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Acquiring Jaw Movement Patterns in a second language: Some lexical factors

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1. Introduction

Understanding how we acquire the production patterns of a second language (L2) is an important topic in phonetic studies. At least among those studies conducted in Japan, it is probably safe to say that research on how Japanese speakers acquire English is far more common than how English speakers acquire Japanese. Among the latter type of studies, common topics include the acquisition of Japanese pitch accent and long-short vowel/consonant distinctions, (e.g. Shport 2016, Hirata et al. 2007). Here, we examine a yet little explored aspect of L2 prosody: Japanese phrasal stress, as manifested via systematic jaw movement patterns, and the articulation thereof by English speakers of Japanese. As background, we are working within a theoretical framework (e.g. the C/D model: Fujimura 1992) in which there are at least two "prosodic articulators": the larynx, which controls pitch (F0) as well as vowel duration and intensity; and the jaw, which controls changes of the resonant frequencies of the vocal tract. Previous studies have observed that increased jaw displacement results in more prominent syllables (e.g. Fujimura 1992) as well as higher F1 values (e.g., Erickson 2002, Erickson et al. 2012). Strong correlations between measures of jaw displacement, F1 and n-ary levels of syllable prominence for each syllable in the utterance have been reported for English (Erickson et al 2015). For languages such as Chinese, French, and Japanese, increased jaw displacement/F1 associates not with n-ary levels of syllable stress, but with phrase final words/syllables (Smith et al. forthcoming, Erickson et al. 2016, Kawahara et al. 2014, 2015). Generally speaking, first-language (L1) prosody can be carried over to the L2, and jaw movement patterns are not exceptional. For instance, Japanese speakers of English show increased jaw displacement/F1 phrase finally, even in sentences where L1 English speakers have reduced jaw displacement/F1 in that position (Erickson et al. 2014). The question we address here is what are the patterns of jaw displacement/F1 of English speakers speaking Japanese as an L2 in comparison with those of L1 Japanese speakers.

2. Method

Articulatory and acoustic recordings were made using 3-D EMA (Carstens AG500 Electromagnetic Articulograph) at the Japan Advanced Institute of Science and Technology (JAIST). One sensor was placed on the lower medial incisors to track jaw motion. Additional sensors were placed on three points of the tongue, and the upper and lower lips, but the analyses of these sensors are not reported.

Four additional sensors (upper incisors, bridge of the nose, left and right mastoid processes behind the ears) were used as references to correct for head movement. The articulatory and acoustic data were digitized at sampling rates of 200 Hz and 16 kHz, respectively. The occlusal plane was estimated using a biteplate with three additional sensors. In post processing, the articulatory data were rotated to the occlusal plane and corrected for head movement using the reference sensors after low-pass filtering at 20 Hz. Custom software – Mview (Mark Tiede, Haskins Laboratories) was used to analyze the data. The lowest vertical position (maximum displacement) of the jaw with respect to the bite plane was located for each target syllable of the utterance using a velocity-based criterion. F1 measurements in the mid region of the vowel were made using Praat software.

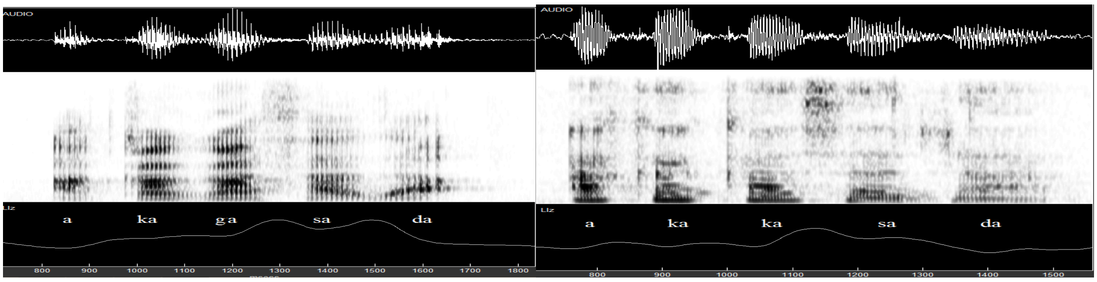

Figure 1: Acoustic waveform, spectrogram, jaw position for [akagasada] for Japanese (left) and American English (right) speaker. L2 speakers said [aka kasa da] failing to apply rendaku.

The L1 speakers spoke standard Tokyo Japanese (1 male, 2 females, in their 30s). The L2 speakers were 3 North American English speakers (2 males, 1 female, approximate ages 30 to 60), fluent in Japanese, having lived in Japan for the past approximately 8 to 17 years. The stimuli, together with stimuli for other experiments, were presented sentence-by-sentence in a randomized order on a PowerPoint screen in front of the speaker. Each speaker pronounced each stimulus approximately 6 times, but due to tracking errors or mispronunciation errors, sometimes the number of tokens varied. Since the magnitude of jaw displacement is nontrivially affected by vowel height (Kawahara et al. 2014, Menezes and Erickson 2013), all vowels of the stimulus sentences were [a]. The sentences were *aka-gasa da* ("That's a red umbrella.") and *aka-pa'jama da* ("Those are red pajamas."). Previous analysis of some of this data, focusing on the production of L1 speakers, was reported in Kawahara et al. 2014; some data are reproduced here for the sake of comparing L1 and L2 speech.

3. Results

3.1. L1 and L2 patterns of jaw displacement and F1 for *aka kasa da*

The articulatory results in the following figures show the amount of average jaw displacement for each syllable as measured from the occlusal plane across the 5 to 6 repetitions of the utterance. The height of each bar indicates the amount of jaw displacement: the higher the bar, the greater the jaw opening, (i.e., the lower the jaw). The results are shown this way to adhere to the hypothesis that syllables with increased jaw displacement have greater prominence. Thus, the y-axis is labeled “Syllable Magnitude (mm)”, since, according to Fujimura’s C/D model hypothesis (1992), syllable magnitude is correlated with the amount of jaw displacement required to articulate each syllable. In the figures below, each syllable has a different magnitude, even though the vowel is phonologically the same. In our figures, ordinate scaling is set individually for each speaker, to better view the patterns of jaw opening.

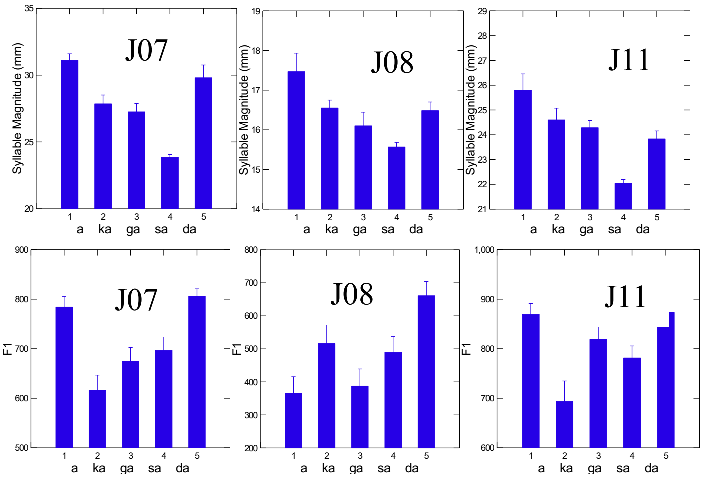

Figure 2: Syllable magnitude and F1 patterns for the Japanese utterance *akagasa da* for L1 speakers J07, J08, J11. The top row shows syllable magnitude patterns; the bottom shows F1 patterns.

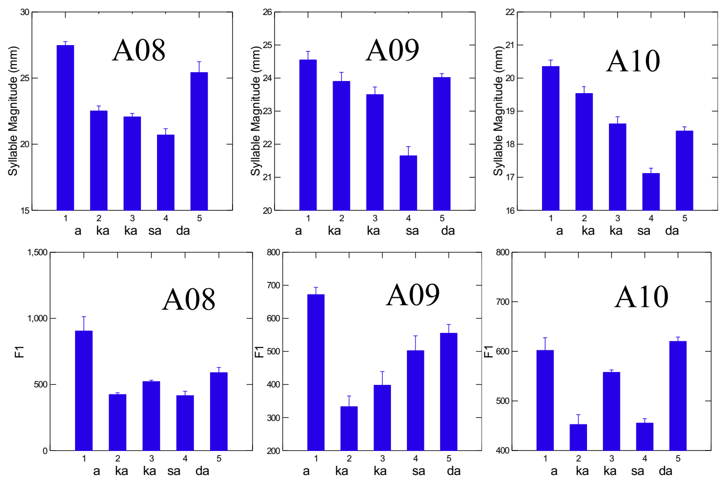

Figure 3: Syllable magnitude and F1 patterns for the Japanese utterance *akagasa da* for L2 speakers A08, A09, A10. The top row shows syllable magnitude patterns; the bottom shows F1 patterns.

Looking at the syllable magnitude patterns in Figure 2, we observe consistent patterns: the initial and final syllables of the utterance show comparatively large jaw displacement patterns, as was reported in Kawahara et al. (2014). The correlations between jaw displacement patterns and F1 seem complicated; for J07, they seem to match except for the second and fourth syllables; for J08 and J11, there do not seem to be systematic correlations.

For this sentence type, the syllable magnitude patterns for the L2 speakers (in Figure 3) are strikingly similar to those of the L1 speakers from Figure 2, again showing utterance initial and final increased magnitudes. Interestingly, the F1 patterns seem to correlate with jaw displacement magnitudes for A08 (r^2=0.60) but not for the other L2 speakers.

3.2. L1 and L2 patterns of jaw displacement and F1 for *aka pajama da*

Looking at the syllable magnitude patterns for the L1 speakers in Figure 4, we again observe large jaw displacement for initial and final syllables. Like the *akagasada* sentence, no strong correlations were found between jaw displacement and F1 for the L1 speakers. Note also that jaw displacement is larger on the first syllable of *pajama* than on the second syllable. It could be argued that this is because in Japanese, *pajama* has a pitch accent on the first syllable; however, Kawahara et al. (2014) show that pitch accent does not affect jaw movement patterns.

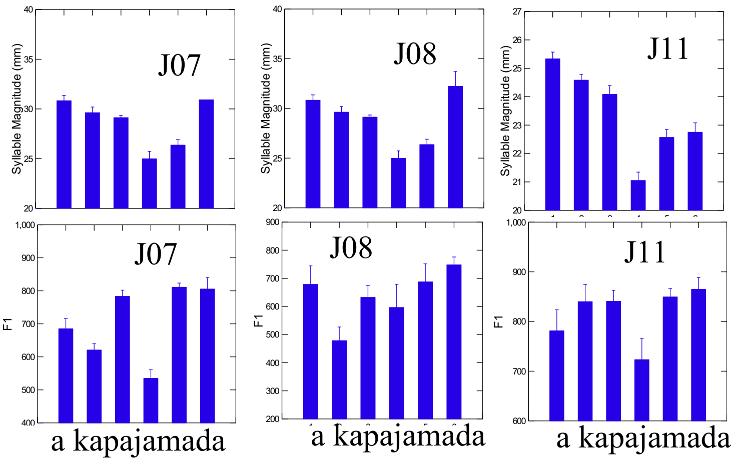

Figure 4: Syllable magnitude and F1 patterns for the Japanese utterance *aka pajama da* for L1 speakers J07, J08, J11. The top row shows syllable magnitude patterns, the bottom shows F1 patterns.

These utterances contain the English cognate word, “pajama”, and for the L2 speakers (in Figure 5), we see a different pattern of syllable magnitude than that for the L1 speakers, and different from the *akagasada* sentence as well. Specifically, [ja] has a larger jaw opening than the preceding [pa]—this is presumably due to negative L1 transfer (i.e., interference) from the lexical stress pattern of the English word *pajama*, where stress is on the second syllable. For cognates, such negative L1 phonetic transfer has been shown for VOT in Amengual (2012). It has also been shown for stress assignment in Ghazali & Bouchhioua (2003), but negatively interfering from Tunisian participants' L2 (French) to their L3 (English) for French-English cognates.

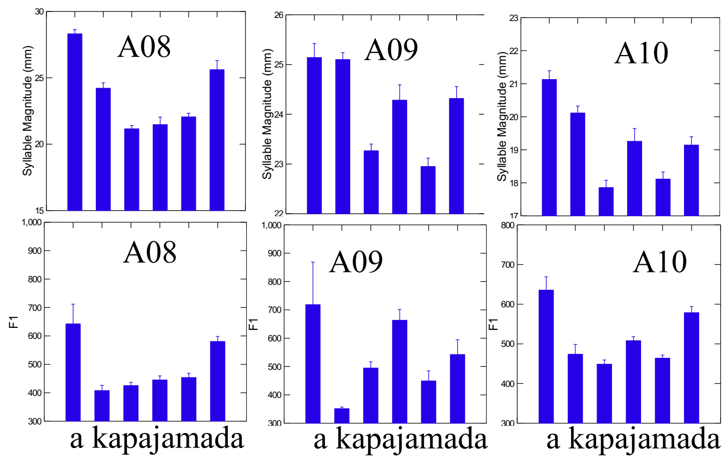

Figure 5: Syllable magnitude and F1 patterns for the utterance *aka pajama da* for English L2 speakers, A08, A09, A10. The top row shows syllable magnitude patterns, the bottom shows F1 patterns.

In Figure 5, the F1 patterns match the syllable magnitude patterns, with increased F1 on the middle syllable. One L2 speaker, A08, however, seems to show almost equal amounts of syllable magnitude as well as F1 values on the three syllables in *pajama*, thus endeavoring to avoid the L1 pattern of increased strength on the middle syllable. Indeed, for the participants in Ghazali & Bouchhioua (2003), the number of misplaced stresses was inversely proportional to their proficiency level, so it is possible that jaw movement here could be an indicator of L2 proficiency level. Regression analyses show positive relationships between jaw displacement and F1 for A08 and A10 (r^2=0.44, r^2=0.39, respectively).

4. Conclusion

The results from this small study suggest that English speakers fluent in speaking Japanese are relatively successful in articulating Japanese edge prominence characteristics of phrasal stress. Specifically, they produce increased jaw displacement patterns similar to Japanese L1 speakers at phrasal edges (both initial and final), thus indicating a lack of interference of English articulatory prosody on that of Japanese. However, in utterances which involve English loan words, there appears to be some negative L1 transfer. Specifically, the L2 speakers of Japanese, especially A09 and A10, show clear increases of jaw displacement on the English lexically stressed middle syllable of *pajama.* This contrasts with the Japanese L1 speakers who show larger jaw displacement on the first syllable of *pajama* than on the second syllable. It is interesting to note that the L2 speakers for the utterance with the English cognate also tend to show a strong relation between jaw displacement and F1. The relation between jaw and F1 is a topic of continued exploration (see, e.g., Huang and Erickson 2019 for discussion of jaw and tongue interaction for prosody articulation).

Acknowledgements

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