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A PRELIMINARY REPORT ON THE TIMING OF CONSONANT AND VOWEL ARTICULATIONS IN ENGLISH*

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In continuous speech, articulations of consonants temporally overlap with those of the surrounding vowels, and the tongue positions in the production of consonants vary depending on the vowel context. In order to understand the characteristics of these coarticulation phenomena, in the production of individual consonants which parts of the articulatory organs are free to be subject to perturbation by surrounding vowels and the relative timing of the articulatory movements for the consonant itself and for the vowel transition from the pre- to the post-consonantal positions must be clarified. In this paper some preliminary results observed for the production of American English will be reported.

As shown in Fig. 1, three pellets were attached to the surface of the tongue and two others were attached to the lower incisors and the lower lip, respectively. The movements of the five pellets were recorded by an x-ray microbeam system at a rate of 130 frames per second. The speech signals were recorded simultaneously, together with the timing pulses which were generated by the computer for each frame of the pellet tracking. The implosion and explosion of consonants were visually identified on the recording of the speech waveform and the temporal patterns of the pellet movements across the consonantal period were examined. The subject was a native speaker of American English, who was born and raised in the city of New York.

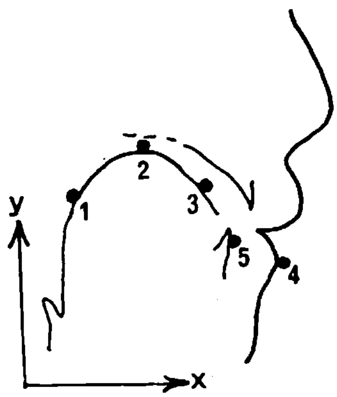

Fig. 1. Locations of the pellets on the tongue, lower incisors and lower lip (schematic).

Fig. 2 (a) compares the pellet movements in the pronunciation of the test words 'apiece, ' 'append' and 'appall'. The test words were uttered in isolation. Each test word contained an intervocalic consonant /p/ preceded by a schwa and followed by one of the vowels [i], [ɛ] and [a]. In the figure, the superimposed display of the time functions of the pellet coordinates for the three utterances is shown. The curves for the different utterances are lined up with reference to the moment of the implosion of /p/. A thick vertical line indicates the line-up point. The other vertical lines show

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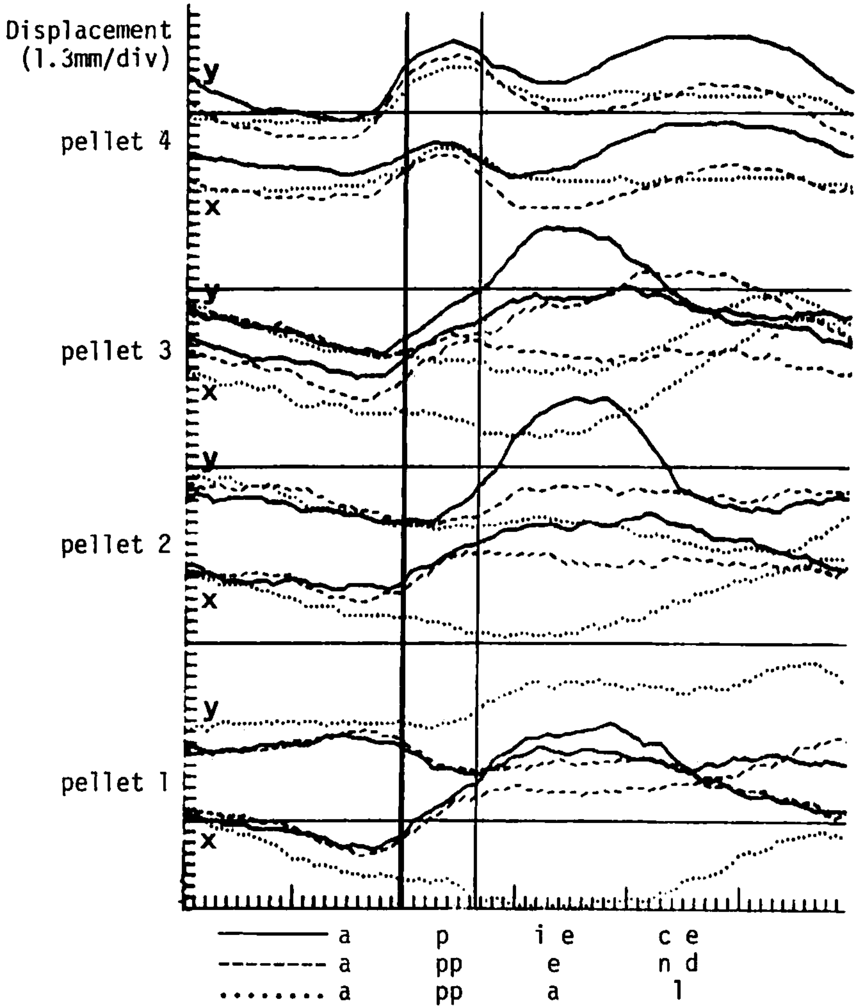
Displacement
(1.3mm/div)
y
pellet 4
x
y
pellet 3
x
y
pellet 2
x
y
pellet 1
x
a p i e c e
a pp e n d
a pp a l

Fig. 2 (a)

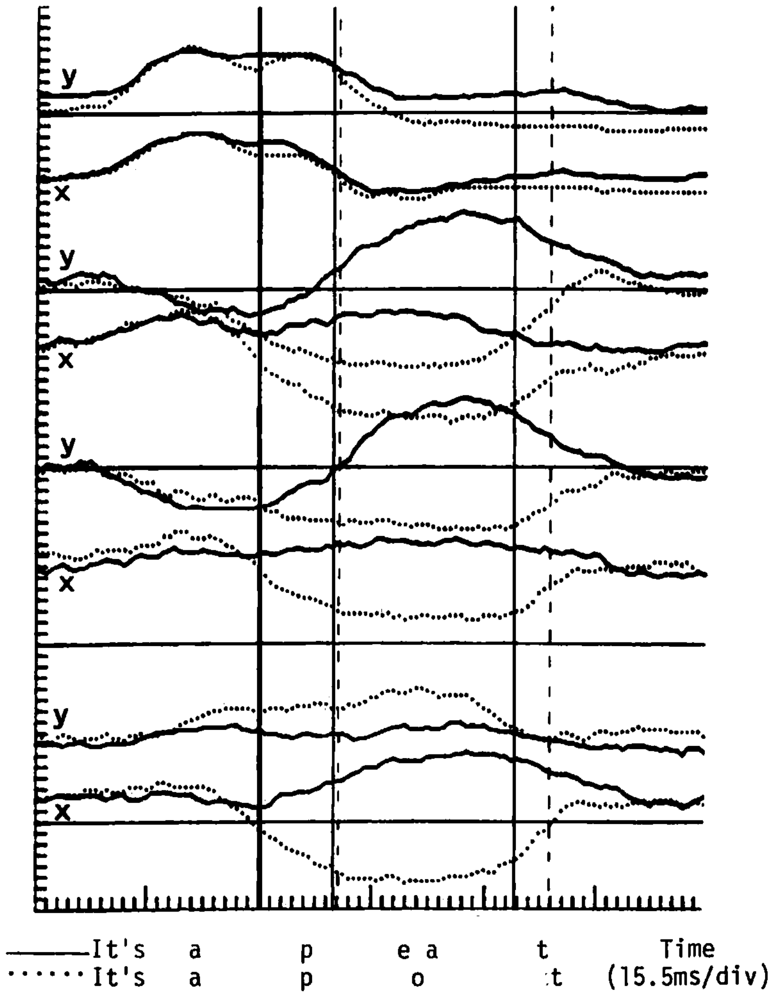
y
x
y
x
y
x
y
x
It's a p e a t
It's a p o t
Time
(15.5ms/div)

Fig. 2 (b)

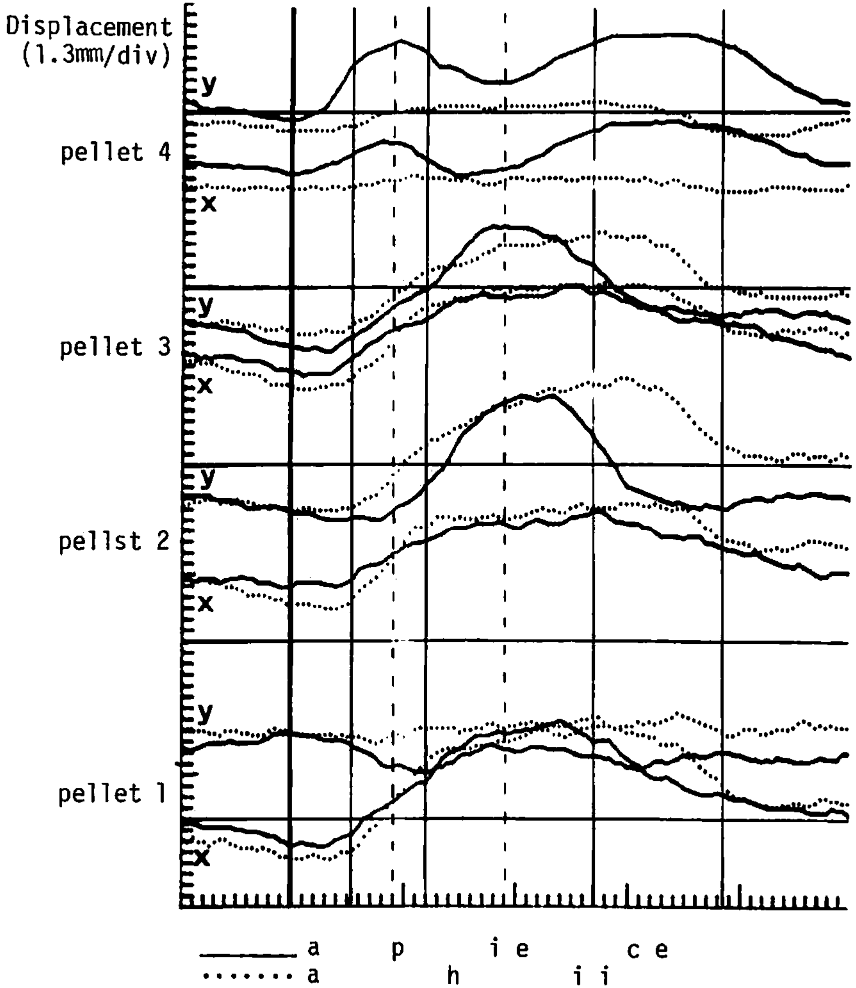
Displacement
(1.3mm/div)
y
pellet 4
x
y
pellet 3
x
y
pellst 2
x
y
pellet 1
x
a p i e c e
a h i i

Fig. 2 (c)

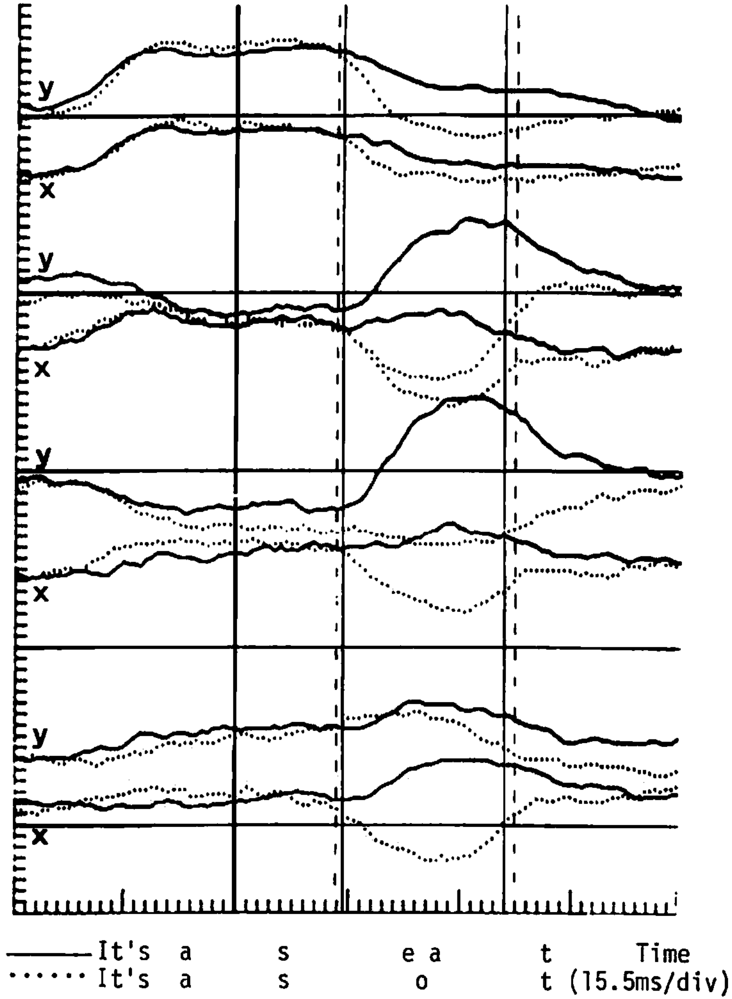
y
x
y
x
y
x
y
x
It's a s e a t Time
It's a s o t (15.5ms/div)

Fig. 2 (d)

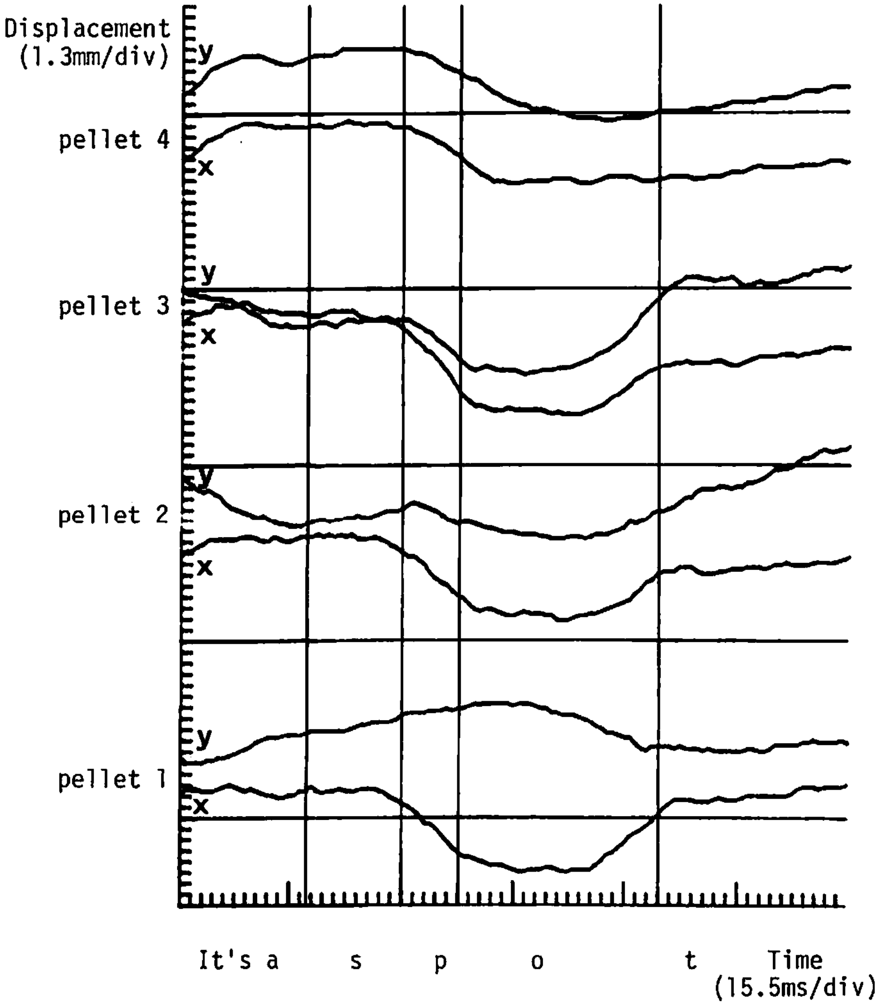

Fig. 2 (e)

Fig. 2. The time functions of the pellet coordinates for the selected utterances. The line-up points of the curves for the different utterances are indicated by the thick vertical lines (implosion of /p/ for (a) and (b), onset of voicing for the word initial schwa for (c) and onset of the frication noise of /s/ for (d)). The other vertical lines show the implosion and explosion of the consonants in the individual utterances.

the moment of the explosion of /p/ (a thin, solid line for 'apiece' and a dashed line for 'append' and 'appall'). It can be observed that the pellet movements during the closure period of /p/ mainly represent the transition toward the post-consonantal vowel.

Since the movements of different pellets were not necessarily synchronous with each other, it is difficult to define the moment of the start of transition which is common to all the pellets. However, it can be seen that, for 'apiece' and 'append', the curves for pellets 1-x, -y and 3-x change direction about 40 msec before the implosion of /p/ and begin to diverge from the curves for 'appall'. Thus, it may be concluded that, in the test words examined, the tongue movement toward the post-consonantal vowel starts before the implosion of /p/.

Comparison of the pellet movements for the test words 'peat' and 'pot' also reveals the same temporal characteristics (Fig. 2 (b)). In this case, the test words were uttered with a carrier phrase "It's a ______". It can be seen that the curves for pellets 1-x, 2-x, 3-x and -y for the two utterances begin to separate about 40 msec before the implosion of /p/, reflecting the different directions of the tongue movement toward the vowel [i] and [a].

Although the tongue movement during the closure period of /p/ mainly reflects the transition to the following vowel, there also exists a component of the pellet movements which appears to be specific to the production of /p/. Fig. 2 (c) compares the pellet movements for the utterances 'apiece' and ahii'. The line-up point is the onset of voicing for the word initial schwa. It can be observed that, in the case of 'apiece', the backmost pellet (1) shows a downward displacement during the transitional period to the vowel [i]. For 'ahii', such an effect was not present. The downward displacement starts at about the time of the implosion of /p/, reaches its maximum at around the explosion of /p/ and then diminished. This movement appears to be comparable to the "temporal depression" of the tongue surface reported by Houde for the closure period of intervocalic /b/.[1)]

Fig. 2 (d) shows the pellet movements for the utterances "It's a seat" and "It's a sot," where the word initial consonant /p/ in the utterances in Fig. 2 was replaced by the dental consonant /s/. In these cases, the pellet positions are almost stationary during the period of /s/, and the tongue movement toward the following vowel [i] or [a] does not appear until near the release of /s/. That is, the difference in the following vowel does not cause any variation in the tongue position during /s/. On the other hand, for the dental consonant /t/ in word final position, effects of the carry over coarticulation of the preceding vowels can be clearly seen. In the present study, a carry over effect was also observed for word final /s/ when the pair of utterances 'peace' and 'bus' were compared. Thus, it is not the case that the constraint on the tongue position in the articulation of /s/ is generally so strong that, for /s/, perturbation by the vowel context scarcely appears. Rather, in the case of word initial /s/, as shown in Fig. 2 (d), the movement toward the following vowel is suppressed during the consonantal period.

An example of pellet movements during the articulation of a consonant cluster is shown in Fig. 2 (e) for the utterance "It's a spot". The pattern of the pellet movements during the cluster /sp/ reflects a simple addition of the characteristics for /s/ and /p/ stated above. Namely, the transitional movement toward the vowel [a] does not appear during the period of /s/ and starts near the moment of the implosion of /p/. It was also noted that, in the case of the cluster /sp/, the closure period for /p/ was shorter than that for /p/ in 'pot'. At the same time, the start of the transition to the vowel [a] was closer to the moment of the implosion of /p/. Consequently, the degree of vowel transition at the explosion of /p/ was smaller.

Concluding Remarks

In the present study it was observed that for intervocalic /p/ the tongue movement toward the following vowel starts about 40 msec before its implosion. In his x-ray motion picture study of the VCV utterances, Gay (1977) reported that anticipatory movements toward the second vowel always begin during the closure period of the intervocalic consonant.[2] The result of the present study does not conform to his findings. However, it must be taken into consideration that there is an apparent difference between Gay's experiment and ours in the phonetic structures of the test materials. Namely, the consonant /p/ was preceded by the unstressed vowel schwa in our study, whereas in Gay's study the preceding vowel was either /i/, /a/ or /u/ in a stressed syllable or in an unstressed syllable.

The different characteristics of the consonants /p/ and /s/ with regard to the transitional movement toward the following vowel can be stated as follows, using Henke's[3] notion of a look-ahead mechanism. In the case of /p/, there is no positive specification of the tongue position and therefore, the tongue movement toward the following vowel can take place at the same time as the articulation of /p/. On the other hand, in the case of /s/ there is a positive specification of the tongue position and the tongue movement toward the following vowel starts at around the release of /s/. However, the carry-over coarticulation of the preceding vowel causes contestual variations in the tongue position for /s/.

References

1) Houde, R. A. (1967), "A Study of Tongue Body Motion During Selected Speech Sounds," Ph. D. Thesis, University of Michigan.

2) Gay, T. (1977), "Articulatory Movements in VCV Sequences," Status Report on Speech Research, Haskins Laboratories, SR-4a, 121-147.

3) Henke, W. (1966), "Dynamic Articulatory Model of Speech Production Using Computer Simulation," Ph. D. Thesis, M. I. T.