様式Ｃ－１９

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研究課題名：日本人英語学習者の英語リズム・イントネーション習得のための調音及び知覚・音響分析

研究課題名（英文）Acoustic, articulatory and perceptual analyses of English Rhythm and Intonation in order to teach Japanese learners of English

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研究成果の概要（和文）：第２言語での円滑なコミュニケーションには、自然な韻律が非常に重要である。本研究では北陸先端科学技術大学院大学の Electromagnetic Articulatograph を用い英語中級日本人英語話者（JS）と米国人話者の音響・調音データの収集・分析・検討を行った。その結果、英語の発話では音韻的韻律構造（リズムと強勢パタン）と顎の開口・F1 パタンは強い関連性を示したが、JT の顎の開口・F1 パタンはリズムパタンと不一致を示した。この成果を応用し、現在英語リズム実現のための発音教授法の開発・試行を行っている。

研究成果の概要（英文）：Natural sounding prosody (rhythm and intonation) is extremely important for communication in a second language. Based on electromagnetic articulographic recordings (EMA) conducted at the Japan Advanced Institute of Science and Technology (JAIST, Ishikawa Prefecture) for intermediate level Japanese speakers of English and American speakers of English, it was reported that the phonological metrical structure (rhythm/stress patterns) of an English utterance match the patterns of jaw movement, as well as the corresponding resonance frequency patterns of the vocal tract, specifically the first formant (F1) patterns; however, the Japanese speakers' patterns of jaw opening/F1 did not always show consistent matches with the rhythm pattern of the utterance.　The findings about articulation of rhythm are currently being applied toward improving teaching of American English rhythm to Japanese learners of English.

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１．研究開始当初の背景

In the current globalized world, English is the language of commerce; many countries, including Japan, have English learning in their academic curricula. Teachers of English as a second language agree that native-like prosody (rhythm and intonation) is necessary for efficiently communicating in a second language, and in fact, perhaps more important than segmental accuracy. Natural sounding prosody (rhythm and intonation) is extremely important for communication in a second language, in terms of both producing understandable utterances and also being able to understand what is being said.

Evidence from experimental articulatory studies suggests that that jaw opening/closing cycle is the articulatory organizer of syllable production. For each prototypical syllable of an utterance, the jaw opens for the vocalic nucleus and closes for the consonantal onset/coda. The more prominent a syllable, (e.g., an emphasized syllable), the greater the jaw displacement. Also, previous studies have shown that increased jaw opening is acoustically manifested by an increase in the first formant frequency (vocal tract resonance frequencies)

２．研究の目的

The goals of the research topic of the past three years was to better understand the acoustic, articulatory and perceptual characteristics of spoken English prosody (rhythm and intonation), and then to apply these findings to teaching better rhythm and intonation to Japanese learners of English.

３．研究の方法

The following methods were used in this research project: (a) Articulatory and acoustic recordings of American and Japanese speakers of English, using the Electromagnetic Articulograph (EMA) at Japan Advanced Institute of Science, Ishikawa Prefecture, Japan, in order to analyze the articulatory and acoustic characteristics of English rhythm; (b) Acoustic data analysis software was free downloadable WAVESURFER and PRAAT; articulatory data analysis software was the MATLAB-based mview tool (developed at Haskins Laboratories, New Haven, Conncecticut, U.S.A.); (c) Rhythm training with Japanese students of English was done using a multimodal online program called NOWGAKU; (d) Rhythm evaluation studies were done using RUNTIME REVOLUTION.

４．研究成果

During the course of this three year research grant, several important findings have been reported.

In terms of perception of Japanese English by American English listeners, it was shown that poor rhythm by Japanese speakers of English affects comprehension of the sentence by American listeners [Menezes, Erickson et al, 2012]; (2) however, a training program with a multimodal online tool that forces Japanese speakers of English to break the sentences into small units (phrases), improves the overall performance of fluency and comprehension as rated by American listeners (college students in the United States) [Erickson, Tanaka et al, 2011].

In terms of acoustics, it was shown that the cues for rhythm and intonation of English spoken by native speakers involve changes in duration and formant frequencies (resonance frequencies of the vocal tract); however, the cues for Japanese speakers of English were primarily changes in voice pitch (fundamental frequency, F0) [Mori, Hori, Erickson et al, 2011].

In terms of articulation, based on electromagnetic articulographic recordings (EMA) conducted at the Japan Advanced Institute of Science and Technology (JAIST, Ishikawa Prefecture) for 3 intermediate level Japanese speakers of English and 3 American speakers of English, it was reported that the phonological metrical structure (rhythm/stress patterns, as

shown in figure 1) of an English utterance match the patterns of jaw movement, as well as the corresponding F1 patterns, as shown in figure 2 [Erickson, Shibuya, Suemitsu, Tiede, 2012];

Utterance			x				
Phrase			x			x	
Foot	x		x			x	
Word	x	x	x			x	x
Syllable	x	x	x	x		x	x
Stress level	3	2	5	1		4	2
(Yes, I saw)	five	bright	high	lights		sky	night

Fig. 1. Metrically generated syllable stress levels for the sentences "(Yes, I saw) five bright highlights (in the) sky (to) night" with sentential stress on "high". (From Erickson et al. 2012, fig. 4).

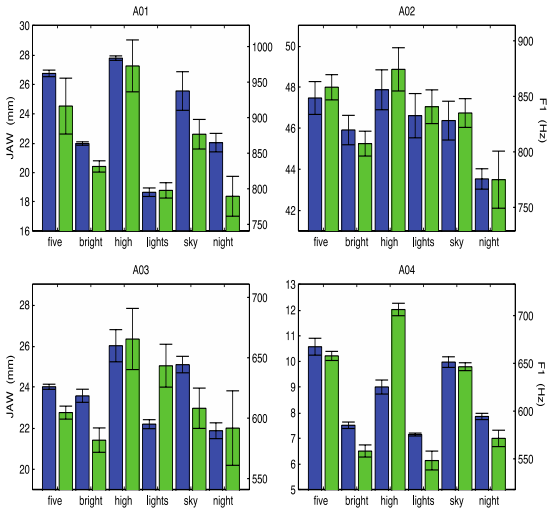

Fig. 2. Jaw displacement (left bar) and corresponding F1 (right bar) pairs for 4 American English speakers producing the sentence "(Yes, I saw) five bright highlights (in the) sky (to) night." N= 5 for A1, A2, A3, and N=10 for A4. The words "in the" and "to" for these speakers have considerably reduced vowels with minimal jaw opening and are not shown. The error bars show standard error of the mean. Ordinate scaling is individual by speaker. (from Erickson et al. 2012)

Notice that for these American English speakers, the patterns of metrical stress shown in figure 1 match those of jaw displacement/F1 (shown in figure 2). A correlation analysis showed the correlation to be significant.

However, the Japanese speakers' patterns of jaw opening/F1 did not always show consistent matches with the American English rhythm pattern of the utterance [Erickson, Shibuya, Suemitsu, Tiede, in progress]. Figure 3 shows a typical jaw displacement pattern of the same sentence (as shown in Figure 2) as spoken by a typical Japanese speaker of English. Figure 3 shows the F1 pattern for this speaker for this sentence. Notice that for the final phrase, "(in the) sky (to)night", the patterns of jaw displacement pattern and F1 for the Japanese speakers of English are different from those of the American speakers (shown in Figure 2). Specifically, American speakers put increased stress (increased jaw opening/increased F1) on the key word "sky", while Japanese speakers of English place it on the final content word "night."

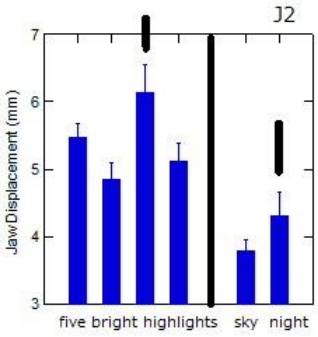

Figure 3. Jaw displacement pattern for a typical Japanese speaker of English for the same sentence as in Figures 1 and 2.

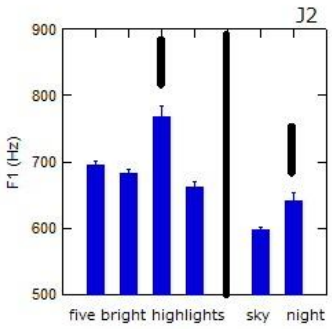

Figure 4. F1 pattern for a typical Japanese speaker of English for the same sentence as in Figures 1, 2 and 3.

It was also reported that both vowel height and sentence stress affects jaw displacement, such that a low vowel (e.g., [a]) has a 4 mm bigger jaw opening than does a high vowel (e.g., [i]) [Menezes and Erickson, 2013].

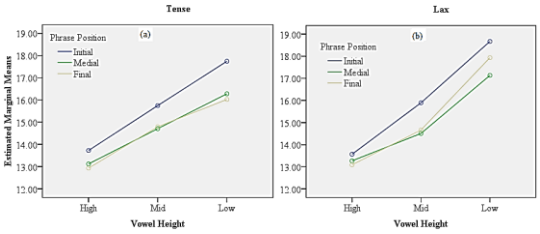

Figure 5. Profile plots showing interaction between *Vowel tenseness* and *Vowel height* and *Phrase position* based on estimated marginal mean jaw displacement values.(from Menezes and Erickson, 2013)

However, initial consonants do not seem to affect jaw displacement [Wilson and Erickson, 2013].

The findings about articulation of rhythm are currently being applied toward improving teaching of American English rhythm to Japanese learners of English. For instance, especially for sentence final phrases, Japanese learners of English need to be trained in placing stress on the key (content) word, not the final content word [Erickson, Shibuya, Suemitsu, and Tiede, in progress].

Along these lines, we hope to develop within the next three years (under the newly awarded kakenhi with Shibuya Yoshiho as PI) an online feedback tool to teach English rhythm, similar to the online feedback method developed for teaching /r-l/ distinction [Suemitsu, Ito and Tiede, 2013].

In addition, the findings about the interaction of rhythm and vowel height are being applied to devising an algorithm for neutralizing vowel height effects on jaw displacement [Williams, Erickson et al., 2013]. Once we can separate vowel effects from prosodic effects on jaw displacement, we can then start assessing rhythmical patterns of jaw displacement/F1 for a wide variety of sentences. In this way, we hope to improve our current understanding of the relationship between jaw articulation and metrical stress patterns [see e.g., the discussion about articulatory implementation of phrasal accents in spoken English by Erickson and Menezes, 2013]. The goal is then to use this new understanding to continue to help teach effective prosody strategies to second language learners of English in order to improve spoken and listening communication.

5. 主な発表論文等

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