TRACT SHAPES OF TENSE AND LAX VOWELS: A COMPARISON OF X-RAY MICROBEAM AND EMG DATA

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ABSTRACT

X-Ray microbeam data for simple /əpVp/ utterances for a single speaker were compared with EMG measures from muscles of the tongue and jaw. For the six vowels /i, ɪ, ɛ, æ, ʊ, u/ pellet displacements at vowel center were roughly proportional for front tongue X and Y pellets and a rear X pellet. The rear Y pellet showed somewhat different relationships among the vowels. The relationships between several of the pellet displacements and normalized EMG appeared to be monotonic.

1. INTRODUCTION

Although there is a tradition of classifying the tongue shapes for vowels along the dimensions of high vs low, back vs front, it is well known that these dimension labels do not accurately mirror any conventional geometrical space (see e. g., [4]). Furthermore, as has been pointed out by Wood [8] these dimensions do not mirror the dimensions of vocal tract shape as it is set primarily by the anatomy of the tongue muscles. While these dimensions have been modelled at least twice [5; 7], the empirical information necessary for the refinement of such models is lacking. The present experiments are a modest beginning towards filling this gap, and are a continuation of the work of Baer, Alfonso, and Honda [2] and Alfonso and Baer [1] on the same topic.

2. METHODS

The experiment was done in two parts. The talker for both was TB, an author of the previous papers in this series. The speech consisted of isolated utterances of the form /əpVp/. While the total set was larger, data from the vowels /i, ɪ, ,ɛ, æ, ʊ , u/ only will be reported here. In all cases, multiple tokens were averaged with respect to a common lineup point at consonant release.

For Part One of the experiment, hooked wire recordings of the electromyographic signal were made from the muscles anterior and posterior genioglossus, (GGA and GGP), hyoglossus, (HG), styloglossus (SG), geniohyoid (GH), mylohyoid (MH), and orbicularis oris (OO). Simultaneously, acoustic recordings were made, as were recordings from jaw movement in the Y dimension, using an optoelectric movement transducer. These data have been previously reported [2].

For Part Two of the experiment, x-ray microbeam data were taken on the same subject for the same inventory. Pellets on mid- and rear-tongue, lower lip and jaw were analyzed with a system then at the Institute of Logopedics and Phoniatrics at the University of Tokyo [6]. An effort was made to keep the utterance rate similar across the two experiments. Success in obtaining comparability could be assessed by comparing audio recording and jaw Y tracings.

3. RESULTS

3.1 X-Ray Microbeam Analysis

Pellet tracings for the averaged tongue front movement in the X dimension is shown in Fig. 1. The results conform fairly well with expectations, in that the extreme vowels fan out forwards and backwards from the initial neutral syllable.

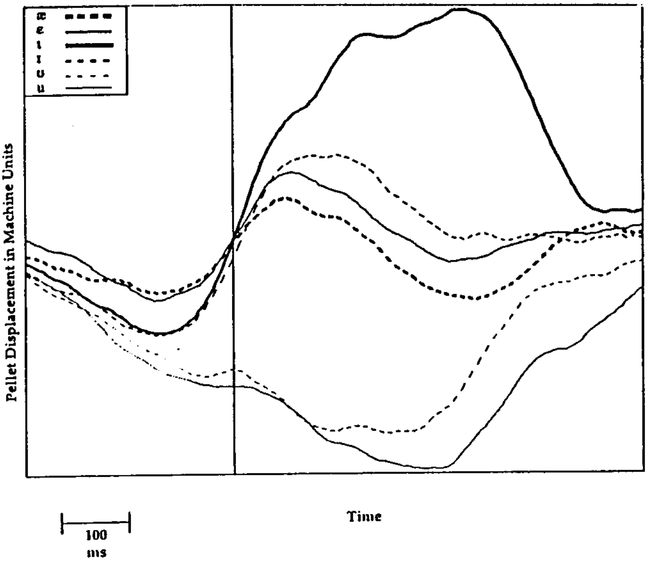

Figure 1. Averaged Front X pellet movement as a function of time. The line up point, /p/ burst release, is indicated by a solid vertical line.

The trajectory shape for the lower-lip Y pellet was used to locate vowel midpoints. Midpoint values were then used in comparisons with the EMG data. The overall relationship of the vowels to each other at midpoint is quite similar for X and Y front pellets, and X rear pellet. Relative positions for the extreme vowels are different for the rear Y pellet.

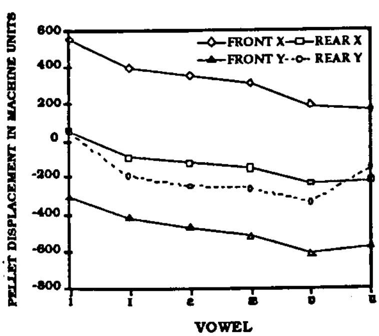

Figure 2. Tongue pellet position at vowel midpoint for X and Y dimensions of front and back pellets.

3.2 Comparison of EMG and x-ray data

In order to compare vowel midpoint positions and EMG data, we assumed a mechanical response time of the muscle of 100 msec, a value calculated in an earlier study [1]. A point in each EMG files 100 msec earlier relative to the lineup than the vowel midpoint was located. The EMG values were normalized so that the largest value observed for that muscle was treated as 100%. These values were used for scatter plots relating (front X, rear X, front Y) or rear Y position to the tongue muscle value, or GH value to jaw Y position. Because the tongue pellet positions have not yet been corrected for jaw position [3], nor have we attempted to adjust the files for the small differences in speaking rate over the two parts of the experiment, as we intend before final presentation, we will present only partial results at this time.

The sole muscle in the experimental set concerned with jaw opening, GH, correlates quite well with jaw Y position.

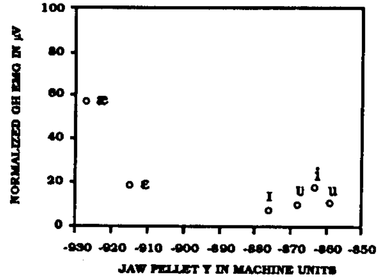

Figure 3. Scatter plot of Jaw Y position as a function of GH EMG activity.

With respect to correlations with the tongue X position group, the strongest relationship is with SG EMG activity.

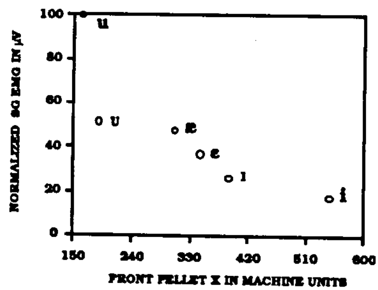

Figure 4. Scatter plot of Front Tongue X position with SG EMG activity.

The strongest relationship to rear Y position is that of GGP EMG.

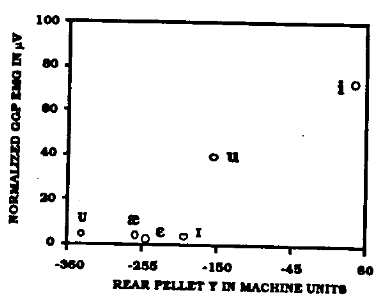

Figure 5. Scatter plot of Rear Tongue Y position with GGP EMG activity.

The activity of MH relates most strongly to Front Pellet X EMG activity. However, a more quantitative assessment must await file correction.

4. ACKNOWLEDGMENTS

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