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THE ORGANIZATION OF SUPRALARYNGEAL ARTICULATION IN STUTTERERS' FLUENT SPEECH PRODUCTION:

A preliminary report

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INTRODUCTION

This paper represents our preliminary report of one of a series of experiments that centered upon the use of the x-ray microbeam pellet-tracking system. The data we report here are taken from our experiments that examine the spatial and temporal coordination among the respiratory, laryngeal, and supralaryngeal systems during stutterers' fluent speech. We ask whether any or all of the kinematic patterns associated with stutterers' perceptually fluent speech are similar to comparable kinematic patterns observed in the fluent speech of normal talkers. The answer to this question is important because it would tell us if the stutterers' speech motor system is generally disposed to spatiotemporal deficits regardless of the percept, or whether the system fails only during moments of observable stuttering.

METHODS

We used the x-ray microbeam pellet-tracking system to monitor the movements of the jaw, lips, tongue blade, and velum. Lead pellets, approximately 2.5 mm in diameter, were attached to each of the articulators. Because of their small size and mass the pellets do not seem to impede normal articulation. We used a Respitrace inductance plethysmograph to monitor movements of the thorax and abdomen, and a Synchrovoice electroglottograph to infer movements of the vocal folds. Three adult Japanese males served as subjects. One was a severe stutterer, one was a mild-moderate stutterer, and the third served as the control subject. Subjects were required to produce nonsense syllables, for example /etete/, when cued by response signals. We are not primarily concerned with reaction-time latencies in the present experiment. Rather, we use the paradigm as a convenient way to measure relative displacement and appropriate peak velocity relationships derived from a quantifiable starting position.

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The procedures we used for the experiment we report here are as follows. When the computer-derived display indicated that the system had captured the location of all the pellets, we instructed subjects to begin inhalation. The first response cue was presented at random intervals after inhalation onset. The subject task was to produce the vowel /e/ as quickly as possible and to sustain vowel production until the presentation of the second response cue. At that time, the subject was required to produce /pepe/, /tete/, /sese/, or /nene/ as quickly as possible. Primary stress was always on the first syllable. The interval between the first and second response cues was either 500, 1000, or 2000 ms and varied systematically. Subjects produced about 12 repetitions of each of the four nonsense syllables.

RESULTS

Fig. 1 shows one sequence of events produced by the normal subject. The top record shows the response signal. The onset of a 1 KHz pure tone served as the first response cue, the offset as the second. Records 2 thru 4 represent vertical displacement of the tongue blade, lower lip, and jaw respectively and were obtained by x-ray microbeam pellet-tracking. The jaw trajectory has been subtracted from the tongue and lip trajectories. The fifth record represents the electroglottograph signal. Upward and downward displacement of this signal corresponds to decreasing and increasing vocal fold contact, respectively. The sixth and seventh records show thoracic and abdominal displacements. Expansion is upward, compression is downward. The bottom record shows the acoustic response.

Analysis of articulator movements following the first response cue allow us to extend our reaction-time experiments (Watson and Alfonso, 1982, 1983, 1985, in preparation) where we examined respiratory and laryngeal prephonatory and phonatory movements, in parallel with the acoustic response, in isolated vowel responses. We found that severe stutterers differed from normal subjects in the organization and timing of prephonatory respiratory and laryngeal movements, regardless of the duration of the preparatory interval. For cases where all subjects used a soft mode of vocal attack, vocal fold adduction usually lagged respiration compression in severe stutterers. Normal subjects initiated these movements faster and nearly simultaneously when compared to severe stutterers. Mild stutterers differed from normal subjects only in the temporal onsets of respiratory and laryngeal movements: At preparatory intervals beyond 700 ms, mild stutterers' vowel responses approached normal latency values. Fig. 1 demonstrates that we can extend our analysis of respiratory and laryngeal coordination in isolated vowel responses by including upper articulator movements. Our initial impression of the data we have analyzed thus far is that the one severe stutterer used in the present experiment initiates respiratory compression before laryngeal adduction as did the severe stutterers from our previous work.

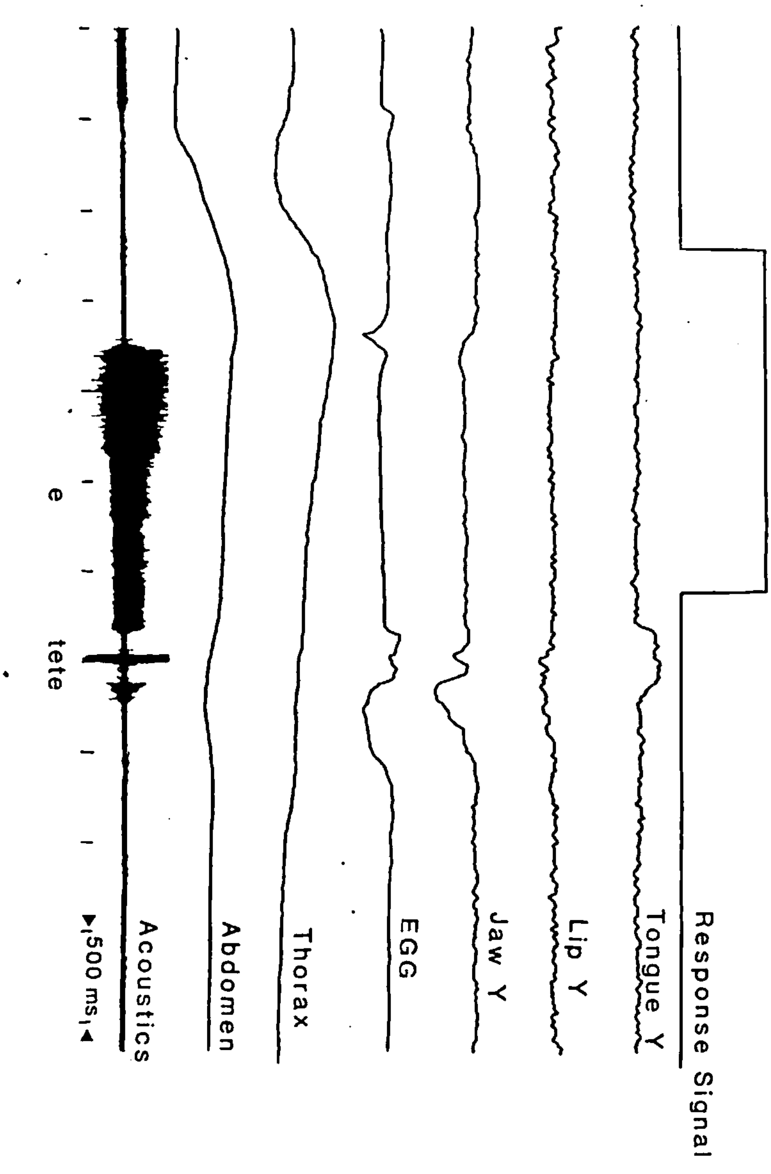

Fig. 1 Normal subject's production of /etete/ in the nonsense syllable condition. A description of the data channels is given in the text.

We now turn our attention to articulator movements following the second response cue. We are presently analyzing the patterns of relative displacement and peak velocity for the lip, tongue, and jaw closing gesture of the initial stop. With respect to onset latency measures, our preliminary analysis indicates that the normal subject's data show a more linear and less variable relationship between relative displacement onsets and peak velocity onsets than do the corresponding data for the fluent utterances of the severe stutterer. For the normal subject, peak velocity occurred later as articulator displacement began earlier, and displacement onset occurred earlier as displacement amplitude increased. We need to expand our analysis before we can say whether this trend significantly distinguishes the severe stutterer from the normal subject.

On the other hand, figures 2 thru 5 demonstrate clear and consistent kinematic differences between the fluent utterances of the severe stutterer and the control subject. For all of the figures, the ordinate represents peak velocity in mm/s and the abscissa represents displacement amplitude in mm. Fig. 2 shows the relationship between these two parameters for closing gestures of the initial /t/ in /etete/ produced by the normal subject. The symbols L, T, and J represent individual token values for lip, tongue and jaw movements respectively. For example, the figure shows five tokens where we measured lip displacement and derived velocity, and 10 tokens where we measured the same parameters for tongue and jaw movements. For the sake of clarity, we have enclosed the data points for each articulator within an ellipse. Note first that, in general, the same relationship between displacement amplitude and peak velocity that is reported for limb movements, including lip and jaw movements (Kelso, Vatikiotis-Bateson, Saltzman, and Kay, 1985) holds for these data. That is, peak velocity increases as the amplitude of the displacement increases. Note also, that the range of displacement amplitudes for each of the articulators is distinct from each other. That is, for the most part, the ellipses are non-overlapping.

Fig. 3 shows displacement amplitude versus peak velocity for the stutterer's fluent productions of the same phonetic utterance shown in Fig. 2. Note first that, in general, the linear relationship between displacement amplitude and velocity is present in the stutterers' data, though perhaps not as clearly as in the nonstutterer's data. As is the case for relative displacement and peak velocity onset latencies, we have not analyzed sufficient data to say conclusively whether the relationship between amplitude and velocity distinguishes the stutterer from the nonstutterer. However, a comparison of Figs. 2 and 3 show that the range of vertical displacement for each of the articulators is greater for the stutterer than for the nonstutterer. Furthermore, note that the ellipses overlap. That is, the stutterer's organization of the closing gesture is such that the relatively wide range of displacement amplitude for a single articulator falls within the displacement ranges for other articulators. We need to complete a token-by-token analysis of these data before we can say whether the relative contributions of the jaw and tongue in achieving /t/ closure are different for the stutterer when compared to the nonstutterer.

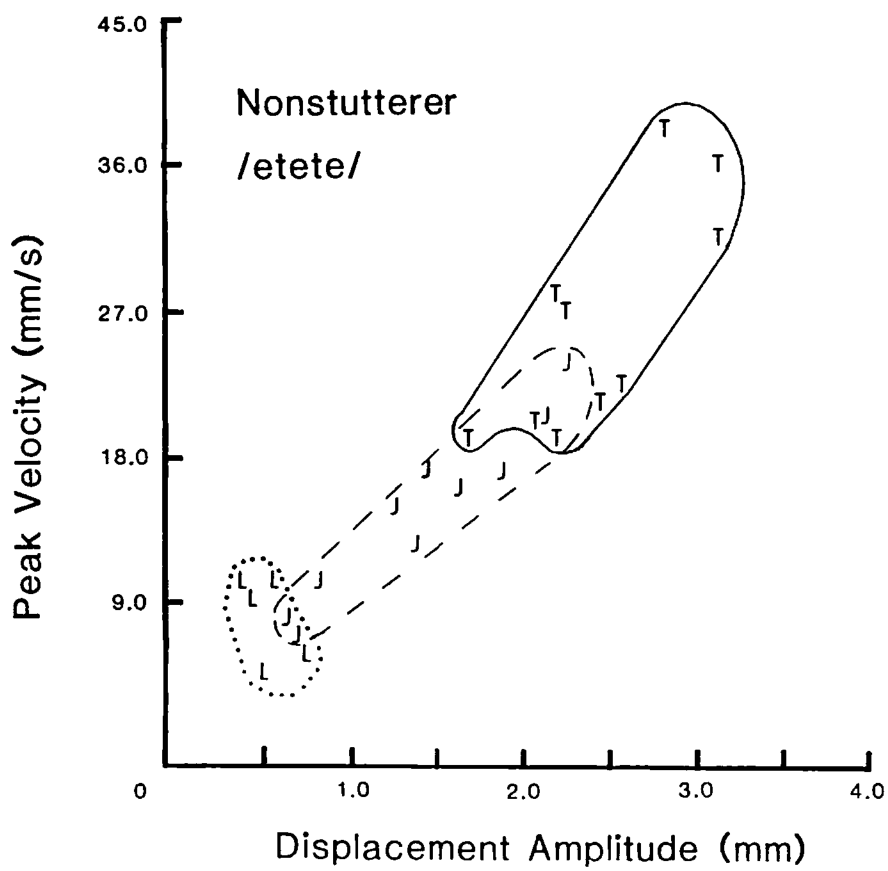

Fig. 2 Displacement amplitude-peak velocity plot for the initial /t/ closing gesture in the nonstutterer's productions of /etete/.

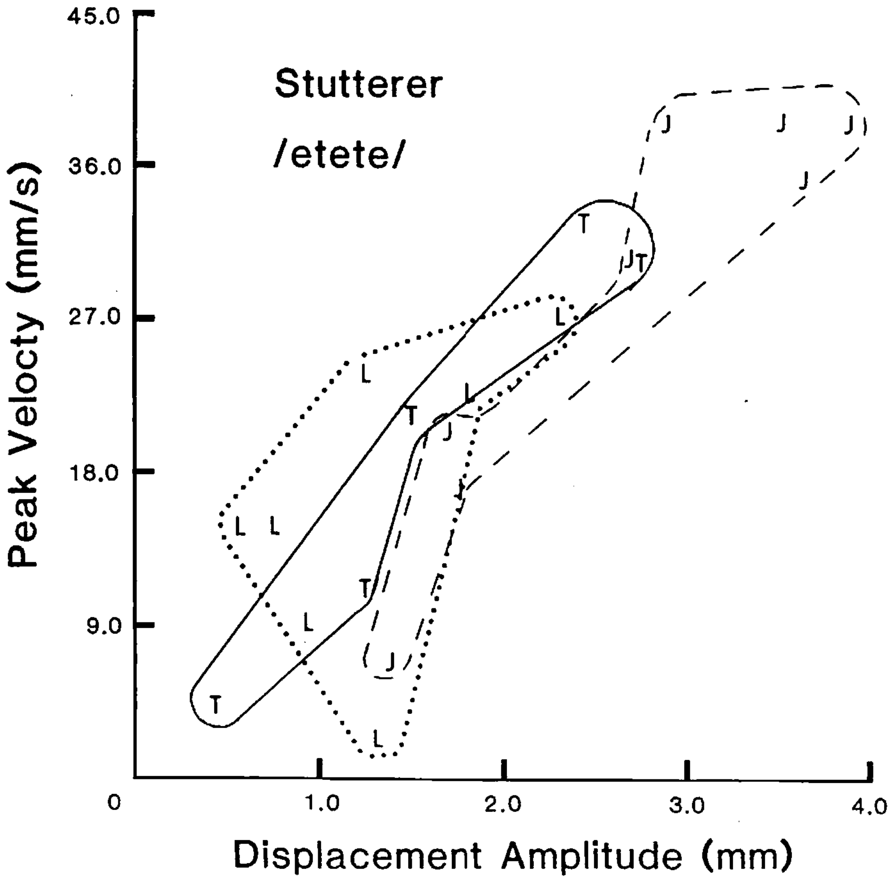

Fig. 3 Displacement amplitude-peak velocity plot for the initial /t/ closing gesture in the stutterer's fluent productions of /etete/.

Fig. 4 shows the same kinematic parameters for the nonstutterer's initial /s/ closing gesture in /esese/. In general, the displacement-velocity relationship for /s/ appears similar to that shown for /t/ in Fig. 2. Note also that the ellipses surrounding the data points for each of the articulators are, once again, non-overlapping. This observation holds even though the tongue-jaw synergy is different for /s/ closure than for /t/ closure. For /s/, the normal subject uses greater jaw elevation and less tongue elevation to achieve the target position. On the other hand, he uses greater tongue elevation than jaw elevation for /t/ closure. We assume that this reversal reflects the tongue's greater contribution to shape than to elevation for /s/ than for /t/, and that the jaw compensates for the decrease in tongue elevation for /s/. The non-overlap in individual articulator regions, in view of the jaw-tongue trading relationship for /s/ and /t/, makes the comparison with the stutterer's data even more interesting.

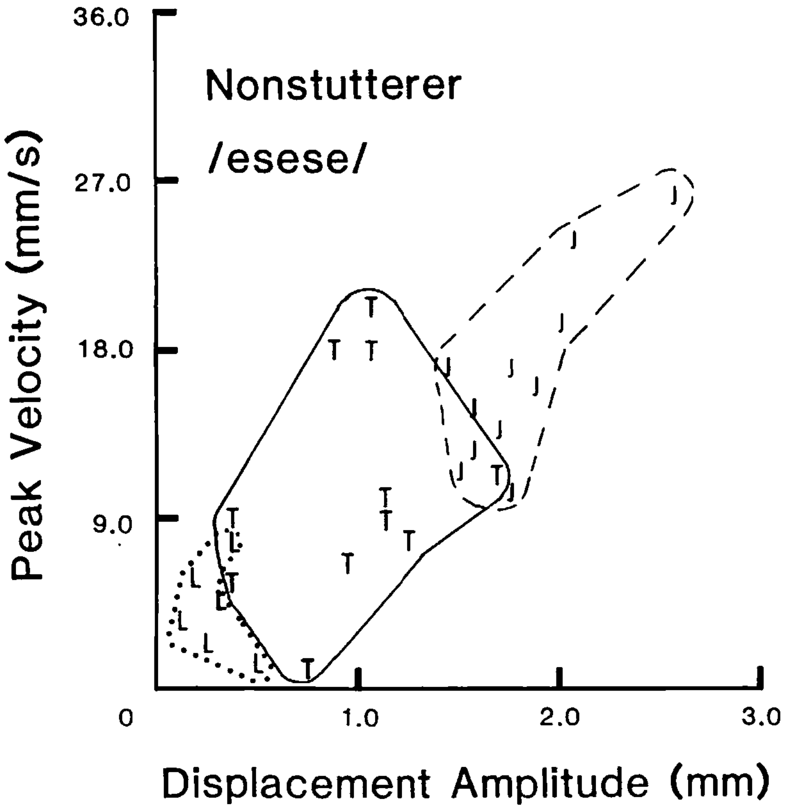

Fig. 4 Displacement amplitude-peak velocity plot for the initial /s/ closing gesture in the nonstutterer's productions of /esese/.

Fig. 5 shows the stutterer's data for fluent productions of /esese/. As was shown in the comparison between Figs. 2 and 3, the range of displacement amplitude for each of the articulators shown in Fig. 5 is greater than that shown for the nonstutterer's data in Fig. 4. Furthermore, a comparison of Figs. 4 and 5 show that whereas the nonstutterer produces repeated gestures of the same type with non-overlapping articulator displacement ranges, the stutterer does not. Rather, the stutterer achieves the same acoustic target with a greater range of articulator movements. Thus, he consistently produces the appropriate perceptual end, but does so with articulatory variability greater than that of the nonstutterer.

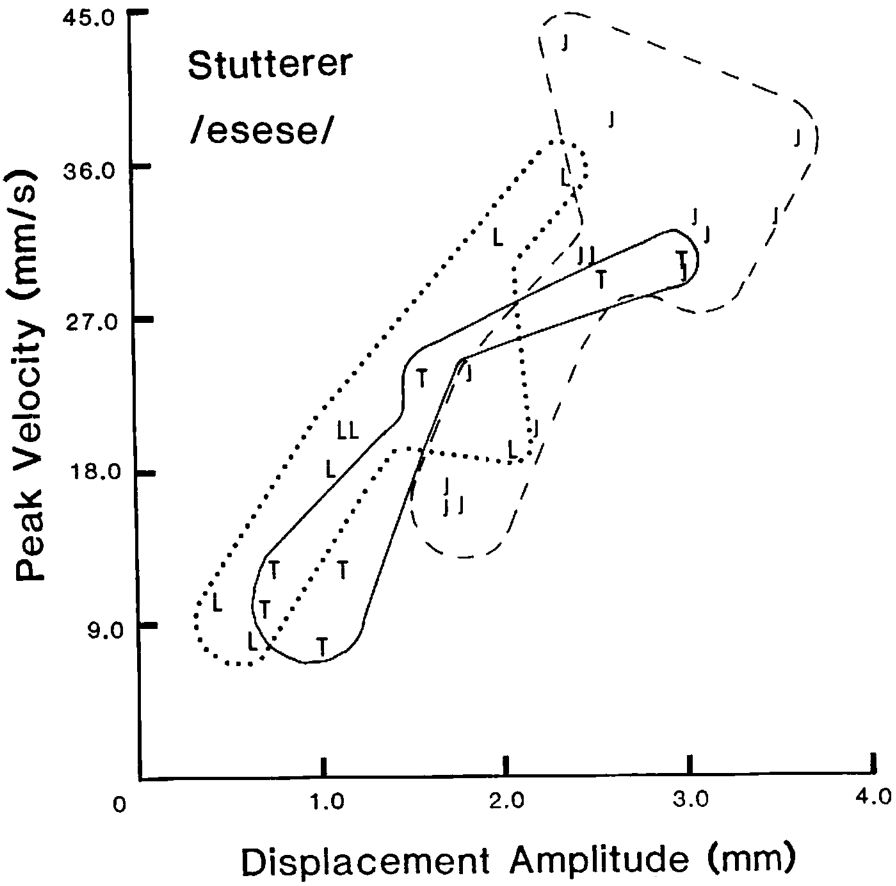

Fig. 5 Displacement amplitude-peak velocity plot for the initial /s/ closing gesture in the stutterer's fluent productions of /esese/.

SUMMARY

We must emphasize that the data we present here are preliminary in that they are based on few observations taken from two subjects. We need to run additional stutterers and control subjects. Nevertheless, the differences between the two subjects with respect to the organization of relative articulator displacement for repeated fluent productions of the same phonetic context are striking and most interesting. In fact, when one considers the constraints imposed by the experimental paradigm, and that the utterances are perceptually fluent, it is interesting that we find any differences at all. We are anxious to increase our data base and apply a task dynamic model of speech production (Saltzman and Kelso, 1983) in our analyses. We cannot discuss the model in detail here. Very briefly, we plan to test our preliminary finding that the similarities between the two subjects with respect to their displacement amplitude and peak velocity ratios indicate that the dynamic parameters that govern the biomechanical properties of articulator movements are non-distinct between normal subjects and stutterers during perceptually fluent speech production. On the other hand, the relative patterns of articulator displacement for repeated /t/ and /s/ closure gestures show less variability in the way the nonstutterer achieves closure when compared to the way the stutterer achieves closure. In fact, the increased variability, or alternatively the greater amount of flexibility, is so great in the stutterer's data that we cannot observe the trading relationship between jaw and tongue elevation for /t/ versus /s/ closure. We plan to test the notion that the subject differences we observe with respect to the overlap in the ellipses surrounding the regions of articulator displacement amplitudes indicate that nonstutterers' organization of articulator movement is more tightly controlled than stutterers. Our underlying assumption is that a well organized speech motor system would show (1) low overall system variability for repeated gestures of the same type, and (2) low system component variability, the lips, jaw, and tongue here, in achieving each of their gestures. Thus, we will test the notion that the high degree of component, and perhaps system, variability that we observe in our preliminary analysis of the stutterer's data indicates that stutterers' fluent speech, in terms of lip, tongue, and jaw relationships, is less well organized than nonstutterers' fluent speech.

If additional analyses support our preliminary observations, then those theories of stuttering that postulate an etiology at a higher cortical planning and organizational stage, rather than a lower neuromotor execution stage, would be upheld. In particular, if our preliminary observations are supported, then the notion that dysfluent speech is characterized by a "lack of anticipatory coarticulation" (Stromsta and Fibiger, 1980) could be extended in some related form to stutterers' fluent speech. That is, stutterers' poorly organized articulatory patterns could result in coarticulation gestures that are different, more variable, and perhaps less efficient than those observed in normal speech production. Such data would support the notion that the organization of speech related movements by stutterers is always different than that of normal subjects regardless of the perceived fluency of the acoustic output.

REFERENCES

Baer, T. and Alfonso, P. J. (1984); On simultaneous neuromuscular, movement, and acoustic measures of speech articulation. In R. G. Daniloff (Ed.) Articulation Assessment and Treatment Issues. (pp. 195-214). San Diego: College Hill Press.

Borden, G. I. and Watson, B. C. (1985); Methodological aspects of simultaneous measurements: Limitations and possibilities. Proceedings of the International Conference on Speech Motor Dynamics in Stuttering, Nijmegen, The Netherlands (in press).

Kelso, J. A. S., Vatikiotis-Bateson, E., Saltzman, E. and Kay, B. (1985); A qualitative analysis of reiterant speech production: Phase portraits, kinematics, and dynamic modeling. Journal of the Acoustical Society of America, 77, 1, 266-280.

Saltzman, E. and Kelso, J. A. S.(1983); Skilled actions: A task dynamic approach. Haskins Laboratories Status Reports on Speech Research, SR-76, 3-50.

Stromsta, C. and Fibiger, S. (1980); Physiological correlates of the core behavior of stuttering. Paper presented at the 18th Congress of the International Association of Logopedics and Phoniatrics, Washington, D.C.

Watson, B. C. and Alfonso, P. J. (1982); A comparison of LRT and VOT values between stutterers and nonstutterers. Journal of Fluency Disorders, 7, 219-241.

Watson, B. C. and Alfonso, P. J. (1983); Foreperiod and stuttering severity effects on acoustic laryngeal reaction time. Journal of Fluency Disorders, 8, 183-205.

Watson, B. C. and Alfonso, P. J.(1985); Coordination of prephonatory events in mild and severe stutterers. Proceedings of the International Conference on Speech Motor Dynamics in Stuttering, Nijmegen, The Netherlands (in press).

Watson, B. C. and Alfonso, P. J.; Physiological bases of LRT in nonstutterers, mild stutterers, and severe stutterers. (in preparation).