Orbicularis Oris Activation in Japanese-English Bilinguals In Code-Switched Environments

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1 Introduction

Code-switching is a communicative strategy often employed by multilinguals to communicate across different social contexts, with substantial research on the acoustic phonetics of code-switching. However, little research has been done on the articulatory measures of code-switching within phonetics, and the influence one's L1 can have on pronunciation within their L2. While some studies [e.g. 1, 2] find no evidence of phonetic transfer between languages, most research identifies some degree of phonetic transfer , with no consensus on the direction of transfer. To explore the complexities of phonetic transfer, the English [u] and Japanese [ɯ] (high)will be examined. It is long understood in Japanese phonetics that the vowel /u/ is produced as the unrounded vowel [ɯ] [3], which contrasts with the rounded articulation of [u] in English. However, a recent study suggests Japanese [ɯ] as a rounded vowel particularly among younger speakers [4]. This study investigates how the degree of activation of the Orbicularis Oris (OO) muscle changes when a language token is articulated in a code-switched or non-code switched environment, with Japanese as an L1 and English as an L2. Furthermore, given that external factors may influence the degree of muscle activation, this paper examines whether high- and low-frequency word tokens within a language influence the degree of muscle activation of the OO in a code-switched environment. Low-frequency word tokens often require more processing capacity to encode than high-frequency word tokens [5]. Moreover, in comparison to low-frequency words, high-frequency words are facilitated subconsciously with more rapid and accurate processing to support the learning of spoken word forms [6].

We hypothesize there will be unidirectional phonetic transfer converging towards the values of the L1, following previous hypotheses [eg. 7, 8] with evidence of phonetic transfer only in the L2, English. Additionally, we predict high-frequency word tokens will have a reduced impact, and low-frequency words will have an increased impact on the degree of muscle activation in the OO on the target phoneme.

2 Methods and Analysis

13 participants were recruited via UBC's Linguistics Outside the Classroom SONA System, and through social media outreach to Japanese clubs at UBC. Following strict participation criteria, data from 9 participants was analyzed. Participants were self-identified L1 Japanese speakers with a self-reported average proficiency rating across speaking, reading, and comprehension of 7 or higher for English.

Stimuli were created for four different conditions: English Monolingual, English-heavy bilingual (henceforth, "English Code-Switch"), Japanese Monolingual, and Japanese-heavy bilingual (henceforth, "Japanese Code-Switch") (see table 1).

Table 1.
Experimental conditions and sample sentences. Target words are bolded and italicized

Condition	English Monolingual	English Code-Switch	Japanese Monolingual	Japanese Code-Switch
Example sentence	His mother put the ***food*** on the table.	The athlete drank 水 before the competition.	アスリートが試合の前に水を飲みました。	彼のお母さんが ***food*** をテーブルに置いたのです。

There were 13 sentences for each condition, with 9 sentences including a target phoneme of the high non-front English [u] or Japanese [ɯ]. The remaining 4 sentences were distractor sentences. For both English and Japanese, 5 high-frequency words and 4 low-frequency words were selected. English frequency was quantified using the Oxford English Dictionary's frequency values. Japanese frequency was quantified by the Balanced Corpus of Contemporary Written Japanese [9] on a web based interface "Shonagon", and reviewed by L1 Japanese speakers.

Participants were shown a slideshow with the stimuli. For each condition, participants first heard a sample recording to control for speech rate and activate the "language mode" under investigation [eg. 1, 10]. After listening to the audio, participants were asked to read 13 short sentences similarly constructed to activate the corresponding bilingual or monolingual language mode for production. Tokens not known to participants were excluded from analysis. Participants were equipped with one Delsys Trigno Mini Sensor for surface EMG on their left upper lip to track the activation of the left OO muscle [11]. A Sony Cyber-shot DSC-RX100 camera was placed on a tripod behind the laptop to record audio and video. Surface EMG was recorded using the Delsys EMG Acquisition software and audio extracted from the video recordings was annotated in a Praat TextGrid [12]. Audio and EMG data were synchronized, and when aligned a Python script was used to find the mean muscle activation during each vowel. These values were then normalized using z-scores, and scaled up by a factor of 10.

3 Results

Results showed no significant effect of condition on OO activation. (see Figure 1)

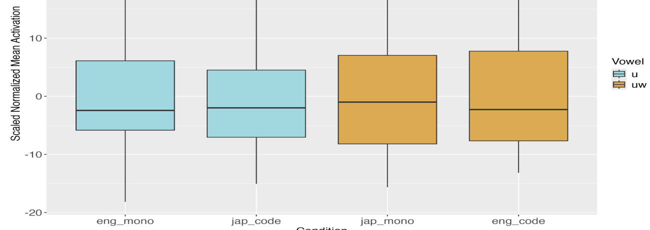

Figure 1. *Normalized mean activation of the OO for all speakers for each of the four conditions.*

Further analysis was done to examine the effect of frequency on activation for each condition independently. A linear regression model was created to analyze the difference between high- and low-frequency words for each condition. Results show a significant effect of frequency for English [u] in the English Monolingual condition ($\beta = -0.78$, $t = -3.79$, $p < 0.001$) and Japanese Code-Switch condition ($\beta = -0.74$, $t = -3.38$, $p = 0.001$), but no significant effect for Japanese [ɯ] in the Japanese Monolingual condition and English Code-Switch condition

Considering the significant effect of frequency, we re-evaluated our analysis of the effect of condition on OO activation with consideration of high- and low-frequency tokens. For the high-frequency tokens, the English [u] vowel in both the English Monolingual and Japanese Code-Switched conditions had more activation than the Japanese [ɯ] vowel in the Japanese Monolingual and English Code-Switched conditions. Japanese Monolingual condition was shown to have significantly less activation from the English Monolingual ($\beta = -0.46$, $t = -2.39$, $p = 0.018$) and Japanese Code-Switch ($\beta = -0.47$, $t = -2.32$, ,$p = 0.021$) conditions. No significant difference was found between the English Code-Switch tokens and the English Monolingual or the Japanese Code-Switch conditions. For the low-frequency tokens, the opposite trend was found to be true; the English [u] tokens in both conditions had less activation than the Japanese [ɯ] and the Japanese Code-Switch tokens also had significantly less activation than the Japanese Monolingual tokens ($\beta = 0.67$, t - 2.82, $p = 0.006$) and English Code-Switch tokens ($\beta = 0.47$, $t = 2.00$, $p = 0.048$) (see figure 2).

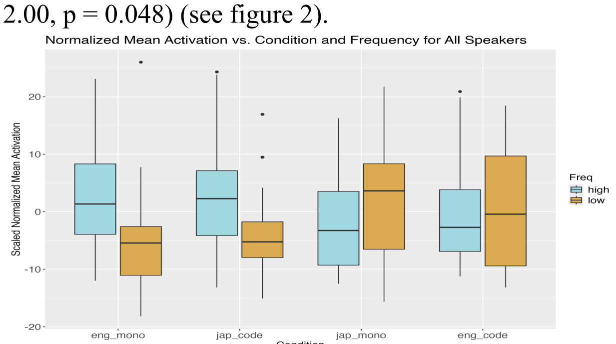

Figure 2. *Normalized mean activation of the OO across four conditions, considering both high- and low-frequency word tokens.*

4 Discussion

The primary research question sought to investigate phonetic transfer in Japanese-English code-switched speech through measuring the degree of OO activation in the high vowels, [u] and [ɯ]. Our hypothesis that code-switched speech would show unidirectional phonetic transfer toward the L1, Japanese, was not supported by the results. When considering just the high-frequency tokens, English /u/ had significantly more OO activation than the Japanese /u/. However, for the low frequency tokens, the opposite pattern was found. Following previous literature, if the Japanese /u/ was unrounded in nature, we would expect English /u/ to always have more OO activation, regardless of frequency. Our results may reflect that the Japanese vowel chart misinterprets the true phonetic properties of the high non-front vowel. Moreover, discrepancies with prior studies may stem from the evolution of technology, as previous research often emphasised acoustics over articulatory gestures. Considering how both tongue retraction and lip rounding lower F2, it can be difficult to determine to what extent each of these articulatory gestures contributes to the production of high non-front vowels [13]. Recent literature has begun to debate the roundedness of Japanese /u/, finding that Japanese speakers' lips when producing /u/ are significantly more protruded than their /o/ vowel productions [14]. Our findings add to this research suggesting that the Japanese [ɯ] is actually rounded, with protrusion rather than compression.

Our secondary research question predicted high-frequency word tokens will have a reduced impact, and low-frequency words will have an increased impact on the degree of muscle activation in the OO on the target phoneme. Contradictory findings were recorded for the English condition, where English [u] in high-frequency words saw more muscle activation of the OO muscle compared to low-frequency words. Analysis of Japanese [ɯ] followed our hypothesis, but with insignificant results. An explanation may be that frequency affects L2 speech patterns differently than L1 speech patterns. While this doesn't explain why the means differ across frequency conditions, it does highlight areas for further investigation.

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