# Effects of Consonant Type and Syllable Position within a Word on Vowel Devoicing in Japanese

*Masako Fujimoto*

Department of Language Research, The National Institute for Japanese Language, Japan
mfuji@kokken.go.jp

10.21437/SpeechProsody.2004-144

## Abstract

"Vowel devoicing" occurs more frequently in the Tokyo dialect (standard Japanese) than in the Osaka dialect. Our previous study showed that devoicing was a) highly frequent when a stop or an affricate was at least on one side, b) less frequent when fricatives were on both sides, and c) infrequent when there was a following /h/. In order to clarify why asymmetric effect of consonantal kind on vowel devoicing arises especially in $C_2$ position, characteristics of glottal opening were examined using photoelectric glottography (PGG). The results showed that glottal opening degree in $C_2$ position, in coordination with vocal tract constriction, can account for such difference of devoicing rate. For the devoiced tokens, glottal opening degree was comparable to that of a single consonant for the Osaka speaker, while it was larger than that of a single consonant for the Tokyo speaker. This fact suggests that the mechanism of devoicing differs between Tokyo and Osaka dialects.

## 1. Introduction

"Vowel devoicing" (hereafter "devoicing") is a widely observed phenomenon in Japanese where high vowels /i/ and /u/ are devoiced when they are preceded and followed by voiceless consonants [1,2]. Several factors are reported to affect the frequency of devoicing, such as speaking rate [3], presence or absence of accent nucleus [4], dialectal difference [5], and consonantal environment [5], among others.

As for dialectal difference, it is observed more frequently in the dialects of eastern Japan including standard (Tokyo) Japanese than in those of western Japan including the Osaka dialect [1,2,5]. However, accent pattern is systematically different between Tokyo and Osaka dialects. For example, "kita" ("north") is pronounced as unaccented [kita] in Tokyo while it is accented [ki'ta] in Osaka. Previous studies often compared the devoicing rate of unaccented syllables (in Tokyo) to that of accented syllables (in Osaka). It is known that devoicing occurs less often in accented syllables than in unaccented ones [4]. Thus comparison without influence of accent pattern was expected. Our previous study using non-sense words indicated that, within pitch accent groupings, some of the Kinki (a region in western Japan) dialect speakers showed devoicing rates similar to that of the Tokyo dialect speakers, while others showed devoicing rates significantly lower than those for Tokyo speakers [7].

## 2. Asymmetric effects of consonant type on devoicing rate

Consonantal environment is another major factor that affects devoicing rate. Devoicing is said to be not obligatory or infrequent when both preceding and following consonants are fricatives [1,2]. However, the effect of consonant type on devoicing is not as simple as it has been claimed. Tables.1 to 3 show the result of comparison between ten Tokyo dialect speakers and ten Osaka dialect speakers. In the tables, the variation of devoicing rate of /i/ in /CiCe/ words are shown for different consonantal environments for unaccented syllables produced at a normal speech rate (duplicated from Fujimoto 2004). Table.1 shows average devoicing rates of ten Tokyo speakers, and table 2 and 3 show results for eight Osaka speakers with a high rate of devoicing and two Osaka speakers with low a rate of devoicing, respectively.

As can be seen from Table 1, devoicing for Tokyo speakers was a) highly frequent (almost without exception) when a stop or an affricate was at least on one side, b) less frequent (seemingly random) when fricatives were on both sides, and c) infrequent (seemingly random) when there was a following /h/. The same tendency was found for the Osaka speakers who had a high rate of devoicing. A similar tendency was found for the Osaka speakers whose devoicing rate was low; devoicing occurred only when a stop or an affricate was at least on one side.

These results indicate that fricatives suppress devoicing only when they are in $C_2$ position. Furthermore, among the fricatives, /s/ suppresses devoicing only when $C_1$ is also a fricative, whereas /h/ does so regardless of the type of $C_1$.

Table 1: *Frequency of devoicing for Tokyo speakers. (n=10)*

| $C_1$ \ $C_2$ | k | t | s | h |
|---|---|---|---|---|
| k | 100% | 100% | 100% | 23% |
| s | 100% | 98% | 58% | 13% |
| h | 100% | 100% | 85% | 13% |

Table 2: *Frequency of devoicing for Osaka speakers with a high rate of devoicing. (n=8)*

| $C_1$ \ $C_2$ | k | t | s | h |
|---|---|---|---|---|
| k | 94% | 94% | 97% | 13% |
| s | 100% | 100% | 53% | 13% |
| h | 100% | 100% | 63% | 3% |

Table 3: *Frequency of devoicing for Osaka speakers with a low rate of devoicing. (n=2)*

| $C_1$ \ $C_2$ | k | t | s | h |
|---|---|---|---|---|
| k | 13% | 25% | 38% | 0% |
| s | 75% | 75% | 0% | 0% |
| h | 0% | 63% | 0% | 0% |

## 3. Asymmetric feature of glottal opening pattern among consonants

Laryngeal activity in Japanese has been extensively examined in view of the vowel devoicing phenomena [5,6,7,8]. In order to clarify why such asymmetry arises, more specifically, why fricatives works as a suppressor of devoicing in $C_2$ position but not in $C_1$ position, observation of glottal activity was carried out using photoelectric glottography (PGG).

### 3.1. Experiment

- **Subjects**: An adult male speaker of Tokyo dialect and an adult male speaker of Osaka dialect served as subjects. They lived until at least the age of 18 in either the Tokyo district or Osaka district and were living in the same area at the time of the experiment.

- **Materials**: Test words were nine nonsense words shown below. Note that devoicing of /i/ is expected most probably in /kike/ and least probably in /hihe/ among test words with a devoicing environment, according to the above mentioned acoustic analysis.

  Voiceless consonant in $C_1$: /kine/, /sine/, /hine/
  Voiceless consonant in $C_2$: /nike/, /nise/, /nihe/
  Voiceless consonant in $C_1$and $C_2$: /kike/, /sise/, /hihe/

  The carrier phrase was "sorede ___ to shimasu" ("So then, I make a decision that it is ____"). Pitch pattern of the sentence in the two dialects is as follows.

  | | So re de | ___to | shi ma su |
  |---|---|---|---|
  | Tokyo | L H H | H H H | H H L |
  | Osaka | H H H | H H H | H H H |

  (L: Low pitch, H: High pitch)

- **Methods of data recording**: Subjects read the test words along with 13 other words in the carrier sentence four times in a randomized order. The temporal pattern of the glottal opening was recorded using PGG simultaneously with the speech signal. The glottis was illuminated by a flexible laryngeal fiberscope, which was inserted through the nasal tract of the subject, with its tip set in an appropriate position above the glottis. The light transmitted through the glottis penetrated through the surface tissue of the neck. The amount of light outside of the neck changed according to the degree of glottal opening. By attaching a light sensor to the skin surface just below the vocal folds, temporal signals were digitally recorded which reflected the variation in the light intensity transmitted through the glottis. Throughout the PGG recording, the laryngeal image from the fiberscope was continuously monitored and video-recorded to confirm that the glottis was adequately. Data were collected at The Research Institute of Logopedics and Phoniatrics, University of Tokyo.

- **Methods of data analysis**: Data were put into a computer and analyzed using Sony PCScan. Voicing/unvoicing of vowels and consonants were determined using speech data.

### 3.2. Result

Figures 1 and 2 show the glottal opening pattern of the test words. Figure 1 shows the result of the Tokyo speaker and figure 2, of the Osaka speaker. In each column, the PGG signal of four repetitions of the /CiCe/ portion are superimposed where the x-axis shows the time (ca. 460ms) and the y-axis shows the degree of glottal opening. Note that the y-axis is arbitrarily scaled, since degree of glottal opening cannot be compared among subjects. For the convenience of comparison, glottal opening degree was normalized so that the maximum opening for /k/ in /kine/ was comparable for the two speakers.

***Voiceless consonants in $C_1$ position***

In $C_1$ position, glottal opening was observed for the Tokyo speaker for all voiceless consonants /k/, /s/ and /h/. Degree of the glottal opening somewhat differed among consonant types and tokens. Opening degree for fricatives /s/ and /h/ were generally larger than that for the stop /k/. Among fricatives, opening degree for /h/ was similar to that of /s/. For the Osaka speaker, te glottal opening pattern shows a similar tendency to that of the Tokyo speaker, except that opening for /s/ is somewhat larger than that of /h/.

***Voiceless consonants in $C_2$ position***

In $C_2$ position, for the Tokyo speaker, appreciable glottal opening was observed for /s/ and /h/ but not for /k/. In the speech signal, /k/ was voiceless for all tokens. Opening degree of the consonants in $C_2$ position was generally smaller than that in $C_1$ position regardless of consonant type. Vocal fold vibration stopped during /s/ but continued during /h/, although the glottal opening degree was comparable for /s/ and /h/. These tendencies were similar for the Osaka speaker.

***Voiceless consonants in $C_1$ and $C_2$ position***

Devoicing of /i/ occurred for both speakers in the test words with a devoicing environment. However, the frequency of devoicing differed between speakers and among test words. Table 4 shows the frequency of devoicing in these test words.

Table 4: *Frequency of devoicing in test words with a devoicing environment*

| Test words \ Speaker | Tokyo | Osaka |
|---|---|---|
| /kike/ | 4/4 | 1/4 |
| /sise/ | 2/4 | 0/4 |
| /hihe/ | 0/4 | 0/4 |

Looking at /kike/ of the Tokyo speaker, glottal opening degree during devoiced /CiC/ was generally larger than that during a single /k/ in /kine/. This is consistent with previous studies [8,9]. For the Osaka speaker, on the other hand, glottal opening during /kike/ was similar among tokens and similar to that of a single /k/ in /kine/, although /i/ was devoiced in one token. That is, unlike the Tokyo speaker, devoicing of /kike/ for the Osaka speaker was achieved with an opening as small as that for a single /k/.

As for /sise/ of the Tokyo speaker, glottal opening during two devoiced tokens was larger than that of a single /s/ in /sine/, while opening during two voiced tokens was similar to that of a single /s/ in /sine/. That is, glottal opening

systematically differed depending on the occurrence of vowel devoicing. For the Osaka speaker, glottal opening during /sise/ produced with a voiced vowel was not larger than a single /s/. It was similar to a series of two /s/s in /sine/ and /nise/. Likewise, glottal opening during /hihe/ with a voiced vowel was similar to a series of two /h/s in /hine/ and /nihe/ for both Tokyo and Osaka speaker.

It was noticed that, regardless of the test words and the dialect, no appreciable glottal opening was observed for /t/ in the post-position "to" in the phrase / $C_1$i $C_2$eto/.

## 4. Discussion

The results showed that, for a single consonant, glottal opening degree was generally larger for the fricatives /s/ and /h/ than for the stop /k/ for both Tokyo and Osaka dialect speakers. These results are consistent with studies on other languages [13]. Within the same consonant, opening degree is larger in word-initial position than in word-final position. It is known that, in English, glottal opening degree is often not noticeable in unaccented syllables compared to that in accented syllables [13]. Also, in English, no appreciable glottal opening for stop consonants is observed in word-final position, presumably due to glottalization [13]. A similar difference in glottal opening degree was observed in the present study. However, the factor that gave rise to such difference was the position of the relevant syllable in the word. Note that both syllables were unaccented in the present test words and not glottalized. Concerning that no appreciable glottal opening was observed for /t/ in the post-position "to" in the phrase /$C_1$i$C_2$eto/, the prosodic scope for such arranging seems to be a phrase, not a word.

Without appreciable glottal opening of /k/ in $C_2$ position, /k/ was voiceless in the speech data regardless of dialects. This is achieved by oral closure. This indicates that vocal fold vibration is easily stopped or suppressed in stop consonants, regardless of the glottal opening degree. This may lead to a frequent occurrence of devoicing with stop consonants in either side of /CVC/.

Vocal fold vibration continued throughout /h/ in $C_2$ position regardless of dialect. This is presumably due to looser constriction of the vocal tract for /h/ than that for /s/. This may lead to an infrequent occurrence of devoicing with the consonant /h/ in $C_2$ position.

Glottal opening for devoiced /CVC/ for the Tokyo speaker is far larger than that for a single $C_1$ and $C_2$. On the other hand, for the Osaka speaker, glottal opening for devoiced /CVC/ is comparable to that for a single $C_1$ and $C_2$. This suggests that the mechanism of devoicing may be different between the Tokyo and the Osaka speakers. Beckman [14] claimed that Japanese vowel devoicing occurs due to the overlap of the gesture for the consonant on the surrounding vowel, contrary to the argument that devoicing is not a mere skip of vowel gesture but it involves a higher-level control in the speech production. It may be possible to interpret the present results in the following fashion: devoicing for the Osaka speaker occurred due to gestural overlap at the glottis level as Beckman claims, while that for the Tokyo speaker involves higher level control as argued by other previous studies.

## 5. Conclusion

In order to clarify why asymmetric effect of consonantal type on vowel devoicing arises especially in $C_2$ position, characteristics of glottal opening were examined using PGG. The results showed that glottal opening degree for the same consonant differs depending on position within a word/phrase. Degree of glottal opening was larger in the word-initial position than in the word-final position. It was also shown that, in $C_2$ position, glottal opening for stop /k/ is not appreciable compared to that for fricatives /s/ and /h/. Nevertheless, vocal fold vibration stopped more easily during stop /k/ than during fricatives, and, among fricatives, it stopped more easily during /s/ than during /h/. Our previous study showed that frequency of devoicing was a) highly frequent when a stop or an affricate was at least on one side, b) less frequent when fricatives were on both sides, and c) infrequent when there was a following /h/. The results of this study showed that glottal opening degree in $C_2$ position, in coordination with vocal tract constriction, can account for such difference of devoicing rate. For the devoiced tokens, glottal opening degree was comparable to that of a single consonant for the Osaka speaker, while it was larger than that of a single consonant for the Tokyo speaker. This fact suggests that the mechanism of devoicing differs between Tokyo and Osaka dialects.

## 6. References


[1] Sakuma, K., 1933, Kokugo onseegaku gaisetu, Dobunkan, Tokyo.

[2] Hirayama, T., 1985, Zennihon no hatsuon to akusento. In *Nihongo*

[3] Maekawa, K., 1989. Boin no museika. In *Koza Nihongo to Nihongo-kyoiku (2)*. Sugito M. (ed). Tokyo, 135-153.

[4] Han, MS., 1962. Unvoicing of vowels in Japanese. In *Study of Sounds 10*, Phonetic Society of Japan. 81-100.

[5] Sugito M., 1966, Boin no museika, In *Nihongo no Oto*, 28-42. (In Japanese).

[6] Fujimoto M., Kiritani S., 2003. Comparison of Vowel Devoicing for Speakers of Tokyo- and Kinki Dialect. *J. Phonetic Society of Japan* 7(1), 58-69.

[7] Fujimoto M., 2004. Vowel Duration and Vowel Devoicing in Japanese: A Comparison between Tokyo and Osaka Dialect Speakers, *Studies in the Japanese Language*, The Soc. of Japanese Linguistics. (In printing)

[8] Sawashima M, 1969. Vowel devoicing in Japanese- A preliminary study by photoelectric Glottography-. *Annu Bull of RILP*, University of Tokyo; 3:35-41.

[9] Sawashima, M., Miyazaki, S., 1973. Glottal opening for Japanese voiceless consonants, *Annu Bull of RILP 7*, University of Tokyo, 1-9.

[10] Yoshioka, H., 1981 Laryngeal adjustment in the production of the fricative consonants and devoiced vowels in Japanese. *Phonetica*. 38:236-351.

[11] Yoshioka H, 1982, Löfqvist A, Hirose H: Laryngeal adjustments in Japanese voiceless sound production. *J Phonetics*; 10:1-10.

[12] Lisker L. et al., 1969, Transillumination of the Larymx in Running Speech, *JASA* 45-6, 1544-1546.

[13] Yoshioka H, Laryngeal adjustment in the production of consonant clusters and geminates in American English, *J Acoust Soc Am* 1981; 70-6:1615-1623.

[14] Beckman M, When is a syllable not a syllable, 1996. In *Phonological Structure and Language Processing, Cross-linguistic Studies*, Otake T., Cutler A. (eds). Mouton de Gruyter, Berlin, 95-123.

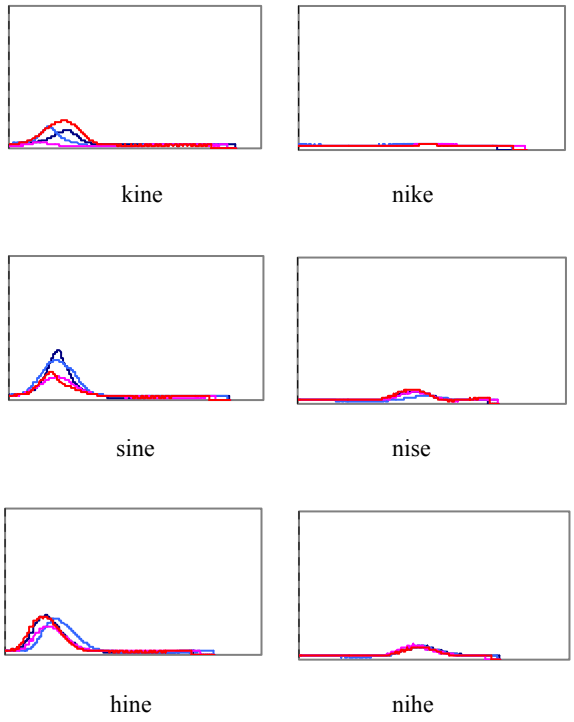
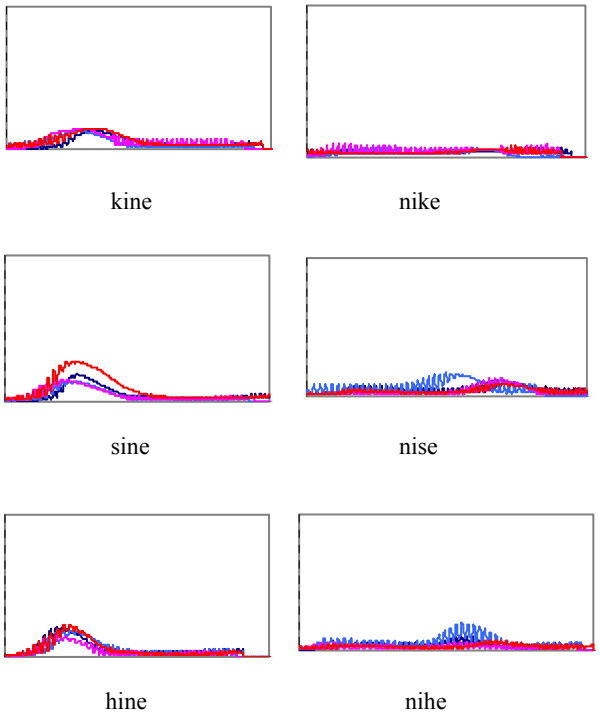



Figure 1: *Glottal opening pattern for each test words of Tokyo speaker. PGG curves of four repetitions are superimposed.*



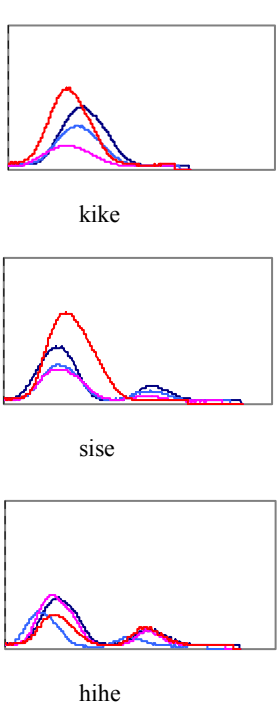




Figure 2: *Glottal opening pattern for each test words of Osaka speaker. PGG curves of four repetitions are superimposed.*