Effect of Normal and Fast Articulatory Rates on Stuttering Frequency

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Running head: ARTICULATORY RATE AND STUTTERING

Abstract

The effect of speech rate on stuttering frequency was investigated with 20 stutterers. Subjects read two different 300 syllable passages at a normal and fast speech rate. Stuttering counts and articulatory rate was determined for each speech sample. Articulatory rates were derived from portions of the passages which were perceptually fluent. No statistically significant difference in stuttering frequency was found between the two speech rate conditions ($p = .16$) while a significant difference was observed for articulatory rate ($p = .0007$). These findings suggest that increased articulatory rate does not determine stuttering frequency with the same consistency as does decreased articulatory rate. It was concluded that a single explanation of the relationship between speech rate and stuttering frequency in terms of speech timing complexity is inadequate.

Effect of Normal and Fast Articulatory Rates on Stuttering Frequency

It is well documented that stuttering is dramatically reduced at speech rates which are below an individual's normal rate (Adams, Lewis, and Besozzi, 1973; Perkins, Bell, Johnson, & Stocks, 1979; Wingate, 1976). The fact that stutterers speak more fluently at slow speech rates has suggested to some theorists (e.g., Perkins, Bell, Johnson, & Stocks, 1979; Starkweather, 1982; Kent; 1984) that stutterers have difficulty coordinating the multiple physiological events of the speech mechanism during speech production. It is reasoned that the task of coordination is simplified at a slow speech rate due to production of fewer gestures per unit time (Starkweather, 1982); slowed transitional movements from sound to sound (Perkins et al., 1979); and/or longer time for planning or programming movement coordination (Perkins et al., 1979; Kent, 1984). It has been speculated that if stuttering is reduced under conditions in which coordination is simplified, then stutterers must have reduced capacity for speech movement coordination.

While there has been a great deal of interest in investigating the relationship between slowed speech rate and stuttering, there has been little interest in determining the effect of increased speech rate on stuttering frequency. A tacit assumption of clinicians and theorists, however, is that stuttering increases when stutterers are under time pressure (Sheehan, 1958; Perkins, Kent, & Curlee, 1991). This notion is consistent with the theory that stutterers have reduced capacity for speech movement coordination. More specifically, if stuttering is reduced at slow rates because of reduced speech timing complexity, then at a fast rate, where temporal complexity and/or demands are presumably greater, stuttering should increase.

Unfortunately, there is a paucity of data exploring this prediction. Moreover, much of these data is difficult to interpret. Johnson and Rosen (1937) included a fast rate condition in an early investigation of the relationship between changes in stutterers' speech patterns and stuttering frequency. They reported essentially identical mean values for 18 subjects of 7.6% and 7.7% for the first normal rate condition and the fast rate condition, respectively. However, because order of condition was held constant for all subjects and there is evidence that stuttering decreased over the course of the experiment, it is possible that the results were confounded by order effects. Thus, Johnson and Rosen's findings should be interpreted with caution. In a more recent investigation, Ingham, Martin, and Kuhl (1974) used a single subject, ABA design to assess the relationship between speech rate and stuttering frequency for three adult stutterers. In the fast rate condition, their two subjects decreased, rather than increased, stuttering frequency relative to the initial normal speech rate condition. Only one subject exhibited more stuttering in the fast rate condition than in the initial control condition. However, these findings were complicated by the fact that stuttering frequency for two subjects failed to return to baseline in the final control condition. Therefore, it is not clear whether changes can be attributed to manipulation of speech rate, or to changes in some other unspecified variable.

A fundamental problem common to both these experiments is their measurement of speech rate. Johnson and Rosen (1937) used total reading time to indicate speech rate while Ingham et al. (1974) measured word output (that is, words per minute). In both cases, stuttered as well as fluent words were included in the measures. As such, speech rate was not assessed independent of stuttering frequency. The impact of any increases in stuttering frequency, therefore, would have been to reduce the absolute value of the speech rate measure. For example, the one subject in the Ingham et al. study who increased stuttering frequency in the fast speech rate condition relative to the initial control condition showed little change in word output. It would not be possible, therefore, to conclude that this speaker increased stuttering in conjunction with increased speech rate. One could say only that under instructions to speak quickly, the speaker exhibited more stuttering than under normal speaking conditions. In order to assess speech rate independent of stuttering frequency, it is necessary to obtain a measure of articulatory rate. An important aspect of calculating articulatory rate is the removal of lengthy pauses as well as stuttering. Removal of both stuttering moments and lengthy pauses are necessary to obtain an accurate representation of the gestures produced per unit time. The removal of lengthy pauses also increases the likelihood that inaudible stuttering moments will be excluded from the sample.

To the best of our knowledge, there is only one study which has obtained measures of stuttering frequency in conjunction with measures of normal and fast articulatory rates. Kalinowski, Armson, Roland-Miezskowski, Stuart, and Gracco (1993) investigated the effect of speaking at normal and fast rates under conditions of altered auditory feedback on stuttering frequency. Under conditions of nonaltered feedback, mean stuttering frequency (that is, the number of stutterings per 300 syllable sample) for nine subjects speaking at a fast rate was higher than their stuttering frequency at a normal rate: 45.4 and 22.6 respectively. Although this difference was substantial, it did not reach statistical significance ($p = .072$). While the group trend was to increase stuttering frequency with an increase in articulatory rate, relative to the normal rate condition, one of the nine subjects stuttered less and one stuttered the same amount.

In conclusion, the relationship between increased articulatory rate and stuttering frequency remains unclear. The purpose of this study was, therefore, to further investigate the effect of increased articulatory rate on stuttering frequency in a relatively large sample of adult stutterers. It was hypothesized that if decreased stuttering at a slowed articulatory rate is a consequence of reduced timing complexity, stuttering should increase at a fast articulatory rate when timing complexity presumably increases. That is, stutterers should stutter more when asked to speak at an increased articulatory rate compared to their normal articulatory rate. If increases in stuttering frequency occur with increases in articulatory rate, an explanation of rate effects in terms of alterations in the temporal complexity of speech would be supported. On the other hand, if stutterers approximate the same stuttering frequency at an increased articulatory rate compared to their normal rate or stutter less, an alternative explanation of the relationship between articulatory rate and stuttering frequency is indicated.

Methods

Subjects

Twenty stutterers, 17 males and three females ranging in ages from 18 to 52 years (M = 32.0, SD = 8.6), served as subjects. All subjects reported a history of therapy although none had been enrolled in a program for at least two years.

Apparatus

All testing was conducted in a double-walled sound treated audiometric test suite (Industrial Acoustics Corporation). A microphone (AKG Model C460B), held with a boom on a stand, was positioned, at a distance of approximately 15 cm with an orientation of 330^0 azimuth and -30^0 altitude, from the subjects' mouth. The microphone output was fed to an audio mixer (Studiomaster Model Session Mix 8-2) and routed in series to a digital signal processor (Yamaha Model DSP-1), amplifier (Yamaha Model AX-630), and video stereo cassette recorder (Sony Model SL-HF860D). Subjects' speech samples were also video recorded with a camera (JVC Model S-62U) and the same video cassette recorder.

Procedure

While seated in the audiometric test suite, subjects read two different passages taken from two junior high school level texts (Sims, G. [1987]. *Explorers*, Creative Teaching Press Inc. and Taylor, C. [1985]. *Inventions*, Creative Teaching Press Inc.). Each passage was 300 syllables in length. Subjects were instructed to read one passage at a normal speech rate while the other at a fast speech rate. During the normal speech rate condition, subjects were asked to read at their "usual" or "normal" reading rate. For the fast speech rate condition, subjects were asked to read as fast as they possibly could while still maintaining intelligible speech. Speech rate conditions were counter balanced across subjects. Between passage readings, subjects read another passage backwards from the same text for approximately one to two minutes in order to minimize any possible carry-over effect of rate from one condition to the next.

The frequency of stuttering was determined from subjects' speech samples by a trained research assistant who was blind to the purpose of the study. Stuttering was defined as part-word repetitions, part-word prolongations, and/or inaudible postural fixations. Intrajudge agreement for 10% of the data, as indexed by Cohen's kappa (Cohen, 1960), for total dysfluencies was .93. A second trained research assistant, also blind to the purpose of the study, independently determined stuttering frequency for 10 % of the speech samples. Interjudge agreement for total dysfluencies, again indexed by Cohen's kappa, was .84.

Articulatory rate (in syllables per second) was examined by analyzing the analogue audio signals, from the audio/video recordings of each subject. Samples were digitized at a sampling rate of 10 kHz and edited with a customized software application (WENDY) from Haskins Laboratories. Sections of fluent speech were identified within passages such that the fluently produced syllables were contiguous and the entire fluent speech sample was separated from stuttering episodes by at least one syllable. The criterion for separation between fluent speech samples and stuttering episodes was adopted because it has been demonstrated that the duration of a fluently produced syllable is greater when it is adjacent to a stuttering episode than when it is adjacent to fluent speech (Viswanath, 1989). For the majority of subjects, fluent speech samples consisted of 50 contiguous fluently produced syllables. Identification of samples on the basis of multiple, contiguous fluent syllables was considered important in order to allow speakers to "get up to speed" following stuttering episodes. Fifty syllables was an upper limit for such a sample because of the large number of stutterings which occurred in many of the conditions. Unfortunately when stuttering frequency was very high, it was not always possible to find 50 fluent syllables which were contiguous. For 10 of the 40 samples, a smaller syllable count was accepted. However, in no case was fewer than 25 syllables used. Speech sample duration was measured from the time of acoustic onset of the first syllable to the acoustic offset of the last fluent syllable. Pauses that exceeded 100 ms were subtracted from speech sample duration measures.

Most pauses were between 300 and 800 ms and were typically used by the speakers for an inspiratory gesture. As most of the pauses had an audible inspiratory record, it was unlikely that these were silent stuttering moments. Articulatory rate (in syllables per second) was calculated by dividing the number of syllables in each fluent speech sample by its duration.

Results

Individual data with group means and standard deviations of stuttering frequency and articulatory rate values as a function of speech

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Insert Table 1 about here

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rate condition are presented in Table 1. The mean values for stuttering frequency were slightly higher in the fast rate condition than in the normal rate condition: 18.4 and 14.9 respectively. Three subjects in the normal speech rate condition and five subjects in the fast speech rate condition could not produce a sample of contiguous fluent syllables, and consequently means were calculated from the remaining available speech samples. Mean values for articulatory rate were 4.79 and 6.50 syllables/s in the normal and fast rate conditions.

As evident in Table 1, there was a large amount of individual variability in stuttering frequency between subjects, within each speech rate condition. As well, subjects displayed differential changes in stuttering frequency between speech rate conditions. For example, several subjects exhibited at least a three fold increase in the fast speech rate condition, relative to the normal speech rate condition, while another subject showed a reduction in stuttering frequency by half.

Differences in stuttering frequency and articulatory rate, as a function of speech rate condition, were examined with separate Wilcoxon matched pairs signed-ranks tests. A statistically nonsignificant difference was found for stuttering frequency ($Z = -1.39$, $p = .16$) while a significant difference was observed for articulatory rate ($Z = -3.41$, $p = .0007$). That is, there was no statistically significant change in stuttering frequency with an increase in articulatory rate. The statistically significant change in articulatory rate across conditions reflects that subjects, indeed, increased their speech rate as instructed.

Differences in stuttering frequency and articulatory rate, as a function of order of speech rate condition, were examined with separate Wilcoxon matched pairs signed-ranks tests. Statistically nonsignificant differences were found for stuttering frequency ($Z = 0.38$, $p = .74$) and articulatory rate ($Z = 0.34$ $p = .73$). That is, there were no statistically significant changes in stuttering frequency or articulatory rate as a function of order of speech rate condition.

Discussion

In this study the absolute difference between stuttering frequencies at normal and fast speech rates conditions was small and failed to reach statistical significance ($p > .05$). It is important to note that subjects exhibited substantial increases in articulatory rate across speech rate conditions: The group mean articulatory rate increased by approximately 35% in the fast rate condition relative to the normal rate condition. Furthermore, each individual subject increased articulatory rate in the fast rate condition relative to the normal rate condition. Thus, the finding of a minimal group difference in stuttering frequency between normal and fast rate conditions cannot be attributed to the subjects' failure to increase articulatory rate.

It is interesting to note that the present data differ somewhat from data reported by Kalinowski et al. (1993). In the latter study, mean stuttering frequency was found to be substantially greater in the fast speech rate condition than in the normal speech rate condition. Differences in subject selection criteria between these two studies may, at least in part, explain the discrepancy in results. In the previous study, subjects were selected for participation only if they exhibited a minimum stuttering frequency of 5% while reading, whereas in the present experiment no such criterion was used. As a result, a larger number of subjects with moderate to severe stuttering participated in the earlier study than in the present study. It is possible that moderate and severe stutterers are more likely to exhibit marked increases in stuttering in conjunction with increased speech rate than are mild stutterers. As well, it is important to point out that in both studies, subjects exhibited differential responses to increased articulatory rate: That is, stuttering frequency increased in some cases, decreased in a few cases, and remained essentially the same for the remainder.

The finding that not all stutterers exhibit increased stuttering frequency as a function of increased articulatory rate, can be contrasted with reports of essentially universal reduction in stuttering at slow speech rates across stutterers (see Andrews, Craig, Feyer, Hoddinott, & Neilson, 1983). The observation of invariant reduction in stuttering at slow speech rates has been interpreted by Perkins et al. (1991) to indicate that "... articulatory rate ... is a major determinant of stuttering" (p. 748). It appears, however, that increased articulatory rate does not determine stuttering frequency with the same consistency or power as does decreased articulatory rate. As such, a single explanation of the relationship between speech rate and stuttering frequency, in terms of speech timing complexity, is inadequate. Further, the finding that stutterers can increase speech rate and with it, timing complexity, without increasing stuttering frequency is contrary to the theory that stutterers have reduced capacity for speech movement coordination (Kent, 1984; Perkins et al., 1979).

The possibility should be considered that while fluency enhancement and reduced temporal demands of a slow articulatory rate co-occur, they may not be causally related. In order words, at slow rates, reduction of stuttering may be unrelated to a reduction in temporal demands for speech movements. Findings reported by Kalinowski et al. (1993) may support this notion. This study revealed that dramatic fluency enhancement can be achieved in the absence of a reduction of timing complexity (i.e., at a fast articulatory rate), suggesting that this variable is not necessary for fluency enhancement. Specifically, their subjects exhibited a marked reduction in stuttering frequency under delayed and frequency-altered auditory feedback at both normal and fast articulatory rates. In that experiment, auditory feedback, rather than speech rate, determined stuttering frequency. It may be the case that altered auditory feedback variables are critical to fluency enhancement generally. To illustrate, it may be noted that auditory feedback is altered when a speaker deliberately slows his articulatory rate. One may speculate, therefore, that the impact of a slowed rate on the auditory signal may be more important to fluency enhancement than the motoric changes per se. According to this line of reasoning, other changes in speech production characteristics other than slow rate may be fluency enhancing because of their alterations to the auditory signal (e.g., continuous phonation). Considering the above, one may entertain the notion that fluency enhancement occurs in the presence of altered auditory feedback which is either produced by speech motor changes or created artificially, as by external manipulation of the auditory feedback signal.

In summary, the finding that stuttering does not necessarily increase at fast articulatory rates is contrary to the notion that stutterers have reduced capacity for movement coordination and to the explanation of the fluency enhancement effect of slowed speech rate in terms of speech timing simplification. Future theories of the nature of stuttering will need to address this unexpected outcome. It is suggested that further exploration of variables associated with alterations in auditory feedback may ultimately lead to a unitary explanation for fluency enhancement.

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Author Notes

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Table 1

Stuttering frequency and articulatory rate as a function of speech rate condition .

Subject Number		Stuttering frequency Normal	Stuttering frequency Fast	Articulatory Rate[a] Normal	Articulatory Rate[a] Fast
1		26	26	*	*
2		4	14	4.76	7.31
3		2	3	5.15	5.86
4		2	0	5.64	5.77
5		9	7	5.15	6.91
6		6	4	3.75	6.06
7		11	6	4.70	6.74
8		5	3	5.00	8.16
9		0	5	5.05	7.32
10		7	24	3.40	*
11		70	96	*	*
12		3	7	5.11	6.51
13		2	3	5.09	6.42
14		18	24	5.32	6.32
15		7	24	4.77	6.59
16		6	8	4.73	6.02
17		47	55	4.61	*
18		35	22	*	*
19		8	9	4.69	5.95
20		30	27	4.54	5.56
	M	14.9	18.4	4.79	6.50
	SD	18.2	22.6	.54	.70

Note: [a] syllables/s; * subject could not produce a sample of contiguous fluent syllables