Ann.Bull.RILP(1984)No.18, 27-31

A COMPARISON OF OPEN TO CLOSED VOWEL TRANSITION AND CLOSED TO OPEN VOWEL TRANSITION
The Duration of Jaw Movements and Formant Transitions

Hiroshi Imagawa,Shigeru Kiritani,
Shinobu Masaki* and Katsuhiko Shirai*

Introduction

In our previous report[1], we analyzed the movement of the jaw in the production of vowel sequences by two subjects. We reported that there was a tendency for the transition speed to be faster for closed to open vowel transitions than for open to closed vowel transitions, and for the duration to be longer for open to closed vowel transitions than for closed to open vowel transitions.

In the present study, similar measurements were performed for an increased number of subjects. Acoustic analysis of the corresponding speech signals was also performed, and the duration of the formant transition in open to closed vowel transitions and closed to open vowel transitions were compared.

Method

Speech materials were the meaningless sequences /aiai/, /iaia/, /eiei/ and /ieie/. The test words were uttered in the carrier phrase /___ desu/. The sentences were produced at three different speaking rates: 1)slow 2)fast and 3)very fast. There were ten tokens for each utterance at each speaking rate. The subjects were four male adults. To observe the jaw movement, the movement of an LED on a solid wire fixed to the lower front teeth was recorded using a PSD(optical spot position sensitive detector). The details of this method have been described eleswhere[2]. The coordinate signals of the LED were sampled by a computer at a rate of 100 frames per second. At the same time, the speech signal was recorded with a taperecorder. The speech signal was sampled at 10kHz through an A/D converter, then analyzed in order to extract the LPC coefficients. Formant frequencies were calculated from the polynominal of the LPC coefficients. For each utterance, the moments of the maximum displacement of the jaw for the individul vowels were determined by a visual inspection of the time function of the jaw movement. The time interval between the successive peaks was taken as the duration of the transition movement. The duration of the formant transition was also measured in the same way using the time function of the formant frequency.

* Department of Electrical Engineering, Waseda University

Result

Figure 1 shows the durations of the movement of the jaw in the V_1V_2 transitions and the V_2V_3 transitions. Each data point compares the duration of the closed to open vowel transition (ordinate) and the open to closed vowel transition (abscissa) within the same test word. The 45° diagonal lines in the figure indicate the condition where the duration of the closed to open vowel transition and open to closed vowel transition are the same. Each data point in the figure represents an average value over ten utterance tokens. It can be seen from the figure that the data points which are located beneath the diagonal line outnumber the data points which are located above it. That is, the duration of the movement of the jaw was longer for the open to closed vowel transition than for the closed to open vowel transition on the average in all of the subjects. In thirty-one of the fourty-eight utterance conditions (four test words X three speaking rates X four subjects) in this experiment, the duration of the open to closed vowel transitions were significantly longer than for the closed to open vowel transitions within the same test word (level of significance: 5%). On the other hand, there were only three cases in which the duration of the closed to open vowel transition was significantly longer than for the open to closed vowel transition.

Figure 2 compares the duration of the formant transitions for /ei/ and /ie/ in the test words /ieie/ and /eiei/. The formant movements for these test words were chosen for analysis because of the simpler correspondence between formant frequencies and articulatory movements than for /aiai/ and /iaia/. Each data point in the figure represents an average value over ten utterance tokens. It can be seen in the figure that, for all subjects, the duration of the F_2 transitions were longer for /ei/ than for /ie/. The duration of the F_1 transitions were also longer for /ei/ than for /ie/, except for the /ieie/ by subject 1. Thus, it was confirmed that there exist durational differences in the formant movement between /ie/ and /ei/ similar to that observed for the jaw movement.

It shoud be noted here that the duration differences in formant movement tend to be greater than those in jaw movement. For subjects 1 and 3, the differences in the duration of the F_2 transitions in /ei/ and /ie/ were longer than the differences in the duration of the movement of the jaw. For subject 4, the differences of the duration in the F_1 transition between /ie/ and /ei/ were longer than the differences in the duration of the movement of the jaw. In these cases, it was observed through visual inspection of the formant curves that the quasi stationary portion of /i/ in the formant movement was longer than that of the jaw movement. Thus, the start of the movement toward the following /e/ was later for the formant movement than for the movement of the jaw. The details of the relationship between the pattern of formant movements and the pattern of movements of the jaw are being further investigated, using X-ray microbeam data on the tongue and jaw movement.

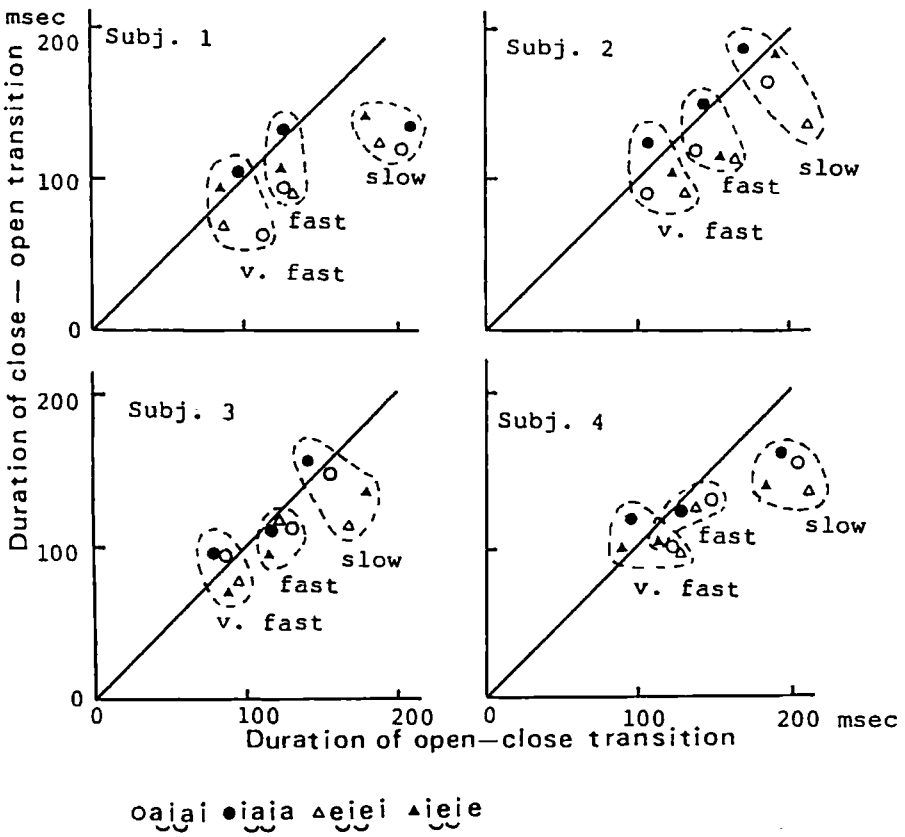

Fig.1 Comparison of the duration of the jaw movement in open to closed vowel transitions and closed to open vowel transitions within the same test word.

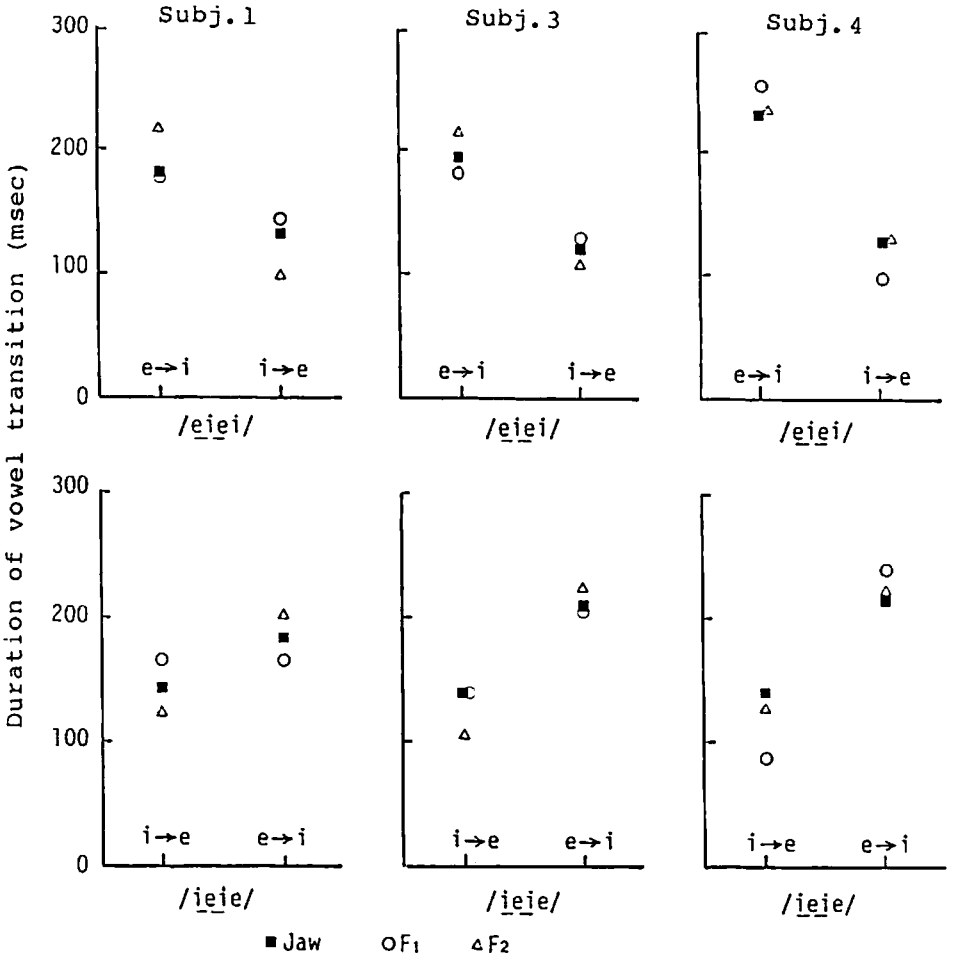

Fig. 2 Comparison of the duration of the formant movement in /ei/ and /ie/ transitions in the test words /eiei/ and /ieie/.

References

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