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Articulatory settings of English, Japanese, and Chinese bilingual and trilingual speakers

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To anyone listening to a foreign language, it is obvious that different languages use a different set of sounds. What is not obvious is the fact that each language (and possibly each dialect) also has a different rest position (or "articulatory setting") of the tongue. We used ultrasound to observe the tongue's rest position in Japanese and Chinese speakers who spoke English as a second language. The COVID pandemic started at the same time as this research grant, making it difficult to collect new speech data for the fist two years. However, after taking precautions against COVID, we invited top-level researchers to the phonetics lab, submitted two journal papers (one in press and the other under review), and prepared to host Ultrafest XI in June 2024, an international conference devoted to the use of ultrasound for speech research.

Articulatory phonetics

articulatory setting speech rest position tongue ultrasound English Japanese Chinese bilingual

To anyone listening to a foreign language, it is obvious that different languages use a different set of sounds. What is not obvious is the fact that each language (and possibly each dialect) also has a different rest position of the tongue, jaw, and lips (henceforth "the articulators"). This underlying or default posture of the articulators is called the "articulatory setting"   , and although it is something that has interested phoneticians for centuries, it has not been deeply studied because it was difficult to measure. Ultrasound, as a technique for observing the tongue during speech, has been used in Japan since at least 1994 [1], but only more recent advances in ultrasound imaging equipment have made articulatory setting easier to measure, and instrumentally verifiable [2], and its study is very significant for the field of phonetics.

Articulatory setting is important because it demonstrates what the language-specific underlying passive muscle activation may be in the vocal tract. This knowledge is key for researchers who create articulatory models of the vocal tract, and for others who use articulatory setting as a baseline from which to make measurements of tongue movement, etc. It also could be extremely important for language teachers and learners who continually look for an easier way to modify pronunciation. It could be that simply by globally modifying one's articulatory setting (or underlying muscle activation in the tongue, jaw, lips), one could change one's pronunciation in a bigger way than modifying each spoken phoneme separately. The possible importance of the vocal tract's passive muscle activation on speech has been revealed in a study on a NASA astronaut's vowel space before, during, and after space travel [3].

One question that we wanted to answer was: "What are the articulatory settings of Japanese and Chinese, and how are they different from that of English?" A language-specific articulatory setting most likely comes about because of the different phonemic inventories of different languages, as well as because of the different frequency of occurrence of the phonemes across languages. So, another question we wanted to answer was: "For a given language, how closely does the articulatory setting of the tongue, lips, and jaw resemble the position of the articulators for the most common phonemes in that language?"

One difficulty of comparing articulatory settings across languages is that the vocal tract morphology is speaker-dependent. In an experiment, if the speakers of one language have a systematically different size or shape of the vocal tract from the speakers of another language, then one cannot draw fair conclusions about differences in articulatory setting. An ideal way to solve this problem, though, is to investigate multilingual speakers and compare their articulatory setting in one language versus another. Together with the students in his laboratory, the Principal Investigator had investigated Japanese articulatory setting using data from ultrasound [4] and electromagnetic articulometry (EMA) [5], but in each case, no highly-proficient bilinguals were tested, so it was very difficult to draw clear conclusions. Thus, the third aim in this study was to determine if bilingual Japanese-English speakers use a different rest position of the tongue in each of their languages.

References:
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[3] Shamei, A. & B. Gick (2019). The effects of outer space on vowel space. *Canadian Acoustics*, 47, 110-111.
[4] Wilson, I., N. Horiguchi, & B. Gick (2007). Japanese articulatory setting: the tongue, lips and jaw. Paper presented at *Ultrafest IV* (the 4th International Ultrasound for Speech Research Conference), NYU
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Our original plan was to collect ultrasound tongue image video data and high-speed lip and jaw data from bilingual and trilingual Japanese and Chinese participants. This was in order to determine differences between the articulatory setting (seen in the rest position of the articulators) of Japanese and Chinese compared to English. However, due to COVID-19 we could not collect any new speech data in the first two years of the grant, which would have required face-to-face mask-less communication.

Our research plan had to be scaled down, and focus was placed on data from Japanese-English bilinguals. Our new focus was on determining whether a language's rest position of the tongue was a result of the weighted frequency of occurrence of the tongue configurations for the phonemes of that language.

Ultrasound tongue imaging data from four bilingual participants was used for analysis of the rest position between Japanese utterances compared to the rest position between English utterances. An accent rating task was done by native listeners to determine whether the speakers sounded nativelike in English (their second language).

Participants read English sentences and (separately) Japanese sentences, pausing for at least one second between each sentence. Ultrasound tongue video frames at stable points during the pause were extracted and the surface of the tongue was automatically detected using software. An average tongue contour for English rest position and for Japanese rest position was calculated. Tongue shapes for the vowels and consonants of each language were also extracted. Each vowel's and each consonant's tongue contour was weighted according to the frequency of occurrence of those sounds in either Japanese or English. Then the average of all the weighted contours was calculated and compared to the actual rest position in each language.

We started our research by purchasing new hardware and software, and training a Research Assistant. We read papers on the frequency of occurrence of phonemes in Japanese versus English. Together with our Research Assistant, we worked on modelling expected articulatory settings based on frequency of occurrence of phonemes across English and Japanese.

After implementing precautions against the spread of COVID-19, we hosted Dr. Kikuo Maekawa, president of the Phonetic Society of Japan, and two accompanying professors for a discussion of ultrasound data collection in our laboratory. We invited Mr. Takayuki Nagamine, a PhD student at Lancaster University (UK), overlapping with Dr. Maekawa. Mr. Nagamine's PhD studies are focused on articulatory settings. We held very fruitful discussions, and the Principal Investigator gave an invited Zoom webinar at the March 2021 National Institute for Japanese Language and Linguistics (NINJAL) Colloquium.

With the continuation of the COVID-19 pandemic in FY2021, it was impossible to collect new ultrasound tongue image video data and high-speed lip and jaw data from bilingual and trilingual Japanese and Chinese participants. We continued to analyze our existing bilingual data, submitting an abstract to the 10th International Symposium on the Acquisition of Second Language Speech ("NewSounds 2022"). Although our submission was accepted for an oral presentation, the conference was held only face-to-face in Barcelona, Spain, and we were unable to attend because of the complications of COVID-19. We continued to model articulatory setting based on phoneme frequencies of occurrence.

New data collection was still not possible in FY2022, and an application was made to extend this kakenhi grant for one year. Instead of data collection, existing data was further

analyzed. Books on the phonology of standard Chinese, on English pronunciation, and on voice quality were purchased to assist with training of research assistants and selection of stimuli for upcoming experiments.

A paper called " Articulatory settings of Japanese-English bilinguals" was submitted to the well-known Scopus-indexed journal " Language and Speech". Strong interest was shown by the publishers and reviewers, and we are currently revising the paper for resubmission in July FY2024.

The Principal Investigator was invited to give the Special Lecture at the 2023 Regular General Meeting of the Fukushima Association of Medical Technologists. About 200 people attended the lecture, which raised awareness among the medical profession of ultrasound speech research.

The Principal Investigator was also invited to give a lecture at the Acoustical Society of Japan 2024 Spring Meeting in March 2024. Feedback on research and ultrasound measurement techniques was obtained at the conference.

Ultrasound movies of the tongue during speech were collected from an additional 16 speakers, 5 of whom were Mandarin Chinese speakers who were also proficient in English and Japanese. This data was analyzed, written up in a paper and submitted to Speech Science & Technology 2024 (SST 2024), an annual conference held in Australia or New Zealand.

In FY2023, preparations were begun for an international conference (Ultrafest XI) to be held at the University of Aizu in June 2024, with the Principal Investigator as the chair of the organizing committee. Ultrafest is the only conference in the world to specifically focus on the use of ultrasound for speech research. This was only the second time for the conference to be held in Asia, and the very first time for it to be held in Japan. There was a total of 81 registrants: 50 in person and 31 online. The two invited speakers, Dr. Bryan GICK of the University of British Columbia and Dr. Wei-Rong CHEN of Yale University attracted many registrants and ended up giving excellent talks that were well received. The conference attendees consisted of both Japanese and non-Japanese researchers from many countries around the world. There were 18 oral presentations and 22 poster presentations at the conference, all of which dealt with the use of ultrasound for speech research. The methodology of ultrasound tongue imaging is still varied around the world, and this conference helped expose researchers to new ideas and techniques for tongue imaging and measurement.

In the future, we expect to be able to collect more data from Japanese and Chinese participants, expanding to include not just bilingual but also trilingual participants. Following on the success of Ultrafest XI, we expect to start more collaborative research with others who are specialists in ultrasound tongue imaging.

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