A Longitudinal Investigation of Speaking Rate in Preschool Children Who Stutter

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Both clinical and theoretical interest in stuttering as a disorder of speech motor control has led to numerous investigations of speaking rate in people who stutter. The majority of these studies, however, has been conducted with adult and school-age groups. Most studies of preschoolers have included older children. Despite the ongoing theoretical and clinical focus on speaking rate in young children who stutter and their parents, no longitudinal or cross-sectional studies have been conducted to answer questions about the possible developmental link between stuttering and the rate of speech, or about differences in rate development between preschool children who stutter and normally fluent children. This investigation compared changes in articulatory rate over a period of 2 years in subgroups of preschool-age children who stutter and normally fluent children. Within the group of stuttering children, comparisons also were made between those who exhibited persistent stuttering and those who eventually recovered without intervention. Furthermore, the study compared two metrics of articulatory rate. Spontaneous speech samples, collected longitudinally over a 2-year period, were analyzed acoustically to determine speaking rate measured in number of syllables and phones per second. Results indicated no differences among the 3 groups when articulation rate was measured in syllables per second. Using the phones per second measure, however, significant group differences were found when comparing the control group to the recovered and persistent groups.

KEY WORDS: speaking rate, childhood stuttering, subtypes, persistence/recovery

Speech rate has been long recognized for its clinical and, more recently, for its theoretical implications for stuttering. *Overall speaking rate*, the traditional measure, is calculated from speech samples that include pauses and disfluencies.[1] This global measure reflects verbal output rather than the timing of articulatory gestures (Costello & Ingham, 1984). Indeed, early research of overall rate confirmed common

[1]The term *overall speaking rate* as applied to speech of people who stutter has been defined typically as "... the total number of words produced in a set amount of time, including pauses, hesitations, and disfluencies" (e.g., Yaruss, 1997, p. 264). Actually, this definition is incomplete, especially in reference to disfluency. A more accurate definition should specify two negations. Accordingly we suggest the following: Overall speaking rate is a measure of the number of words uttered by a speaker per minute (or of syllables per second) where pauses, unusually prolonged sounds, or other interruptions are *not* subtracted from the total speaking time, and where extra repetitions of syllables, words, or phrases are *not* added to the count of the measured unit. For example, in the sentence "I-I-I like to go home" only one "I" would be counted as a word. Typically, overall speaking rate has been reported in terms either of words or syllables per minute, but sometimes in terms of syllables per second.

*Currently affiliated with Tel Aviv University, Israel impressions that people who stutter talk slower than normally fluent speakers, emitting fewer words in a given time unit due to disfluencies and other interruptions that occur in their speech. Bloodstein (1944) found that the mean overall speaking rate for adults who stutter was 122.7 words per minute (w/m), substantially slower than the approximately 170 w/m established for normally fluent speakers (Walker, 1988). A more recent measure of speaking rate is *articulatory rate*. Expressed as the number of syllables or phones uttered per second, after either excluding or removing pauses and disfluent segments from the timed speech sample, this measure is a better estimate of speech execution time.

Growing clinical interest in speaking rate, regardless of measure, can be seen in procedures used to assess stuttering severity (Costello & Ingham, 1984), impact of parents' speech modeling (Stephanson-Opsal & Bernstein Ratner, 1988), and results of treatment (Onslow, van Doorn, & Newman, 1992; Prosek & Runyan, 1982). Rate measures also have been used as dependent variables in research of various phenomena in stuttering, including effects of auditory stimulation and rhythm (Martin, Johnson, Siegel, & Haroldson, 1985), the adaptation effect (Prins & Hubbard, 1990), and listener-judged naturalness (Ingham, Martin, Haroldson, Onslow, & Leney, 1985).

From the theoretical perspective, there are two major links between stuttering and speech rate. First, psycholinguistic models of stuttering have suggested that both children and adults who stutter require additional time for linguistic and phonological processing to plan motor speech movement (cf. Karniol, 1995; Nudleman, Herbrich, Hoyt, & Rosenfield, 1989; Perkins, Kent, & Curlee, 1991; Peters, Hulstijn, & Starkweather, 1989; Postma & Kolk, 1993). This delay can be expected to result in a rate of fluent speech slower than that of normally fluent speakers.[2] It has also been suggested that differences between groups in timing of articulatory movements reflect a compensatory motor control strategy used by individuals who stutter to avoid disfluencies (Van Lieshout, 1995). Conture, Louko, and Edwards (1993) theorized that children who stutter speak faster than their ability to achieve correct phonological encoding. Indeed, Kloth, Jannsesn, Kraaimaat, and Brutten (1995) found that the preonset articulation rate of children who later developed stuttering was faster than that of children who remained normally fluent. Second, considerations of stuttering as a neuromotor and timing disorder (e.g., Kent, 1984; Van Riper, 1982) draw attention to articulatory rate that has been regarded by scientists as an indicator of the development of speech motor control (DiSimoni, 1974a, 1974b, 1974c; Gilbert & Purves, 1977; Kent & Forner, 1980; Naeser, 1970; Smith, 1978; Tingley & Allen, 1975).

Although many studies of speech rate in normal speakers, regardless of measure, have been inconclusive, requiring replications and modifications (see review by Hall & Yairi, 1997), several trends emerge. The most consistent observation is considerable individual variability, especially in segment duration (Miller, Grosjean, & Lomanto, 1984; Shewan & Henderson, 1988). Of special relevance to the present study, however, is the evidence that (a) duration of speech segments is greater and more variable in young children than in older children and adults (DiSimoni, 1974a, 1974b, 1974c; Gilbert & Purves, 1977; Kent & Forner, 1980; Naeser, 1970; Smith, 1978; Tingley & Allen, 1975), and (b) articulatory rate tends to increase with age (Kelly, 1994; Kent & Forner, 1980; Kowal, O'Connel, & Sabin, 1975; Tingley & Allen, 1975; Walker, Archibald, Cherniak, & Fish, 1992). Other investigators, however, have concluded that developmental decreases in segment duration (Kubaska & Keating, 1981; Nittrouer, 1993; Robb & Saxman, 1990; Smith, 1992) and rate (Pindzola, Jenkins, & Lokken, 1989) are not necessarily linear. Typically, these developmental studies relied on cross-sectional designs; there have been no longitudinal investigations of the development of the velocity of speech.

At present, information about speaking rate at the very early stage of stuttering, regardless of specific measure, is limited and/or obscured by methodological constraints such as participants' wide age range. Two studies have dealt strictly with school-age children who stutter (Onslow, et al., 1992; Zebrowski, 1994). At the next lower level of children's age, several studies have reported rate data for samples of children spanning an age range that mixed preschool and school-age children. For example, Yaruss, Logan, and Conture (1995) studied children 48 to 83 months of age. Other investigations in this group include Kelly (1994), Yaruss, and Conture (1995) and Yaruss (1997). Typically, investigators have concentrated on the articulatory rate in fluent speech where pauses longer than 250 ms were excluded from the sample. Either acoustic analyses or a video timer have been used to measure time. All four studies using a wide age range of participants reported no statistically significant group differences between stuttering and nonstuttering children.

Other investigators examined a narrower set of ages, closer to the preschool range but still including children over 5 years old. They employed several methods of calculating rate and did not always include normally fluent controls. Meyers and Freeman (1985) used video time code to compare the 15 longest sentences from speech samples of stuttering boys 4 to 5 years of age with a matched control group. Only fluent utterances were

[2]It may also slow the overall speaking rate of stuttered speech

used, but pauses shorter than 2 seconds were retained. Children who stutter spoke slower than controls, and severe stutterers spoke slower than mild stutterers. On the other hand, Ryan (1992), using a stopwatch, found no differences in overall speaking rate between stuttering and nonstuttering children ages 2;10 to 5;9. Yaruss and Conture (1996) compared the articulation rate of stuttering children 3 to 6 years of age with and without phonological disorders. The rate of the first group was slightly slower. No control group of normally fluent children was included.

The only study we were able to identify confined to children below 5 years was conducted by Kelly and Conture (1992). They compared overall speaking rate as well as articulatory rate of 13 children who stutter (ages 3;3 to 4;8) with a matched control group during 300-word conversational speech samples with the mother. Rate was measured from acoustic signals using computer software. The stuttering children had a somewhat faster overall speaking rate than the controls at 189 and 177 syllables per minute (s/m), respectively. The corresponding articulatory rate was 200 and 180 s/m. Of methodological interest to us is the procedure used in this study, as well as other studies, whereby disfluent segments were eliminated from utterances, but the remaining portions of those utterances were included in the analyses.

Inasmuch as articulatory rate may be viewed as an indicator of speech motor control maturity (Kent & Forner, 1980; Smith, 1978), and considering theories that depict stuttering as a disorder of motor timing and coordination (Alfonso, Watson, & Baer, 1987; Kent, 1984), or those that imply relations among stuttering, central planning, and rate (Conture, Louko, & Edwards, 1993; Postma & Kolk, 1993), it is reasonable to hypothesize that children near stuttering onset would differ from their normally fluent peers with regard to articulatory rate. The present literature, however, has been inconsistent as to whether preschool children who stutter speak perceptually fluent utterances with a different (Meyers & Freeman, 1985; Richardson, 1985) or a similar rate (Kelly, 1994; Kelly & Conture, 1992; Ryan, 1992) compared to normally fluent controls. In part, such inconsistencies may be attributed to factors in subject selection that are especially important to our perspectives on the rate parameter and early stuttering that were not previously considered. Although appreciable progress has been made by recent investigators toward studying younger children with shorter histories of stuttering, the goal of obtaining rate information from children close to the onset of stuttering, before long stuttering histories might have influenced their fluent speech, has remained a challenge. Data obtained from very early stuttering is particularly relevant in evaluating the theories mentioned above. The desirability of such data increases if the relation between the developmental course of early stuttering and the development of articulatory rate (as an indicator of motor speech control) are investigated simultaneously by means of longitudinal studies.

From a clinical point of view, to the extent that speech-rate measures are used in diagnostic evaluations and treatment, rate information for age-specific groups of both stuttering and normally fluent children are needed. Longitudinal data also are particularly useful in this respect because current information is not clear about the extent of age-related increase in articulatory rate, or whether the developmental process differs for children who stutter and those who are normally fluent. A second clinical motive is the growing awareness of the heterogeneity of stuttering (e.g., Conture et al., 1993; Schwartz & Conture, 1988) and the attention given to the distinction between persistent and recovered stuttering (Ambrose, Cox, & Yairi, 1997). Attempts to identify early predictors of these two subgroups have included several speech variables such as disfluency, phonological skills, and segment duration (Yairi, Ambrose, Paden, & Throneburg, 1996). Within the theoretical context discussed earlier, articulatory rate appears to be a reasonable variable for prognosis. Unique opportunities to obtain information on the articulatory rate of the two subgroups, before their divergent developmental pathways have become apparent, were presented for this study.

Finally, a review of the literature also raises methodological issues concerning the metric of articulatory rate. Whereas early research of overall speaking rate used words per minute, a more precise metric associated with articulatory rate (though not exclusively) is syllables per second. This metric has been employed in more recent studies and is characterized by less variability. Because of the appreciable differences in syllable length in English, however, Perkins, Bell, Johnson, and Stocks (1979) advocated an even more sensitive metric, phone rate, stating that it is "...a direct index of the speed with which speech coordination is measured" (cf. p.748). In view of more recent research showing differences in temporal demands for CV and CVC (Browman & Goldstein, 1989), as well as proposing models of phonological gestures' demands on articulation (Browman & Goldstein, 1992) we would argue that an important way to evaluate the temporal achievements of speech production is in terms of phone rate rather than the relatively more global utterance units of syllables. This metric has been used in several recent investigations of stuttering (Onslow et al., 1992; Prins & Hubbard, 1990), but not with preschool children.

Based on the theoretical, clinical, and methodological motivations presented above, this study had a threefold purpose. It sought to (1) compare the development of articulatory rates of young stuttering children near the onset of stuttering, who were followed longitudinally, with those of matched normally fluent children, (2) compare articulatory rates of stuttering children who were known to recover at a later time without intervention with those who eventually developed persistent stuttering, and (3) compare syllable and phone metrics of articulatory rate.

Method

Participants

Two groups of children who stuttered and one group of normally fluent children participated. Each group consisted of 8 children: 6 boys and 2 girls. The children in the stuttering groups constituted rare samples, recruited over a period of several years, in that they were identified and first evaluated and recorded within 3 months after the reported onset of stuttering. The procedures followed in ascertaining the date of onset are detailed in Yairi and Ambrose (1992). Two investigators, who were also certified clinicians with extensive experience with stuttering, agreed with the parents' judgment that the child exhibited a stuttering disorder. To enter the study, children had to be rated by parents and investigators as having at least a mild degree of stuttering (2 on an 8-point scale of stuttering severity); have at least 3 stuttering-like disfluencies (SLDs) per 100 syllables that consisted of part-word repetition, single-syllable word repetition, and disrhythmic phonation (primarily sound prolongation and broken words); and have no history of neurological disorders and speech therapy. Because these children participated in a longitudinal study for several years, which involved periodic observations, testing, and recordings (see Yairi et al., 1996, for additional details), information was available as to the eventual outcome of their stuttering status. Based on the outcome, they were divided into two groups:

Persistent Group

At the time of the initial evaluation from which the speech samples used in the present investigation were taken, the 8 subjects ranged in age from 39 to 55 months (M = 46.25, SD = 5.23). They exhibited from 4.04 to 19.31 stuttering-like disfluencies per 100 spoken syllables of conversational speech, with a mean of 10.38 (SD = 5.52). Children were defined as "persistent" if they stuttered for at least 3 years after the initial evaluation and were currently stuttering as defined by the entry criteria specified above. In other words, their initial speech samples were selected for analysis after the passage of several years of close follow-up at which time their classification as persistent was possible.

Recovered Group

At the time of entrance to the study, when the children in this group were classified as stutterers, they ranged in age from 38 to 58 months (M = 45.62, SD = 7.13). The number of SLDs in their conversational speech ranged from 4.40 to 32.56 per 100 syllables with a mean of 14.69 (SD = 9.32). To be categorized as "recovered," a child needed to meet the following criteria: (a) clinician and parental general judgment that the child did not exhibit stuttering behaviors, (b) parental or clinician rating of stuttering severity less than 1, (c) SLD frequency fewer than 3 per 100 syllables, and (d) continuing to meet these criteria for at least 12 months. (In fact, all 8 children were recovered for more than 3 years.) The initial samples of these subjects were selected after waiting several years until their classification as recovered was possible.

Control Group

The third group consisted of 8 children who ranged in age from 37 to 55 months, with a mean of 42.25 months (SD = 7.23). They had no history of stuttering or neurological disorders, were judged by parents and investigators as being normally fluent, were rated by them as 0 in stuttering severity, and exhibited fewer than 3 SLDs per 100 syllables of conversational speech. The number of SLDs in their speech ranged from .56 to 2.69 with a mean of 1.28 (SD = .79).

The three groups had identical sex distributions and were similar in age range, mean age, and dispersion of age. Although there was no precise matching, when the subjects were arranged in 8 triads, the mean age difference between the stuttering children was less than 1.5 months. The mean difference between stuttering and controls was 4 months. The speech samples used in the present study were taken from the time when the eventual classification of the children as persistent or recovered was still unknown. This design allowed for exploration of possible clues for early prediction.

Speech Samples

Articulatory rate for each child was calculated from spontaneous speech recorded during conversation with adults at three sessions, 12 months apart. For the children who stuttered, the first recording served as baseline and was obtained within 3 months of the onset of stuttering. Baseline recordings for the normally fluent children were taken at corresponding ages. The second and third recordings were 1 and 2 years following baseline, respectively.

In each session the children were audio- and videotape recorded while engaged in spontaneous speech with an adult (experimenter and parent) for a period of 30–40 minutes. Speech samples contained approximately

1,000 words. To balance possible variations in disfluent speech, each session was recorded in two parts, 1 week apart. The general protocol for speech-language sample collection was conversation while the child played with clay and included several standard, open-ended questions posed to the child to elicit a conversational discourse (e.g., questions about favorite toys, TV shows, movies, siblings, and school or daycare experiences, as well as talk about the ongoing play).

Listening to the audiotapes, the speech samples were orthographically transcribed, and all disfluencies were marked on the transcript independently by two investigators using a routine described previously (Yairi, Ambrose, & Niermann, 1993). Videotapes were used when necessary to determine the presence or absence of disfluencies. The unmarked portion of each sample, regarded as fluent, was again inspected independently by the present authors. Relistening to the previously identified fluent segments, only those that were again independently regarded as perceptually fluent were retained for analysis. Thus, from each subject's conversational speech sample, 45–50 fluent utterances were selected for analysis. An utterance was defined as a string of words that (a) communicated an idea, (b) was bounded by a simple intonational contour, and/or (c) was grammatically complete (Gollinkoff & Ames, 1979; Walker, et al., 1992). In addition, all utterances contained at least three consecutive words, excluded nonspeech sounds, and did not contain a pause greater than 250 ms (Miller et al., 1984). In other words, utterances containing longer pauses were not included.

Articulatory rate was defined as the number of syllables or phones spoken per second during segments of perceptually fluent speech. A phone was defined as an individual speech sound produced by a speaker and represented by a single symbol in the phonetic system (Nicolosi, Harryman, & Kresheck, 1996). A diphthong was considered one phone.

Data Analysis

Articulatory rate was determined using a speech analysis computer program, CSpeech, Version 4.0 (Milenkovic, 1987). All of the fluent speech utterances produced by the individual subjects were recorded through a cardioid microphone (Crown PCC-160) onto high quality recording tapes (Maxell II S 90) using a Tascam 122 MKII professional cassette recorder. The utterances were low-pass filtered (Frequency Devices 901) at 7.5 kHz and digitized (DT 2821 analog-digital converter) at 20 kHz. A time waveform and corresponding FFT-based spectrographic display of each utterance were verified through playback of the auditory signal.

Durational measures were made (in ms) by placing the left cursor at the enhanced onset and offset of each utterance. Onset was visually defined as the first peak (maximum amplitude in millivolts) that corresponded with a burst of spectral energy of the corresponding spectrogram. Offset was defined as the last consecutive peak in the waveform that was followed by a nonspeech signal and also corresponded to the termination of spectral energy. Onsets and offsets of voiceless consonants that could not be clearly identified were excluded from the analysis. Next, the duration of each utterance (in ms) was calculated by subtracting the offset time from the onset time. Finally, the number of syllables and the number of phones for each utterance were divided by the duration of the utterance to provide two measures of articulation rate: syllables per second (s/s) and phones per second (p/s). Individual subject means for each measure were derived.

Reliability

Acoustic Measures

A total of 3,368 utterances were identified for analysis in this investigation. To improve precision of the data, the present investigation included only utterances whose duration was independently determined by two investigators. All temporal measurements of onsets and offsets were made by the first author and independently verified by one of two other investigators (the second author and a third trained person). Differences in total utterance durations between the first author and one of the other two investigators that were shorter than 3 ms were considered acceptable for inclusion. Differences in total utterance durations that exceeded 3 ms were considered unacceptable. Only 85 utterances, or 2.5% of the total sample whose measurements exceeded the 3-ms difference criterion, were excluded. In other words, for the usable data, the interjudge reliability within a narrow 3-ms range was 100%.[3] Given that reliability is defined in terms of the ratio of error variance to obtained variance, the procedure imposed extraordinary precaution to minimize the error variance through experimental control thus maximizing reliability.

Syllable/Phone Counts

The total number of syllables spoken by each subject was independently tallied from the transcripts by two investigators. The few discrepancies between the listeners' calculations were resolved by repeatedly listening to the utterance until a unanimous agreement was met. Second, each utterance was listened to again

[3]Previous investigations typically used measures obtained by a single investigator. Their interjudge reliability estimates revealed larger differences For example, Yaruss (1997) reported mean interjudge difference of 0.25 s/s This can be translated to approximately 67.75 ms (based on the group mean articulatory rate of 3.69 s/s)

and phonetically transcribed by the first author. The number of phones was tabulated. Next, the independent investigator verified the phonetic transcription and phone counts. Again, any discrepancies were resolved by unanimous decision. Consequently, all measurements of duration were performed on utterances for which there was a unanimous agreement regarding their size.

Results

Articulatory Rate: Syllable Metric

Group means for articulatory rate in syllables per second are presented in Table 1. As can be seen, the children who eventually recovered spoke somewhat slower than both the children who eventually persisted in stuttering and the nonstuttering children. This was particularly evident in the first visit where the recovered group spoke approximately 0.5 syllable per second slower than the other two groups. On the 1-year follow-up visit, the recovered group demonstrated an increase in speaking rate, again approximately 0.5 syllable, to approximate the rate of the other two groups. It is interesting to note that the persistent and the control groups had very similar speaking rates, demonstrating identical values for the syllables per second measure in the first two visits and rather similar values in the third visit.

A series of planned comparisons using analysis of variance was performed to assess the statistical significance of group differences at each visit. To control inflating the error rate across these planned comparisons, a very conservative method, the Bonferroni's procedure (Dunn, 1961) was employed. Accordingly, the per contrast alpha level was set at .005 (.05 divided by 9 comparisons = .005). Also, a two-way analysis of variance with repeated measures was performed to determine if overall differences were detected between groups and visits (alpha = .05).

A two-way analysis of variance with repeated measures indicated no significant differences between the groups [$F(2, 42) = 1.81, p = .189$], whereas rate was found to increase significantly across visits [$F(2, 42) = 5.83, p = .006$]. This significant difference was most likely due to the increase of rate for the recovered group from Visit 1 to Visit 2 [$F(2, 21) = 6.06; p = .008$]. With this exception, no other statistically significant differences were found when comparing each group at each visit.

Articulatory Rate: Phone Metric

Group means for the number of phones spoken per second are presented in Table 2. Apparently, because the phone metric is based on smaller units, the differences between groups are easier to detect. Similar to

Table 1. Means and standard deviations (in parentheses) of articulation rate (in syllables per second) at the initial visit, 1-year visit, and 2-year visit for normally fluent children and children who stutter

	Recovered	Persistent	Control
Initial visit	3 18	3 84	3 84
	(0 45)	(0 52)	(0.57)
1-year visit	3 87	3 94	3 94
	(0.30)	(0 44)	(0.65)
2-year visit	3.75	4 12	3.92
	(0 38)	(0 47)	(0 68)

Table 2. Means and standard deviations (in parentheses) of articulation rate (in phones per second) at the initial visit, 1-year visit, and 2-year visit for normally fluent children and children who stutter.

	Recovered	Persistent	Control
Initial visit	7 68	9 56	11 42
	(1.08)	(1 25)	(2 77)
1-year visit	9 78	9.66	12.17
	(0.62)	(1 16)	(2 10)
2-year visit	9 38	10.22	11 88
	(0 98)	(1 50)	(1 86)

the data shown in Table 1, the phone measure also reflects the tendency of the recovered group to demonstrate the slowest articulation rate. Contrary to the data reported in Table 1, however, the control group appears to use faster articulation rates than the two stuttering groups. In fact, the difference between control and stuttering children is larger than the differences between the two stuttering groups. A two-way analysis of variance with repeated measures indicated significant differences [$F(2, 42) = 12.83; p < .0001$] among groups. Phone rates also varied significantly across visits [$F(2, 42) = 4.05; p = .025$]. All groups demonstrated an increase in phone rates from Visit 1 to Visit 2. The increase in rate from Visit 1 to Visit 2 was statistically significant [$F(2, 21) = 4.3; p = .027$], whereas the differences between Visit 2 and 3 were not. Multiple planned comparisons using the conservative alpha level (<.005) showed that the recovered group spoke significantly slower than the control group at all three visits. The persistent group spoke significantly slower than the control group only at Visit 2.

Discussion

Although recent years have seen several contributions to understanding the relation between childhood stuttering and articulatory rate, the present investigation offers new data bearing on this issue from a number of unique angles. The intricacies of the development of children who stutter were observed as close as possible to the beginning of the disorder and with respect to the epidemiological diversity of stuttering (persistent and recovered subgroups). Therefore, in evaluating the contributions of this study, several features should be considered: (a) It is the first to report speech rate data in children, either normal or stuttering, based on longitudinal data of rate (preliminary data were reported by Hall and Yairi in 1997). This design offers an important advantage by facilitating the study of idiosyncratic developmental variables such as rate. (b) All the participating children who stutter were very close (within 3 months) to stuttering onset, providing the unique opportunity to consider rate with respect to the nature of very early stuttering. (c) The participants enabled examination of heterogeneity factors; namely, the distinction between children who later recovered and those who persisted in stuttering. (d) The procedures employed make a methodological contribution, first by comparing two metrics and second by delineating rate in fluent speech using only perceptually fluent utterances that did not contain disfluencies or pauses longer that 250 ms. That is, the fluent utterances were *not* experimentally altered by extracting pauses and disfluencies to calculate rate on the remaining portion of the utterance. With this in mind, the discussion will focus on methodological, general developmental, group comparisons, and clinical considerations.

Methodological Considerations: Phone vs. Syllable Rate

Although there is evidence that the syllable (e.g., CV) serves as a larger goal that governs the temporal planning of articulatory gestures (Browman & Goldstein, 1989), these investigators have also argued that the basic units of phonological contrast are gestures, each with an intrinsic time or duration (Browman & Goldstein, 1992). Accordingly, as a measure of the demand on the speech motor planning system, the number of phones that must be coordinated within the utterance is important. Even when a phoneme has no acoustic result, the underlying articulatory gesture may have occurred. Indeed, x-ray microbeam data (Browman & Goldstein, 1989) revealed that although the phonological gestures for initial consonants and vowels overlap in time, postvocalic consonants are timed differently, implying that the number of phones to be produced reflects an important aspect of utterance timing demands that syllable-related measures may be less likely to reflect.

The present findings, that the p/s metric is capable of detecting differences not identified by the s/s metric when calculating articulatory rate, would appear to support this point of view. Also, Walker et al.'s (1992) report that the correlations between s/s and p/s in conversational speech of 3- to 5-year-old normally developing children in various speaking tasks varied from .655 to .934, is in congruence with this conclusion. Such a wide range of correlation values would seem to imply a complex relation between speed of speech, the nature of the speaking task, and the metric used. Such relations were also reflected in a recent study by Amir and Yairi (1997).[4] Overall, from methodological perspectives the present findings justify further consideration of the phone metric in future research of articulatory rate of young children who do not exhibit gross motor speech disorders. This is especially important when conversational speech, which is impossible to control for equivalency for all subjects, is the material subjected to analysis.

Developmental Aspects

Generally, the rate data that were derived from speech samples recorded over two different days can be assumed to be a more stable representation of the children's speech. The present phone rate data provide qualified support to previous reports of cross-sectional studies showing an increase across time in speaking rate of children (Amster & Starkweather, 1987; Kent & Forner, 1980; Kowal et al., 1975; Tingley & Allen, 1975; Walker et al., 1992). It is apparent in our three groups, however, that a significant increase occurred only between the first and second visits, which were separated by approximately 1 year. This finding is not in agreement with data reported in cross-sectional studies showing that speech rate steadily increases with age (Kelly, 1994; Kent & Forner, 1980, Walker et al. 1992). Perhaps rate does not necessarily increase at a continuous pace through age intervals. The possibility that rate development is not linear was also supported by data reported by Pindzola et al. (1989). Further data from longitudinal investigations could shed light on this phenomenon.

Stuttering vs. Normally Fluent Children

Past reports concerning articulatory rates of children who stutter and those who are normally fluent, often derived from children with relatively long histories of stuttering, have been inconsistent. Although Kloth et al. (1995) reached the conclusion that rate and early

[4] Their results indicated that, for adults, the w/m metric was not sensitive to the differences found between the groups and the speaking tasks when rate was measured in s/s and p/s. That is, differences were "masked" by the w/m metric. On the other hand, both s/s and p/s measures were equally sensitive to changes in rate across tasks.

stuttering are related, the possible etiological or functional relation between them has remained unclear. The present phone rate data taken from speech recorded closer to stuttering onset suggests that, at the very early stage of stuttering, children tend to exhibit a somewhat slower articulatory rate than their normally fluent peers. This finding is consistent with conclusions of several previous investigators who studied rate in children who stutter (Meyers & Freeman, 1985; Richardson, 1985) although it disagrees with others (Hall & Yairi, 1997; Kelly, 1993; Kelly & Conture, 1992; Logan & Conture, 1995; Yaruss, 1997; Yaruss & Conture, 1995). Kloth et al. (1995) also thought that the high preonset articulatory rate they found was still slower than normal. The findings are also in harmony with theories that emphasize slower motor execution (Van Riper, 1982) as contributing factors in early stuttering and those relating stuttering to longer central processing prior to motor execution of speech (Karniol, 1995; Nudleman et al., 1989; Perkins et al.,1991; Peters et al., 1989; Postma & Kolk, 1993). These and other sources suggested that someone who needs to self-monitor and repairs speech more often is more apt to use slower speech, resulting especially from monitoring "inner speech" (Kolk & Postma, 1997), and that problems with central planning may have strong repercussions with speech motor execution, such as slower rate (Postma, Kolk, & Povel, 1990).

The continuously conflicting literature reports may be partially understood in relation to differences in the research methodologies. For example, utterance length could influence articulatory rate in that longer utterances are typically produced faster (Malecot, Johnson, & Kizziar, 1972). The definition and selection of "fluent" utterance and the metric employed could be additional factors. The possible influence of the heterogeneity of the stuttering population was also hinted at in the present findings. In addition to age and post-onset interval, subgroup differences are also a potential factor, although, as discussed below, not yet proven.

Persistent vs. Recovered Children Who Stutter

Even though at Visit 1 there was a tendency for children who later recovered to articulate speech at a slower rate, in comparison to those whose stuttering persisted and the control group, the present lack of a statistically significant difference prohibits conclusion that articulatory rate can be used as a prognostic indicator for the divergent developmental paths of stuttering. At this exploratory stage, however, such a tendency should not be ignored, especially in light of the very conservative statistics used. Further research of this possibility is warranted. If this tendency is confirmed, it could be hypothesized that the same deficiencies (e.g., oral-motor or central planning) responsible for stuttering also contribute to slowing of speech. As these deficiencies subside, both the fluency and articulatory rate improve. Alternatively, it would be tempting to suggest that the children who eventually recovered employed a strategy, not necessarily consciously, of slowing down their articulatory rate to cope with stuttering that was more severe than that of the persistent group (the mean SLD for the recovered group was 14.69 as compared with 10.38 for the persistent group). Meyers and Freeman (1985) also found that children with severe stuttering spoke slower than those with moderate stuttering. As future research pursues factors that contribute to natural recovery, additional attention to articulatory rate is warranted.

Clinical Implications

Information concerning the use of articulation rate for diagnostic purposes was recommended by Costello and Ingham (1984). They entertained the possibility that people who stutter may have optimal and/or maximum rates that facilitate production of stutter-free speech. In our clinical experience, many parents believe that their children stutter because they speak too fast. Also clinicians believe that children who stutter may exceed their optimal rate (Starkweather, Gottwald, & Halfond, 1990). Conture et al. (1993) were more specific, hinting that the rate might be faster in relation to the children's phonological encoding processes. Not surprisingly, current treatment strategies for young children who are just beginning to stutter emphasize slow speech training for the child via direct practice or via parent modeling as one target of stuttering therapy (e.g., Conture & Fraser, 1989; Conture et al. 1993; Coppola & Yairi, 1982; Culp, 1984; Meyers & Woodford, 1992; Peters & Guitar, 1991; Shine, 1984). In fact, Starkweather, Gottwald, & Halfond (1990) set one of their goals as "a reduction of the child's speech rate to the norms for the child's age and sex" (p. 96). Although the distinction between slowing of overall speaking rate and articulatory rate is not always clear, the correlation between the two is quite high (Kelly & Conture, 1992). The present findings showing that fluent speech of children at a very early stage of stuttering is already slower than normal raises questions regarding the rationale underlying the general clinical approach of achieving slower speech in those children. Although the objective of slow rate might be justified, the exact rationale and the logic underlying the application of specific procedures remains uncertain.

Some Caveats and Future Research

In spite of the methodological achievements of this study, the number of participant children is modest, and inspection of the size of the mean differences and the standard deviations would seem to indicate that not all children who stutter spoke slower than normally fluent children. Also unknown is the effect of intrasubject variability of articulatory rate. Therefore, more data from a larger number of children representing each subgroup, recorded during several different days, are needed to verify the trends that were identified. Additional experimental attention is needed to further assess and refine the metric employed both in research and clinical settings. With a refined and tested technique, new data can be used to re-assess present information, resolve conflicting findings, and advance our understanding of the tempo of utterances as a key causative or correlative variable underlying stuttering. The variety of possible clinical alternatives regarding the role of articulatory rate in treating and predicting early stuttering, as well as the theoretical significance of articulatory rate, require considerable more research in this domain.

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