Correspondence between the Glottal Gesture Overlap Pattern and Vowel Devoicing in Japanese

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ABSTRACT

Correspondence between the glottal opening gesture pattern and vowel devoicing in Japanese was examined using PGG with special reference to the pattern of glottal gesture overlap and blending into the neighboring vowel. The results showed that most of the tokens demonstrated either a single glottal opening pattern with a devoiced vowel, or a double glottal opening with a voiced vowel during /CiC/ sequences as generally expected. Some tokens, however, showed a double glottal opening with a devoiced vowel, or a single glottal opening with a partially voiced vowel. From the viewpoint of gestural overlap analysis of vowel devoicing, an intermediate process of gestural overlap may explain the occurrence of the case in which the vowel was devoiced and showed a double phase opening. Nevertheless, the presence of a partially voiced vowel with a single opening phase clearly shows the complexity of vowel devoicing in Japanese, since there are possibly two different patterns of glottal opening (single phase and double phase), which could be observed in PGG analysis, in utterances with partially voiced vowels.

1. INTRODUCTION

Vowel devoicing or deletion, is a commonly seen phenomenon in many languages. In standard Japanese, high vowels surrounded by voiceless consonants tend to be devoiced. It is known that, when a medial vowel is devoiced in a /C_1VC_2/ sequence (where C stands for voiceless consonants and V for a high vowel), the glottis shows a single opening phase, instead of a double opening phase, each corresponding to the C_1 and C_2 voiceless consonant (Sawashima 1971).

The devoicing phenomenon, including Japanese, is recently claimed to occur due to gestural overlap (Jun and Beckman 1993, Beckman 1996). In this view, vowel devoicing is regarded as a result of C_1 and C_2 glottal opening overlap in a /C_1VC_2/ sequence. It is assumed to be a continuous phonetic process rather than a discrete phonological process. Actually, utterances show various degrees of vowel devoicing, which could range from fully voiced to partially voiced, and completely devoiced (see Kondo 1993). This is assumed to correspond to the variance of glottal overlap; i.e. no overlap, partial overlap and full overlap. However, no direct evidence has been shown for the assumed correspondence between glottal movement and vowel devoicing for the Japanese /C_1VC_2/ sequence.

It is generally known that, where the production of a single consonant is concerned, vocal fold vibration occurs throughout the opening phase for /h/, while it does not occur for /s/, although both consonants are characterized by the same wide glottal opening (Yoshioka 1981). This fact suggests that the medial vowel is not necessarily devoiced in /CVC/ utterances with a single glottal opening phase. In the present study, the correspondence of the pattern of glottal opening and the presence or absence of vowel devoicing for /CiC/ sequences with the consonants /k/ and /s/ was investigated using photoelectric glottography (PGG).

2. METHOD

A male adult of standard (Tokyo) Japanese served as the subject. Four meaningless /C_1iC_2e/ words composed of voiceless consonants /k,s/ were selected as test words. No accent nucleus was set on the test words. The subject was asked to pronounce each test word along with other filler words four times in a frame sentence ‘ soreo…to kae-masu’, ‘ we replace it with ___.’ Test and filler words were produced in random order at self-selected normal and slow speaking rates. In slow speech, more variation in vowel voicing and glottal opening degree was expected than in normal speech.

Recordings of glottal opening and closure during utterances were made using PGG. A fiberscope provided illumination of the larynx, and the light passing through the glottis was sensed by a phototransistor placed medially on the neck at the level of the cricothyroid membrane. The PGG signal and audio signal were recorded simultaneously by a data recorder.

PGG data were processed on computer, and the time course of glottal opening and closure for each token was traced. Glottal opening patterns during the /CiC/ sequence were categorized into two grops according to the number of glottal opening peaks; a single opening and double opening. Audio signals were processed on computer as well, and a waveform and wide-band spectrogram for each token were shown on a monitor to decide whether the medial vowel [i] was voiced. Voiced vowels were further categorized as fully voiced or partially voiced. Vowels without any full periodic pattern on waveform, and/or without clear formant pattern on spectrogram were categorized as partially voiced.

3. RESULTS

Thirty-two tokens (4 words X 2 speech rates X 4 repetitions) were examined. Table 1 shows the frequency of vowel devoicing in the test words during normal and slow speech. During normal speech, medial vowels were devoiced in all tokens except one [kike], which showed partial voicing. The average devoicing rate for normal speech was 94 %. During slow speech, medial vowels were voiced in three tokens; two partially voiced for [sike] and one fully voiced for [sise]. In all other tokens, vowels were devoiced. The average devoicing rate for slow speech was 81 %. Note that a fully voiced vowel was seen only in one [sise] token during slower speech.

	kike	kise	sike	sise
Normal rate	75%	100%	100%	100%
Slow rate	100%	100%	50%	75%

Table 1. Frequency of tokens with devoiced vowel

Table 2 shows the frequency of tokens that showed a single glottal opening during the /CVC/ sequence. Figure 1 shows the waveform and the PGG of representative tokens, for each test word. During normal speech, all tokens showed a single glottal opening in PGG data as exemplified by /kike/, /kise/, /sike/ and /sise-A/ in figure 1. During slow speech, most tokens showed a single glottal opening similar to that in normal speech. Two exceptional tokens showed double openings; one complete (/sise-C/ in figure 1) and one incomplete (/sise-B/ in figure 1). The PGG of the incomplete-opening pattern showed a large peak followed by a shoulder-like small peak, indicating the occurrence of another opening gesture for the second consonant [s]. These double opening patterns were, again, seen only in /sise/ tokens.

	kike	kise	sike	sise
Normal rate	100%	100%	100%	100%
Slow rate	100%	100%	100%	50%

Table 2. Frequency of tokens with a single glottal opening phase.

Table 3 shows the number of tokens classified according to the glottal opening pattern and voicing of the vowel. Out of 32 tokens, 30 showed a single opening phase (27 with a devoiced vowel, and 3 with a voiced vowel), and 2 showed a double opening phase (1 with a devoiced vowel, 1 with a voiced vowel). Thus, in most of the cases, tokens showed either a single opening with a devoiced vowel, or a double opening with a voiced vowel, as generally expected. However, there was 1 token with a double opening phase, accompanied by a devoiced vowel, and 3 tokens with a single opening phase accompanied by a partially voiced vowel.

glottal opening pattern	voicing of vowel	
	devoiced	voiced
single opening	27	3
double opening	1	1

Table 3. Number of tokens classified according to the glottal opening pattern and voicing of vowel.

To summarize, of the 32 tokens, 27 devoiced tokens with a single glottal opening gesture were recorded. The exceptions included one /kike/ and two /sike/ tokens with a single opening phase accompanied by a partially voiced vowel; one /sise/ token with an incomplete double opening phase accompanied by a devoiced vowel; and one /sise/ token with a complete double opening phase accompanied by a fully voiced vowel.

4. DISCUSSION

In the present study at least one instance was observed in each of the glottal patterns for both vowel-voicing distinctions. Results above suggest that there is no straightforward correspondence between the glottal opening pattern and devoicing of the vowel.

Jun and Beckman (1993) proposed that vowel devoicing in Japanese could be “same-tier overlap and blending”. They assumed that “the glottal opening gesture for the consonant overlaps and blends into the glottal closing gesture for the following vowel,” in effect weakening the vowel’s voicing specification. In this view, the complete overlap of two glottal openings for the preceding and the following consonants in a /CVC/ sequence is expected to results in complete devoicing of the medial vowel.

In the present study, two unique instances were observed: an incomplete double opening with a devoiced vowel, and a single opening with a partially voiced vowel. An intermediate process of gestural overlap may explain the former case in which the vowel was devoiced and showed a double opening phase, instead of a single opening phase as expected. On the other hand, the latter case may not straightforwardly fit to the assumption stated above, as it clearly indicates that a single glottal opening does not necessarily correspond to a devoiced vowel. At the same time, the latter case suggests the necessity of more detailed explanation for the instances in which a partially voiced vowel is observed. It appears that the gestural overlap analysis generally assumes that the presence of partially voiced vowel in acoustic data is suggestive of the presence of the intermediate glottal overlapping pattern. However, caution is needed since there may be two different glottal opening patterns that will produce a partially voiced vowel.

As for the token with a double opening phase accompanied by a fully voiced vowel, it is puzzling that this case was seen only in the [sise] token, namely fricative-vowel-fricative sequence, but not in the [sike], [kise] or [kike] tokens. This fact may suggest that the /CVC/ sequence with fricatives on both sides of vowel has a tendency to show a double opening phase. It is known, however, that when a single consonant occurs, the degree of glottal opening is larger in fricatives than in stops (Sawashima 1971). Hence, it seems natural that the two consonantal gestures overlap and blend into a single opening in a fricative-vowel-fricative sequence, rather than in a stop-vowel-stop sequence.

Previous papers that have investigated the laryngeal gesture during the /CVC/sequences with respect to vowel devoicing in Japanese do not always agree on the glottal opening pattern for a fricative-vowel-fricative sequence. Although a single glottal opening phase for a [sis] sequence is reported or suggested in many studies (e.g. Sawashima 1971, Yoshioka 1982), there are a few papers in which a double opening phase is also suggested. Sawashima (1969) includes PGG data for two tokens, with a [sis] sequence reported for one of the two subjects, which may be comparable to the incomplete double opening pattern for /sise/ token in the present study. Furthermore, Tsuchida (1997) reports that all four tokens with a [sis] sequence show a double opening phase. Extended study is needed to examine if fricative-vowel-fricative sequences have a tendency to produce a double opening phase.

It is worth noting that, in the previous acoustic studies of vowel devoicing, a fricative-vowel-fricative sequence demonstrates different characteristics from a single fricative context. It has been claimed that vowel devoicing is frequent when the initial consonant of a /CVC/ sequence is a fricative (Han 1962). Recently, vowel devoicing has been studied using large databases, aiming an improvement of synthesis by rule. Among those studies, one agrees with Han’s claim (Takeda and Kuwabara 1987). However, another study revealed that devoicing is less likely in a fricative-vowel-fricative sequence (Kimura et al. 1988). An acoustic examination currently under

way in our laboratory, in which many subjects are involved, also shows the same tendency. These acoustic data, in which devoicing is less likely in a fricative-vowel-fricative sequence, suggest a tendency for the sequence to be produced with a double opening phase, despite the fact that no laryngeal study focussed on the contextual variation of glottal opening for /CVC/ sequence.

Although the material and subjects were limited, the present study revealed the variation and complexity of vowel devoicing in Japanese. These findings lead us to believe that more careful observation and more precise analysis are needed to understand the devoicing phenomenon in Japanese.

5. CONCLUSION

The correspondence between the pattern of the glottal opening gesture and vowel devoicing in Japanese /CVC/ sequences is more complex than currently assumed. Gestural overlap analysis needs to be compatible with particular cases, such as the single opening pattern for the /CVC/sequence accompanied by a partially voiced vowel. Further study is essential to investigate the correspondence between glottal movement and vowel devoicing, and to clarify the mechanism of vowel devoicing in the Japanese language.

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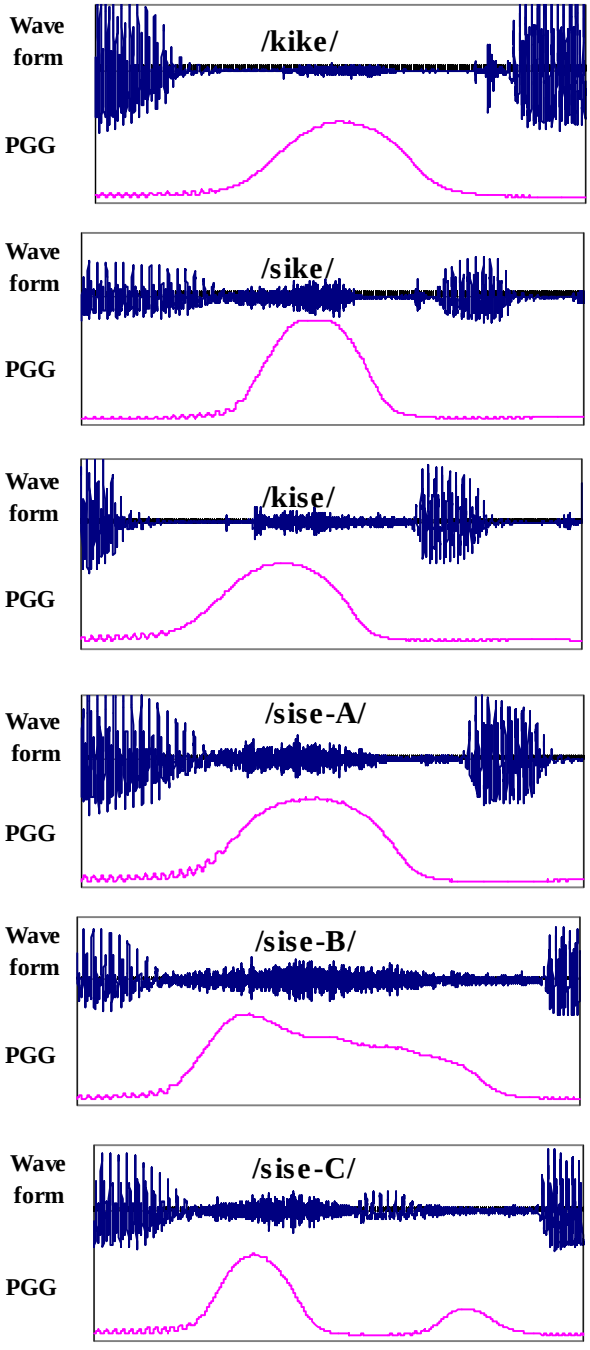

Figure 1. Waveform and PGG for representative tokens of each test word.