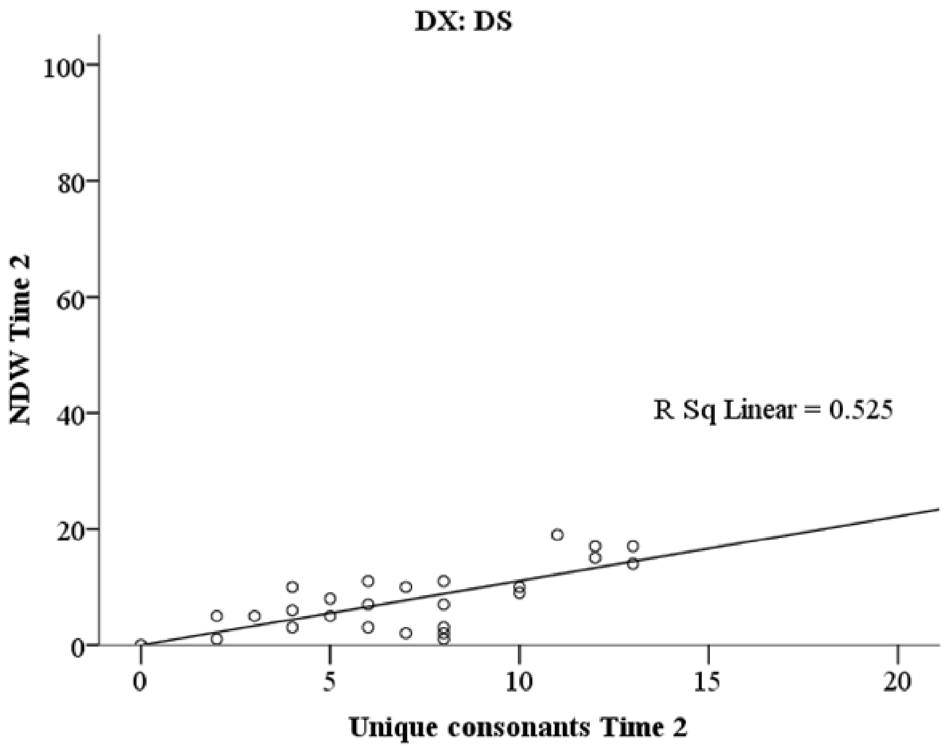

Figure 14. Correlation between consonant inventory size and number of different words (NDW) at Time 2 for the DS group.

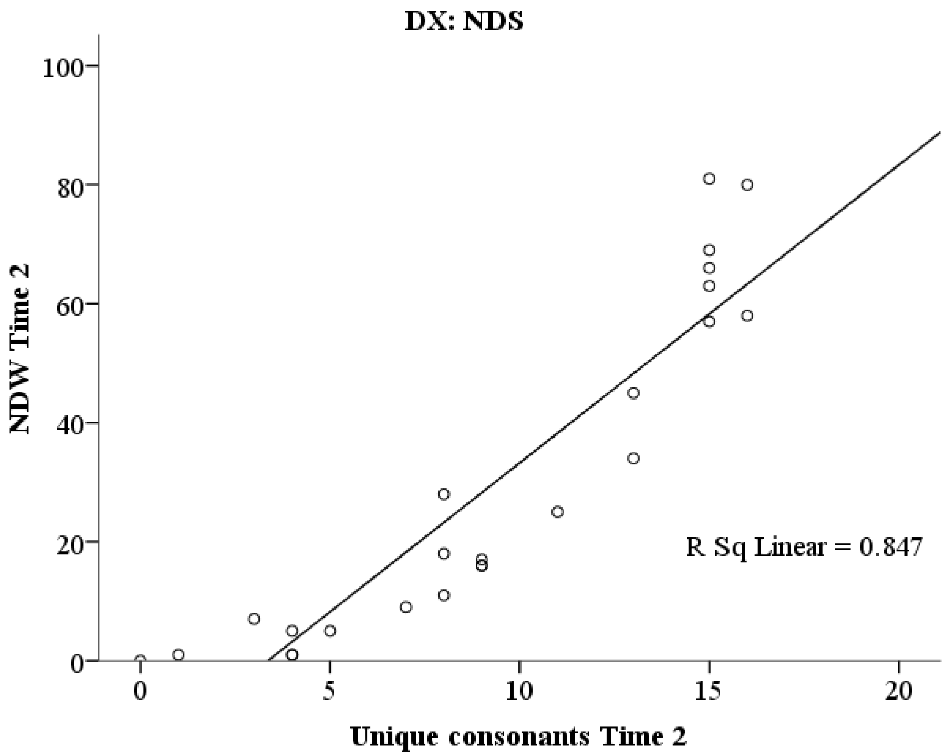

Figure 15. Correlation between consonant inventory size and NDW at Time 2 for the NDS group.

Chapter 4: Discussion

The two questions asked in this dissertation focused on the phonological development of children with developmental delays, who either have or do not have DS at two ages, approximately 25 months and 43 months, which for most of these children covered the stage of earliest word development. The first question asked whether the phonetic output of the children with DS, evaluated by measures of consonant inventory size, syllable shape, and frequency of vocalization, differed from those of CA- and MA-similar children with developmental delays not attributable to DS. In other words, did the presence of DS differentiate the phonological growth rate of the two groups of children, who were similar in age, cognitive status, and lexical size at the beginning point of observation (~25 months) and again 18 months later? The second question dealt with the extent to which phonological factors were related to word use. Analyses were conducted predictively, to examine whether phonological variables were related to word use 18 months later, and also synchronously, to examine the effect of phonological variables on the lexicon at the endpoint in the study, when these children were 3 ½ years old.

DS and NDS group differences

The results related to group differences in speech sound development paint a clear and unequivocal portrait. At Time 1, when the children were approximately 25 months of age, the DS group, on average, was comparable or superior to the NDS group on all phonological measures. At Time 2, 18 months later, the NDS group was comparable or superior to the DS group in these same skills. In every case, significant group by time interactions indicated that the rate of growth from Time 1 to Time 2 was greater for the NDS group than the DS group.

The presence of DS clearly differentiated the two groups' lexical growth. At approximately 44 months of age, the children without DS, on average, produced 4 times as many words (mean = 30) as the children with DS (mean = 7.7) in a 15-minute communication sample with their primary caregivers. As was reported in Warren et al. (2008), using the same database but slightly different measurement criteria, the early lexical growth in the population of children who have DS is very slow; slower than could be expected or explained by MA alone.

The parallel result that children with DS are also delayed in their phonological growth at this early lexical period, from ages 25 to 43 months, is a new finding. The children with DS in this study were at no disadvantage and in most cases were superior to the MA- and CA-similar children without DS in terms of the number of sounds and average utterance complexity at the beginning of the study, when all the children were at the early stages of lexical development. At this time, no child was producing more than 10 words or signs. Eighteen months later, the DS group had clearly lost that sound-producing advantage. Table 7 summarizes these findings.

Table 7

Results of Phonological and Lexical Measures by Group and Time

Variable	Time 1	Time 2
All consonants (initial or final)	DS = NDS	DS = NDS
Initial consonants only	DS = NDS	DS = NDS
Advanced initial consonants	DS = NDS	DS < NDS
Final consonants only	DS = NDS	DS < NDS
Advanced final consonants	DS = NDS	DS < NDS
All non-advanced consonants (NOS)	DS = NDS	DS = NDS
All advanced consonants (FALC)	DS > NDS	DS < NDS
SSL	DS > NDS	DS < NDS
CVCA	DS > NDS	DS < NDS
NDW	DS = NDS	DS < NDS

Note. Each measure resulted in a significant ($p < .05$) interaction effect.

Both groups had very limited consonant inventories at 25 months of age, averaging 1 or 2 non-glide initial consonants and 1 or fewer consonants in final position. Eighteen months later, the consonant inventory sizes did not differ significantly between the two groups either, although in each case, the NDS group had higher average scores. Both groups averaged between 6 and 8 initial consonants at Time 2. Average consonant inventory size, per se, did not differentiate the two groups of children at either observation point. The significant interaction between the groups occurred because the NDS group's slightly lower average consonant inventory at Time 1 was paired with a slightly higher average consonant inventory size at Time 2 with respect to the DS group. In other words, the rate of growth was greater for the NDS as opposed to the DS group.

In contrast to the findings for total number of consonants in the inventory, the consonant type, or number of advanced, mostly "late-8" consonants (i.e., fricatives, affricates, liquids, and clusters, or FALC) reliably distinguished the DS and NDS groups at Time 2, when they were 3 ½ years old. At 25 months of age, most children produced no advanced (fricative, affricate, liquid, and cluster, or FALC) consonants, with a restricted range of 0 – 3 advanced consonants. At Time 1 of this study, only 7/26 (27%) of the children with DS produced any of these consonants, and only 3/23 (13%) of the children in the NDS group produced any FALC consonants.

In the present study, a few children had final fricatives (notably, [s]) established in their productive repertoire at the first sampling. It was not unusual for such sounds as well as liquids ([r,l]) to emerge in utterance-final position before initial position. Affricates were produced infrequently, and most often by the children with the most complete sound inventories at Time 2. All advanced consonant sounds were more common at the second sampling session than the first, for both groups of children. Also, nasals and oral stops were more prevalent than the advanced consonant types at both testing periods for both groups of children.

Paul and Jennings (1992) suggested that consonant inventory size is a sensitive marker for both lexical development and delay. Certainly both groups of children in the current study were markedly delayed in consonant inventory size compared to both the TD children and late talkers from Paul and Jennings. Typically-developing children in Paul and Jennings's study produced around 14 different consonants between 18 and 23 months and about 18 different consonants between 24 and 34 months. Late talkers, on the other hand, produced approximately 6 different consonants at 18-23 months and 10 consonants at 24-34 months. Paul and Jennings's inventory counts included glides as well as consonants in initial, medial, and final utterance positions. However, most of the consonants for these children were from initial position. Singleton fricatives were more prevalent in final position for younger TD children only (ages 18-23 months), but not for older TD children or late talkers. Late talking children, according to Paul and Jennings, followed a slowed-down version of typical development, and thus, most of the consonants in the count came from initial utterance position.

The older groups of TD and late-talking children in Paul and Jennings's study (24 to 34 months) are comparable in age to the children in the present study at Time

1. In the present study, taking glides into account, children with DS averaged 4.42 unique (non-vowel) sounds in either initial or final position (*SD* = 2.87) at 25 months of age. At 43 months of age, children with DS averaged 8.81 (*SD* = 4.0) different sounds in the inventory. This is somewhat comparable to late talkers at 24-34 months, who averaged 10 different sounds, but smaller than TD children's average inventory size of 14 unique consonants at 18-23 months. Children in the NDS group averaged 2.43 non-vowel sounds (*SD* = 2.37) at 25 months of age, fewer than even the youngest (18-23 month old) late-talking children. At 44 months of age, however, the children in the NDS group, with 11.83 (*SD* = 5.69) sounds, were much more comparable in consonant inventory size to the older late talkers, who averaged 10 sounds at 34 months, and even the younger and older TD children, who averaged 14 and 18 sounds, respectively.

One point of caution is in order regarding consonant inventories and cross-study comparisons. For both TD children and children with language delays, both the age of onset and the particular sounds emerging are highly variable. Some of this variability is due to different standards of reporting (e.g., mastery vs. emergence), different sampling contexts (e.g., spontaneous vs. elicited productions), as well as differences among the children themselves. The fricatives [s] and [z] in particular vary the most among studies of age of emergence of consonants, ranging from age 3 (Dodd, Holm, Hua, & Crosbie, 2003) to age 9 (Chirlian & Sharpley, 1982). Differences in age of acquisition may be attributable to the amount of distortion accepted (i.e., dentalized [s/z] in particular) among the various studies.

Most researchers conclude that the order of acquisition of consonant sound types is similar in the DS population to the typical population (Bleile & Schwarz, 1984; Dodd, 1972; Smith & Stoel-Gammon, 1983; Stoel-Gammon, 1997, 2001a) in much the way that the order of acquisition of consonants in late-talking children is similar to that of the TD population (Paul & Jennings, 1992). However, Kumin, Councill, and Goodman (1994) came to a different conclusion after reviewing the quarterly progress reports of 60 youngsters with DS, aged 9 months to 9 years, and finding differences from typical norms in the order of emergence of several phonemes. For example, the post-alveolar fricative [ʃ] emerged most frequently at age 1;11 in Kumin et al.'s sample of children. Many other early-, middle-, and late-8 consonants (Shriberg, 1993) emerged in the expected order, however. The most striking differences are in the emergence of liquids before glides (2;2 for the former, 2;10 for the latter) in Kumin et al.'s study.

The data from Robb and Bleile's (1994) longitudinal study of the growth of phonetic inventories in 7 TD children from ages 8 to 25 months also provide a useful comparison with the data in the present study and help to put the performance of the children in this study into perspective. Robb and Bleile audiotaped communication samples on a monthly basis with these children over the course of a year in the children's homes or day-care centers. These investigators included a phone in their count if it occurred in at least 60% of the samples taken at each age period. The children produced labial and alveolar stops most frequently. At 8 months of age, they produced 5 initial consonants (4 non-glide consonants) and 3 final consonants (2 non-glide consonants). Between 8 and 16 months of age, the children in Robb and Bleile's study produced approximately 6 initial consonants, primarily voiced oral and nasal bilabial, alveolar, and glottal stops. Between 17 and 25 months, these children produced approximately 10 initial consonants, with an increase in voiceless consonants, fricatives, and velar consonants.

The final consonant inventory was more restricted at each age period in Robb and Bleile's (1994) study. Between 8 and 16 months, children produced approximately 2 final consonants. These were primarily voiced nasal stops, voiceless alveolar and glottal stops with some bilabials, and some fricatives. Between 17 and 25 months, the children produced approximately 5 final consonants, with voiced consonants predominating. Nasals, oral stops, and fricatives were most common, with the addition of velar sounds to the bilabials, alveolars, and glottals. At age 25 months, they produced 15 initial consonants (12 non-glide consonants) and 11 final consonants (10 non-glide consonants).

Compared to Robb and Bleile's sample of younger TD children, the children in the present study are delayed in the size of their phonetic inventories at both points of observation. Table 8 compares the data from Robb and Bleile's (1994) study and Paul and Jennings's (1992) study to the data from the present study.

Table 8

Consonant inventory size of TD children, later-talkers, and DS and NDS Groups

Age in months	Late Talkers *N* = 23		TD *N* = 7[r], *N* = 25[p]		DS group *n* = 26		NDS group *n* = 23	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8[r]			4	2	--	--	--	--
18-23[p]	6		10					
24-34[p]	14		18					
25-26			12	10	2	1	1	0
43-44			--	--	6	2	8	4

Note. TD children, *N* = 7 is from Robb & Bleile, 1994. TD children, *N* =25 is from Paul & Jennings, 1992. Data from Paul & Jennings are not reported by utterance position.

The developmental relationship between lexical behavior and phonetic measures

The second question in the study examined the relationship between phonological variables and later lexical development. At first glance, the results of the present analyses do not fit with the results from Yoder and Warren (2004), who found that CVCAs were a significant predictor of later lexical density only in 30-month-old children with developmental delays not due to DS. The children in the present study were, on average, approximately 6 months younger than the children in Yoder and Warren's study, and they were evaluated again following an 18 month time lag. In contrast, outcome measures for the children in Yoder and Warren's study were measured after only a 6 month time lag, when the children averaged around 36 months of age. In the present study, the size of the phonetic inventory at Time 1 predicted 35% percent of the variance in lexical scores (as measured by number of different words spontaneously produced in the PCX) 18 months later for the group of children with DS. For the children without DS, only MA (as measured by the Bayley) predicted 27% of the variance in later lexical scores.

Many factors may account for these discrepant findings. As mentioned, the age at which the children were observed and the time lag between measurement points may account for significant differences in the findings between these two studies. Importantly, the average lexical size of the 30-month-old children in Yoder and Warren's (2004) study was much higher than that of the children in the present study, even at 43-44 months of age. The median value of the lexicon (spoken and signed) for the children with DS in the Yoder and Warren study at age 30 months was

74 (*SD* = 85). The median value of the total spoken or signed lexicon for the 29-month-old children without DS in that study was 58 (*SD* = 55). The differences in mean scores were statistically nonsignificant. It is unknown what percentage of the lexicon was signed or spoken in the Yoder and Warren study.

In contrast, the median value for spoken or signed words on the CDI for children with DS in the present study at 30 months was 37 (*SD* = 20.48). The median value for spoken or signed words on the CDI for children without DS at 30 months in the present study was 34 (*SD* = 54.33). For spoken words only, the median value of the children with DS in the present study at 30 months of age was 14.50 (*SD* = 19.22). For the children without DS in the present study, the median value of spoken words only at 30 months of age was 21 (*SD* = 55.56). However, these values are not the ones corresponding to the ages of the children in the study. The present study examined these same children at approximately 25-26 months of age, when they had even more restricted lexicon sizes and again at 43-44 months of age. At Time 1 in the present study, the children with DS had a median spoken or signed word score of 12 (*SD* = 14.41). The children without DS at Time 1 had a median spoken or signed word score of 9 (*SD* = 4.45). For spoken words only, the median of the DS group was 5 (*SD* = 5.26), and the median of the NDS group was 3.50 (*SD* = 4.44). Thus, the children in the present study were severely restricted in initial lexicon size compared to the children in the Yoder and Warren study. It is important also to remember that the children in the present study qualified for it precisely because they had very low rates of intentional communication.

At Time 1 in the present study, the average size of the phonetic inventory was extremely restricted for both groups of children, averaging about 3 non-glide sounds for the children with DS and about 1 sound for the children in the NDS group. This very limited variability in the phonetic inventory predictor variable and its strong positive skew contributed to its nonsignificance as a predictor for later lexicon size in the NDS group. For that group, only cognitive level, as measured by the Bayley, was a significant predictor, accounting for 24% of the variance in later lexical size in this group of children. The variability in the phonetic inventory size in the DS group was also small, but greater than that of the NDS group and enough to be a valid predictor of later lexicon size. Children with DS who had the largest set of sounds were the ones from their diagnostic group who used the most words 18 months later.

Stated another way, the present study looked at relationships between the sound system and later communication at very different time points than were examined by Yoder and Warren (2004), and this difference is important. Yoder and Warren (2004) point out that the children with DS in their study had lower mean and less varied language scores than those without DS, which is definitely true for Time 2 of this study. Thus, these discrepant findings between the present study and that of Warren and Yoder are not so troubling because they are based on skills that have different rates of growth over time.

As Miller (1999) points out, the linguistic and communication profiles of children with DS do not remain static over time. Moreover, for children with DS, certain components of language are on par with MA- and CA-similar peers, and other components are markedly delayed. Prior to the present study, we knew that the onset of speech was delayed in children with DS compared to a NDS group of children with cognitive delays. We also knew that children with DS usually begin producing canonical syllables at ages only slightly delayed from that of TD children. What we did not know was whether children with DS showed a slowed pattern of phonological growth during the period of first word acquisition, from ages 25 to 43 months. It appears then, that the phonological system and the lexical system, at this point in development, are closely related and slow to develop, despite an early appearance of canonical syllables in children with DS.

The present study confirmed several hypotheses about the speech development of children with DS: they are delayed in comparison to MA and CA-similar peers in their rate of phonological growth, throughout the third year of life. Children with DS have slower phonological growth between 2 - 3 1/2 years of age compared to other MA- & CA- similar children without DS. Phonology is thus another component of language that is affected by deficits beyond that predicted by MA, and is apparent even during the early stages of lexical acquisition. This slowdown in phonological growth is accompanied by a concomitant deficit in the rate of vocabulary acquisition. The present study does not address directionality of this relationship, however, but it does underscore its relevance.

Correlational analyses revealed that, at a given point in time, at ages as young as 25 months, children with relatively many sounds use them to communicate. This study showed that CVCAs are closely related to both the consonant inventory and to the lexicon. It was theoretically possible that children could be producing very few sounds frequently in a communication sample, leaving them with a relatively high CVCA for their sound inventory, and making them look similar on this measure to children who combine many sounds together but vocalize at the same rate. This was not the case. Although the phonetic inventory proved to be the best predictor of the lexicon for both groups of children, CVCAs also predicted the lexicon, and were closely correlated with the phonetic inventory. Of course, as children moved to more verbal means of communication, CVCAs became more of a direct count of the lexicon, at least for the most advanced communicators in this study.

Finally, phonetic/phonological measures such as the consonant inventory and CVCAs are useful predictors of later language use all by themselves for children with developmental delays both with and without DS, provided these children have at least about 5-6 productive sounds in their inventory. Consonant inventory alone accounted for close to 40% of the variance in later lexical size for children with DS. It accounted for over half the variance in concurrent lexical scores for children with DS, and close to 85% of the variance in concurrent lexical scores for children without DS. Children in both the DS and NDS groups who use relatively many sounds are the same children who have the largest productive lexicons, and those who use the fewest numbers of sounds have the poorest lexical outcomes.

However, as demonstrated by this study and Warren et al. (2008), "relatively many words" means different things for different groups of children. For the children with DS in this study, those with the largest sound inventories (around 12 sounds) were producing around 15-20 different spontaneous words in a 15-minute parent-child conversational sample at age 3-1/2. In contrast, children without DS in the present study who had the largest sound inventories (around 16 sounds) produced around 40-80 different spontaneous words in the same type of conversational sample. Clearly, the significant deficit in word learning, in absolute terms, that is observed for young children with DS cannot be accounted for by their slow phonetic/phonologic development over the third year of life. Nevertheless, this study shows that children with DS who have at least 10 consonants in their productive inventory by age 3-1/2 have the best lexical outcomes. Future studies could examine whether a strong focus on speech sound development in treatment for young children with DS will have a reliable effect on their lexical growth.

Appendix

Transcription Flowchart
(N/A is a “No” response)

1. Did the child utter something?	No—keep listening to tape
	Yes—time mark the utterance and go to step 2
2. Did any of the utterance get clipped off?	No—go to step 3
	Yes—adjust time onset to just before beginning of child utterance and go to step 3
3. Is this a codable utterance?	No—choose exclusion code and move on to next utterance
	Yes—go to step 4
4. Do you hear any consonants?	No—mark as SSL 1 and [nc] and continue listening for next child utterance
	Yes—go to step 5
5. Do you hear an initial consonant?	No—go to step 8
	Yes—go to step 6
6. Can you identify a CLEAR* initial consonant?	No—go to step 7
	Yes—listen up to 4 times to identify initial consonant and go to step 8
7. Can you use the decision table to distinguish between two closely related consonant types?	No—mark as (x) and go to step 8
	Yes—enter initial consonant and go to step 8

8. Do you hear a final consonant?	No—go to step 12
	Yes—go to step 9
9. Can you identify a CLEAR* final consonant?	No—go to step 10
	Yes—listen up to 4 times to identify initial consonant and go to step 11
10. Can you use the decision table to distinguish between two possible consonant types?	No—mark (x) and go to step 12
	Yes—enter initial consonant and go to step 11
11. Do you have initial AND final consonants differing in place or manner of articulation?	No—go to step 12
	Yes—mark SSL 3 and [c] and continue listening for next child utterance
12. Do you hear at least one medial consonant?	No—go to step 13
	Yes—go to step 14
13. Is (x) the only consonant choice marked for the utterance?	No—go to step 14
	Yes—mark utterance as SSL 2 and [c] and continue listening for next child utterance
14. Do you hear at least 2 medial consonants?	No—go to step 15
	Yes—go to step 17
15. Is the medial consonant the only consonant in the utterance?	No—go to step 16
	Yes—mark SSL 2 and [c] and listen for next child utterance
16. Does the medial consonant differ in place or manner of articulation from EITHER the initial or final consonant?	No—mark SSL 2 and [c] and listen for next child utterance

	Yes—mark SSL 3 and [c] and listen for next child utterance
17. Do the medial consonants differ in place or manner from each other?	No—mark SSL 2 and [c] and listen for next child utterance
	Yes—mark SSL 3 and [c]and listen for next child utterance

*Clear = I am at least 95% sure that this is the correct consonant. If it is a stop in final position, it is fully released and unambiguous.

OR

This consonant <u>cannot</u> be any other consonant but it's not a perfect exemplar of the consonant chosen (i.e., there may be prevocalic voicing or slight distortion)

Decision Table

Decide between	Initial position	Final position	Either position
Homorganic voiced vs. voiceless stop [b] vs. [p]; [d] vs. [t]; [g] vs. [k]	Choose voiced [b]; [d]; [g]	Choose voiceless [p]; [t]; [k]	
Homorganic voiced vs. voiceless fricative [ð] vs. [θ]; [v] vs. [f]; [z] vs. [s]; [ʒ] vs. [ʃ];	Choose voiced [ð]; [v]; [z]; [ʒ]	Choose voiceless [θ]; [f]; [s]; [ʃ]	
Homorganic voiced vs. voiceless affricate [ʤ] vs. [ʧ]	Choose voiced [ʤ];	Choose voiceless [ʧ];	
Glide/vowel vs. liquid [j] vs. [l] [w] vs.[r]	Choose glide [j] [w]	Consider as vowel unless you hear a clear liquid final consonant	
Stop: [d] vs. [g]	Choose [d] if there is another alveolar sound; Choose [g] if there is another velar sound in utterance; otherwise, (x)-i		
Nasal: [m] vs. [n]			Choose [m] only if you see child's lips are closed together when making the

			nasal sound
Fricative: [s] vs. [ʃ]			Choose [s] (palatalized [s])
Fricative: [z] vs. [ʒ]			Choose [z] (palatalized [z])
Fricative: [s] vs. [θ]			Choose [s] (dentalized [s])
Fricative: [z] vs. [ð]			Choose [z] (dentalized [z])

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