It is well known that a noisy environment negatively affects human perceptual ability. Simultaneously, the accuracy of production of spoken language also declines. Especially, when a person pronounces non-native consonant clusters, his/her pronunciation becomes less accurate. However, the mechanism of this phenomenon is not clear. In order to elucidate this problem, in this research first we studied in a quiet environment. We investigated the difference of articulatory movement between native and non-native consonant clusters. English has consonant clusters, but Japanese does not. Therefore, speakers were two native English speakers and two native Japanese speakers. Speech samples consisted of four words, "blat," "bnat," "plat," "pnat." In these words, /bl/ and /pl/ are English consonant clusters, but /bn/ and /pn/ are not. These four consonant clusters, /bl/, /pl/, /bn/, /pn/, do not exist in Japanese. We measured the movement of the tongue tip, the mandible and the lower lip using WAVE system (NDI corp.). There were remarkable differences in the mandible and the lower lip movement between native (/bl/, /pl/) and non-native (/bn/, /pn/) clusters in English speakers. Specifically, with the non-native consonant clusters the difference of the articulatory movement in the mandible and the lower lip of every utterance was quite large; however, in native consonant clusters, the difference was quite small. For Japanese speakers it was large for all consonant clusters. Therefore, it was revealed that the articulatory movement of the mandible and the lower lip in non-native consonant clusters was not stable in native English speakers, even though English has consonant clusters. We will carry out these experiments in noisy environments in future.

Keywords: non-native consonant clusters, articulation, WAVE system, vowel epenthesis
thesis [1], [2]. In the case of native Japanese speakers, they usually insert the vowel [ɯ] in consonant clusters when they pronounce them [3], [4]. This phenomenon in native Japanese speakers might arise from the perception of an “illusory vowel [ɯ]” in consonant clusters [3], [4].

We have up until now investigated this phenomenon by measuring the amount of displacement of articulators. In our previous studies, we found that one of the mechanisms of vowel epenthesis in consonant clusters is for the articulatory tongue displacement from the first to the second consonant in native Japanese speakers to be larger than that in native German and native English speakers (their languages allow consonant clusters.), [5], [6]. Namely, co-articulation between first and second consonant is weak for Japanese speakers.

However, we have not found that how English speakers pronounce non-native consonant clusters. In this study, therefore, we investigated the movement of articulators of English speakers during pronunciation and performed the comparison of the movement of articulators of English speakers and that of Japanese speakers.

2. Methods

2.1 Speakers and speech samples

The speakers were 2 Japanese (2 males: J1, J2) and 2 English (1 male, 1 female: E1, E2) speakers. Speech samples were four words, “blat”, “bnat”, “plat”, and “pnat”. /bl/ and /pl/ are possible clusters in English. The other two words have non-English consonant clusters. All the second consonants, /l/, /n/, are articulated with the tongue tip placed behind the alveolar ridge. These words (X) were embedded in an English sentence “Say X.”. These sentences were shown in random order on a display placed in front of the speaker. The 2 Japanese and 2 English speakers pronounced these sentences 5 times each.

2.2 Wave recordings and data analyses

Articulatory movement and acoustic data were recorded simultaneously using the WAVE system (NDI Corp.). In the articulatory measurement, sensor coils were placed on the tongue tip, tongue middle, tongue back, mandible, upper and lower lips on the mid-sagittal plane, as well as on the nasion (reference sensor) for head movement correction (Fig. 1). The movements of each sensor were recorded separately for x and y axes. The x axis is the anterior-posterior axis, and the y axis, the superior-inferior axis. Both axes are on the mid-sagittal plane.

We used MVIEW (Haskins Laboratories) for the movement analyses of each sensor. We measured the movement of the tongue tip, the mandible and the lower lip transfer time (T) from the burst point of the first plosive consonant, /b/, /p/, to the completed articulation point (the maximum value of tongue tip height) in the second consonant, /l/, /n/. We also measured the tongue tip (TT), the mandible (J) and the lower lip (LL) displacement (D) from the burst point of the first plosive consonants, /b/, /p/, to the completed articulation point in the second consonant, /l/, /n/ (Fig. 2). In this figure, the first window shows the wave form, the second, the sound spectrogram, and the third, y-displacement of tongue tip.
3. Results and discussion

Fig. 3 shows the transfer time and the displacement of TT, J and LL in speaker E1. In native clusters, /bl/ and /pl/, the highest points of J and LL were on the early time before the burst point in all utterances. In non-native clusters, /bn/ and /pn/, the highest points of J and LL were on the late time after the burst point in some utterances. There were remarkable differences in J and LL movement between native (/bl/, /pl/) and non-native (/bn/, /pn/) clusters in English speakers. Namely, with the non-native clusters the difference of the articulatory movement in J and LL of every utterance was quite large; however, in native clusters, the difference was quite small. Fig. 4 shows the transfer time and the displacement of TT, J and LL in speaker J1. In all clusters, the highest points of J and LL were on the late time after the burst point in some utterances. In spite of languages, Japanese or English, in non-native
clusters the articulation would tend to become unsteady. Since non-native clusters are hard to pronounce in the quiet environment, they will be much harder to pronounce in the noisy environment. In any case, future experiments will be needed.

Figure 3: Articulatory movement of TT, J, and LL in the speaker E1.
4. Concluding remarks

In English speakers, with the non-native consonant clusters the difference of the articulatory movement in the mandible and the lower lip of every utterance was quite large, however, in native consonant clusters, the difference was quite small. For Japanese speakers it was large for all consonant clusters. Therefore, it was revealed that the articulatory movement of the mandible and the lower lip in non-native consonant clusters was not stable in native English speakers, even though English has consonant clusters. We will carry out these experiments in noisy environments in future.

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