An ultrasound examination of taps in Japanese

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ABSTRACT

This paper used ultrasound technology to examine the plain and palatalized taps in Japanese. Six participants of Japanese produced nonsense words containing /ɾ/ and /ɾʲ/. The mid-sagittal contours were compared in three intervocalic contexts: a_a, o_o, u_u.

The results showed that /ɾ/ had a great deal of variability around the tongue dorsum. This suggests that /ɾ/ lacks a dorsal gesture; unlike the other members of the rhotic class, it is solely a tongue tip gesture. /ɾʲ/ was articulated with a raised tongue body and fronted tongue dorsum. The palatalization gesture was resistant to coarticulatory effects, suggesting that it is important for contrast maintenance.

The results also suggest that an inconsistency between palatalization and rhotics cannot be related to the constraints on the dorsal gesture because the dorsal gesture seems to be inert for the taps. Rather palatalization is likely to interfere with the apical gesture associated with rhotics.

Keywords: taps, rhotics, ultrasound, Japanese

1. INTRODUCTION

Alveolar taps are categorized as members of the natural class of rhotics and are often described as a quick movement of the articulator. The tongue-palate contact creates a brief closure against the alveolar ridge [16]. Taps are often separated from trills on the basis that the tongue-palate contact for a tap is created solely from muscular activation of the articulator, while trills involve muscular activation of the articulator and aerodynamic forces to cause the tongue-palate contact [26].

Secondary palatalization involves raising the tongue body to make a secondary constriction in the palatal region [3, 4, 14]. While secondary palatalization is a fairly common cross-linguistic phonological process [1, 2], rhotics are particularly resistant to it [11, 20]. The inconsistency between secondary palatalization and rhotics has been examined by many researchers [12, 13, 21, 22]. Proctor [22] suggests that rhotics involve a tongue dorsum gesture which can be observed through the stability of a tongue dorsum target across environments. However, secondary palatalization involves tongue dorsum fronting with the tongue body raising to create a secondary constriction in the palatal region. Thus, the palatalization gesture interferes with the tongue dorsum gesture associated with rhotics. Iskarous & Kavitskaya [12] suggest found that the strength of the palatalization gesture was maintained across word positions (initial, intervocalic and final), despite predictions that the intervocalic realization of the palatalization gesture would be reduced [19]. Thus, Iskarous & Kavitskaya [12] suggest that the palatalization contrast has been maintained in Russian due to maximizing the difference between the segments (i.e. trilling).

Japanese is a language which has a plain tap, /ɾ/, and a palatalized tap, /ɾʲ/, in its phonemic inventory. This makes Japanese an excellent testing group for previously mentioned hypothesis. Because the plain and palatalized tap always make a single tongue-palate contact, they cannot be contrastive based on the number of contacts; there must be other factors. Proctor [22] also suggests that the tongue dorsum gesture associated with rhotics is a strong source of the instability between rhotics and palatalization; however, previous studies on taps have shown little association between taps and a dorsal gesture [24]. Therefore, it is expected that the tap will show variability in the tongue dorsum and tongue body for the plain tap, but less variability in the tongue body gesture for the palatalized tap. The palatalization gesture should be maximized across contexts to help maintain contrast.

While articulatory differences between taps and trills have been researched, little has been discussed about the underlying phonological representation regarding these segments. Using articulatory evidence, we seek to uncover more about the underlying representation of palatalized taps from both gestural and featural perspectives.

2. METHODS

2.1 Participants

Six female native speakers of standard Japanese (J1-J6) participated in the experiment (ages: 19-21;

mean: 20). Participants were all born and raised in Japan and have been outside of Japan for less than one year. Participants were exchange students (from Ritsumeikan University) studying at the University of British Columbia.

2.2 Stimuli

Stimuli were presented in the form of a word list written in hiragana, using nonsense words in order to control for phonetic variability due to environment more carefully. The plain and palatalized taps were produced in three intervocalic environments: /aɾa/ vs. /aɾʲa/; /uɾu/ vs. /uɾʲu/; /oɾo/ vs. /oɾʲo/. The stimuli was randomized and participants produced each of the target words in the carrier phrase *kore wa ___ to iimasu* (This is called ____). Each phrase was produced 14 times, but the first and last repetitions were discarded, resulting in a total of 432 tokens (2 phonemes x 3 environments x 12 repetitions x 6 participants).

2.3 Procedure and analysis

Data was collected at the Interdisciplinary Speech Research Laboratory (ISRL) at the University of British Columbia. The ultrasound was an Aloka SSD-5000 with a UST-9118 endo-vaginal 180 degree electronic curved array probe and recorded data at 29.97 fps. A Sennheiser MKH 416 P48 super-cardiod short shotgun microphone was placed approximately 1 foot away from the participant in order to capture audio data. Subjects sat in an ophthalmic examination chair (American Optical Co. model 507-A) with a headrest to minimize head movement during recording. Ultrasound gel was applied to the transducer to enhance image quality. Audio and acoustic data were recorded onto a Macintosh using iMovie and converted to DV files. The audio data was used to make texgrids in Praat [5], marking the onset, offset and midpoint of /ɾ/ and /ɾʲ/. Images were captured at the offset.

Edgetrak [16, 18] was used to trace the tongue contours. The coordinates of the tongue contours were analyzed statistically using smoothing spline (SS)ANOVAs [9] in R [23]. The SSANOVA plots mean tongue contours with 95% Bayesian confidence intervals based on the input coordinates. This allowed for statistically significant areas of interest to be identified.

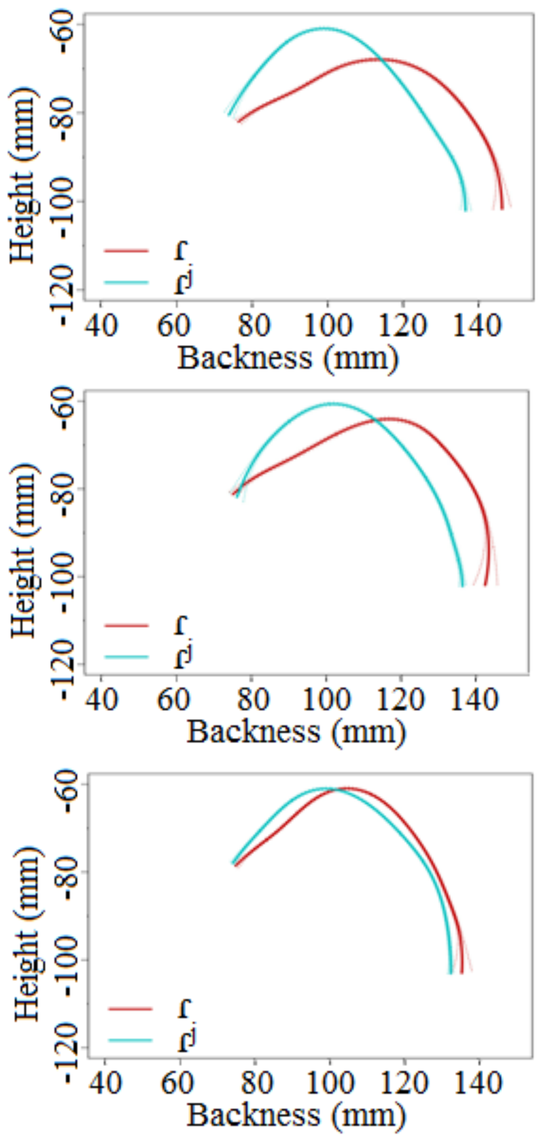
3. RESULTS

Section 3.1 shows the results of the direct comparison of the plain and palatalized pairs. Section 3.2 presents the analysis comparing each of the three environments.

3.1 Comparison of the plain and palatalized taps

Overall, the results for the comparison between the plain and palatalized taps revealed that the tongue dorsum for the plain tap involves more retraction than the palatalized tap. The tongue body is also significantly lower. This suggests that the tongue body is an active articulator for palatalized taps in Japanese. All participants (J1-J6) showed the same direction of difference between the plain and palatalized taps in Japanese. Figure 1 shows J1's articulation of the plain and palatalized taps in each environment.

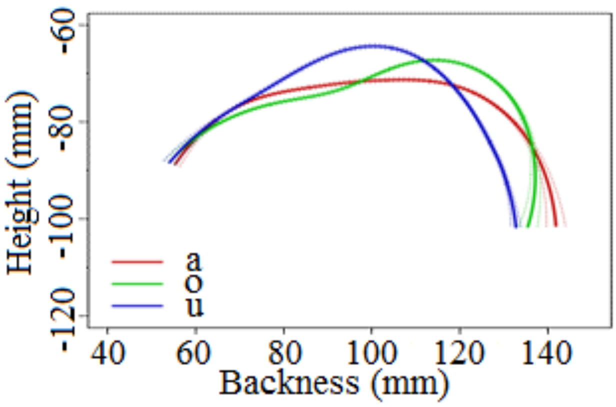
Figure 1. SSANOVA comparisons of the plain and palatalized taps as produced by J1 in the three environments: a_a (top), o_o (middle), u_u (bottom). The tongue tip is on the left side of each image.



3.2 Comparison of the taps in each environment

The comparison of the taps in each environment revealed that the plain tap, /ɾ/, showed significant variability in the tongue dorsum. Both the height and the backness of the tongue dorsum were found to be significantly affected by the height and backness of the vocalic environment. The largest affect was observed when the tap was surrounded by the high back vowel, /u/. This environment caused the tongue body to be raised and the dorsum to be advanced approximately 10 mm more than the other two contrasting environments (Figure 2). However, it should be noted that not all participants showed this direction of difference. J6 showed a consistently retracted tongue dorsum across all environments, while J5 showed consistent tongue dorsum retraction for the vocalic environments a_a and o_o, with tongue dorsum fronting and tongue body raising in the u_u environment. There was also a tendency for only a few millimetres of separation in height of the tongue body for each environment for the plain tap. J3 showed that the environment for o_o was approximately 4 mm higher than for a_a, which in turn was approximately 2 mm higher than for u_u (Figure 3).

Figure 2. SSANOVA comparison of J2's production of the plain tap in each of the intervocalic environments: a_a, o_o, u_u. The tongue tip is on the left of each image.



The comparison of the palatalized taps in each environment revealed a smaller amount of variation than was found for plain taps. The degree of tongue fronting and raising was generally invariable. However, J2 did show a somewhat lower tongue body for the u_u environment (Figure 4).

The palatalized tap showed a tendency for dorsum fronting which was observed across all environments. However, the tongue dorsum fronting was not significantly different across environments. Some participants did show variation in the degree of tongue dorsum fronting: J2 had slightly less tongue dorsum advancement for the o_o environment, while J4 had slightly more tongue dorsum advancement in the o_o environment.

Figure 3.SSANOVA comparison of J3's production of the plain tap in each of the intervocalic environments: a_a, o_o, u_u. The tongue tip is on the left of each image.

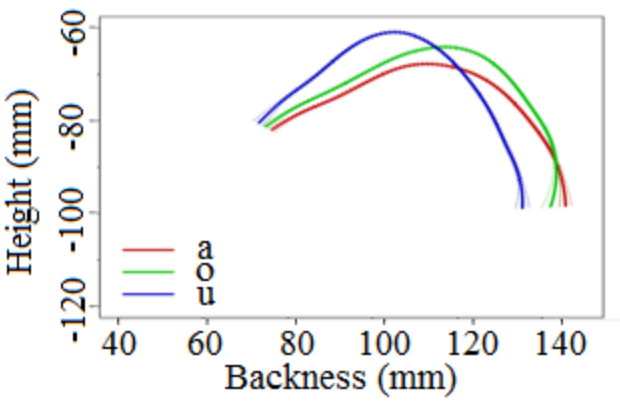
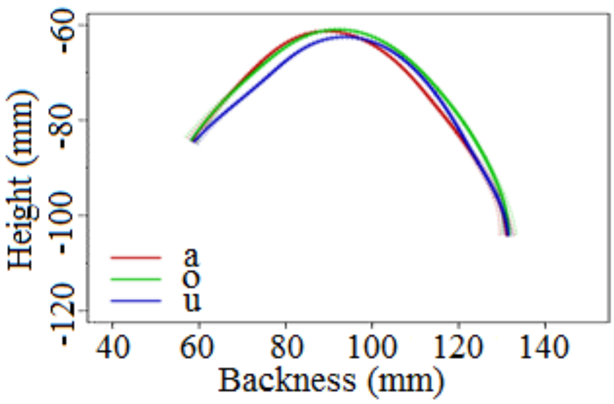


Figure 4. SSANOVA comparison of J2's production of the palatalized tap in each of the intervocalic environments: a_a, o_o, u_u. The tongue tip is on the left of each image.



4. DISCUSSION

The lack of a tongue dorsum target observed in the plain tap is expected given previous research by Recasens & Pallarès [25]. Their findings showed that taps in Catalan have low coarticulatory resistance. On the other hand, trills are described as a tongue tip gesture coordinated with a vowel-like tongue dorsum gesture [6]. The fact that the tongue tip gesture is not coordinated at all with a tongue dorsum gesture allows greater variability in the coarticulatory effects that the tongue dorsum can undergo.

Kavitskaya, Iskarous, Noiray, & Proctor [13] also suggest that an inconsistency between the tongue dorsum gesture and palatalization gesture for trills is the reason for the sound change from Proto-Slavic $*r^j$ to the various reflexes in the daughter languages. However, if this is true, it does not explain the resistance of the class of rhotics in general to secondary palatalization. Palatalized taps are typologically rare [11] and this is consistent with fact that it belongs to the natural class of rhotics [16]. However, the Japanese and Catalan facts demonstrate that plain taps do not appear to have a stable tongue dorsum gesture because it is not particularly resistant to environmental effects. It may be the case that the palatalization gesture causes a more laminal tongue tip/blade articulation which interferes with ability to produce tongue tip vibration [16].

The description by Bhat [4] that secondary palatalization involves tongue body raising is consistent with the findings here. The palatalized tap involves a significant amount of tongue body raising. However, the fact that the palatalization gesture is highly resistant to coarticulation effects is somewhat surprising. The Degree of Articulatory Constraint (DAC) model put forth by Recasens [24, 25] states that segments that are more vocalic in nature (more open) are more susceptible to coarticulatory effects. This may imply that the palatalization gesture should be more susceptible to coarticulatory effects than the results show. The findings here also mirror the findings in Iskarous & Kavitskaya [12], where they found the palatalization gesture for Russian trills to be highly resistant to coarticulatory effects. This is compatible with the Target & Interpolation Model of Cohn [8], which predicts that if a certain feature is contrastive and present for a segment, its phonetic implementation is stable and categorical, but if the feature is not contrastive, its implementation should show greater contextual variability. This suggests that contrastive articulatory gestures are more resistant to coarticulation effects than non-contrastive elements of a segment. Therefore, the palatalization gesture in palatalized taps are resistant to coarticulatory effects.

Under a featural representation, Clements and Hume [7] suggest that palatalization is a spreading of the [coronal] place of articulation under the V-place onto the preceding C-place feature. However, the articulatory data suggests that the raising of the tongue body - the tongue body gesture - is part of the underlying representation. The resistance to coarticulatory effects strongly supports this conclusion.

5. CONCLUSION

This paper presented the results for an ultrasound analysis of plain and palatalized taps in Japanese. The ultrasound evidence showed significant variability in the tongue dorsum for the plain tap suggesting that the plain tap only involves a tongue tip gesture. Thus, Japanese rhotics make a sharp contrast from English rhotics: English rhotics involve a dorsal component shared with vowels [10], while Japanese rhotics do not. Furthermore, the palatalized tap showed a high degree of resistance to coarticulatory effects on the palatalization gesture. This suggests that the underlying representation for palatalized segments involves a tongue body gesture analogous to the feature [high] [21]. Finally, the results also suggested that the inconsistency between rhotics and palatalization cannot be attributed to a conflict between the tongue dorsum and the palatalization gesture because /ɾ/ lacks a tongue dorsum target. It is more likely that palatalization interferes with the tongue tip gesture.

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