PHONETICS OF STUTTERING

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ABSTRACT

Articulatory and acoustic records of the speech of severe stutterers, mild stutterers, and nonstutterers were measured. Although severe stutterers spoke more slowly when fluent than other subjects, they did not significantly differ in the first few glottal pulses of voicing, their coordination of lip/jaw movements with vocal fold positioning for voicing, in kinematic relationships between displacement and velocity, nor in proportional segment durations as measured from sound spectrograms. Stuttered samples were aberrant in all measures, but the normal phasing of lip/jaw and vocal fold movements remained evident during tremors. Findings from this study fail to support a temporal motor deficit theory of stuttering.

INTRODUCTION

Since no one understands exactly what is happening when someone stutters, much less what originally caused it, theories of stuttering appear, disappear, and reappear with the passing of time. At times, the psycho-social aspects of stuttering are emphasized, at other times the biological motoric aspects of it are emphasized, and at times it is viewed primarily as learned behavior. Some theorists view stuttering as a problem in self perception (Harrington, 1987), while others view it as a deficient timing mechanism for speech (Van Riper, 1973; Perkins et al,1976; and Kent,1984). One view holds that stuttering is part of a continuum of fluency ranging from a high degree of fluency to the high degree of disfluency evident in the speech of severe stutterers (Starkweather, 1987). Another possible view is that normal disfluency and stuttering are discontinuous representing an abrupt change in speech mode.

What can we learn of these things by examining the phonetics of stuttering, the articulatory and acoustic correlates of speech ? A popular view of stuttering at the present time is that stutterers exhibit motor deficiencies of the speech production systems even when they are perceived to be fluent by listeners. Evidence to support the motor deficiency view includes slower speech rate, slower speech reaction times, and slower articulatory movements in the fluent speech of stutterers than in the speech of nonstutterers (See Bloodstein, 1983 and Starkweather, 1987 for reviews).

METHOD

We have collected and analyzed a large amount of data on severe stutterers, mild stutterers, and normal speakers performing a task of repeating numbers 4253 and 3425 until speech was fluent. Articulatory and acoustic analyses were performed. To perform the articulatory analysis, respiratory, laryngeal, and supralaryngeal (lip/jaw) movements were inferred from recordings made from a pneumograph, an electroglottograph, and an optical tracking system. Velocity changes were derived from the movement waveforms. The articulatory analysis included temporal measures, kinematic measures, and qualitative inspection of voice initiation indices. Temporal measures included speech rate, duration of movements, times from onset of movement to peak velocity of the movement and to voice onset, and cross-system (laryngeal-lip/jaw) intervals between corresponding onsets and peak velocities. Kinematic analysis involved plotting relative velocity by displacement measures. Qualitative inspection of electroglottographic waveforms of voice initiation was performed on both fluent and stuttered samples.

For the acoustic analysis, sound spectrograms were measured for voice onset time (VOT), duration of the stop-

gap, and duration of the vowel in the utterance ´two´ /tu/ in the context ´425´. Consonant/vowel ratios and stop-gap to VOT ratios were computed as well as the proportions of time taken within the mean total utterance duration for the stop-gap, VOT, and vowel segments.

RESULTS

Our results generally support a view of stuttering that goes against the currently popular notion of a motor timing deficit underlying even the fluent speech of stutterers. Our data suggest that although the speech motor system is vulnerable to breakdown, that breakdown is an abrupt change in the mode of speaking, discontinuous with the fluent speech of the same speaker. This is not to deny the presence of covert stuttering. We see evidence of stuttering in some samples perceived to be fluent.

When speakers are truly fluent, however, they do not significantly differ from nonstutterers on several critical articulatory dimensions:(1.) initiation of voicing as determined from analysis of the first few glottal pulses according to the EGG signal, (2.) coordination of lip/jaw movement with vocal fold positioning; for all subjects there is close coordination between lip/jaw opening and vocal fold adduction for the vowel, and (3.) relationship between the kinematic features of displacement and velocity (Figure 1); normally, increased displacement is correlaated with increased velocity. Further, there is no significant difference between groups for three acoustic characteristics: VOT, consonant to vowel ratios, and segment durations as a percentage of total utterances times. Although severe stutterers are slower than normal in speech rate and thus exhibit longer vowel and stop-gap durations, normal acoustic relationships among segments are maintained (Figure 2)

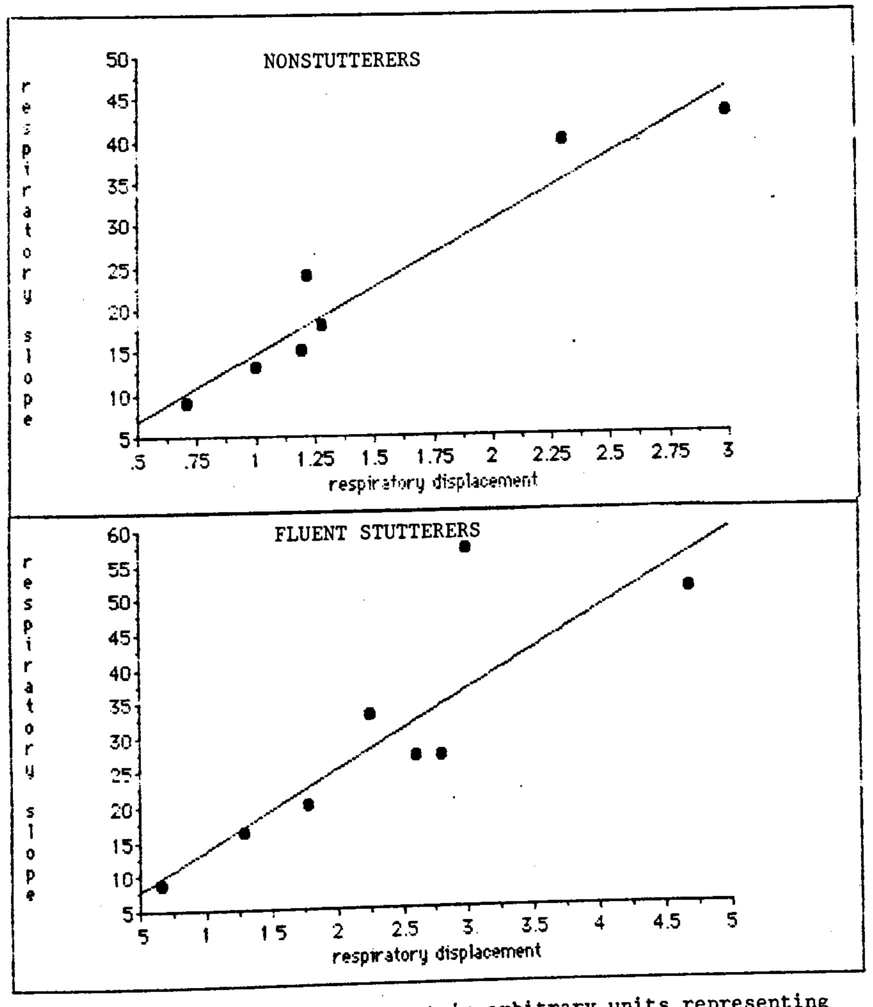

Figure 1. Peak to peak displacement in arbitrary units representing exhalation are plotted according to slope. Stutterers like nonstutterers exhibit steeper slopes for larger displacements.

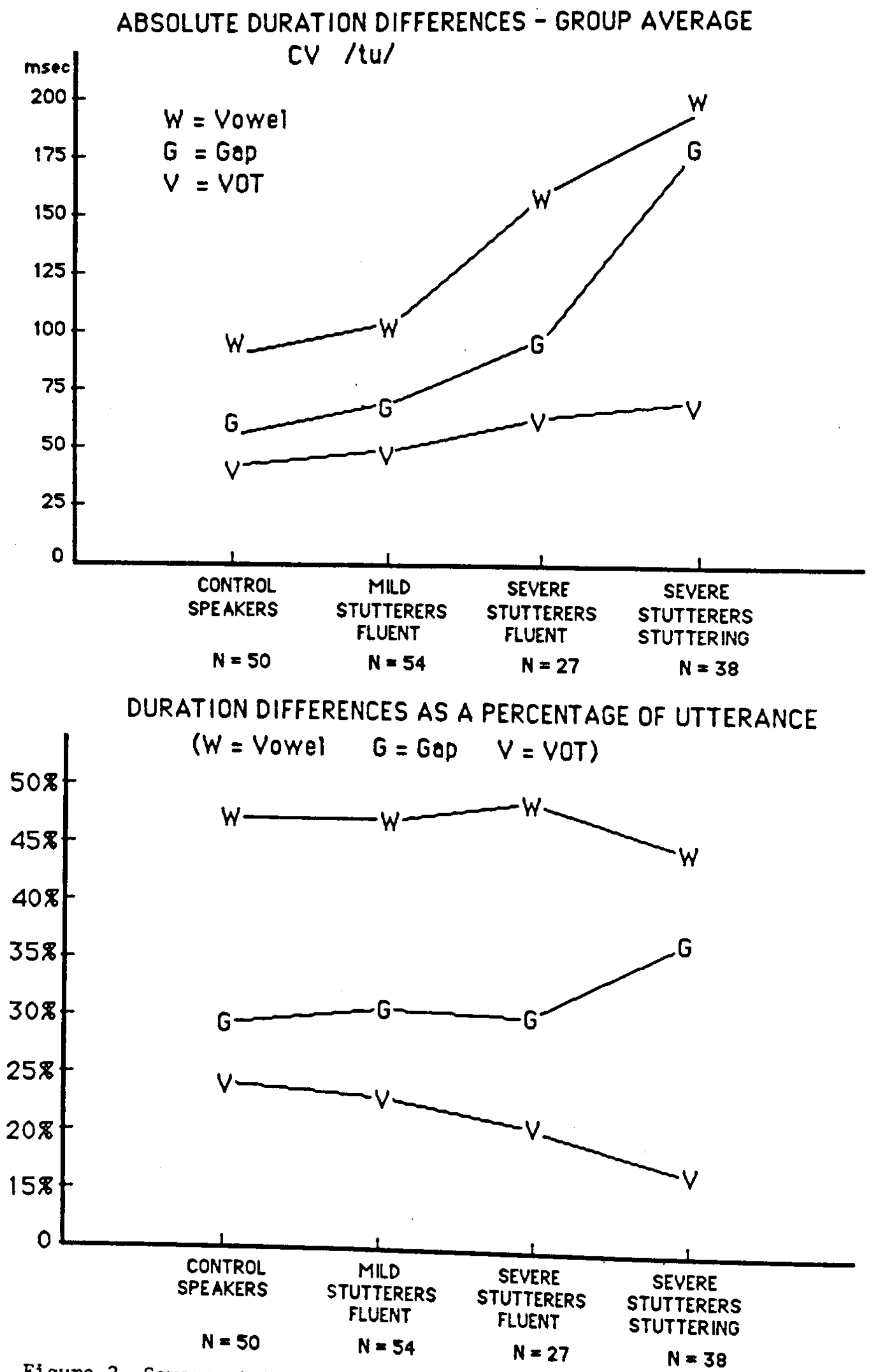

Figure 2. Severe stutterers were significantly slower for the stop-gap and vowel segments than nonstutterers. Proportionally, there was no difference.

There are some significant differences between the fluent utterances of the severe stutterers and those of the nonstutterers. All of the articulatory and acoustic measures that significantly differ from normal are positively correlated with speech rate. Severe stutterers, unlike the mild stutterers, are slower in speech rate than the nonstutterers. The slower rate is reflected in certain articulatory measures: longer times between onset of exhalation and voice onset, between lip/jaw opening for the vowel and voice onset, and in the duration of lip/jaw opening for the utterance ´five´. Slower rate for the severe stutterers is also reflected in certain acoustic measures: significantly longer stop-gap durations and vowel durations.

We were impressed, however, with the evidence that despite the slowed speech of some stutterers, their fluent speech maintains its proportional relationships in the acoustic signal and preserves the coordination between the movements of the lip/jaw system and the positioning of the vocal folds for voicing.

For stuttered samples, of course, all indices, temporal, kinematic, EGG traces during voice initiation, and spectrographic measures are highly aberrant. The kinematic relationships between displacement and velocity changed during stuttering tremors with higher velocities per unit of displacement (indicating a stiffer system) than for fluent samples. Voice initiation according to EGG patterns reveal an abnormally gradual rise in amplitude to effect continued vibration upon release of a stuttering block. Other qualitative differences between stuttered and fluent samples were that whereas fluent voicing gives evidence of a relatively stable open phase and more gradual opening, voicing upon release of a stuttering episode reveals a sharper opening and a brief, less stable open phase. This may indicate a stiffer than normal system. Highly ritualized patterns used to break the blocks were observed. An indication of the cross-system coordination that can occur during the most ´uncoordinated´ moments of stuttering, two severe stutterers who demonstrate simultaneous and phase related tremors of the lip/jaw system and of the vocal folds also show that throughout the tremors, the lip/jaw opening phase of the tremor is coordinated with the vocal fold adductory phase of the laryngeal tremor. These actions are appropriate for vowel initiation, although voicing failed to occur or was aborted upon each trial (Borden et al,1985). Finally, spectrographic measures of stuttered samples show significantly longer stop-gap durations, vowel durations, and voice onset times (VOT) than normal (especially when the block occurred upon the release of the stop).

When we inspected data for evidence of continuity between the initial disfluent utterances and the fluent utterances across the 10 or more repetitions, we found instead evidence of discontinuity, a step function that separated fluent from disfluent samples. Nor did we find a fluency continuum going from normal speakers to mild stutterers to severe stutterers. Rather, the mild stutterers, when fluent, were indistinguishable from normal, while the severe stutterers, when fluent, were notably slower in their speech, although they preserved proportionally normal acoustic segments and normal articulatory coordination across speech motor systems.

DISCUSSION

These findings may not generalize to all stutterers; they await further data for verification. The significantly slower rate that we found for severe stutterers, as well as the articulatory and acoustic indices found to be correlated with the slow rate might be interpreted by some theorists to support the idea of a temporal motor deficit that is hard-wired into the speech motor system or possibly a fault in the temporal programming of the systems. The evidence, however, of normalized acoustic relationships in the speech and of normal articulatory patterns, especially the high degree of lip/jaw coordination with the larynx force us to reject a temporal motor deficit explanation. The slower speech of the severe stutterers may simply reflect a technique acquired for avoiding increased tension in the speech mechanisms. The problem may not lie in timing mechanisms but in the tension settings of the muscles. During the fluent speaking mode, the settings may be appropriate, but during stuttering episodes, the settings may be out of balance across muscle groups cooperating for a certain function. Especially vulnerable to disruption are the settings required to position and tense the vocal folds appropriately for voicing.

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