Distribution and Trichotomic Realization of Voiced Velars in Japanese – An Experimental Study

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Abstract

In this paper, we demonstrate the trichotomic realization of voiced velars in Japanese, challenging the traditional plosive/nasal dichotomy of velar allophones, and examine the distribution of these allophones taking phonetic/phonological factors into account. We conducted the quantitative analysis based on some speech production experiments. The results show that voiced velars are more likely to realize as plosives in word-initial positions, as nasals in post-nasal positions, and as fricatives in sequential contexts; velars in word-initial positions can realize as fricatives; the decline of velar-nasalization has been accelerated; following vowels and dialectal differences can affect the distribution.

Index Terms: speech production, phonological context, Japanese, velar-nasalization, spirantization

1. Introduction

This research reexamines the voiced velar allophones [g] (henceforth, velar allophones) in Japanese through the quantitative analysis based on some speech production experiments, taking phonological factors governing the distribution of these allophones into account. It has been traditionally assumed that voiced velars (henceforth, velars) in Japanese realize as either plosives [ɡ] or nasals [ŋ] [1–9, among others].

The distribution of velar allophones has been assumed to be governed by the contextual factors. The fundamental restriction concerns the position within a word: velars realize as plosives in word-initial positions as in gakuhi ‘tution’ (Figure 1); on the other hand, in word-internal positions velars realize as nasals, as in dokuga ‘venom fang’ (Figure 2).

The positional restriction interacts with some other factors such as the lexical strata (e.g. Sino-Japanese, Yamato Japanese, or loanwords), and the word-internal structure in compounds [4, 8, among others]. The intricate interactions of contextual factors define the variable distribution of velar allophones.

The distribution of velar allophones, however, shows some variation and change. In terms of the dialectal difference, in Tohoku dialect nasals are remarkable; on the other hand, in Kansai dialect, velars categorically realize as plosives, and Kanto dialect is intermediary [8, among others]. Thus, the dialectal difference of velar allophones is characterized as in Tohoku dialect > Kanto dialect > Kansai dialect, with respect to nasals. As for the change, the decline of velar-nasalization has been reported, namely, cases have been increasing where velars in word-internal positions realize as plosives instead of supposed nasals, in violation of the aforementioned restrictions [1, 2, 4]. Specifically, the rate of velar nasals has been declining starting with speakers born in the 1910s [4]; 48% of all the velars in word-internal positions realized as nasals in the data collected in 1986 [1, 2]. Incidentally, a few works point out that velars can realize as fricatives [ɣ] as in Figure 3 (spirantization, [4, 10, 11]).

Figure 1: Waveform and spectrogram of [ɡ] in gakuhi (speaker #03).

Figure 2: Waveform and spectrogram of [ŋ] in dokuga (speaker #01).

Figure 3: Waveform and spectrogram of [ɣ] in eigo ‘English’ (speaker #02).

However, as we saw above, the in-depth analysis of the data has been insufficient, phonetic/phonological aspects of the distribution of velar allophones have been underresearched, and crucially the velar fricatives has been overlooked, as the previous studies had mainly been based on the “word” as their unit of analysis. The goals of the present research, therefore,
include: 1) to challenge the claims of previous studies such as the traditional plosive/nasal dichotomy and the decline of velar-nasalization; 2) to examine the effects of factors which govern the distribution of velar allophones. Specifically, the analysis focuses on the following points: the distributions 1) in word-initial positions, 2) in post-nasal positions, 3) in sequential contexts; and 4) the effects of following vowels; 5) the dialectal differences. Throughout the analysis, we assume the trichotomy among plosives, nasals and fricatives following the claim of spirantization.

This paper is organized as follows: Section 2 introduces the details of the experiments; in Section 3, we present the results and the discussion; Section 4 concludes the discussion.

2. Method

2.1. Target words

In the speech production experiments, we selected target words exclusively from Sino-Japanese words with three morae length for the purpose of eliminating the effects of word length and of lexical strata. In addition, in Sino-Japanese words the distribution of velars is relatively free, allowing us to set up various contexts. Specifically, we arranged target words focusing on the following factors: phonological contexts such as word-initial velars, post-nasal velars, and sequential velars; the types of following vowels. The target words include the following six phonological contexts:

(1) [u ɣ] (no carrier sentence) e.g. gakuhi ‘tuition’
(2) [l ɣ] e.g. gimi ‘review’
(3) [v ɣ] e.g. dokuga ‘vendetta’
(4) [n ɣ] e.g. gingo ‘galaxy’
(5) [v ɣ][v ɣ] e.g. eigo-ga ‘English-case particle’
(6) [ŋ ɣ][ŋ ɣ] e.g. rongo-ga ‘Analects-case particle’

Velars, in themselves, appear in word-initial positions both in (1) and (2). In (1), however, target words are not embedded in carrier sentences (kare-wa ‘……’ to itta ‘He said ‘……’ ’), yielding velars in utterance-initial positions; on the other hand, in (2) target words are embedded in carrier sentences, yielding velars in word (prosodic word, accentual phrase) -initial positions. Every target word is presented as embedded in carrier sentences except for (1). In (3) velars appear in post-vocalic positions. In (4) velars appear in post-nasal positions. (5) and (6) include the sequential contexts where syllables involving velars are adjacent. (5) involves two post-vocalic velars; on the other hand, (6) involves post-nasal velars followed by post-vocalic velars. Every sequential context includes the case-particle ga.

For each context listed above, we arranged five extra contexts with respect to the types of following vowels (/ɣi/, /go/, /goi/, /go/, /gu/).

2.2. Participants

We randomly sampled three participants according to the following criteria: 1) age: under 25; 2) gender: male/female; 3) hometown: Tohoku/Kanto/Kansai areas; 4) experience abroad: less than one month. Specifically, in order to examine the progress of velar-nasalization, we focused on younger speakers; for the examination of dialectal differences, we sampled one speaker from each of these areas; and to eliminate the influence of foreign languages, we limit the experience abroad within the short time-period. In the prior questionnaire, no participants reported auditory impairments.

2.3. Recording

The recordings have been conducted in the Sophia Univ. Phonetics Lab. soundproof chamber for each participant individually. The utterances were recorded onto a digital recorder through a microphone and digitized at 48 kHz sampling frequency with 16 bit quantization. In the recordings, we randomly presented target words and distracters embedded in carrier sentences one by one; participants read the whole sentence according to the presented script. We recorded at least five tokens for each target word/distractor.

2.4. Segmentation

The recorded audio data were in turn analyzed by Praat version 4.5.08. [12]. Spectrogram settings were as follows: View range: 0-5000 Hz; Window length: 0.005 s; Dynamic range: 50 dB. We extracted the parts corresponding to velar allophones from the audio data and classified these into plosives, fricatives, and nasals. The criterion for the classification of velar allophones is schematized below.

[Figure 4: Criterion for the classification of velar allophones]

Firstly, if an obvious burst (closure and release) is observed with respect to the waveform (e.g. Figure 1), the velar allophone is categorized as a plosive; if no obvious burst is observed, then we refer to the nasal formant; if a nasal formant is observed (e.g. Figure 2), the velar allophone is categorized as a nasal; if no nasal formant is observed (e.g. Figure 3), then the velar is categorized as a fricative.

3. Results and discussion

3.1. Overall distribution

As mentioned above, we arranged six phonological contexts and five contexts for the types of following vowels. Thus, the total tokens we focus on amount to 600 (6 phonological contexts × 5 vowels × 5 tokens × 3 speakers + 2 phonological contexts × 5 vowels × 5 tokens × 3 speakers).

The overall distribution of velar allophones is summarized in Table 1.

[Table 1. Distribution of velar allophones]

<table>
<thead>
<tr>
<th>Allophone</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>ɣ</td>
<td>277</td>
<td>46.17%</td>
</tr>
<tr>
<td>ɣi</td>
<td>269</td>
<td>44.83%</td>
</tr>
<tr>
<td>go</td>
<td>54</td>
<td>9%</td>
</tr>
<tr>
<td>Total</td>
<td>600</td>
<td>100%</td>
</tr>
</tbody>
</table>

As Table 1 shows, the frequency (269) as well as the probability (44.83%) of fricatives are almost the same as those of plosives (frequency: 277; probability: 46.17%); on the other hand, the frequency (54) and the probability (9%) of nasals are extremely low. The result shows that velar fricatives, which have been overlooked in previous works, are frequently observed in actual utterance and that the decline of velar-nasalization has been accelerated, considering the younger age of the participants.
3.2. Distribution by phonological contexts

Next, we examine the distribution of velar allophones by six phonological contexts arranged in the target words.

**Figure 5: Distribution of velar allophones according to phonological contexts (p < 0.001).**

In Figure 5, “NgVg1st” and “VgVg1st” represents the preceding velars in sequential contexts (e.g. rongo-ga, eigo-ga), and “NgVg2nd” and “VgVg2nd” represents the following velars (e.g. rongo-ga, eigo-ga).

As Figure 5 shows, every velar categorically realizes as plosives in utterance-initial positions; on the other hand, in word-initial positions the probability of plosives is 80% and that of fricatives is 20%, and no nasals are observed. The result slightly differs from the claims of previous studies: although plosives are predominant, not a few fricatives are observed in word-initial positions. Thus, we can argue that the difference in utterance-initial and word-initial positions affects the distribution of velar allophones, and that velars can realize as other allophones than plosives due to some phonological factors even if they are in the same positions within a “word”. The result further shows that in word-initial positions velar allophones are not categorically restricted to plosives; rather the distribution should be characterized in a gradient manner where plosives are more frequent than fricatives in word-initial positions.

At this point, we consider the reason for the different distributions in utterance-initial and word-initial positions in terms of the difference in levels of strengthening in prosodic structure: initial segments of each prosodic category undergo the strengthening; the degree of strengthening depends on the level of the category in prosodic structure: the higher the level, the stronger the strengthening (e.g. utterance > intermediate phrase > accentual phrase > prosodic word) [13, among others]. In the present case, the utterance-initial positions are higher, while word-initial positions, which are categorized as accentual phrases or prosodic words, are lower with respect to the levels in prosodic structure. This gives more chance for word-initial positions to be spirantized, where weaker strengthening is expected.

In post-nasal positions, nasals show a relatively higher probability (Ng: 35%; NgVg2nd: 21%) compared with other positions. In post-nasal positions, velars preferentially realize as nasals compared with other positions. This process can be thought of as a kind of progressive assimilation. All in all, however, the probability of nasals is lowest in either context compared with that of plosives and that of fricatives, showing that the higher likelihood of nasalization in post-nasal positions is suppressed by the effect of the decline of velar-nasalization. The interaction among factors is demonstrated to play a crucial role in defining the distribution.

In sequential contexts, we can observe the higher probability of fricatives (NgVg1st: 41%; VgVg1st: 64% (preceding velars); NgVg2nd: 75%; VgVg2nd: 85% (following velars)). The results show that, in sequential contexts, velars are more likely to realize as fricatives and that, in sequential contexts, following velars are more likely to realize as fricatives than preceding velars.

Here, we examine whether preceding and following velars in a single token match or mismatch with respect to the allophonic realization.

**Table 2. Cross-tabulation of the distributions of preceding and of following velars (p < 0.001).**

<table>
<thead>
<tr>
<th>Preceding</th>
<th>g</th>
<th>y</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>g</td>
<td>15 (60%)</td>
<td>6 (24%)</td>
<td>4 (16%)</td>
</tr>
<tr>
<td>y</td>
<td>37 (31%)</td>
<td>73 (61%)</td>
<td>10 (8%)</td>
</tr>
<tr>
<td>n</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>5 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td>52</td>
<td>79</td>
<td>19</td>
</tr>
</tbody>
</table>

In Table 2, cases where preceding and following velars match show a higher probability (shaded cells). Furthermore, putting tokens all together, the probability of “match” constitutes 62% of all cases (“mismatch”: 38%), showing that preceding and following velars in sequential contexts are more likely to match. Note that, in sequential contexts, velars are not adjacent as there is an intervening vowel as in eigo-ga. Therefore, we argue that the matching in the present case is an instance of assimilations in nonlocal contexts, in support of the Long Distance Consonant Agreement (LDCA, [14]), which assumes the agreement of consonantal features in nonlocal contexts.

Based on these results, we make a generalization of the distribution of velar allophones with respect to the phonological context: 1) word-initial positions – {g}; 2) post-nasal positions – {ŋ}; 3) sequential contexts – {ɣ}.

3.3. Effects of following vowels

A number of phonetic/phonological researches to date point out that consonants undergo some changes, with respect to their features, being affected by following vowels [15, 16, among others]. If this is on the right track, the distribution of velar allophones should vary according to the types of following vowels. We examine the distribution of velar allophones for five vowels.

**Figure 6: Distribution of velar allophones according to following vowels (p < 0.001).**

As shown in Figure 6, the probability of plosives is higher before /i/ and /e/ vowels; on the other hand, the probabilities of fricatives and nasals are higher before /a/ and /o/ vowels. The
result shows that the distribution of velar allophones is affected by the types of following velars, as expected; specifically, plosives are more compatible with high and front vowels, while fricatives and nasals are more compatible with low and back vowels. This can be attributed to articulatory reasons: to articulate velars followed by low and back vowels, a relatively larger tongue movement is required, compared with high and front counterparts, resulting in the half-way-closure, and velars are likely to realize as fricatives or nasals, rather than as plosives.

3.3. Effects of dialectal difference

Finally, we examine the distribution in terms of the dialectal differences. As mentioned above, the dialectal difference of velar allophones is characterized as in Tohoku dialect > Kanto dialect > Kansai dialect, with respect to nasals. Even with the decline of velar-nasalization, is the characterization of dialectal difference still valid? If so, we would obtain the similar distribution as above even in the present analysis, which focuses on utterances of younger speakers. For the examination, we classified velar allophones according to the hometown of each speaker. The result is shown below.

![Figure 7: Distribution of velar allophones according to hometown of speakers (p < 0.001).](image)

As Figure 7 shows, with respect to nasals Tohoku shows remarkably higher probability (20%), and nasals are frequent in the following order: Tohoku > Kanto > Kansai, showing that the characterization of dialectal difference remains valid. Although no significant difference is observed with respect to plosives, the following tendency is observed concerning fricatives: fricatives are most frequent in Kansai, least in Tohoku, and Kanto is in between. This order is the exact opposite of the one in nasals.

4. Conclusions

In this paper, we presented the analysis of Japanese velar allophones. Specifically, we challenged the traditional categorization of velar allophones, and we examined the distribution of these allophones taking phonetic/phonological factors into account. The examinations brought forth the following findings: 1) the decline of velar-nasalization has been accelerated; 2) word-initial velars can realize as fricatives although plosives are predominant [contra 4]; the distribution is governed by the prosodic structure, cf. [13]; 3) post-nasal velars preferentially realize as nasals; 4) velars in sequential contexts preferentially realize as fricatives; 5) progressive assimilation is observed in post-nasal positions and sequential contexts (LDCA, [14]); 6) velars preceding front and high vowels preferentially realize as plosives, while those preceding low and back vowels are more likely to realize as fricatives or nasals; 7) the characterization of dialectal difference can still be valid (nasals: Tohoku dialect > Tokyo dialect > Kansai dialect). Incidentally, the distribution of velar allophones in Japanese shows some similarity with that in Spanish with the plosive/fricative dichotomy, except for nasals (Japanese: utterance-initial positions: plosives, post-nasal positions: nasals, other contexts: fricatives; Spanish: utterance-initial/post-nasal positions: plosives, other contexts: fricatives, cf. [17]).

We propose that the traditional plosive/nasal dichotomy is insufficient to figure out the nature of the velar allophones in Japanese; instead, the velar allophones need to be discussed in terms of the trichotomy with fricatives; the distribution of velar allophones is defined by the interaction between language change and phonological factors. Furthermore, it can even be predicted that nasal will disappear; the velar allophones will be comprised only of plosives and fricatives.

5. Acknowledgements

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6. References