



Laryngeal Characteristics during the Production of Geminate Consonants

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Abstract

Analysis of high-speed digital video images showed no apparent constriction or tenseness in the larynx and glottis during the production of geminate consonants. Glottal width for geminate consonants is slightly, but not much wider than their singleton counterparts. The glottal width depends largely on consonant types. Analysis of photo-electric glottograms showed that an interruption of glottal opening movement and/or abrupt cessation of the preceding vowel may be involved during the production of geminate consonants.

Index Terms: speech production, high-speed digital video recordings, geminate consonants, Japanese

1. Introduction

Previous studies on Japanese geminate consonants have mainly focused on their acoustic properties. It has been found that geminate, or moraic, consonants are longer than their singleton ones in the silent periods for stop and affricate consonants, and frication period, for fricatives [1,2]. Some studies claim that, in addition to the acoustic differences, physiological characteristics differ between those two consonant types. Hattori notes that the first half of geminate consonants has glottal tension, and, /ippoo/ “one side”, /itto/ “first class”, /ikko/ “one piece,” for example, could be transcribed as /iʔpoo/, /iʔtoo/ and /iʔko/ [3]. Also, the term “choked sound,” another English translation of geminate consonant, suggests that the sound has an association with laryngeal or glottal constriction [4]. However, physiological characteristics in producing geminate consonants are not well explored and it is not clear whether any laryngeal/glottal tension takes place in producing geminate consonants. This study reports on physiological examination of geminate consonants using a digital high-speed video recording system.

2. Method

2.1. Materials and subject

Materials are the following six sets of words.

/te/-set: etete, ette
 /ke/-set: ekeke, ekke
 /se/-set: esese, esse
 /chi/-set: echichi, etchi
 /ki/-set: ekiki, ekki
 /shi/-set: eshishi, esshi

They are nonsense words with a three mora count. Note that the first half of geminate consonants consists of one mora. Also note that the vowel /i/ in words of /ki/-, /chi/-, /shi/- sets can undergo devoicing, because they are preceded by a voiceless consonant and followed by a voiceless consonant or a pause.

The subject is a male Tokyo speaker in his mid 30s. He read word lists with other filler words. Each list contains one of the test word sets.

2.2. High-speed digital video recording systems

We recorded laryngeal images using a high-speed digital video recording system with the rate of 4500 frames/sec.. Audio signal and photo-electric glottogram signal were recorded simultaneously with the video images. Maximum recording time for one session is 5.8 seconds. Each session includes one of the test words’ set. We recorded twelve sessions, resulting in two tokens for each test word.

3. Results

3.1. Acoustic analysis

Acoustic analysis showed that the vowel /i/ was devoiced in the second mora in /ekiki/, /echichi/ and /eshishi/ (denoted by italic letters). The exception was one token of /eshishi/. These results are in agreement with previous studies that showed vowel devoicing occurs less frequently when adjoining consonants on both sides are fricatives [5].

3.2. Glottal openings

Figures 1 to 6 show the maximum glottal openings during singleton /C/ and geminate consonants /CC/. Left panels in figures 4 to 6 show the openings during /CiC/, since /CiC/ is produced as one unit with the intermediate vowel /i/ being devoiced. As is clear in the figures, no apparent constriction or tenseness appears in the laryngeal and glottal shapes. Glottal width for geminate consonants (right panels) is slightly, but not much wider in comparison with their singleton counterparts (left panels). Glottal width depends largely on consonant type and place of articulation. It is wider in fricatives than in plosives: i.e. /ss/ > /tt/, /kk/. Also, it is wider during palatal and palatalized consonants than in non-palatal counterparts: i.e. /tch/ > /tt/, /ssh/ > /ss/, and /kk(i)/ > /kk(e)/. As seen in the figures, the frication noise is longer and stronger during palatal and palatalized consonants. Wider glottal openings are thought to be a prerequisite condition in order to produce the long and strong noise for those consonants.

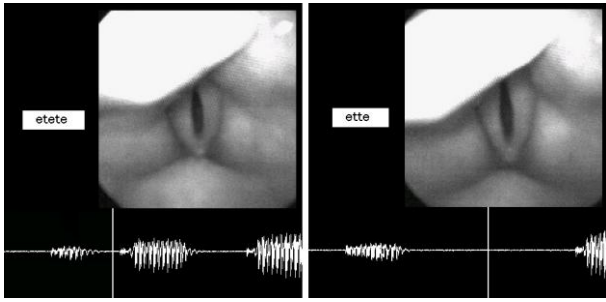


Figure 1: Maximum glottal openings during /t/ in /etete/ (left) and /tt/ in /ette/ (right). Each panel shows the view of larynx (above) at the time of the vertical line on speech wave (bottom).

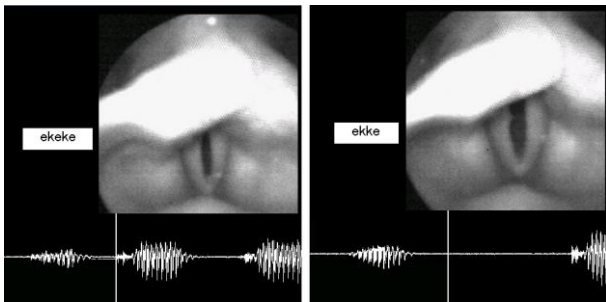


Figure 2: Maximum glottal openings during /k/ in /ekeke/ (left) and /kk/ in /ekke/(right).

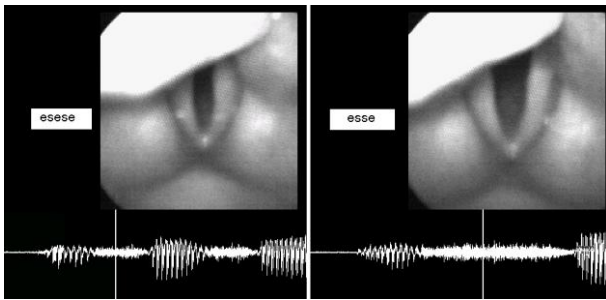


Figure 3: Maximum glottal openings during /s/ in /esese/ (left) and /ss/ in /esse/(right).

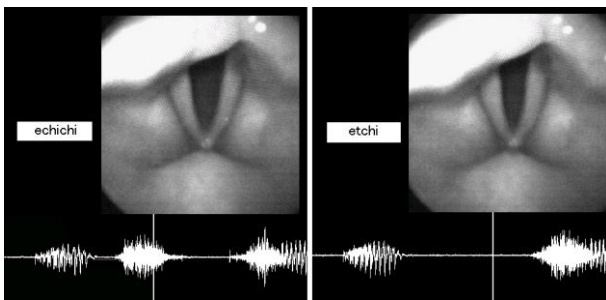


Figure 4: Maximum glottal openings during /chich/ with deviced /i/ in /echichi/ (left) and /tch/ in /etchi/(right).

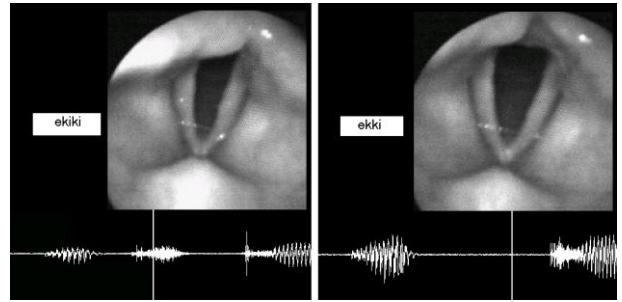


Figure 5: Maximum glottal openings during /kik/ with devoiced /i/ in /ekiki/ (left) and /kk/ in /ekki/ (right).

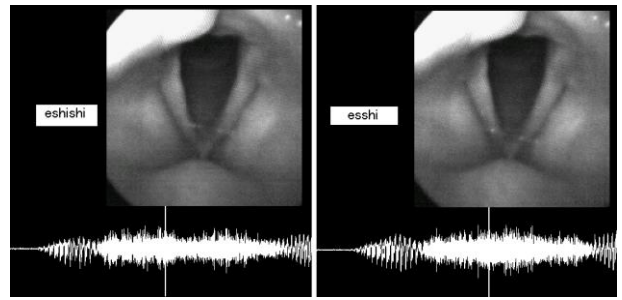


Figure 6: Maximum glottal openings during devoiced /shish/ with devoiced /i/ in /eshishi/ (left) and /ssh/ in /esshi/ (right).

3.3. Photoelectric glottogram

Figures 7 to 9 show the time course of glottal area during a singleton /C/ (left figure) and geminate consonants /CC/ (right figure). Figures 10 to 12 show the glottal area during /CiC/, with devoiced /i/, and geminate consonants /CC/. Speech signals (above) and photoelectric glottograms (below) in each panel are time-aligned. Scales of photoelectric glottogram (hereafter PGG) signals differ among panels so that smaller displacements could easily be seen.

Peak glottal area for geminate consonants is generally wider than their singleton counterparts. This result is in good agreement with the above mentioned results from high speed video images. Two notable differences are found in PGG signals between singleton- and geminate consonants. One is the gross trajectory of glottal opening movement, and another is the cessation of voicing of the preceding vowel.

As for the opening movement, time course during geminate consonants sometimes shows a dip, or an interruption of smooth opening, while no such cases are seen during singleton consonants. For example, the opening trajectory during /ette/ in figure 7 is interrupted and shows a dip. Also, during /ekke/, the opening trajectory turns abruptly into its closing movement. Such interruption is seen in some other samples during /CC/s but not during /C/s or /CiC/s with devoiced /i/.

Voicing of the preceding vowel before glottal opening ceases faster during /CC/ than for /C/. For example, vocal fold vibration for /e/ in /etchi/ and /ekki/ stops quicker than for /e/ in /echichi/ and /ekiki/.

At least one of these two characteristics is found in all the tokens of /ekke/, /ette/, /ekki/ and /etchi/. However, it is not apparent in the tokens of the fricative /CC/, /esse/ and /esshi/.

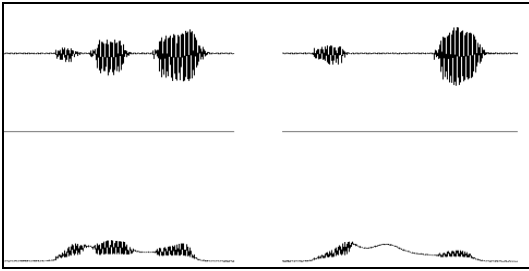


Figure 7: Comparison of time course of glottal area during /etete/ (left) and /ette/ (right). Speech signal (above) and photoelectric glottogram (below) are aligned in time.

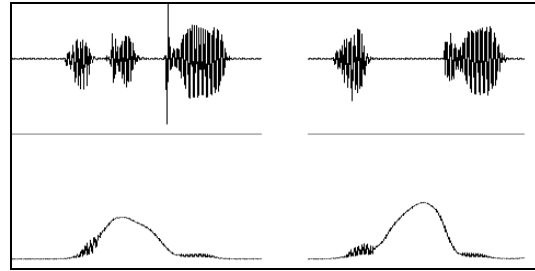


Figure 11: Comparison of time course of glottal area during /ekiki/ (left) and /ekki/ (right). First /i/ during /ekiki/ is devoiced.

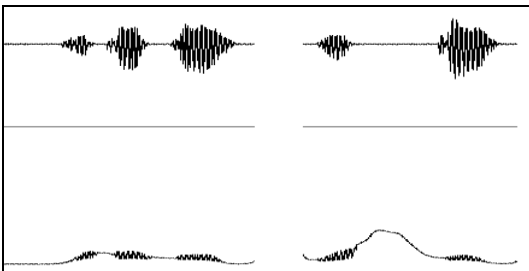


Figure 8: Comparison of time course of glottal area during /ekeke/ (left) and /ekke/ (right).

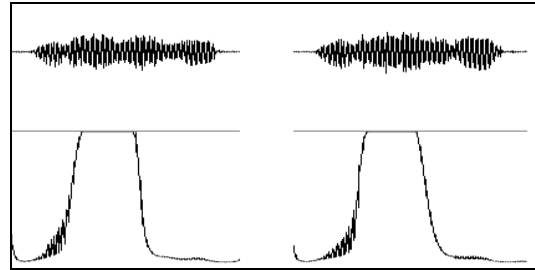


Figure 12: Comparison of time course of glottal area during /eshishi/ (left), /esshishi/ (right). PGG signals were saturated during these tokens since glottal areas were much larger than that during other test words. First /i/ during /eshishi/ is devoiced.

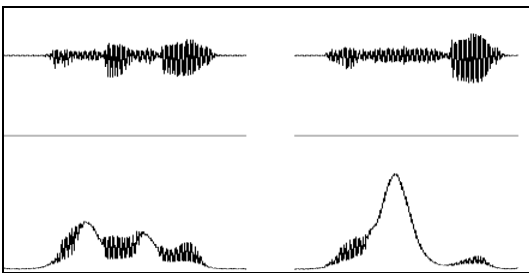


Figure 9: Comparison of time course of glottal area during /esese/ (left) and /esse/ (right).

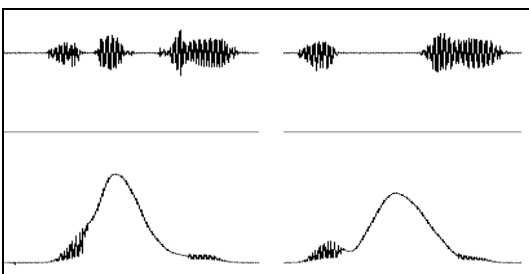


Figure 10: Comparison of time course of glottal area during /echichi/ (left) and /etchi/ (right). First /i/ during /echichi/ is devoiced.

4. Discussion

The results showed that the degree of glottal width was wider in fricatives than in plosives. It is wider as well during palatal and palatalized consonants than during non-palatal counterparts. Wider glottal openings are considered to be necessary to produce long- and strong noise for those consonants. In contrast, glottal width for geminate consonants is only slightly wider in comparison with their singleton counterparts. These facts suggest that neither choking nor expanding the larynx/glottis gesture is characteristic of geminate consonants.

Although no apparent laryngeal or glottal constriction appeared during the production of geminate consonants in the images, PGG signals detect differences between singleton- and geminate consonants: i.e. interruption of opening movement and abrupt cessation of the preceding vowel. Such differences are possibly due to tighter closure or faster movement in making articulatory closure within the vocal tract. It may also be due to tension in one of the laryngeal muscles, such as the Vocalis. The term “choked sound” or Hattori’s phonological transcription /ʀ/ for geminate consonants may be an auditory impression caused by increased tension in articulatory or laryngeal muscles.

The fact that neither an interruption of glottal opening movement nor abrupt cessation of the preceding vowel was found in fricative /CC/ may be because complete oral closure is not involved for fricatives; uninterrupted frication noise is required during /CC/ production.

Detailed analysis of high speed video images, especially at the beginning part of /CC/s, is necessary in order to clarify the characteristics of geminate consonants.

5. Conclusion

This study showed that no apparent laryngeal/glottal constriction is made in association with producing geminate consonants. Instead, interruption of glottal opening movement and/or abrupt cessation of the preceding vowel may be involved during geminate consonants. Additional data that involves more subjects and further examination is necessary to confirm the present results.

6. Acknowledgements

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7. References

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