MODIFICATIONS TO STUTTERERS' RESPIRATORY, LARYNGEAL, AND SUPRALARYNGEAL KINEMATICS FOLLOWING SUCCESSFUL FLUENCY THERAPY

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ABSTRACT

Within-subject comparisons of respiratory, laryngeal, and supralaryngeal kinematics of severe stutterers immediately before and after successful completion of intensive fluency therapy reveal that an increase in post-therapy fluency co-occurs with a number of spatial and temporal modifications within and among each of the three monitored speech systems. Some of the post-therapy modifications can be distinguished from therapy-directed clinical targets and are presumed to be natural requisites to perceptually fluent speech.

1. INTRODUCTION

It is well known that stutterers' respiratory, laryngeal, and supralaryngeal movements during moments of overt stuttering are radically different from those observed in normally fluent speakers. However, it is not clear whether stutterers' control of the speech mechanism is generally abnormal; that is, abnormal even during production of speech that is perceived as fluent. Clarification of this issue would have important clinical ramifications. Thus, we have undertaken a research program that seeks to resolve the following three questions: 1) are certain kinematic profiles associated with stutterers' perceptually fluent speech distinct from those of normally fluent speakers, and if they are different, 2) which aberrant kinematic profiles, if any, can be modified by speech therapy to become more like those of normally fluent speakers? In addition, 3) we seek to determine which post-therapy kinematic modifications are requisite to perceptual fluency. We report here the results of experiments that focus on the third aim of this research program. The results demonstrate that not all of the kinematic modifications that are observed post-therapy are reflective of clinical instruction but rather are reflective of certain speech motor control strategies that are observed in normally fluent subjects.

2. PROCEDURES

Within-subject pre- and post-therapy kinematic comparisons of the respiratory system (using Respitrace inductive plethysmography), laryngeal system (using photoglottography), and supralaryngeal system (using optoelectric tracking to monitor the movements of the lips and jaw) were made from eight stutterers immediately before and after completion of either one of two intensive fluency programs, and from four control subjects. Program 1, the Summer Residential Stuttering Clinic of Geneseo, New York, represents a Van Riperian type of program that primarily emphases speech rate control, and Program 2, the Communication Reconstruction Center's (CRC) of New York City version of the Precision Shaping Fluency Program (PFSP), represents a highly structured physiologically oriented program. The comparisons across different therapy programs are primarily motivated by our attempts to differentiate therapy induced kinematic modifications from kinematic modifications that are requisite to stutterers' increase in fluency. For example, kinematic modifications that occur in Program 2 subjects who show post-therapy increased fluency but not in equally successful Program 1 subjects could be considered requisite to the achievement of Program 2 clinical targets but not necessarily requisite to increased fluency. On the other hand, a kinematic modification that occurs in all successful subjects, including those who completed Program 1, which does not emphasize physiological clinical targets, could be considered a physiological requisite to increased fluency. All stutterers who took part in these experiments were diagnosed as severe or moderate pre-therapy and as mild post-therapy. Kinematic measurements included traditional motor control indices, e.g. sequential ordering of articulator movements, and those that more directly address the achievement of the various clinical targets. Two paradigms were used: a variable-foreperiod simple reaction-time (RT) task and a paradigm that assesses relatively natural speech, the production of the phrase "he see CVC again" where "C" represents various stops and fricatives and "V" represents /i,e/. Only fluent utterances, defined perceptually and physiologically, are discussed here.

3. RESULTS

3.1. Respiratory-Laryngeal Kinematics in Reaction-Time Tasks

In a related reaction-time study, we showed that quantitatively different respiratory and laryngeal behaviors underlie stuttering severity and variable-foreperiod (response preparatory interval) effects on acoustic RT. Severe stutterers showed both delayed initiation and inappropriate organization of respiratory and laryngeal events leading to phonation at all foreperiods, while mild stutterers differed from severe stutterers primarily at short but not long foreperiods [6,7]. In our first experiment that compares within-subject pre- and post-therapy acoustic RT performance, we found that post-therapy increase in fluency covaries with acoustic RT improvement for both Program 1 and 2 subjects, that the magnitude of acoustic RT improvement depends on therapy program type and for some subjects approaches normal values, and suggests that acoustic RT represents a dynamic measure of respiratory-phonatory function rather than a fixed and presumably neurologically based delayed latency [1]. We continue to use the same variable-foreperiod RT protocols to evaluate the effects of therapy on respiratory-laryngeal kinematics in stutterers because we have found that an isolated vowel response in the RT paradigm represents a relatively easy stimulus for stutterers to produce fluently, presumably because an isolated vowel is less physiologically complex compared to reiterate speech, and because the protocol provides a large number of perceptually fluent responses in a relatively short amount of time. Equally important, the wide variety of respiratory-laryngeal kinematic patterns exhibited by stutterers in reiterate contexts makes analysis of respiratory-laryngeal control strategies much more straightforward in RT tasks. However, important subject differences in post-therapy respiratory-laryngeal pre-phonatory strategies are still evident, some of which cannot be explained in terms of achievement of therapy-directed clinical target behaviors. For example, the RT data shown in Figure 1 demonstrate that this Program 1 stutterer reduces post-therapy phonation response latency primarily by reducing the time, relative to pre-therapy performance, required to complete respiratory and laryngeal pre-phonatory maneuvers, e.g., appropriate levels of respiratory inflation and preparatory vocal fold adjustment for phonation. On the other hand, Figure 2 shows that a different Program 1 stutterer reduces post-therapy phonation latency primarily by improvement in respiratory-laryngeal temporal coordination, e.g., the moment of onset of respiratory compression relative to laryngeal adduction for phonation.Taken together, the results indicate that stutterers who increase fluency following therapy generally demonstrate RT improvement at acoustic, respiratory, and laryngeal levels of measurement. However, the differences in response strategies among stutterers indicate that the the physiological bases for the covariation between acoustic RT improvement and perceptual fluency improvement are complex and are not entirely related to clinical target behaviors. For example, respiratory-laryngeal temporal coordination may make a greater contribution to improved acoustic RT than either respiratory RT or laryngeal RT in those stutterers who demonstrate either: 1) relatively short pre-therapy response latencies, and/or 2) appropriate levels of lung volume inflation for speech, and/or 3) appropriate laryngeal abductory/adductory gestures for normal phonation.

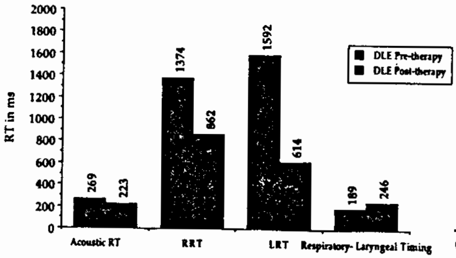

Fig. 1. Pre- (left bar) and post-therapy RT values (right bar), subject DLE.

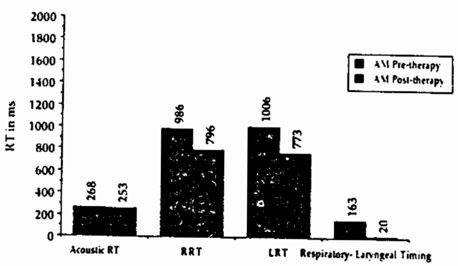

Fig. 2. Pre- (left bar) and post-therapy RT values (right bar), subject AM.

3.2. Supralaryngeal Kinematics in Phrase Length Utterances

In more natural speech tasks, post-therapy increase in fluency co-occurs with kinematic modifications at all measured levels of speech production. Some of these modifications appear to be related to specific therapy-directed clinical targets while others do not and appear to be related to motor control strategies observed in normally fluent subjects. For example, Figure 3 shows an example of stuttering severity and therapy influences on lip and jaw relative timing and sequence patterns during /p/ closure for perceptually fluent productions of /pit/ in "he see pete again" [5]. The data for two controls, shown on the left, represent two different sessions about six weeks apart and are consistent with the results obtained from a larger group of control subjects [3], with respect to both inter-articulator relative-timing and sequence patterns. The stutterers' data, shown on the right, are quite different. Recall that these stutterers were classified as severe pre-therapy and mild post-therapy. Considering inter-articulator latencies first, note that pre-therapy latencies for stutterer AB (specifically lower lip lag of the upper lip) and for stutterer PC (specifically jaw and upper lip lag of lower lip) are much greater than the corresponding control subject latencies. For both of these subjects, post-therapy latencies are significantly reduced relative to their pre-therapy latencies, even though their post-therapy speech rate was significantly reduced compared to their pre-therapy rate. Turning next to sequential order, note that two of the stutterers, KH and PC, do not show the expected upper lip, lower lip, and jaw sequence in either the pre- or post-treatment condition. Also note that for stutterer KH, the pre- and post-treatment comparison shows a complete sequence reversal. Similar results were obtained for /pet, fit, and fet/ and indicate that post-therapy increased fluent speech can be marked by improved inter-articulator relative-timing and, less frequently, by alteration of the sequence patterns, although the altered sequence may not be like that of the controls. The lip and jaw sequence pattern observed in normally fluent speakers most likely is related to neural and biomechanical interactions [2] and thus reflects differences in both neural control and biomechanical processes between stutterers and controls.

4. DISCUSSION

In conclusion, the results we have obtained thus far suggest that post-therapy increase in fluency co-occurs with spatial and temporal adjustments of the respiratory, laryngeal, and supralaryngeal systems. For example, we have observed 1) an increase in inspiratory and expiratory lung volume exchange,

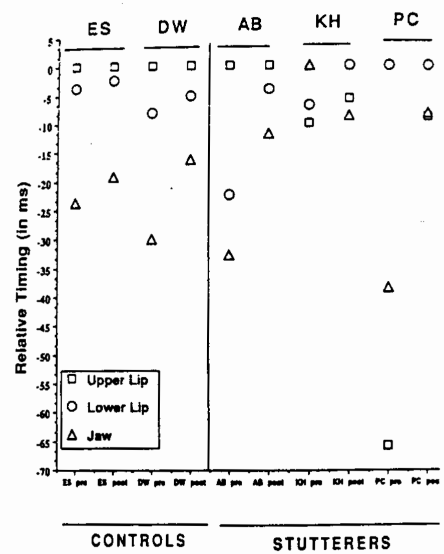

Fig. 3. Temporal organization of upper lip, lower lip, and jaw. Controls left, stutterers right.

duration, and flow, all of which approach values exhibited by normally fluent subjects during phrase length utterances, 2) an increase in the duration of laryngeal abduction and adduction gestures although speech rate decreases post-therapy, 3) a reduction in the frequency of inaudible and phase-locked respiratory-laryngeal kinematic abnormalities, and 4) a reduction in the displacement, peak velocity, and duration of lip and jaw movements in target obstruent-vowel sequences. In addition, certain intra- and inter-system spatial and temporal coordinative adjustments co-occur with post-therapy increase in fluency. Some of the kinematic modifications we observe appear related to the clinical strategies associated with specific therapy programs while others do not. The latter modifications may be manifestations of post-therapy adoptions of certain normal motor control strategies that are requisite to fluent speech production. Our plan is to compare the kinematic modifications of stutterers who successfully complete a variety of different therapy programs, the notion being that the most important modifications leading to fluency will be shared by all successful stutterers even though the clinical instructions to the different groups can differ. In this way, we hope to identify those kinematic strategies that are requisite to the production of perceptually fluent speech.

5. ACKNOWLEDGEMENT

This research is supported by NIH Grant DC-00121. The manuscript was prepared during the first author's tenure as Fulbright Research Scholar, The University of Nijmegen.

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