AN ELECTROPALATOGRAPHIC STUDY OF SIBILANTS PRODUCED BY HEARING AND HEARING IMPAIRED SPEAKERS

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ABSTRACT

This experiment examined the production of the sibilants /s/ and /ʃ/ followed by the vowels /i/ and /u/ produced by four normally hearing and four hearing-impaired college students who each wore a Rion semi-flexible palate. Electropalatographic and acoustic data were collected simultaneously. Analyses show production pattern differences between hearing and hearing-impaired talkers.

1. INTRODUCTION

The use of palatography as a measurement technique in speech production studies has a long history in experimental phonetics [1,2,4]. Recently, a semi-flexible palate [4] has been developed in a variety of sizes for use with morphologically normal adults and children. Research [5] indicates that these semi-flexible palates can be fitted to many subjects and that high correlations can be obtained in repeated measure comparisons of custom-fitted and semi-flexible palates thus permitting studies of a broader population that might previously have been examined with custom-fitted prostheses.

We have suggested in our on-going work [3] that speech produced by hearing-impaired persons has characteristics in common with that of young normally developing children, namely, that it is slower, more variable, and hence unskilled. Hearing-impaired talkers are often said to articulate on a segment-by-segment basis. Sibilant production is known to be particularly problematic. Although there are a number of competing coarticulatory theories regarding skill development in normal children, there have been essentially no studies of coarticulation in hearing-impaired speakers. This study was therefore conducted to examine sibilant production using electropalatography as an objective index of production.

2. PROCEDURES

2.1 Subjects

The subjects were four normally hearing and four severely-profoundly hearing-impaired college students attending a university in New York. The university provides academic support services for the hearing-impaired students. Two of the test subjects sustained adventitious hearing losses post-lingually due to meningitis; two subjects had congenital hearing losses. All subjects used speech as their primary mode of communication.

2.2. Stimuli and instrumentation

The subjects produced twenty repetitions each of the utterances "see, she, sue, and shoe" while wearing a Rion semi-flexible palate. The palate embedded with 63 electrodes arranged in rows was calibrated against plaster casts of the subject's dental arch to insure correct size and placement.

2.3. Analysis

Audio and electropalatographic data were collected simultaneously on FM tape.The data were analyzed using computer programs at Haskins Laboratories. Palatographic records were analyzed on a frame by frame basis (15.6 msec. per frame) for approximately 600 msec. before and after the onset of voicing for the vowel., essentially the entire utterance. In addition, the records of the 63 electrodes were also grouped in "rows".

While various combinations of electrodes were analyzed, the areas of particular interest for production of the phoneme contrasts were defined from the palatal records as the back side rows and the front side rows.

Acoustic measurements of the subjects' fricative productions were done using discrete Fourier transforms on selected intervals of the acoustic file [6] which corresponded to points of interest in the palatographic records.

2.4. Listener Judgments

The audio recordings of the subjects' productions were presented to panels of listeners unfamiliar with the speech of the hearing impaired for identification in a closed-set response task. Preliminary results for the hearing and three hearing-impaired subjects show that the productions were nearly always identified as intended and relatively high identification scores (greater than 90% correct) were achieved. Analysis of one hearing-impaired person's productions showed somewhat poorer scores (71%) due to consonant confusions. .The /s/ was primarily identified as /ʃ/. This speaker is identified as EW below.

3. RESULTS

Fig. 1 is a plot of a hearing subject (JR) that shows the averaged percent of electrodes contacted over time for each of the four stimuli. The vertical axis is the averaged percent of electrodes contacted; the horizontal axis is the time in frames from -40 to +40 where each frame is 15.6 ms. The 0 frame is the onset of voicing for the vowel. Each of the stimuli were produced over twenty times and the data plotted represent the average. This normally hearing control produces /si/ (solid line) with two well defined peaks corresponding to the /s/ and /i/ respectively; when contrasted to production of /su/ (dashed line), there is only one peak that decreases nearly coincidentally with the onset of voicing of the vowel, in this case /u/. The /ʃ/ contrast shows a greater number of electrodes contacted in the front side rows but the same double vs. single peak pattern associated with vowel differences (dotted versus thin lines respectively). Fig. 2 shows that essentially the same plots can be described for the electrode patterns contacted in the back rows during production of the /si / vs. /su/ and /ʃi/ vs. /ʃu/. These patterns were fairly typical of the normal talkers.

These patterns described for one hearing control are contrasted to those for the least intelligible hearing-impaired speakers Fig. 3 is a plot for the front side rows of electrodes. The pattern for /si/ shows the two peaks associated with consonant and vowel respectively; the plot for /su/ shows a decrease in the number of electrodes contacted for /u/. This is as the normals. However, this speaker does not differentiate /s/ and /ʃ/; the plots are essentially overlapping. In Fig. 4, the plots for the back side rows show a more diffuse undifferentiated pattern across the four stimuli types until about frame +10 (approximately 150 msec) after onset of voicing for the vowel.

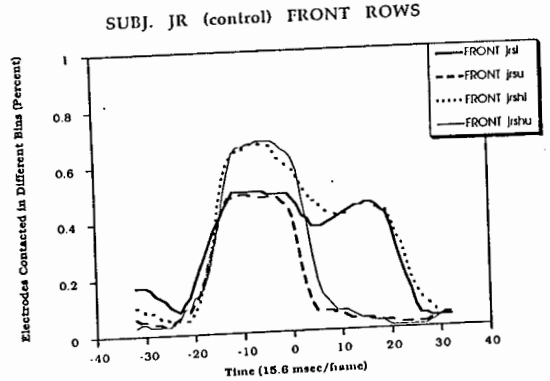

Fig. 1 shows data for a hearing control. See text for explanation.

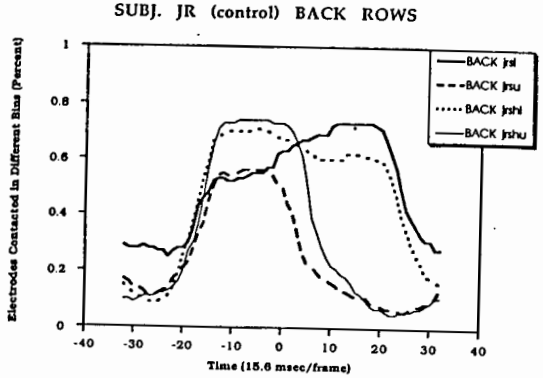

Fig. 2 shows data for a hearing control. See text for explanation.

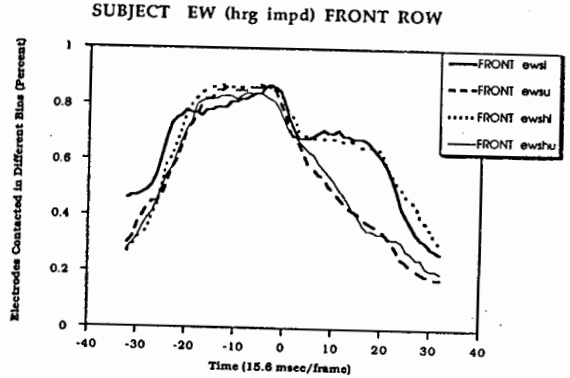

Fig. 3 shows data for a hearing-impaired subject. See text for explanation.

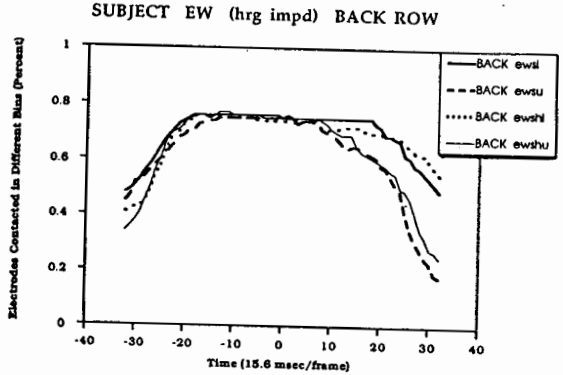

Fig. 4 shows data for a hearing-impaired subject. See text for explanation.

Plots for the other hearing-impaired speakers differed in some instances from normal controls and also from other hearing-impaired talkers. For example, in production of /si/, three of the hearing-impaired subjects produced a single pattern extending over a considerable time frame and did not differentiate the consonant and vowel. In still other instances, e.g. production of /su/, the hearing-impaired subjects were like the normals although the timing of the change in electrodes contacted from the sibilant to the vowel production occurred late relative to the onset of voicing. Additional electropalatographic patterns of contact and the corresponding acoustic measures will be presented in greater detail.

4. DISCUSSION

Electropalatographic contact differed for /s/ and /ʃ/ and for /i/ and /u/. Normal hearing controls had similar patterns of production. Specifically, there was more anterior palatal contact (front side rows) for the vowel /i/ than for /u/. This difference was related to sibilant context, both vowels evidencing less contact following /s/ than /ʃ/. There was more palatal contact for /ʃ/ than /s/. Moreover, there was considerable articulatory movement that occurred over a relatively short time frame around the onset of voicing for the vowel. In contrast, some hearing-impaired speakers achieved relatively correct electropalatal contact for the target phonemes but that "correct" pattern was often extended inappropriately over time.

These data show evidence of coarticulation in speech produced by hearing-impaired persons and do not substantiate the notion of segment-by-segment production. Coarticulatory studies of speech produced by young normally hearing children suggest that development is skilled based and that children should coarticulate less than adults because the phonemic elements of speech are not appropriately blended. Speech would be viewed as slower, more variable and unskilled. Other work [6, 7] suggests that units of speech produced by young children are somewhat larger than the single phoneme size. Because these units are not differentiated, coarticulation across syllable size units is greater in children than in adults, and decreases as skills develop. The data in this study suggest that while hearing-impaired persons coarticulate, the units are not fully differentiated and in that regard, resemble the unskilled productions of young normal children.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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