Longitudinal Changes in Articulation Rate and Phonetic Phrase Length in Children With Speech Delay

This study examined long-term changes in articulation rate (the pace at which speech segments are produced) and phonetic phrase length in the conversational speech of two groups of children with speech delay (SD) of unknown origin. Initial testing for both groups occurred at preschool age, with follow-up testing conducted for the Early Follow-Up Group (n = 17) at age 9 years and for the Late Follow-Up Group (n = 36) at age 12–16 years. At follow-up testing both groups produced significantly faster articulation rates (measured in both syllables per second and phones per second) and significantly longer phonetic phrases (measured in both syllables and phones) than at initial testing. Articulation rates at both test times were also judged to be similar to published values from typically developing children of similar ages when measured in syllables per second. However, findings for rate in phones per second suggested that at least at initial testing the children were articulating speech at a slower rate than their typically developing peers. This latter finding, however, may have been an artifact of the high frequency of errors—such as cluster reduction and final consonant deletion—observed in the initial samples. It would appear, therefore, that children with SD of unknown origin may start out with slower than normal articulation rates but eventually catch up to their typically developing peers.

KEY WORDS: speech delay, longitudinal, children, articulation rate, acoustic

The current study was part of a larger project undertaken to evaluate the long-term outcomes of children diagnosed with speech delay of unknown origin at preschool age. This group (hereafter SD of unknown origin) has historically been referred to as having functional articulation disorders. (More recently some have referred to them as having “developmental phonological disorders.”) Despite considerable effort to date, our understanding of the nature of the problem being experienced by these children remains fairly limited (see Shriberg, 1997 for a recent discussion). The current study was intended to add to our understanding of this population, specifically by examining how conversational articulation rate and phonetic phrase length change over time in two groups of these children.

1 The term delay is used here in a very generic sense and should not be interpreted as a condition orthogonal to disorder. The question of whether the error pattern exhibited by these children represents simply a temporal shift in the normal pattern of acquisition or some different pattern remains unresolved (cf. Shriberg, Gruber, & Kwiatkowski, 1994).
Articulation Rate

Articulation rate represents the pace at which speech segments are produced (Turner & Weismer, 1993). It is one component of speaking rate, the other being pausing. Early work suggested that the bulk of variability in speaking rate occurred in pauses (e.g., Goldman-Eisler, 1968), but more recent analyses (e.g., Miller, Grosjean, & Lomanto, 1984) have suggested considerable variability in articulation rate as well. The current study focused on articulation rate in conversation. Although conversational articulation rate indexes the time spent in production of speech segments, it likely also includes time spent in language formulation. Both Rochester (1973) and Butterworth (1980) have made the case that pauses represent time for language formulation, but it does not necessarily follow that language formulation occurs only during pauses. Butterworth suggested that formulation may take longer than articulation, and pauses may simply represent time to catch up. Levelt (1989, p. 24) has argued that, particularly in discourse, formulation must be occurring while speech is ongoing or significant dysfluency would result. Allen (1975) would appear to agree, having suggested that speech rhythm, of which rate is an element, is “...a product of both performance universals and language-specific grammatical rules” (p. 75).

Because it likely includes both speech-motor and language formulation components, conversational articulation rate may provide a general index of speech development. In addition, it may provide some insight into the nature of the problem in children with SD of unknown origin. Hall, Amir, and Yairi (1999) found that differences in conversational articulation rate (in phones per second though not in syllables per second) may differentiate children who stutter from typically developing children.

Conversational Articulation Rate in Children

Findings from previous studies of articulation rate in spontaneous contexts produced by typically developing children are shown in Table 1. Pairwise comparison of the studies in Table 1 at each age level revealed overlap in the confidence intervals across all of the studies. This suggested significant agreement in the findings obtained by these investigators. Four of the six studies in Table 1 reported significant increases in articulation rate with age. Pindzola, Jenkins, and Lokken (1989) did not observe significant differences across age, and Hall et al. (1999) noted increasing rate only from Time 1 to Time 2 (mean age 3;6 to mean age 4;6). Both of these latter studies included the smallest total sample sizes (Pindzola et al. = 30, Hall et al. = 8), suggesting that limited statistical power may have precluded finding a significant age trend. Conversely, both Pindzola et al. and Hall et al. suggest that rate changes may be less likely in the 3- to 5-year-old range (see also Smith & Kenney, 1999). Overall, however, findings from Table 1 do suggest that articulation rate in the spontaneous speech of typically developing children increases across the developmental period. Four of the six studies in Table 1 (Amster, 1984; Haselager, Slis, & Rietveld, 1991; Kowal, O’Connell, & Sabin, 1975; Walker, Archibald,...

<table>
<thead>
<tr>
<th>Age or grade</th>
<th>Kowal et al., 1975 b</th>
<th>Pindzola et al., 1989 b</th>
<th>Walker et al., 1992 b</th>
<th>Amster, 1984 c</th>
<th>Haselager et al., 1991 c,d</th>
<th>Hall et al., 1999 c,e</th>
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<tr>
<td>2 years</td>
<td>2.78 (1.98–3.58)</td>
<td>2.84 (2.32–3.37)</td>
<td>3.82 (2.80–4.84)</td>
<td>2.99 (2.07–3.91)</td>
<td>3.84 (2.70–4.98)</td>
<td>11.42 (5.88–16.96)</td>
</tr>
<tr>
<td>3 years</td>
<td>2.92 (2.46–3.75)</td>
<td>3.10 (2.46–3.75)</td>
<td>3.20 (2.46–3.94)</td>
<td>3.20 (2.46–3.94)</td>
<td>3.94 (2.64–5.24)</td>
<td>12.17 (7.97–6.37)</td>
</tr>
<tr>
<td>4 years</td>
<td>4.28 (3.14–5.42)</td>
<td>4.28 (3.14–5.42)</td>
<td>4.34 (3.40–5.28)</td>
<td>4.01 (3.35–4.67)</td>
<td>3.92 (2.56–5.28)</td>
<td>11.88 (8.16–15.60)</td>
</tr>
<tr>
<td>Grade 2</td>
<td>2.86 (1.80–3.92)</td>
<td>3.01 (2.14–3.89)</td>
<td>3.42 (2.54–4.32)</td>
<td>3.34 (2.40–4.28)</td>
<td>4.01 (3.35–4.67)</td>
<td>11.88 (8.16–15.60)</td>
</tr>
<tr>
<td>Grade 4</td>
<td>3.24 (2.22–4.26)</td>
<td>4.28 (3.14–5.42)</td>
<td>4.34 (3.40–5.28)</td>
<td>4.01 (3.35–4.67)</td>
<td>3.92 (2.56–5.28)</td>
<td>11.88 (8.16–15.60)</td>
</tr>
<tr>
<td>Grade 6</td>
<td>3.26 (1.94–4.58)</td>
<td>3.26 (1.94–4.58)</td>
<td>3.42 (2.54–4.32)</td>
<td>3.34 (2.40–4.28)</td>
<td>4.01 (3.35–4.67)</td>
<td>11.88 (8.16–15.60)</td>
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<tr>
<td>Grade 8</td>
<td>3.83 (2.83–4.83)</td>
<td>3.83 (2.83–4.83)</td>
<td>3.42 (2.54–4.32)</td>
<td>3.34 (2.40–4.28)</td>
<td>4.01 (3.35–4.67)</td>
<td>11.88 (8.16–15.60)</td>
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<td>Grade 10</td>
<td>4.00 (2.98–5.02)</td>
<td>4.00 (2.98–5.02)</td>
<td>3.42 (2.54–4.32)</td>
<td>3.34 (2.40–4.28)</td>
<td>4.01 (3.35–4.67)</td>
<td>11.88 (8.16–15.60)</td>
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<tr>
<td>Grade 12</td>
<td>3.84 (2.80–4.88)</td>
<td>3.84 (2.80–4.88)</td>
<td>3.42 (2.54–4.32)</td>
<td>3.34 (2.40–4.28)</td>
<td>4.01 (3.35–4.67)</td>
<td>11.88 (8.16–15.60)</td>
</tr>
</tbody>
</table>

* Expressed in syllables per second (95% confidence interval in parentheses), numbers in boldface are phones per second. * Based on narrative samples. * Based on conversational speech samples. * Grade levels adjusted to be consistent with other studies. * Longitudinal data from control speakers only.
Cherniak, & Fish, 1992) tested for possible sex differences in articulation rate during development, with no significant differences observed.

The bulk of the data in Table 1 represents articulation rate measured in syllables per second. An alternative measurement unit is phones per second. Tiffany (1980) reported that most of the variance in articulation rate during oral reading could be accounted for by the number of phones in each syllable. And, as noted previously, Hall et al. (1999) found differences between children who stutter and typically developing children when rate was measured in phones per second but not when measured in syllables per second. These findings suggested that rate should be examined in both syllables per second and phones per second.

Two of the studies in Table 1 (Hall et al., 1999; Walker et al., 1992) reported their findings in phones per second; the data are shown in boldface in Table 1. The Hall et al. (1999) data represent those from their control speakers. As with the across-study comparisons in syllables per second, the confidence intervals from these two studies overlap, suggesting agreement in their findings. Hall et al. reported that articulation rate in phones per second increased significantly from Time 1 to Time 2 but not from Time 2 to Time 3. Walker et al. also reported that articulation rate in phones per second was significantly faster in their older speakers.

### Conversational Articulation Rate and SD of Unknown Origin

Articulation rate (and/or speaking rate) has long been cited as an important clinical and theoretical variable in both fluency disorders (see Hall et al., 1999) and motor speech disorders (see Yorkston, Beukelman, & Bell, 1988, pp. 326–352). It has received considerably less attention, however, in relation to other disorder populations. No previous study could be identified that examined longitudinal changes in articulation rate in children with SD of unknown origin. One study presented one-time conversational articulation rate data in this population. Schulze (1991) examined three groups of 10 children each (all German speakers) during parent-child interactions and found that typically developing and phonologically disordered children did not differ significantly from each other. Both groups were faster than the children who stuttered.

### Phonetic Phrase Length

Several investigators (Haselager et al., 1991; Malecot, Johnston, & Kizziiar, 1972; Miller et al., 1984; Walker et al., 1992) have suggested that in order to minimize the influence of language formulation on articulation rate, the most appropriate measurement unit is the stretch of speech bound by pauses. Malecot et al. referred to this unit as an “utterance,” both Miller et al. (1984) and Walker et al. (1992) labeled it a “run,” and Haselager et al. (1991) called it a “phonetic phrase.” For purposes of the current study, this same unit was termed “phonetic phrase” (after Allen, 1973). This label emphasizes an attempt to capture something closer to output behavior only (hence phonetic), and it avoids confusion with the more conventional meaning of the term utterance (hence phrase).

Haselager et al. (1991) noted that this unit eliminates the influence of pause time on rate. Although simple subtraction of the time spent in pausing from the utterance durations might accomplish this same end, using linguistic boundaries to define the units of measurement means that there could still be considerable influence of language formulation on rate. The phonetic phrase is neutral relative to linguistic boundaries because not all pauses occur at such points (Henderson, Goldman-Eisler, & Skarbek, 1966), and thus the influence of language formulation is reduced.

### Phonetic Phrase Length in Children

As a unit that is somewhat independent of language formulation, the development of the phonetic phrase in children may also provide additional insight into the development of speaking skill. There appears to have been limited study of this length unit to date, however. Phonetic phrase length data were available from two of the studies in Table 1. Haselager et al. (1991) provided mean values of 5.4, 6.6, 7.3, and 7.4 syllables for their four groups respectively but did not report standard deviations. Walker et al. (1992) reported mean values of 3.87 syllables (95% C.I. = 1.91–5.83) for their 3-year-old speakers and 4.77 syllables (95% C.I. = 3.27–6.27) for their 5-year-old speakers. Walker et al. also reported length in phones with values of 8.89 (95% C.I. = 3.97–13.81) and 11.04 (95% C.I. = 7.16–14.92) for the two age groups, respectively. Both Haselager et al. and Walker et al. reported that the observed length increases with age were significant; both studies found no significant sex differences. The two studies overlapped only in age of participants at age 5 years, but there appears to be relatively close agreement as to the values obtained at that one age level.

No phonetic phrase length data appear to be available for children with SD of unknown origin.

### Goals of the Current Study

The current study examined longitudinal changes in mean articulation rate and phonetic phrase length in the conversational speech of two groups of children with SD of unknown origin. The intent was both to document
any long-term trends and to determine whether the pattern of development parallels that found in studies of typically developing children. Analysis of articulation rate was measured in both syllables per second and phones per second. Phonetic phrase length was measured in syllables and phones.

Method

Participants

The current study included two groups of participants originally recruited as part of separate studies. Both groups had been recruited at preschool age from the Madison, Wisconsin, area. Follow-up testing for both groups occurred concurrently. All of the children in both groups received treatment from clinicians in the community for some or all of the period between initial and follow-up testing.

The Early Follow-Up Group (see also Gruber, 1999) was recruited by asking clinicians to refer children who met the following inclusionary criteria: (1) age 3–5 years; (2) presenting with SD of unknown origin, including (a) no significant defects in the structure or function of the speech and hearing mechanisms, (b) no significant cognitive deficits, (c) no significant psychosocial dysfunction; (3) producing speech errors of sufficient severity to interfere with intelligibility and to warrant speech services; (4) no previous speech-language services; and (5) native speakers of General American English. This group consisted of 25 children who also participated in a short-term follow-up program, with testing conducted approximately every 6 months for 2 years.

Children in the Late Follow-Up Group (see also Shriberg & Kwiatkowski, 1994) were recruited using the same criteria as the Early Follow-Up Group with two exceptions. Children up to age 6 years could be included, and receipt of previous speech-language services was permitted. The group included 64 children, most of whom were referred shortly after initial identification and thus had not yet received any speech-language services. A short-term follow-up was conducted 1 year after the original assessment, at which time 54 (84%) of the children participated (Shriberg, Kwiatkowski, & Gruber, 1994).

The children in the Early Follow-Up Group had all reached their 9th birthdays before follow-up testing; the net result was an approximate 5-year gap between initial and follow-up testing. Of the original group, 19 (76%) of the children were located and completed the assessment protocol. The Late Follow-Up Group were between the ages of 12 and 16 years at follow-up testing, with a resulting gap between initial and follow-up testing of approximately 10 years. Of this latter group, 39 (61%) of the children were located and completed the assessment protocol.

The two study groups differed significantly in age at both initial and follow-up testing. As well, analysis by Flipsen (1999) indicated that the Early Follow-Up Group was more severely involved than the Late Follow-Up Group. Thus the groups could not be pooled for subsequent analysis.

Included in the 58 children available for the current study were five same-sex twin pairs (two from the Early Follow-Up Group and three from the Late Follow-Up Group). Shriberg, Austin, Lewis, McSweeny, and Wilson (1997a) have proposed that one subtype of SD of unknown origin (which may include up to 60% of this population) includes children for whom a genetic background increases the risk for delayed speech. Although zygosity of the pairs could not be reliably determined from the available data, retaining both members of the twin pairs might introduce a potential bias through repeated measures on the same genetic material. Therefore, before beginning the analysis, one member of each of these twin pairs was randomly excluded, with resulting samples sizes of 17 and 36 children for Early and Late Follow-Up Groups, respectively.

Participant characteristics are shown in Table 2. Sex ratios for both groups (twice as many males as females) are typical of this population (Shriberg & Kwiatkowski, 1994). Sex ratios were not significantly different across the two current study groups \( \chi^2(1) = 0.082, \ p = .775 \), but median ages were significantly different at initial testing (Wilcoxon-Mann Whitney \( p = .0192 \)). Also shown in Table 2 is performance of the two groups on the Peabody Picture Vocabulary Test–Revised (PPVT-R, Form M; Dunn & Dunn, 1981) administered at initial testing. As shown, all of the children in the Early Follow-Up Group scored 85 or above (i.e., no more than one standard deviation below the mean) on the PPVT-R. Standard scores for the Late Follow-Up Group ranged from 69 to 141, but only two children scored below 85. Although it could be argued that these two children might have had a “known” reason for their speech delay (i.e., a possible cognitive delay), no cognitive assessment data were available for any of the children. It was, of course, also possible that they simply had co-morbid receptive language disorders, which have been shown to occur in up to 20% of this population (Shriberg & Austin, 1998). In addition, an examination of the distributions for the Late Follow-Up Group indicated that these two children were not outliers in terms of segmental accuracy, intelligibility, or articulation rate at initial testing; thus these two children were retained in the current study.

It should be noted that not all of the participants in the current study were producing fully normal speech...
by follow-up testing; 12/17 from the Early Follow-Up Group and 6/36 from the Late Follow-Up Group continued to produce speech sound errors. A study in progress (Flipsen, 2001) will examine the relationship between articulation rate and normalization in the current study participants.

Representativeness

Those children who completed the study were compared with those who did not (17 vs. 6 for the Early Follow-Up Group and 36 vs. 25 for the Late Follow-Up Group) using data from the initial test session to ensure that there was no systematic bias in subject loss across the study period. Comparisons were made based on age, sex ratio, number of siblings, parental education, standard scores on the PPVT-R, a set of speech severity metrics (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997b), and two measures of syntactic complexity (“Assigning Structural Stage,” Miller, 1981; “Grammatical Morpheme Use Stage,” Paul & Shriberg, 1982). Syntactic analyses were based on 50 utterances taken from those same conversational speech samples. Across all of the comparisons, the only significant differences were obtained for the Early Follow-Up Group, in which both the mothers and fathers of the children who participated in both initial and follow-up testing had significantly more formal education than the mothers and fathers of those who had only taken part in initial testing (Wilcoxon-Mann-Whitney ps of .0067 & .0412 for mothers and fathers, respectively). These findings suggested that generalization of any findings from the Early Follow-Up Group should be made with considerable caution. Generalizability for the Late Follow-Up Group did not appear to have been compromised.

Assessment Procedures

Both initial and follow-up testing included a large number of tasks representing several domains. Data for the current study were based on analysis of the conversational speech samples obtained at both test times using similar procedures (Shriberg, 1986). Recordings at both test times were made in the same quiet test suite using a table-top mounted microphone positioned so that mouth-microphone distance was approximately 6–8 inches. All recordings were made on high-quality analog cassette tapes.

Initial testing and transcription of the samples for the Early Follow-Up Group were conducted by a single experienced, certified speech-language pathologist—a university instructor with nearly 30 years of experience in child phonology. Initial testing for the Late Follow-Up Group was carried out by two graduate students in communicative disorders, selected because of their extensive experience working with young children. These testers underwent a comprehensive training program before beginning data collection. Children were randomly assigned to the two examiners. Transcription of the obtained conversational samples was conducted by a two-person consensus team using procedures described in Shriberg, Hinke, and Trost-Steffen (1987); Shriberg, Kwiatkowski, and Hoffman (1984); and Shriberg (1986). Follow-up testing and transcription for both groups was conducted by a single experienced speech-language examiner. Transcriptions of all the samples were carried out at the narrow phonetic level using the system of Shriberg and Kent (1982, 1995).

Of the 53 initial samples, 7 (2 from the Early Follow-Up Group and 5 from the Late Follow-Up Group) posed potential problems for the current analysis and were excluded. In each case, subsequent samples from the short-term follow-up study, evoked either 6 or 12 months later, were used for the current analysis.

The original diagnoses of speech delay were based on conversational speech samples containing the first 90 nonquestionable word types. Transcripts of this size have been shown to provide a relatively representative sample of all English phonemes and canonical forms (Shriberg, 1986). Conversational samples obtained at follow-up testing were transcribed based on samples containing 100 nonquestionable word types. Once transcribed, the samples were analyzed using an updated

<table>
<thead>
<tr>
<th>Variable</th>
<th>Early Follow-Up</th>
<th>Late Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>17 (12 Males, 5 Females)</td>
<td>36 (24 Males, 12 Females)</td>
</tr>
<tr>
<td>Age a at Initial Testing</td>
<td>2;11–5;3 (M = 4;1, SD = 0;7)</td>
<td>3;3–5;11 (M = 4;6, SD = 0;8)</td>
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<tr>
<td>Age at Follow-Up Testing</td>
<td>9;0–9;10 (M = 9;4, SD = 0;3)</td>
<td>12;8–16;9 (M = 14;7, SD = 0;10)</td>
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<tr>
<td>Initial PPVT-R scores b</td>
<td>98 (85–138)</td>
<td>100 (69–141)</td>
</tr>
</tbody>
</table>

a Expressed in years; months. b Entries are group median standard scores (and ranges). c Based on n = 31 (data unavailable for 5 participants).
version of the PEPPER software program called the Speech Disorders Classification System\(^2\) (SDCS; Shriberg, Allen, McSweeny, & Wilson, 2001).

**Rate Measurements**

Analysis of articulation rate on all 106 conversational speech samples (53 initial & 53 follow-up) was conducted by the current author using digitized versions of the samples created using the Record utility of the software program CSpeech (Milenkovic, 1996). Digitizing conditions included a sampling rate of 22 kHz, 15 bits of quantization, 72 dB of dynamic resolution, and low-pass filtering at 9.8 kHz. Analyses were carried out on all of the follow-up samples first, in the same order as follow-up testing had been conducted (i.e., an order that was neutral to initial testing). The same order was then used for analysis of the initial samples.

For purposes of delimiting phonetic phrases, pauses were identified using wideband (500 Hz) spectrograms and initially defined as silent intervals in the acoustic record of 250 ms or longer (e.g., Miller et al., 1984; O’Connell & Kowal, 1972; Walker et al., 1992). However, cases in which silent intervals in the acoustic record were bounded by two stop consonants posed a problem for this criterion. Stops in post-vocalic position are frequently unreleased (Shriberg & Kent, 1995, p. 64); in cases in which the next word or syllable begins with a stop consonant, the closure for the post-vocalic stop could not easily be separated from the closure for the subsequent stop. The two silent periods (the stop closures) might then combine to exceed 250 ms in duration and thus might be misinterpreted as a pause. A conservative position was taken, and it was assumed that the combination of the two closure durations might be longer than 250 ms; silent periods in the acoustic record bounded by two stop consonants needed to be at least 400 ms in duration before being considered a pause.

Consistent with being neutral relative to linguistic boundaries, the segmentation of phonetic phrases was not limited by sentence parsing in the transcripts. Especially in the follow-up samples, it was possible for a phonetic phrase to extend across a sentence boundary if a pause was not observed. Such carryovers were relatively rare in the initial samples, however.

Phonetic phrases beginning or ending with unintelligible syllables were excluded because of concerns about measurement precision. In addition, phonetic phrases were also excluded if (a) they consisted of single words or frank imitations of the examiner, (b) they were produced during obviously excited states or using a play register, (c) they contained extraneous noise or simultaneous talk by both participants, or (d) there was insufficient energy present to reliably identify the initial or final speech segment from the spectrogram. Phonetic phrases containing obvious dysfluencies (e.g., sound repetitions, prolongations) were also excluded, but those containing normal nonfluencies (e.g., whole-word repetitions or interjections) were retained. Previous analysis (Flipsen, 1999) indicated that inclusion of phonetic phrases containing normal nonfluencies would not result in statistically significant differences in either articulation rate or phonetic phrase length in either the initial or the follow-up samples.

In an attempt to equate the size of the samples across participants, a subsample of up to 30 phonetic phrases was then selected for each child, with phrases occurring earlier in the sample chosen before phrases occurring later in the sample. The 30 phrases were also selected to retain the overall distribution of phrase lengths available for each child to avoid possible bias based on particular phrase lengths. In cases where 30 or fewer phrases were available (9/53 initial samples; 18/53 follow-up samples), all usable phrases were included.

The precise beginning and end of each usable phonetic phrase were identified from the spectrograms relative to the first segment in the transcript. Phrases were judged to begin at the onset of F1 energy for vowels and resonant consonants, the onset of broadband noise for fricative consonants, and the onset of the burst release for stop and affricate consonants. The reverse of these criteria were used to establish the ending of each phrase. Durations of the phonetic phrases were then recorded. Syllable counts were obtained manually from the phonetic transcriptions by the author. A syllable was defined as any vowel, diphthong, or syllabic consonant in the child’s production; vowelized consonants (e.g., /br/ for /brɛt/), vowel onglides, or vowel offglides were not counted as syllables. Unintelligible syllables (where they did not interfere with identifying the precise beginning or end of a phonetic phrase) were also counted because listeners can reliably identify syllables in unintelligible strings (Shriberg, 1986). Phone counts were obtained later from the phonetic transcriptions by a trained research assistant. Phone counts could be obtained only from phrases that were fully intelligible, resulting in a slight reduction in the number of phonetic phrases used for the calculations involving phones. Reductions occurred for 16/17 children in the Early Follow-Up Group and 22/36 children in the Late Follow-Up Group at initial testing and 7/17 in the Early Follow-Up Group and 12/26 in the Late Follow-Up Group at follow-up testing (in no case were fewer than 15 phrases available).

Phonetic phrase lengths in both syllables and phones were averaged for each speaker across the subsamples of available phonetic phrases described above. Syllable...
and phone counts were combined with phrase durations to yield two articulation rate values per phrase (syllables per second and phones per second), and rates were then averaged for each child.

**Measurement Reliability**

Reliability of the articulation rate measures on the conversational speech samples was assessed using remeasurements from 12/106 (11.3%) samples made approximately one month after the original measurements. Six samples were randomly chosen from the 53 initial samples, and six were randomly chosen from the 53 follow-up samples. Remeasurements were made by the current author on the entire set of previously digitized utterances for each of the 12 samples selected. Mean point-to-point agreement on the location of pauses was 93.4%. Test-retest correlations (Pearson) on the duration measurements ranged from 0.96 to 0.99 across the 12 samples. Relative to syllable counts, exact matches were obtained on 332/363 (91.4%) of the recounted phrases. Reliability of the phone counts was established using a separate randomly chosen set of 12/106 (11.3%) of the samples (6/53 initial and 6/53 follow-up). Exact matches on phone counts were obtained on 478/483 (98.9%) of the recounted phrases.

**Results**

**Articulation Rate**

**Syllables per Second**

Mean articulation rate values for both groups at both test times are shown in Table 3. Analysis of variance indicated that rate increased significantly from initial to follow-up testing for both the Early Follow-Up Group \[ F(1, 16) = 39.02, p < .001 \] and the Late Follow-Up Group \[ F(1, 35) = 149.39, p < .001 \]. Relative to individual children, rates increased from initial to follow-up testing for all 17 children in the Early Follow-Up Group and 35/36 children in the Late Follow-Up Group. There were no significant sex differences for either the Early Follow-Up Group \[ F(1, 15) = .001, p > .05 \] or the Late Follow-Up Group \[ F(1, 34) = .006, p > .05 \]. Rates at initial and follow-up testing were significantly correlated for the Early Follow-Up Group \( r = .592, p < .05 \) but were not significantly correlated for the Late Follow-Up Group.

Rate in syllables per second and severity of involvement (as indexed by Percentage of Consonants Correct [PCC] and Intelligibility Index, the percentage of words understood [II], Shriberg et al., 1997b) were not significantly correlated \( ps > .05 \) for either group at initial testing. Correlations were not carried out on the follow-up samples because there was limited variability in severity at follow-up (i.e., few speech errors remained).

Where comparisons were possible group mean rates obtained at both test times for both groups fell within the confidence intervals in the studies reported in Table 1.

**Phones per Second**

Group mean values for the two groups at both test times in phones per second are also shown in Table 3. Analysis of variance indicated that rate increased significantly from initial to follow-up testing for both the Early Follow-Up Group \[ F(1, 16) = 67.70, p < .001 \] and the Late Follow-Up Group \[ F(1, 35) = 253.88, p < .001 \]. Relative to individual children, rates increased from initial to follow-up testing for all the children in both

<table>
<thead>
<tr>
<th>Sample</th>
<th>Early Follow-Up</th>
<th>Late Follow-Up</th>
<th>Early Follow-Up</th>
<th>Late Follow-Up</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Articulation Rate</td>
<td></td>
<td>Phones per Second</td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>3.35 (2.49–4.21)</td>
<td>4.15 (2.85–5.45)</td>
<td>7.65 (5.33–9.97)</td>
<td>9.90 (7.00–12.80)</td>
</tr>
<tr>
<td>Follow-Up</td>
<td>3.43 (2.59–4.27)</td>
<td>4.94 (3.74–6.14)</td>
<td>7.81 (5.81–9.81)</td>
<td>12.01 (9.05–14.97)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Phonetic Phrase Length</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>5.01 (2.77–7.25)</td>
<td>5.07 (2.77–7.25)</td>
</tr>
<tr>
<td>Follow-Up</td>
<td>6.97 (4.51–9.43)</td>
<td>7.32 (3.56–11.08)</td>
</tr>
</tbody>
</table>

\(^4\) Cell entries are group means (and 95% confidence intervals).
groups. Again there were no significant sex differences for either the Early Follow-Up Group \([F(1, 15) = .001, p > .05]\) or the Late Follow-Up Group \([F(1, 34) = .010, p > .05]\). Rates at initial and follow-up testing were significantly correlated for the Early Follow-Up Group \((r = .650, p < .01)\) but were not significantly correlated for the Late Follow-Up Group.

Rate in phones per second and severity (as indexed by PCC) were not correlated for either group at initial testing. Rate in phones per second and severity based on \(t\) were significantly correlated for the Early Follow-Up Group \((r = .526, p < .05)\) but were not significantly correlated for the Late Follow-Up Group.

Group mean rates obtained at initial testing for both groups fell within the confidence limits for the 3- and 5-year-old speakers reported in Walker et al. (1992) but below the lower confidence limit for the data for 4-year-olds reported in Hall et al. (1999). No comparison data were available for articulation rate from continuous speech measured in phones per second for either of the follow-up samples.

**Phonetic Phrase Length**

**Syllables**

Group mean values for length in syllables for the two groups at both test times are shown in Table 3. Analysis of variance indicated that phrase length in syllables increased significantly from initial to follow-up testing for both the Early Follow-Up Group \([F(1, 16) = 38.97, p < .001]\) and the Late Follow-Up Group \([F(1, 35) = 56.27, p < .001]\). Relative to individual children, phrase length increased from initial to follow-up testing for all children in both groups. There were no significant sex differences for either the Early Follow-Up Group \((r = .707, p < .05)\) or the Late Follow-Up Group \((r = .539, p < .05)\). Length in syllables at initial and follow-up testing were not significantly correlated for either group.

Length in syllables in the initial samples for the Early Follow-Up Group was significantly correlated with both \(t\) \((r = .626, p < .05)\) and PCC \((r = .520, p < .05)\). Length in syllables in the initial samples for the Late Follow-Up Group was significantly correlated with \(t\) \((r = .391, p < .05)\) but not with PCC.

As with length in syllables, length values in phones obtained for both groups at initial testing fell within the confidence intervals reported in the precedent studies of typically developing children (Haselager et al., 1991; Walker et al., 1992). No comparisons were possible for the follow-up samples.

**Discussion**

Results of this study suggest that, as with typically developing children, both articulation rate and phonetic phrase length in children with SD of unknown origin increase significantly with age. These findings suggest that the general pattern of speech skill development in children with SD of unknown origin is similar to that of typically developing children.

Articulation rates at initial and follow-up testing were significantly correlated for the Early Follow-Up Group on both rate measures but were not significantly correlated for the Late Follow-Up Group (regardless of measurement unit). This suggests that rate may be a relatively stable parameter in this population from preschool age to age 9 years but not up to age 12 years or beyond. Unlike articulation rate, however, phonetic phrase lengths at initial and follow-up testing were not significantly correlated for either group in either measurement unit. Length of phonetic phrase, therefore, does not appear to be a stable parameter across time in this population. This is not totally surprising given the open-ended nature of conversation. Topics of discussion in the conversations in the current study varied widely, resulting in varying language formulation and short-term memory demands on each of the children at the
two different test times; such variation might motivate wide variations in the amount of information produced between pauses.

The specific rates values obtained in the current study indicate that children with SD of unknown origin articulate speech at comparable rates to those reported in studies of typically developing children when measurements are made in syllables per second. The findings are less certain when rate is measured in phones per second. The children articulated speech at rates consistent with the findings of the study by Walker et al. (1992) but at what appear to be slower rates than the values obtained for the control speakers in Hall et al. (1999). Reconciling the difference is difficult because of the many differences in detail among the three studies. It is perhaps most noteworthy that Walker et al. sampled narratives, whereas Hall et al. sampled conversational speech—the same sample format used in the current study. As well, Hall et al. analyzed their samples using the same software program (CSpeech) used in the current study. This suggests that comparison of the present data to those of Hall et al. is more appropriate. By extension, then, children with SD of unknown origin appear to articulate speech at slower than normal rates when rate is measured in phones per second. This is consistent with the findings of Hall et al. for children who stutter.

The potentially slower rate in phones per second (but not in syllables) may indicate that children with SD of unknown origin target (or at least realize) simpler syllables than their typically developing peers. Some of the error patterns of young, typically developing children can be described as arising from natural phonological processes that result in simpler syllables (e.g., cluster reduction, final consonant deletion). Grunwell (1982, p. 183), however, has suggested that such simplifications are largely eliminated by age 4:0. The possibility that the children in the current study groups producing simpler syllables was confirmed using a phonological process analysis (Shriberg & Kwiatkowski, 1980) of the initial conversational speech samples. Results for the Early Follow-Up Group indicated a mean occurrence of cluster reduction of 83.8% of word-initial opportunities and 49.4% of word-final opportunities, with a mean occurrence of final consonant deletion of 10.7% of opportunities. Corresponding values for the Late Follow-Up Group were 82.6%, 40.0%, and 11.8%, respectively. This suggests that the slower rate in phones per second may have been an artifact of their speech production errors.

Comparison data appear to be lacking on articulation rate in phones per second for older children, making it difficult to know if the phones per second rate values in the current study are comparable to those for typically developing children. It is noteworthy that only three of the children in the current study (two in the Early Follow-Up Group and one in the late Follow-Up Group) were producing any substitution or omission errors at follow-up testing. Thus the majority had resolved all simplification processes. If one assumes that the slower rates at initial testing were indeed an artifact of their errors, articulation rates (in phones per second) at follow-up would likely be comparable to those of typically developing children. This, then, would suggest that children with SD of unknown origin may start out with slower than normal articulation rates but eventually would catch up with their typically developing peers.

Specific phonetic phrase length values obtained in the current study for the initial samples also appeared to be consistent with findings from the few available studies of typically developing children. The combination of the lack of normal comparison data for the follow-up samples and the lack of stability of length over time noted above makes such findings difficult to generalize from.

The only significant correlation between articulation rate and severity of involvement was obtained for the Early Follow-Up Group between II and the phones per second rate measure (obtained at initial testing). Put another way, the presence of speech sound errors does not appear to have a significant effect on the pace at which such speech segments are attempted. The fact that the one significant correlation indexed severity using intelligibility is of some interest. Perhaps listener feedback about comprehension of the message might be having some impact on articulation rate in children with SD of unknown origin. Previous studies of this relationship with other populations have yielded mixed findings. Meyers and Freeman (1985) reported a significant correlation (r = 0.40) between articulation rate and Templin-Darley scores for a group of 12 preschool-age children who stuttered. And in a study of 10 adults with dysarthria, LeDorze, Ouellet, and Ryalls (1994) reported no significant correlation between rate and intelligibility ratings.

Unlike articulation rate, there were significant correlations between phonetic phrase length and severity in the current study. It would appear that phonetic phrase length is more closely associated with severity than articulation rate. The positive correlations suggested that the less severely involved children were using (on average) longer phonetic phrases. Longer phrases contain more units (both phones and syllables), which should make them more likely to contain errors. This suggested that the more severely involved children may have learned to avoid longer phrases; conversely it may simply be that because the longer phrases produced by those with more severe involvement might contain more errors, they would be less likely to have been understood.

Overall the findings in the current study present a picture of children with SD of unknown origin producing
speech at articulation rates and in length units that are generally comparable to data observed in studies of typically developing children. The finding for rate in phones per second at initial testing may have been an artifact of their delayed acquisition of speech sounds. If this were the case, the resolution of such errors observed in the follow-up samples suggests that rate in phones per second at follow-up would be comparable to that of typically developing children. Such a conclusion would provide support for the proposition that speech development in this population is best characterized as a delay in development rather than a deviant pattern (Shriberg, Gruber, & Kwiatkowski, 1994).

The current study suffers from several important limitations. First, no control group was used; comparison of data across studies can be problematic because of differences in recruitment criteria, sampling methods, and analysis procedures. Second, the samples used herein were not randomly selected but rather were convenience samples; this limits the generalizability of the findings somewhat. Recall also that subject loss in the Early Follow-Up Group from initial to follow-up testing was not random; thus generalizability of the results for that group are especially tentative. As well, recall that data for 7 of the children in the current study were based on samples taken 6 or 12 months after initially being recruited; the influence of therapy during the intervening period may have affected the rate they used and thus modified the group level outcomes here. Finally, although articulation rate in conversational speech does provide a general index of speech development, conversational speech samples do not allow us to separate speech-motor and language formulation contributions to rate.

Clearly additional study of the phenomenon of rate in phones per second in typically developing speakers is warranted so that we can both evaluate this question and gain a broader understanding of speech development in general. Additional longitudinal examination of the current study population with the inclusion of structured tasks that allow for the separation of the speech-motor and cognitive-linguistic contributions to articulation rate would go a long way to helping us understand this population. Finally, investigation of the differences in articulation rate between conversational speech and narratives in this population might be helpful given the previously discussed problem of reconciling the current study findings with those of Hall et al. (1999) and Walker et al. (1992).

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References


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