Using Functional Principal Component Analysis for articulatory dynamics of English liquids: L1 Japanese speakers’ production of English /l ɹ/ and Japanese /ɾ/

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It is well-known that first-language (L1) Japanese speakers have difficulty in producing English liquids. How the L1 liquid category (Japanese /ɾ/) influences their production of English liquids, however, remains rather inconclusive due to lack of research comparing English and Japanese liquids. In this study, I seek accounts in articulatory dynamics given different articulatory coordination and vocalic coarticulation patterns between English and Japanese liquids (Proctor et al., 2019; Yamane et al., 2015). I hypothesise that L1 Japanese speakers show distinct liquid-vowel coarticulatory patterns in English liquids according to vowel contexts compared to L1 English speakers due to a carry-over effect from articulatory strategies for Japanese /ɾ/ (cf. Beristain, 2022).

Data collection and processing. Midsagittal ultrasound tongue images and audio recordings have been collected from 29 L1 Japanese speakers and 14 L1 North American English speakers. Target words include 16 English words (eight minimal pairs) contrasted by word-initial /l/ and /ɹ/ and five Japanese words with word-initial /ɾ/ preceding /a/, /i/ and /u/. Recording results in 1,309 tokens of /l/, 1,322 tokens of /ɹ/ and 445 tokens of /ɾ/ for analysis. Tongue splines are tracked based on a set of XY Cartesian coordinates for 11 reference points along the tongue surface using the DeepLabCut plug-in on the Articulate Assistant Advanced (AAA) software, which have then been *z*-score normalised for cross-speaker comparison. Tongue splines have been extracted in the analysis window consisting of acoustically delimited word-initial liquid-vowel intervals and an additional 350ms interval padded before the liquid onset given that articulatory onset could precede acoustic onset.

Analysis 1: Identifying primary lingual dimensions. First, I run Principal Component Analysis (PCA) to identify key dimensions in midsagittal tongue shape for English and Japanese liquids and summarise them into numeric values (PC scores). The first two PCs explain the largest variation in the data: 39.28% for PC1 and 30.59% for PC2. PC1 seems to be associated more with tongue body raising and lowering whereas PC2 with tongue tip movement. Here, I focus on PC1 given the study’s focus on tongue body movement and its proportion of variance being the largest.

Analysis 2: Time-varying changes in tongue body retraction. I then conduct *Functional* Principal Component Analysis (FPCA) to investigate time-varying changes in tongue retraction (captured by PC1) from 350ms prior to the onset through to the offset of the word-initial liquid-vowel interval. FPCA takes functional data (e.g., time-varying trajectories) as input and summarises their key dimensions into numeric values (FPC scores). FPC1 captures the largest variation (58.10%). Larger FPC1 scores correspond to a greater degree of tongue raising and fronting (i.e., towards the red ‘+’ signs in the top panel in Figure 1), with a greater variation captured during the liquid interval. The box plot in Figure 1 shows a general expected coarticulatory pattern in which FPC1 scores are higher in the /i/ context for both L1 English and L1 Japanese speakers. FPC1 scores for L1 Japanese speakers are more variable across vowel contexts than for L1 English speakers, suggesting a strong vocalic coarticulation due to L1 articulatory strategies judging from the results for Japanese /ɾ/. Finally, linear mixed-effect modelling suggests a significant interaction effect between vowel context and speaker group, with a greater variability for L1 Japanese speakers in FPC1 scores across vowel contexts for both English /l/ and /ɹ/.

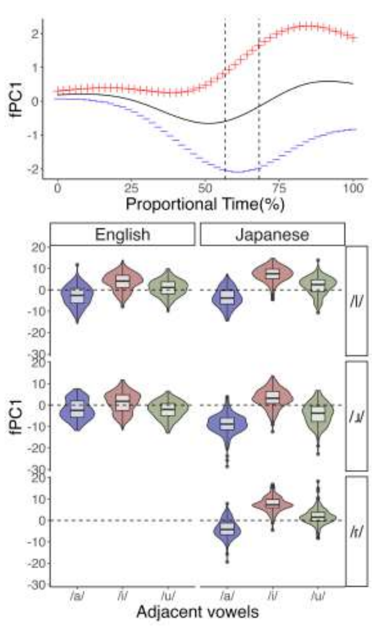

Figure 1: (Top) Variation of time-varying changes in PC1 captured by FPC1, with the mean trajectory represented in black and dashed vertical lines representing mean liquid interval. (Bottom) FPC1 scores by participants group (column) for liquid categories (row) in three vowel contexts (colour).

Conclusion. L1 Japanese speakers differ from L1 English speakers in the magnitude of vowel context effects on tongue retraction for English liquids. This may result from different articulatory coordination patterns in English and Japanese liquids. Methodologically, a combination of PCA and Functional PCA can be a versatile tool for data-driven investigation of articulatory dynamics using ultrasound.

References

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