A LINGUISTIC RHYTHM OBSERVED FROM THE RESPIRATORY MUSCLE MOVEMENTS AND SPEECH WAVEFORMS BY ENGLISH, JAPANESE AND CHINESE L1 AND L2 — THE RECITATION OF A STORY

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ABSTRACT

To investigate the relationships between respiratory control and the speech signal in the recitation of a story in English, Japanese, and Chinese, I compared and analysed the respiratory muscle movements utilising Strangage and simultaneously recorded speech signal. The subjects were English, Japanese and Chinese speakers. The results showed that (1) the Chinese showed no significant difference in durations in reading a story regardless of the language, but the converse was true for the English and Japanese, (2) English speakers may have a tendency to have chest and stomach movements accord with each other regardless of the language and the peaks of the movements linked to the speech waveforms, all being related to the boundary at the sentential or phrasal level by pausing, (3) Chinese speakers explicitly have chest and stomach movements which accord with each other regardless of the language, but the peaks of the movements cannot be linked to speech waveforms, (4) Japanese speakers may have a tendency to have the chest and stomach movements accord with speech waveforms at the phrasal level, but often chest and stomach movements do not accord.

Keywords: linguistic rhythm, respiratory muscle movements, English, Japanese, Chinese

1. INTRODUCTION

The purpose of this research is to exploit the relationships between respiratory control and speech signal in read speech (the recitation of a story) in relation to linguistic rhythm. For this purpose, I use Strangage which is utilised for medical treatment of sleeplessness symptoms, and which observes the breathing state. With this method, I can take advantage of the opportunity to observe the chest and stomach muscle movements which control respiratory pressure through the diaphragm. (See [1]) Strangage has already been used in order to investigate how these muscle movements are related to singing and pauses in speech (cf., e.g., [4]). [3] was the first attempt to investigate the relationships between English and Japanese respiratory control and speech signal.

English, Japanese and (Mandarin) Chinese are linguistic-typologically different and their rhythm sounds differ considerably from each other impressionistically. In these three languages the syntactic, syllabic and phonotactic structures are different in addition to their sound structures, and accordingly the number of phonemes in a sentence differs from language to language. These affect speech rate. Apart from these linguistic, phonetic, and phonological issues, however, a pause occurring on the syllabic, phrasal or sentential level can be either dependent or independent of these factors. A pause is also inevitably included in the consideration of respiratory control in addition to these factors, as is semantically required timing.

Taking into considerations of all these factors, it is assumed that linguistic rhythm is produced by respiratory effort. Thus, it is essential to observe the relationships between the physiological speech mechanisms produced by respiratory effort, more concretely by respiratory muscle movements and speech signal (sound pressure), in investigating linguistic rhythm. The diaphragm controls not only the breathing mechanism, but also speech rhythm. The Strangage is not harmful to human health and easily controlled for experimental purposes, in order to investigate respiratory muscle movements. Moreover, with this method I can simultaneously investigate how these language speakers move their respiratory muscles while they are learning a target foreign language(s).

Thus, in this research, I shall investigate (1) speech rate: how long respective language speakers take to read the same story in their own language and in a foreign language (s) and (2) how

their respiratory muscle movements are related to the speech signal (sound pressure). In (2) I shall simultaneously observe the relationship between chest and stomach muscle movements using electric pressure.

2. EXPERIMENTAL METHODS

In cross-linguistic comparison of typologically different languages, it is ideal to use exactly the same material. The material for reading was the "The North Wind and the Sun" [2] (hereafter, story) in Japanese, English, and Chinese. For analytical purposes, the number of punctuation points in the story in the respective language must be noted. (See Table 1) English had least punctuation, Japanese more than English and Chinese most.

Table 1: No of punctuations in the story according to the language (*A semicolon is included).

Language	No. of sentences	No. commas	No. of periods
English	6*	3	9
Japanese	8	7	15
Chinese	10	10	20

2.1. Subjects

The subjects were English speakers (EL1) who study Japanese (EJL2), Japanese (Tokyo dialect) speakers (JL1) who study English (JEL2) and Mandarin Chinese speakers (CL1) who study Japanese (CJL2) and understand English (CEL2). All are university students who study the Japanese university and live in Japan, their ages ranging from 22 to 27. All Chinese speakers had passed the highest grade in the Japanese proficiency test, whereas the English speakers had only passed the lower grade although they spoke Japanese fluently. The Japanese students had studied English over nine years and the Chinese students from zero to 10 years. The number of English speakers were three (two males from the U.S.A. and Australia respectively, and one male from the U.S.A.), Japanese speakers three (two males and one female), and Chinese speakers four (females). All the subjects were highly educated and spoke their standard language as are mother tongue.

2.2. Procedures

Before the experiments, each subject was given some time to read the materials fluently. Also, I visually secured the muscle movements of chest and stomach on Power Lab, checking the proper pressure by binding, because the body structure depends on the subject. During the experiments, Strangage was bound on their chest area and stomach area respectively. The data from the Strangage were stored into Power Lab 7. This was used for analysis as well. Simultaneously, their speech was digitally recorded in EDIROL (sampling rate 41.1 kHz). To acquire a stable speech signal, a headset microphone was used. Thus, the subject was wearing the two Strangage cables and a microphone at the same time during the experiment. The recording was conducted in a quiet room. The subject was asked to stand for the purpose of getting better data on the muscle movements for respiratory control.

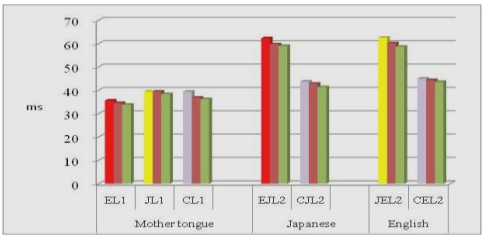
EL1 read the story in English and JL1 in Japanese and English, while CL1 read in Chinese, English and Japanese. All subjects repeated the story three times. Since the story in [2] was written in Taiwanese Chinese, I rewrote the story using Mandarin script.

3. RESULTS

3.1. Speech rate of the read story

Figure 1 shows how long the EL1, JL1, CL1, EJL2, CJL2, JEL2, and CEL2 took to read the story in English, Japanese and Chinese respectively, with three repetitions. There was a strong tendency that the more often they read the story, the less time they took in both their own language (L1) and in the foreign languages (L2). However, the EJL2 took a much longer time than the JL1 and more time than the CJL2 when they read the story in Japanese. Thus, there was a considerable difference between the EJL2 and CJL2. When the JEL2 and CEL2 read the story in English, the JEL2 took a much longer time than the EL1. As for the CEL2, they took more time than did the EL1 but not as long as the Japanese EL2. Thus, there was a considerable difference between the JEL2 and CEL2. Consequently, for the Chinese the durational variance reading the story was not largely dependent on whether or not the story was in the mother tongue or a foreign language, whereas for the English and Japanese speakers, it was dependent.

Figure 1: Durational comparison of the story read in English, Japanese and Chinese by EL1, JL1, CL1, EJL2, CJL2, JEL2, and CEL2 with three repetitions.



3.2. Muscle movements and speech signal

In this section, I describe how I selected more clearly visible chest and stomach muscle movements and speech signal when my informants read the story in their own language or in a foreign language. For analysis purpose, I focused on where the peaks of the muscle movements appear at a sentential level or at a phrasal level or at a pause and whether or not they were parallel to speech signal as a whole.

All the figures presented below were taken from the second utterance of any language speaker. Also, it must be noted that the scale in the figures varies depending on the subject's utterance, although the figure frame size looks quite similar.

Figure 2 shows the muscle movements of the chest (uppermost) and stomach (middle), and speech waveforms (lowest) of the story (hereafter, those) when a male General American EL1 read the story in English. This presentation applies to all the figures cited below. The peaks of the chest and stomach muscle movements appear immediately before the beginning of the sentence-initial utterance, and the peaks of the stomach muscle movements appear immediately before the chest muscle movements. These are natural physiological efforts probably because the stomach is closer to the diaphragm than the chest and the respiratory muscle is closer to the chest, and consequently the speech signal is produced from the mouth following these muscle movements. There are six sentences in the English story and there are six peaks of chest and stomach muscle movement. The chest and stomach muscle movements accord with each other and appear to link to the speech waveforms at the sentential level. It must be noted that there are five longer pauses (< 500ms) between the peaks.

Figure 3 shows those of a male JEL2 who read the story in English. The peaks do not occur regularly, unlike EL1 seen in Figure 2. The chest and stomach muscle movements do not accord with each other nor do they appear to link to the speech waveforms at the sentential level at all. There are very many irregular peaks and pauses.

Figure 4 shows those of a female CEL2 reading the story in English. The peaks do not occur regularly, unlike EL1 seen in Figure 2. However, the chest and stomach muscle movements accord with each other, but do not appear to link to the speech waveforms at the sentential level at all. There are very many smaller peaks.

Figure 5 shows those of when a male JL1 read the story in Japanese. The peaks may show that the chest and stomach muscle movements relatively accord with each other. The stomach muscle movements may appear to link to the speech waveforms at the phrasal level. These are clearer, compared to those in Figure 2 produced by the same subject.

Figure 6 shows those of when a male General American EJL2 read the story in Japanese. The chest and stomach muscle movements almost accord with each other, although the peaks are smaller for the stomach muscles. (Cf. the same subject in Figure 2.) The peaks are larger in the sentential-initial position compared to the other peaks probably occurring at a phrasal-initial position and thus, the peaks seem to link to the speech waveforms. The same phenomena are seen in the other EJL2.

Figure 2: Muscle movements of the chest and stomach, and speech waveforms of the story when read in English by EL1.

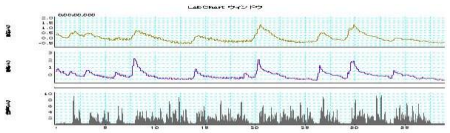


Figure 3: Muscle movements of the chest and stomach, and speech waveforms of the story when read in English by JEL2.

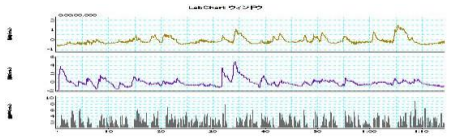


Figure 4: Muscle movements of the chest and stomach, and speech waveforms of the story when read in English by CEL2.

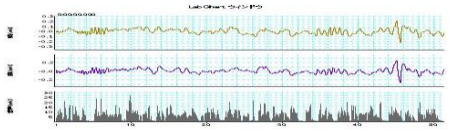


Figure 5: Muscle movements of the chest and stomach, and speech waveforms of the story when read in Japanese by JL1.

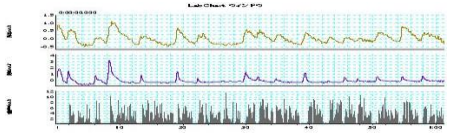


Figure 6: Muscle movements of the chest and stomach, and speech waveforms of the story when read in Japanese by EJL2.

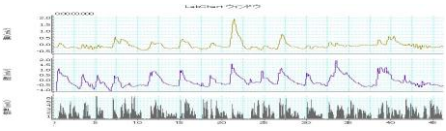


Figure 7: Muscle movements of the chest and stomach, and speech waveforms of the story when read in Japanese by CJL2.

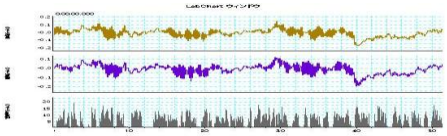


Figure 8: Muscle movements of the chest and stomach, and speech waveforms of the story when read in Chinese by CL1.

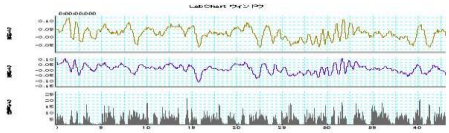


Figure 7 shows those of a female CJL2 who read the story in Japanese. The chest and stomach muscle movements explicitly accord with each other. However, there is no evidence at all that these movements link to the speech waveforms at any level. Also, the same is true of the other CJL2 and in addition, the chest and stomach muscle movements considerably depend on each CJL2, with no common movements.

Figure 8 shows those of a female CL1 reading the story in Chinese. The chest and stomach muscle movements clearly accord with each other. However, the peaks irregularly occur and no higher peaks are observed on the phrasal or sentential boundary. Thus, these movements do not appear to link to the speech waveforms at any level.

4. SUMMARY AND DISCUSSION

In terms of the speech rate of the story read, the results are summarised as follows: (1) there was no large difference among the three language speakers, but the order according to the language was: EL1 < CL1 < JL1; (2) when they read the story in English: EL1 < CEL2 < JEL2; (3) when they read the story in Japanese: JL1 < CJL2 < EJL2; (4) there was a strong tendency that the more often they read the story, the less time they took in both their own language (L1) and in a foreign language (L2). EJL2 and JEL2 took significantly longer to read the L2 story, but this did not apply to CEL2/CJL2, that is, Chinese speakers.

The accordance between the chest and stomach muscle movements, where the peaks occur and whether or not there is a linkage to speech waveforms (at a phrasal, sentential level or none) are summarised in Table 2. 'Yes' or 'No' is a relative classification.

Table 2: Summary of the relationships between the chest and stomach muscle movements, and speech waveforms.

Subject	Muscle Accordance	Phrasal-level	Sentential-level	Linkage to speech
EL1	yes	no	yes	yes
JL1	no	yes	no	yes
CL1	yes	no	no	no
JEL2	no	no	no	no
CEL2	yes	no	no	no
EJL2	yes	yes	yes	yes
CJL2	yes	no	no	no

5. CONCLUSIONS

The results showed that (1) the Chinese showed no significant difference in durations in reading a story regardless of the language, but the converse was true for the English and Japanese, (2) English speakers may have a tendency to have chest and stomach movements accord with each other regardless of the language and the peaks of the movements linked to the speech waveforms, all being related to the boundary at the sentential or phrasal level by pausing, (3) Chinese speakers explicitly have chest and stomach movements which accord with each other regardless of the language, but the peaks of the movements cannot be linked to speech waveforms, (4) Japanese speakers may have a tendency to have the chest and stomach movements accord with speech waveforms at the phrasal level, but often chest and stomach movements do not accord. These results may suggest that the differences between respective language speakers might be related to respective linguistic timing and that to master L1's respiratory muscle movements might help improve L2's pronunciation. For future studies, more statistical analysis of more number of subjects will be of necessity to reinforce the results.

6. ACKNOWLEDGEMENTS

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