Cumulative Strengthening and Distribution of Velar Allophones in Japanese

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ABSTRACT. In this paper, I demonstrate how the prosodic structure governs the segmental features of velars in Japanese in their allophonic realization. I conducted the quantitative analysis based on some speech production experiments, and subsequently I formalized the correlation between positions/levels in prosodic structure and the allophonic realization in terms of the recursive φ model and the consonantal strength. 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; the gradient distribution of velar allophones can be attributed to the cumulative strengthening effect.

Keywords: trichotomy, consonantal strength, recursive φ model, cumulative prosodic effect

1. Introduction

Among the factors that contribute to the phonological processes, the positions/levels in prosodic structure have been shown to play a crucial role (Fougeron and Keating 1997, among others). This research reexamines the distribution of voiced velar allophones /g/ (henceforth, velar allophones) in Japanese based on some speech production experiments, focusing on the effect of positions/levels in prosodic structure as one of the factors governing the allophonic realization of velars, and gives a formal account to the distribution in terms of the recursive φ model (Ito and Mester to appear).

It has been traditionally assumed that voiced velars (henceforth, velars) in Japanese realize as either plosives [g] or nasals [ŋ] (Kindaichi 1942; Otsu 1980; Vance 1987, 2008; Hibiya 1995; Okada 1999; Kindaichi and Akinaga 2001, 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 ‘tuition’; on the other hand, in word-internal positions velars realize as nasals, as in dokuga ‘venom fang’. 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 (Kindaichi 1942; Vance 1987, 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 (Vance 1987, 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, a 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 (Kindaichi 1942; Hibiya 1995). Specifically, the rate of velar nasals has been declining starting with speakers born in the 1910s (Kindaichi 1942); 48% of all the velars in word-internal positions realized as nasals in the data collected in 1986 (Hibiya 1995). Incidentally, a few works point out that velars can realize as fricatives [ɣ] (spirantization, Kindaichi 1942; Kamei 1956; Hattori 1957).

However, 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 have been overlooked, as the previous studies were mainly based on the “word” as their unit of analysis. The goals of the present research, therefore, include: 1) challenging the claims of previous studies such as the traditional plosive/nasal dichotomy and the decline of velar-nasalization; 2) examining the distribution of velar allophones according to phonological contexts; and 3) giving a formal account to the allophonic realization of velars in terms of prosodic effects, where the cumulative strengthening plays a crucial role. Throughout the analysis, I assume the trichotomy among plosives, nasals, and fricatives following the claim of spirantization. This paper is organized as follows: Section 2 introduces the method; in Section 3, I present the results; Section 4 presents the methodological preliminaries; in Section 5, I conduct the analysis; Section 6 concludes the discussion.

2. Method

2.1. Target words

I 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. \[u\]g (no carrier sentence) e.g. `gakuhi` ‘tuition’
2. \[v\]g e.g. `gimmi` ‘review’
3. Vg e.g. `dokuga` ‘venom fang’
4. Ng e.g. `ginga` ‘galaxy’
5. VgVg e.g. `eego-ga` ‘English-case particle’
6. NgVg 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, I arranged five extra contexts with respect to the types of following vowels (/gi/, /go/, /ga/, /go/, /gu/).
3. Results

3.1. Overall distribution

As mentioned above, I arranged six phonological contexts and five contexts for the types of following vowels. In addition, each target word in sequential contexts includes two velars. Thus, the total tokens I 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>
<thead>
<tr>
<th></th>
<th>frequency</th>
<th>rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[g]</td>
<td>277</td>
<td>46.17</td>
</tr>
<tr>
<td>[ɣ]</td>
<td>269</td>
<td>44.83</td>
</tr>
<tr>
<td>[ŋ]</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.

3.2. Distribution by phonological contexts

Next, I examine the distribution of velar allophones according to the phonological contexts.

![Figure 1. Distribution of velar allophones according to phonological contexts (p < 0.001)](image-url)
As shown in Figure 1, in utterance-initial positions ([Ug]), velars categorically realize as plosives, and no fricatives and nasals are observed. In phonological phrase-initial positions ([φg]), henceforth, φ-initial positions), plosives are predominant; however, some fricatives are also observed; on the other hand, nasals are still not observed here. Finally, in non-initial positions (other six contexts), overall velars are more likely to realize as fricatives, and plosives show the next highest probability. Importantly, only in non-initial positions is there a chance for nasals to occur.

3.3. Interim summary and generalization

As we saw above, there is a correlation between positions/levels in prosodic structure and the allophonic realization of velars. The distribution of velar allophones by levels in prosodic structure is summarized in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Utterance-initial</th>
<th>φ-initial</th>
<th>Non-initial</th>
</tr>
</thead>
<tbody>
<tr>
<td>[g]</td>
<td>☆☆☆☆</td>
<td>☆☆</td>
<td>☆</td>
</tr>
<tr>
<td>[γ]</td>
<td>–</td>
<td>☆</td>
<td>☆☆☆</td>
</tr>
<tr>
<td>[ŋ]</td>
<td>–</td>
<td>–</td>
<td>☆</td>
</tr>
</tbody>
</table>

Generalizing the results, we can argue that moving down the levels of prosodic structure, possible allophones increase from plosives only, to fricatives in addition to plosives, and finally to all three: in utterance-initial positions, velars are restricted to plosives; in φ-initial positions, fricatives can occur; in non-initial positions, nasals can occur. Plosives are most frequent at the highest level and decrease in accordance with the descending level; on the other hand, fricatives and nasals are rather frequent at lower levels. With these results in mind, I will demonstrate how the distribution of velar allophones can be accounted for in a formal manner.

4. Preliminaries to the analysis

4.1. Consonantal strength

Firstly, I will consider the relationship among velar allophones in light of the strength of consonants. According to the hierarchy of the relative strength of consonants (Hyman 1975; Escure 1977; Trask 2000; Honeybone 2008), voiced velar plosives are categorized as the level 5 that is the second strongest consonant; voiced velar fricatives, as the level 4; velar nasals, as the level 3 (Figure 2).

<table>
<thead>
<tr>
<th>weaker</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>stronger</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>voiceless</td>
</tr>
<tr>
<td>φ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>voiced stops</td>
</tr>
<tr>
<td>φ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>voiced liquids</td>
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<tr>
<td>φ</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>φ</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>voiced nasals</td>
</tr>
<tr>
<td>φ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>voiceless fricatives</td>
</tr>
<tr>
<td>φ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>fricatives</td>
</tr>
</tbody>
</table>

Figure 2. Hierarchy of the relative strength of consonants (Trask 2000:190)
If we take a closer look at the relationship among 3 allophones, plosives can be regarded as stronger velars, nasals as weaker velars, and fricatives as intermediate velars (Figure 3). Combining the observations so far, we can argue that the utterance-initial positions are characterized by stronger velars; the φ-initial positions, by intermediate velars; and the non-initial positions, by weaker velars.

### 4.2. Recursive φ-model and cumulative prosodic effect

For the relationship between the distribution of velar allophones and the prosodic effects, the recursive φ model in Figure 4 (Ito and Mester to appear) can give a straightforward account.

![Figure 4. Recursive φ model and cumulative prosodic effect](diagram)

In the recursive φ model, only a single prosodic category is introduced: the phonological phrase, instead of two distinct prosodic categories such as Major phrase and Minor phrase (cf. MajorP/MinorP model, Selkirk and Tateishi 1988, 1991, among others). As a consequence of introducing a single prosodic category, the recursive projection is prerequisite in order to extend the phonological structure. Due to the recursive projection of φ, any φ can become a maximal/minimal projection. In that sense, the level of the prosodic category is not absolutely fixed but only relatively defined.

Furthermore, in this model, the cumulative prosodic effect at the beginning of all φs is assumed. The strengthening effect is generally assumed to be inherited from lower projections to higher ones (Fougereon and Keating 1997, among others). Therefore, if a segment is at the left edge of the maximal projection, it would undergo the maximum prosodic effect; on the other hand, if a segment is at the left edge of the minimal projection, then it would undergo the minimum prosodic effect.

\[(7) [φ [φ A ] [φ B ] [φ C ]]]\]

In configuration (7), the recursive φ model predicts a more significant prosodic effect for segment A, compared with B and C, because segment A is at the left edge of minimal φ, and at the same time A is also at the left edge of maximal φ. Given the recursive projection, we can argue that even the prosodic words can be maximal φ and the leftmost segment would undergo the maximum prosodic effect, without any stipulation. This would be one of the crucial outcomes of recursive φ model. Thus, the gradient distribution of velar allophones can be attributed to the upward-inheritance...
of the strengthening effect.

5. Analysis

In this section, I will formalize the correlation between positions/levels in prosodic structure and the allophonic realization of velars in terms of the recursive $\varphi$ model and the consonantal strength.

5.1. Utterance-initial positions

In utterance-initial positions, velars categorically realize as plosives, namely stronger velars. As schematized below, the velar in gakuhi, which is at the left edge of the prosodic word, is mapped onto the maximal $\varphi$, being at the left edge of maximal projection; the velar can undergo the highest degree of strengthening effect. This process contributes to the categorical realization of plosives.

(8) $\varphi$ (maximal $\varphi$)  
     \[ \omega \]  
     \[ [gakuhi] \]

5.2. $\varphi$-initial positions

Next, I move on to the $\varphi$-initial positions. In $\varphi$-initial positions, fricatives, namely intermediate velars, are observed in addition to plosives. As shown in the prosodic structure, the velar in gakuhi-to, which is at the left edge of minimal $\varphi$, is not simultaneously at the left edge of maximal $\varphi$, because the minimal $\varphi$ in the middle is preceded by kare-wa. Therefore, the velar can undergo a higher strengthening effect. As a result, some velars can realize as fricatives.

(9) $\varphi$ (maximal $\varphi$)  
     $\varphi$  
     $\varphi$ (minimal $\varphi$)  
     [kâre-wa]  
     [gakuhi-to]  
     [itta]

5.3. Non-initial positions

Finally, I consider the non-initial positions. In non-initial positions, some nasals, namely weaker velars, and a lot of fricatives are observed. As illustrated below, the velar in eego-to, which is in the $\varphi$-internal position, is neither at the left edge of maximal $\varphi$, nor at the left edge of minimal $\varphi$. Therefore, the velar cannot undergo any strengthening effect. It follows that some velars can realize as nasals.

If we adopt the MajorP/MinorP model, the maximal $\varphi$ in (8) would be labeled as minor phrase, and the minimal $\varphi$ in (9) would also be labeled as minor phrase. Then the MajorP/MinorP model cannot account for the difference in prosodic strengthening assigned to these two positions and the distributional difference, where the recursive $\varphi$ model can, giving the latter model an advantage.
6. Conclusion

In this paper, I formalized the correlation between positions/levels in prosodic structure and the allophonic realization of velars in terms of the recursive φ model and the consonantal strength. As for the descriptive findings, in actual utterances fricatives are frequently observed, suggesting the necessity of a trichotomy rather than the traditional plosive/nasal dichotomy, and the decline of velar-nasalization has been accelerated. In utterance-initial positions, velars categorically realize as plosives; in φ-initial positions, plosives are more frequent than fricatives; in non-initial positions, fricatives are most frequent, nasals are least frequent, and plosives are in between.

As for the formal account, velars in utterance-initial positions occupy the left edge of maximal φ, and they undergo the highest degree of prosodic strengthening; as a result, all velars realize as stronger velars, namely plosives. Velars in φ-initial positions occupy the left edge of minimal φ, and they undergo the higher prosodic strengthening; as a result, intermediate velars can occur in addition to stronger velars. Non-initial positions correspond to φ-internal positions, and velars cannot undergo any strengthening effect; therefore, some weaker velars are observed.

Finally, I will conclude the discussion by mentioning a possibility of fortition implied by the results of the present research. As we saw above, the decline of velar-nasalization has been accelerated; in other words, more and more nasals have been replaced by plosives; consequently, nasals are decreasing; on the other hand, plosives are increasing. Given the hierarchy of velar allophones in terms of their strength (Figure 3), we could argue that the progress of denasalization implies that velars currently undergo the diachronic process of fortition: velar allophones are moving toward the stronger side.

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Notes

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1 For acoustic characteristics and example spectrograms for each of the three types of velars, and the detailed procedure of the experiment, refer to Sano (to appear) and Sano and Ooigawa (2010).

2 In Figure 1, “NgVg₁st” and “VgVg₁st” represents the preceding velars in sequential contexts (e.g. rongo-ga, eego-ga), and “NgVg₂nd” and “VgVg₂nd” represents the following velars (e.g. rongo-ga, eego-ga).

3 In Table 2, stars in each cell represent the probability of allophones: more stars indicate higher
probability; fewer stars indicate lower probability.

Due to the lack of previous studies focusing on the distribution of fricatives, here I do not consider the potential effect of the decline of velar-nasalization on the distribution of fricatives.

References

Escure, Geneviève. 1977. Hierarchies and phonological weakening. Lingua 43.55-64.


