Exploring the impact of phonological restrictions on phonetic implementation patterns using singing voice: The case of kobushi singing in Japanese

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Summary: How phonological patterns may be shaped by phonetic considerations and how phonological restrictions may affect phonetic implementation patterns have continued to be exciting areas of research throughout the history of phonetic and phonological investigations (e.g., [1]). The current work explored the influence of phonological restrictions on phonetic patterns from a novel perspective through an analysis of singing voice known as *kobushi* in Japanese, which involves an abrupt rise-fall of the F0 contour. A previous study has shown that one type of kobushi usually appears with a neighboring voiceless obstruent, whereas another type of kobushi rarely appears with an adjacent voiceless obstruent. The current study has found that these phonological restrictions affect the phonetic implementation patterns of these two types of kobushi.

Background: Kobushi is a singing technique that is found in several traditional Japanese singing styles. While there are various kinds of kobushi, the kinds that we focused on involve an abrupt F0 rise-fall of about 70 Hz that is implemented within as fast as 30 ms. Minami Kizuki is a professional singer who applies this singing technique to pop song music. [2] has shown that Ms. Kizuki uses two types of kobushi, shown in Figure 1: one type appears near a VC-transition ("right-aligned kobushi") and another type appears near a CV-transition ("left-aligned kobushi").

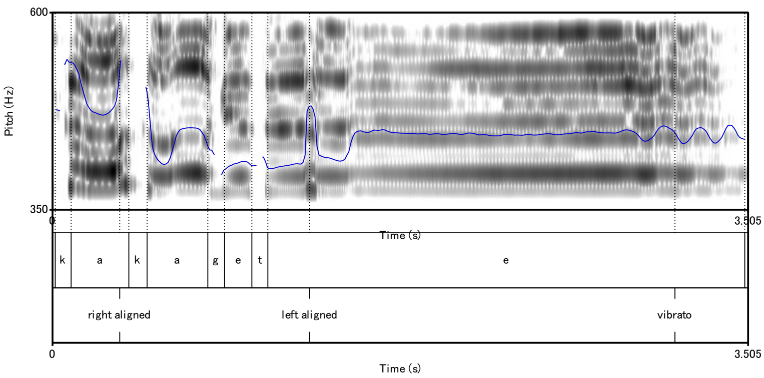

Figure 1: Two types of kobushi; (1) right-aligned kobushi which appears at the end of the first [a] and (2) left-aligned kobushi which appears at the beginning of the long [e].

[2] has also found phonological restrictions on these types of kobushi. The right-aligned kobushi usually appears with a following voiceless obstruent; it looks as if Ms. Kizuki is exaggerating the F0 perturbation effect due to a voiceless obstruent (e.g., [3]) to create this type of kobushi. On the other hand, left-aligned kobushi rarely appears when the preceding consonant is an obstruent, either voiced or voiceless. This phonological restriction may have its roots in the fact that the F0 is perturbed by obstruents, and therefore, the vowel following an obstruent may not be the optimal interval to place left-aligned kobushi; i.e., kobushi is "licensed", in the sense of [4], in a syllable with a sonorant onset. In this presentation, we report on an experiment which tested whether these phonological restrictions impact the phonetic implementation of kobushi.

Methods: Ms. Kizuki sung two songs once with [ta]-syllables and again with [ma]-syllables, as in the research using reiterant speech (e.g., [5]). Based on these sounds, we measured (i) the rise magnitude of kobushi in each condition, (ii) the speed of kobushi implementation (the rise magnitude divided by rise time), and (iii) the distance between the consonantal offset and left-aligned kobushi onset. We expected that left-aligned kobushi may be less easily implemented in the [ta]-rendition than in the [ma]-condition, but the opposite pattern would hold for right-aligned kobushi. For the first two measures, we assessed the results using Bayesian regression models with the [t]-[m] difference and the kobushi-type difference as sum-coded independent variables. We expected that the interaction term between these factors would be meaningful. For the last measure, we analyzed the duration between the consonant offset and the left-aligned kobushi onset and compared the difference between the [t]-condition and the [m]-condition.

<u>Results</u>: *(i) <u>The rise magnitude</u>*. As shown in Figure 2, we found that left-aligned kobushi, which disfavors an obstruent onset, shows smaller rise after [t] than after [m]. The right-aligned kobushi, which takes advantage of a following obstruent, shows larger rises after [t] than after [m]. The Bayesian regression model shows that the central estimate of the crucial interaction term is β_1 = -5.13, with its 95% credible interval being [-16.82, 2.08]. The probability of this coefficient being negative given the posterior distribution is .87.

(ii) <u>The rise speed</u>. Figure 3 shows the pattern of the speed in which kobushi is implemented in semi-tones per second [6]. As expected, for left-aligned kobushi, which is marked with [t], speed is faster in the [m]-condition than in the [t]-condition, whereas the opposite pattern holds for the right-aligned kobushi. The Bayesian regression shows the estimate of the interaction term is β_1 = -0.37 with its 95% credible interval being [-0.49, -0.25]. The probability of this coefficient being negative is 1.

(iii) <u>Distance</u>. The distance between the consonantal offset and the left-aligned kobushi's onset showed a result in the expected direction. We found tokens in the [m]-condition in which the kobushi rise starts almost at the same time as [m]'s offset, whereas there were tokens in which left-aligned kobushi was "repelled" after [t]. The overall results appear in Figure 4. The duration is indeed longer after [t] than after [m] (β_1 = 1.89), but its 95% credible interval was rather large [-9.37, 23.31], and $p(\beta_1>1)=0.58$. While being in the expected direction, the evidence based on this data is a modest one.

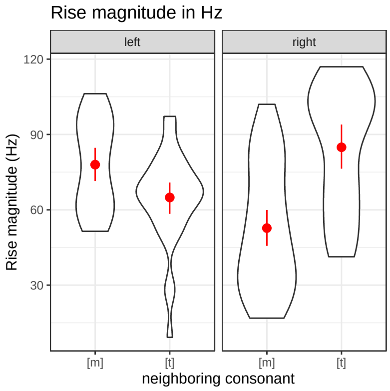

Figure 2: Rise magnitude. Red circles represent the means; the error bars represent bootstrap 95% CIs.

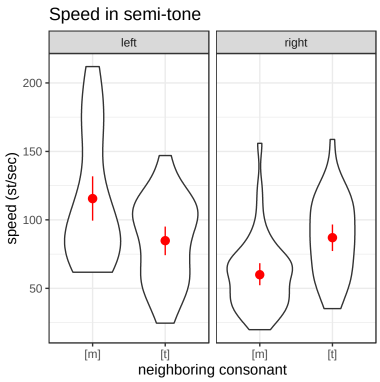

Figure 3: Speed of kobushi.

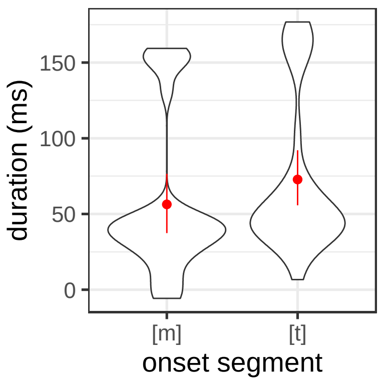

Figure 4: Distance between the consonant and kobushi.

<u>Conclusion</u>: The phonological generalizations that [2] has identified are that left-aligned kobushi is phonologically marked with a voiceless obstruent, whereas right-aligned kobushi is unmarked with a voiceless obstruent. The current quantitative study has shown that these phonological restrictions impact the phonetic implementation patterns of singing patterns, as sung by a professional singer, which was most evident in terms of the speed in which kobushi is implemented. Admittedly, our data is limited (singing voice of two songs sung by one singer), and we hope to collect more data to examine how robust the current findings are. Nevertheless, already as it stands, the present study opens up a new area of research in which we can explore the interaction between phonetics and phonology through the analysis of singing voice.

<u>References</u>: [1] Hayes, B. et al. (2004) Phonetically based phonology. CUP. [2] 川原繁人・古澤里菜 (2023) 城南海の「こぶし」の音声学的特徴と音譜上の分布について. 慶應義塾大学言語文化研究所紀要 54. [3] Kingston, J. & R. Diehl (1994) Phonetic knowledge. *Lg*. [4] Steriade, D. (1997) Phonetics in phonology. Ms. [5] Kelso, J.A. et al. (1985) A qualitative dynamic analysis of reiterant speech production. *JASA*. [6] Xu, Y. & Sun, X. (2004) Maximum speed of pitch change and how it may relate to speech. *JASA*.