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特集論文

Comparison of Jaw Displacement Patterns of Japanese and American Speakers of English: A Preliminary Report

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英語話者と日本語話者の英語発音時における下顎の開きの比較

要旨：Erickson 他（2012）は，英語において文レベルの強勢パターンが，下顎の開きの大きさに現れることを示している。例えば，(I saw) five bright highlights (in the) sky tonight という文では，強勢パターンが {{3_{five} 2_{bright}}{4_{high} 1_{light}}}{3_{sky} $2_{tonight}$} となり，顎の開き具合がこのパターンに一致する。本研究ノートでは日本語母語話者がこの文を発音したとき，どのようなパターンを示すかを EMA によって検証した。その結果，{five bright highlights} という句では英語母語話者と同様のパターンを示すのに対し，{sky tonight} では，英語母語話者と異なり tonight が sky より大きい顎の開きを示した。筆者らによる同時進行中の実験（Kawahara et al. 2014）では，日本語では文末に大きな顎の開きが見られることが明らかになっていることから，この結果は音声的母語転移（phonetic L1 transfer）の可能性が高いことを主張する。また本実験の結果に基づき，EMA による実験が L2 獲得研究一般に活用される可能性について考察する。

Key words: phrasal stress, metrical phonology, American English, Japanese English, jaw displacement, F1, second language acquisition, EMA

1. Introduction

This research note is about the acquisition of English as a second language by Japanese speakers, focusing on the acquisition of different stress levels manifested in English, through the lens of jaw displacement patterns. At the lexical level, English shows a tripartite distinction between unstressed, secondary stressed, and primarily stressed syllables (Chomsky and Halle 1968 *et seq*). In addition to these distinctions at the lexical level, phrasal and sentential stress can make the distinctions even finer (e.g., Chomsky and Halle 1968, Liberman and Prince 1977, Selkirk 1984, Hayes 1995)[1]. Since these distinctions in stress levels do not exist in Japanese, they present a challenge to Japanese speakers who try to acquire English as their second language, as most of those who have an experience teaching English to Japanese students would agree (see e.g., Archibald 1997, Kawagoe 2003, Kondo 2009 for various views). This note is a preliminary report of our research that attempts to tackle this general problem, through the study of jaw displacement, a significant correlate of distinct stress levels in English. Our goal is not so much to propose a new theory of second language acquisition, let alone a new teaching method, but instead to illustrate a research methodology which may allow us to obtain quantifiable measures of stress both in first language (L1) and second language (L2) speech.

As reviewed above, for English utterances, each syllable can manifest itself with different degrees of stress levels, due both to lexical and phrasal factors. From the perspective of articulation, recent work by Erickson et al. (2012, 2014) reported that the amount of jaw displacement shows a significant correlation with the *n*-nary stress levels, which is also acoustically manifested by changes in F1 (see also e.g., Kelso et al. 1985, Vatikiotis-Bateson and Kelso 1993, de Jong 1995). In other words, we can take jaw displacement as an objec-

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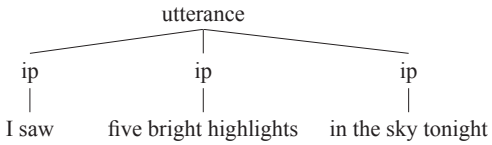
tively quantifiable measure of stress levels in English. Our current research program takes advantage of this observation and investigates how Japanese speakers acquire different levels of English stress in learning English.

To this end, this research note offers our first attempt to compare jaw displacement and F1 patterns produced by American speakers of English, as reported in Erickson et al. (2012), with those produced by Japanese speakers of English (new data). The sentence examined is *(Yes, I saw) five bright highlights in the sky tonight)*, with the six underlined words as the target words. These words with the low /aɪ/ vowels were chosen because jaw displacement and formant frequencies vary according to vowel height (e.g., Kawahara et al. 2014a, Keating et al. 1994, Recasens 2012, Stevens 1998, Williams et al. 2013, Menezes and Erickson 2013). The sentence has three intermediate phrases (ips; a.k.a. intermediate phrases or phonological phrases), {(*Yes*) *I saw*} {*five bright highlights*} {*in the sky tonight*} with {} indicating the phrasal breaks—for visual aids, the tree representation is also given in (1):

(1) A metrical representation of "I saw five bright highlights in the sky tonight"



Since the second and third ips contain the target low vowels, the analysis concentrated on these last two phrases. Erickson et al. (2012) studied the jaw movement of these phrases of four speakers of American English: the largest stress (phrasal stress) in the final phrase was found to be on *sky*, and for three of the four speakers, for the pre-final phrase, phrasal stress, was on *high(lights)*. Moreover, these two words also had the highest F1 (since as the jaw opens more, F1 also increases: Stevens 1998).

Using this same sentence, the current paper compares jaw displacement and F1 of phrasal stress as produced by three American speakers of English with those produced by three Japanese speakers of English. This comparison allows us to investigate how Japanese speakers' native language affects their pronunciation of English stress.

2. Methods

The utterance examined, *Yes, I saw five bright highlights in the sky tonight*, was part of a larger corpus, elicited from all of our participants in five randomized presentation orders. The speakers read the sentences from PowerPoint presentations on a computer screen. No instructions were given about where or how to place stress.

The Japanese speakers were three male graduate students at a university in Ishikawa Prefecture, Japan, who were intermediate level in spoken English [2]. The American speakers were two female English teachers in Japan, and one male research scientist; all were speakers of standard American English with no obvious strong regional accent, one from New York, one from Ohio, and one from Minnesota, respectively [3].

The articulatory movement and speech data were recorded simultaneously for the three male Japanese speakers (J1, J2, and J3) and the two female American English speakers (A1 and A2) using 3D EMA (Electromagnetic Articulograph) (Carstens AG500) at the Japan Advanced Institute of Science and Technology (JAIST), Ishikawa Prefecture, Japan. One sensor was placed on the lower medial incisors to track jaw motion, and 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 additional (male) American English speaker (A3) was recorded with a similar experimental arrangement at Haskins Laboratories, New Haven, Connecticut.

The occlusal plane was estimated for these speakers 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, Haskins Laboratories) was used to analyze the data. The lowest vertical position (maximum displacement) of the jaw [4] with respect to the biteplane was located for each target syllable of each utterance using the snapex tool in mview. Readers who are unfamiliar with EMA can take "jaw displacement" in this paper to mean, roughly, the distance between the biteplane and the lower incisor. See Erickson et al. (2012) and Kawahara et al. (2014b) for further illustration.

F1 measurements were made at the same point in time as the maximum jaw displacement, using the software PRAAT (Boersma and Weenink 2011).

3. Results

Auditory impressions by the first author suggest that both Japanese and American speakers produced the sentence as three phrases, {*Yes I saw*}{*five bright highlights*}{*in the sky tonight*}. Japanese speakers sometimes pronounced the /aɪ/ diphthong as the low vowel /a/, but this monophothongization did not present an analytical problem, since generally the measurements for both groups of speakers were made during the /a/ interval.

Figure 1 (adapted from Erickson et al. 2012) shows the jaw displacement measurements for the American English speakers (their L1 speech); Figure 2, that of the Japanese speakers (their L2 speech). Thick black lines are pointing to the words receiving phrasal stress per auditory impression of the first author, a native speaker of English.

The phrasal stress in the *five bright highlights* phrase is on *high(lights)* for both English speakers and Japanese speakers. In this sense, Japanese L2 speech matches with that of L1 speech by native speakers of English[5]. However, the phrasal stress for the last phrase is located on *sky* for the American speakers and *night* for the Japanese speakers. Here we observe that there is a difference between L1 speech and L2 speech.

The next two figures show the F1 values of the recorded phrases; Figure 3 shows those of English speakers and Figure 4 those of Japanese speakers.

Comparing Figure 1 against Figure 3, as well as Figure 2 against Figure 4, we observe positive correlation: the more open the jaw is, the higher the F1. To statistically assess this correlation, Table 1 shows results of a correlation analysis of jaw displacement and F1, giving

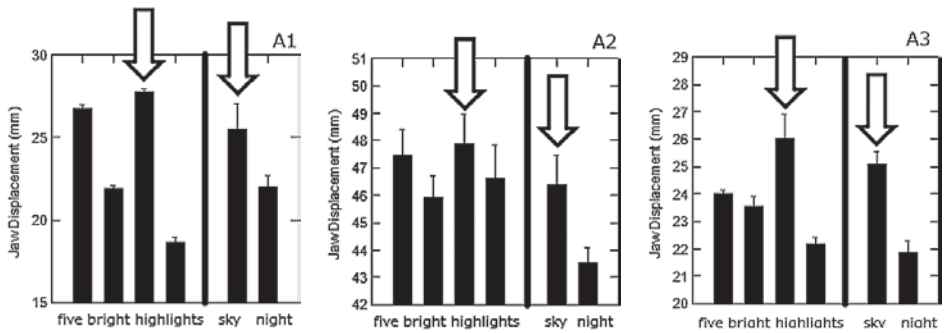


Figure 1 **Jaw displacement (mm) for target low vowel syllables for three American English speakers producing the sentence *(Yes, I saw) five bright highlights (in the) sky (to)night.* Higher values indicate larger displacement. Number of repetitions is five for each speaker. The words 'in the' and 'to' for these speakers have considerably reduced vowels with minimal to no jaw opening and are not shown. The solid vertical line indicates the phrase break; the arrows indicate the phrasal stress for each phrase. The error bars show standard error of the mean. Ordinate scaling is individual by speaker in order to better show the patterns of jaw opening for each speaker. Adapted from Erickson et al. (2012), with permission from Karger Publishers.**

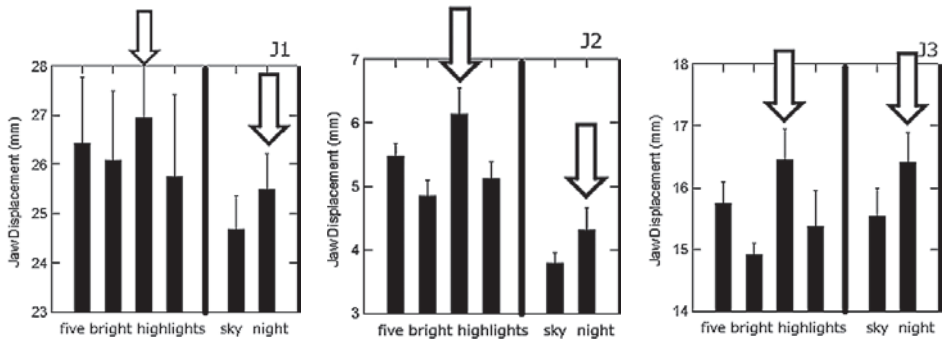


Figure 2 **Jaw displacement for target low vowel syllables for three Japanese speakers of English. See caption for Figure 1 for further details. The number of repetitions for J1 is N = 4; the others are N = 5.**

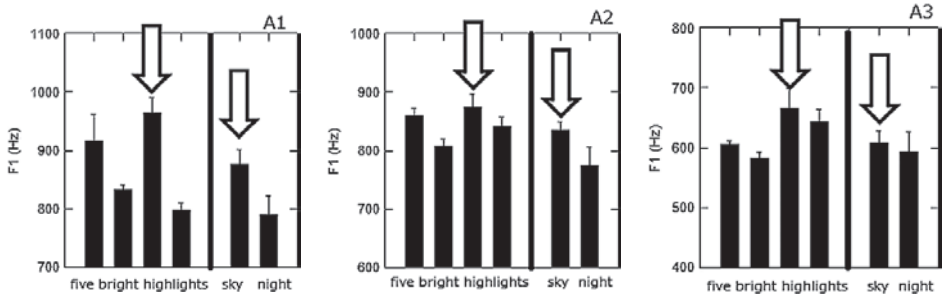


Figure 3 F1 values for target low vowel syllables for three American English speakers. See caption for Figure 1. Adapted from Erickson et al. (2012) with permission from Karger Publishers.

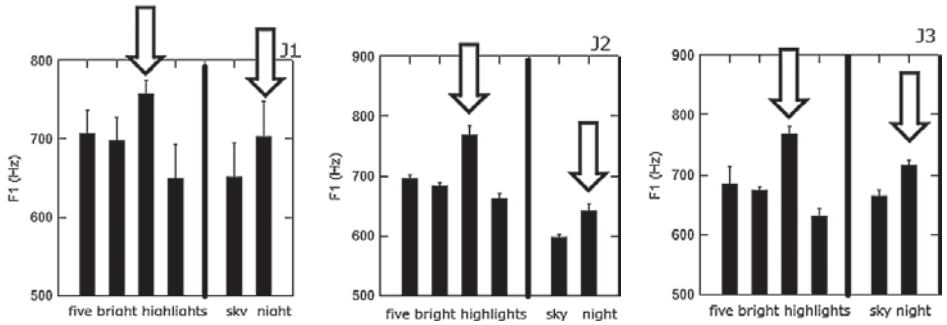


Figure 4 F1 values for target low vowel syllables for three Japanese speakers. See caption for Figure 1.

Table 1 Correlation analysis of jaw displacement and F1 showing *r* and *p* values[6].

Speaker	*r* (jaw vs. F1)	*p*
A1	.77	<.001
A2	.51	=.001
A3	.60	<.001
J1	.60	<.001
J2	.77	<.001
J3	.45	=.01

Pearson coefficients *r* and *p*-values, for both the Japanese and American speakers of English. For both Japanese and American speakers of English, Pearson's *r* showed significant correlations between F1 and jaw displacement. The results of Japanese speakers further corroborate the results of Erickson et al. (2012) by showing that the amount of jaw displacement and F1 correlate to a significant degree (see also Stevens 1998 for the correlation between F1 and degrees of oral constriction).

4. Discussion

For the *five bright highlights* phrase, the Japanese speakers of English show stress patterns similar to those of the American speakers of English—with phrasal stress on *high* (largest jaw opening, and highest F1)[7]. Either Japanese speakers have learned the "right" jaw displacement pattern in English, or that the Japanese phonetic grammar would put the highest prominence on *high* anyway[8].

However, for the final phrase, the American English speakers consistently put phrasal stress on *sky* (largest jaw opening, highest F1), whereas Japanese put phrasal stress on *(to)night* (largest jaw opening, highest F1). A question arises as to why this difference arises.

One interpretation is that for American speakers, phrasal stress is a matter of conveying meaning, that is, stressing the one important word in the phrase. Generally, American speakers feel that the important information that needs to be conveyed in this sentence is *sky*—i.e., *sky* carries informational focus—where the highlights were seen, and thus, *sky* receives phrasal stress. Since *sky* receives focal stress, then *(to)night* cannot be stressed, as there can only be one phrase

stress per phrase. If *(to)night* received phrase stress, which of course is possible with *contrastive* focus, then the speaker's intended meaning would change to indicate that it was *tonight*, not some other night, or other time, that the highlights were seen (see Katz and Selkirk 2012 for phonetic differences between informational focus and contrastive focus in English).

The Japanese speakers, however, showed increased jaw displacement/increased F1 on the final word, *(to)night*. An important question is why we observe this pattern; i.e., where the discrepancy between L1 pronunciation and L2 pronunciation comes from? One hypothesis would be that they had "mislearned" that the last content word in English should be stressed, and consequently, stressed *(to)night*, possibly for the following reason. Japanese is said to not have phrase final lengthening (e.g., Takeda et al. 1989, Kaiki and Sagisaka 1992, Mori and Erickson 2008), and Japanese speakers of English are often described as producing insufficient phrase final lengthening (e.g., Mori 2006). Perhaps in this case, the Japanese speakers may be aware that their native language lacks sufficient final lengthening compared to English, and may be trying to "overcompensate"[9]. Impressionistically speaking, Japanese speakers sometimes "curl their tongue" too much when they try to pronounce English [r] to "over-mimic" the retroflection, and extend this over-retroflection when they speak English in general—maybe we are observing something similar here (see Maeda 2013 for a similar observation).

Another possible reason for Japanese speakers putting phrase stress on *(to)night*, which is more interesting and seems plausible for us in the light of our own recent findings (Kawahara et al. 2014b), is that phrase final prominence in fact occurs in the L1 speech of Japanese. As mentioned above, although phrase final lengthening in Japanese is generally thought to not occur (Takeda et al.1989, Kaiki and Sagisaka 1992, Mori 2006, Mori and Erickson 2008), these studies examined read, i.e., semi-formal, speech. For isolated word utterances, Sagisaka and Tohkura (1984) reported lengthening of word-final vowels compared to word-medial vowels. Also, Maekawa and Kagomiya (2000), in their study of segmental articulation changes due to expressiveness and position in the utterance, show clear lengthening of phrase final vowels. These findings raise doubts about the overcompensation hypothesis discussed above.

A recent study of jaw displacement patterns of Japanese speakers of Japanese indicates that actually Japanese speakers show increased jaw lowering at the end of sentences, especially those that end in a non-high vowel (Erickson et al. 2013, Kawahara et al. 2014b). Thus, it may be that, at least for non-formal read speech as well as expressive speech, Japanese speakers *do* lengthen the final word in their native language and place prominence at phrase-final positions. Thus the large jaw opening on *(to)night* which we observed in this study might be a prosodic carry-over from their native language. If this explanation is on the right track, then our observation instantiates a case of transfer of L1 articulation to their second language (Flege 1995). This explanation has an additional appeal in the sense that L1 transfer at the phonetic level is a common observation. This hypothesis, if correct, would imply that L1 transfer can happen at the level of control of jaw movement. This conclusion is hardly surprising, as our L1 jaw displacement patterns are presumably hardwired in our speech.

5. Conclusions

The current study suggests that jaw and F1 are important phonetic characteristics of phrasal stress in English, and perhaps also in Japanese, but perhaps used differently between L1 speech and L2 speech. Japanese speakers of English showed rhythmical jaw/F1 patterns similar to American speakers for non-final phrases for the sentence examined here, but not for the final phrase, at least not for the final phrase examined here. Specifically, we found that Japanese speakers of English increased jaw displacement and F1 on the last word of the final phrase, while the American speakers of English showed increased jaw displacement/F1 on the penultimate word in the phrase, not on the last word[10]. We entertained a hypothesis that this L2-accented speech may be a case of L1 transfer, the rhythmic characteristic of Japanese which places phrase-final prominence. Our conclusion remains tentative for various reasons, and much research into the articulation of phrase stress, in both English as well as Japanese, is still needed.

While we admit that our finding is preliminary, we reiterate that we are not proposing a new theory of second language acquisition or language teaching. Instead, what we hope to have shown is that articulatory movement data do provide objective and easily quantifiable measures of stress levels both in L1 and L2 pronunciations. These measures[11] allow us to directly and quantitatively compare L1 and L2 pronunciations, without relying on impressionistic observations We thus hope that this methodology will bring new light in the issue of the acquisition of L2 pronunciations more generally.

Also while we remain conservative about the possible implications of the current research on language teaching, we believe that teaching jaw displacement patterns of target L2 languages explicitly may help learners improve their pronunciations [12].

Acknowledgments

A version of this paper was given at the Phonetics Society Meeting, June 23, 2013 at NINJAL. This research note is a preliminary report on a curious difference in jaw displacement patterns of American vs. Japanese speakers of English. It is a sister-piece to an earlier research paper reported in Erickson et al. (2012). This paper is also a part of our general research enterprise to investigate the phonetics-phonology interface through the study of jaw displacement. This work was supported by the Japan Society for the Promotion of Science, Grants-in-Aid for Scientific Research (C)#22520412 to the first author. A special thanks to Jianwu Dang for the use of the EMA Lab at JAIST and Haruka Fukazawaka, Hinako Masuda, Yukiko Yugiyama, Yoko Sugioka for our discussion on issues L2 acquisition of English by Japanese speakers. Thanks for two anonymous reviewers for useful comments on a previous version of the paper. Remaining errors are ours.

Notes

1) In the work by the American Structuralists, up to five levels of distinctions were posited (Liberman and Prince 1977, pp. 251–252). Likewise, Chomsky and Halle (1968, Chapter 3) used a four-level feature for stress, in addition to unstressed syllables.

2) The assessment of English skill level was done informally by the first author, who has many years of experience teaching English in Japan. How L2 proficiency levels affect the acquisition of L2 jaw displacement patterns is currently under investigation. In this on-going project, we are testing the jaw displacement patterns in the English pronunciations of Japanese speakers with various English proficiency levels.

3) The results and methods describing the American speakers were previously reported in detail in Erickson et al. (2012).

4) By measuring the distance from the occlusal plane to maximum amount of jaw opening in the syllable, we normalize differences in palate shape across different speakers. Also, we do not average jaw displacement across speakers, since we are interested in patterns of jaw displacement by individual speakers.

5) We observe that error bars are generally larger for the Japanese L2 speech (Figure 2) than the English L1 speech (Figure 1): compares especially A1 and J1. The larger variance in L2 speech may represent their uncertainty of their pronunciation.

6) The correlation measures between jaw opening and F1 values are slightly different from those reported in Erickson et al. (2012) due to re-measuring the F1 values we conducted after the publication of Erickson et al. (2012).

7) The fourth speaker in Erickson et al. (2012) showed highest stress on *five*; see also Mori et al. (2014) for relevant data.

8) As discussed just below, Japanese speakers show large jaw opening phrase-finally in their L1 speech. If the current speakers treat *highlight* as one word, and for some reason know that *high* is more prominent than *light*, then the Japanese phonetics grammar may put phrasal stress on *high*. This story is admittedly speculative, and has to be verified empirically more thoroughly.

9) This particular final phrase consists of a noun phrase (*in the sky*) followed by a time phrase (*tonight*). Perhaps this combination of noun phrase plus time phrase in English requires the native speaker to put the phrasal stress on *sky*, thus indicating that *sky* is the key piece of information (p.c., Haruo Kubozono).

10) This study includes only three Japanese speakers with intermediate level proficiency of English. Current work is investigating the effect of English proficiency on jaw displacement patterns.

11) Future work will investigate additional acoustic measures, such as duration, intensity and fundamental frequency, along with jaw as well as articulation.

12) Obtaining EMA data is not easy. In collaboration with Ian Wilson (Aizu University), we are working on getting similar data of jaw displacement via video recording.

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