Articulation in a bilingual speaker: Preliminary models and phonemic comparisons

Thomas R. Sawallis, Pierre Badin, Laurent Lamalle

Articulation in a bilingual speaker:
Preliminary models and phonemic comparisons

Thomas R. Sawallis New College, University of Alabama
tom.sawallis@ua.edu

Pierre Badin GIPSA-Lab, CNRS, Grenoble-Alpes Université
Pierre.Badin@gipsa-lab.grenoble-inp.fr

Laurent Lamalle IRMaGe, Grenoble-Alpes Université

Purpose

MRI investigation of articulatory strategies of bilinguals
- overall strategies, not single articulator
- articulatory modeling and comparison across models
- L1 v. L2 comparisons of individual phones & groups of phones

Themes:
- dynamics of L2 articulatory development
- *intra-individual* comparisons of articulatory phonetics

General methodology

Subject: 1 so far, L1 Am. English, skilled late learner of L2 French
More language pairs and more skill levels planned
Corpora: Isolated Vs and VCV combos for (nearly) all phonemes
CVCs and words when warranted
MRI: Static mid-sagittal MRIs of all targeted phones
Efforts underway to obtain dynamic MRI capabilities
Curves: Outlines of articulators extracted manually, oriented to bony articulators
Modeling: Linear models of articulatory components derived from targeted sub-corpora
Comparisons: L1 vs L2 for phonemes, phonemic classes, articulator models

Subject

Male, born mid-1950s, raised in S FL.
Parents and friends monolingual American English speakers.
French from 7th through 10th grades (~12 – 16 years). ALM method.
French minor in college, literature emphasis, no communicative competence.
6 years of residence in Grenoble, France, in academic situations
- ages 24-27 for MA, 34-36 for dissertation research, 56-57 as visiting instructor

Corpora

English L1	French L2
Target Phoneme Inventories	
p t k iɪ ʊ u f θ s ʃ e o m n ŋ ɛ ə ɔ ɬ ɻ ɹ æ ʌ w j ɐ ɹ ɔʲ aʲ aᵘ	p t k i y u f s ʃ e ø o m n ɛ œ ɔ l ʁ a ɛ̃ œ̃ ɑ̃ ɔ̃
MRI Images	
All Vs in isolation Cs in VCVs: (i e æ ɐ o u) x (p t k f θ s ʃ m n ŋ ɬ ɻ ɹ w j) i.e., [ipi, iti, . . . uwu, uju] V allophones in CVCs: (m ɬ ɻ ɹ) x all Vs i.e., [mim, mɪm, . . . ɹaʲɹ, ɹaᵘɹ] Vɹ / (C) _ {(#) or (V …)} in natural words e.g., ‘hearing, irritate, . . . pyre, purr’ Vɬ / (C) _ # in natural words e.g., ‘peel, pill, . . . coil, Kyle’	All Vs in isolation Cs in VCVs: (p t k f s ʃ m n ʁ l) x (i e ɛ a ɔ o u y ø œ ɛ̃ ɑ̃ ɔ̃) i.e., [ipi, iti, . . . ɔ̃ʁɔ̃, ɔ̃lɔ̃]

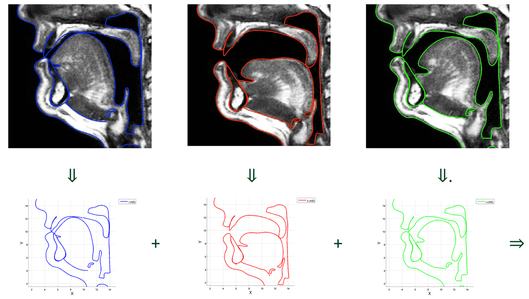
MRI

Grenoble’s research MRI facility, IRMaGe. Philips Achieva 3.0T TS scanner.
Midsagittal section 4 mm thick, 1 mm / pixel resolution, 256 x 256 mm field of view.

Two sessions, Am. Eng and FR, 6 weeks apart.
All interaction in target language, to maintain language mode.
Reclining position.
Image acquisition required 8.1 seconds fixed in the targeted articulatory position.

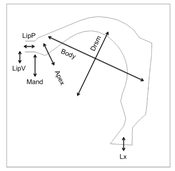
Contours

Contours of all articulator surfaces were traced manually using smooth spline curves.
Bony structure contours (teeth, palate, mandible, hyoid) are identical across images, so…
All images comparable, superimposable, by reference to teeth-&-palate. E.g.:



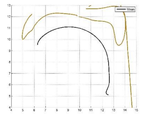
Models

Articulation is modeled by linear combination of basic components:

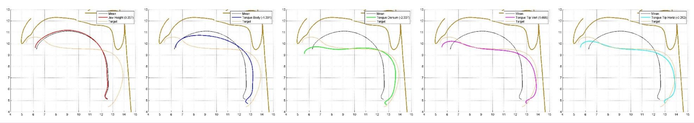


Each component has a mean and standard deviation of location.
Each component gives a weighted contribution to a full articulation.

Starting from this mean tongue position:



Model AmEng [l] / [_e] by adding +0.375 Jaw Height, -1.391 Tongue Body, etc., thus:



Comparisons

Through contours and models, three kinds of comparisons can be made:

Phone to phone:
Specific images representing targeted phones can be compared across languages.

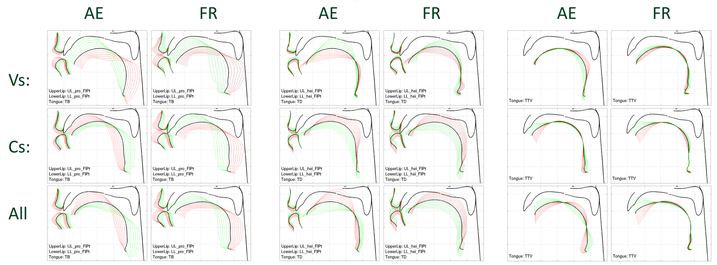
Group to group:
Different interesting subsets of the two languages can be compared.

Nomograms:
Modeling can compare overall articulatory strategies through nomograms.

Nomograms

To model each basic component:
- the mean and standard deviation is calculated from an input set of curves, and
- those results can be illustrated as ‘nomograms’, so
- using appropriately different sets of curves as input:

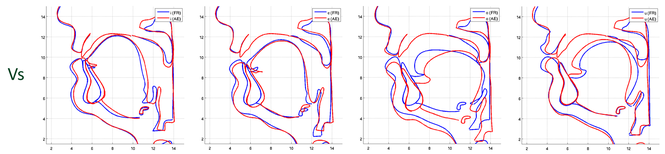
Nomograms can illustrate contrasting patterns in different categories of articulation., e.g.:
Three banks of paired comparisons of lip and tongue model components, based on:
Top Row: Vowels only; Middle row: “analogous” Consonants; Bottom Row: full corpus



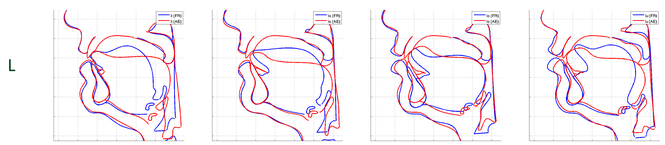
(Note differences in protrusion, tongue root, and shifts in ‘node’ locations.)

Phone to Phone

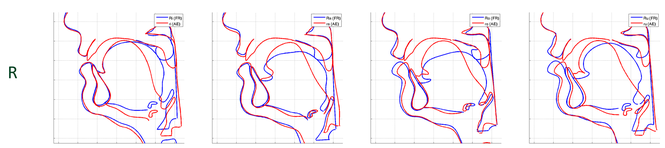
Individual phones are shown to be sometimes nearly identical, sometimes quite different:



American English (AE) vs. French (FR) Vowels, [i e o u]



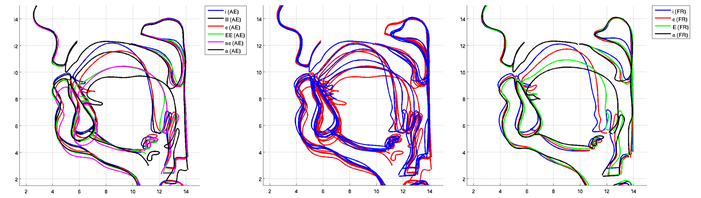
AE [ɬ] vs. FR [l], in [i e o u] context



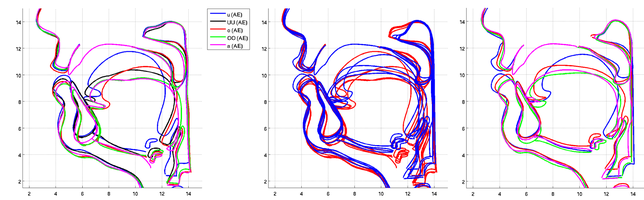
AE [ɹ] vs. FR [ʁ], in [i e o u] context

Group to Group

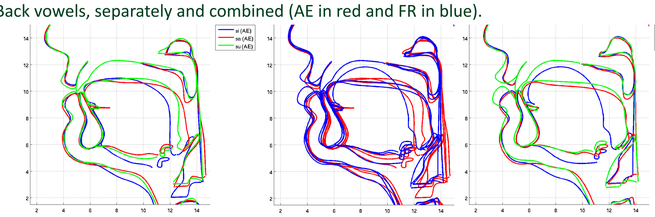
Phonetic subsystems can be constructed in both languages and overlaid for comparison:



Front vowels, separately and combined (AE in red and FR in blue).



Back vowels, separately and combined (AE in red and FR in blue).



[s] in context [i a u], separately and combined (AE in red and FR in blue).

Conclusion

Evidence suggests subject has two distinct articulatory systems for L1 English and L2 French:
- Some phones are very near matches in AE and FR, but
- Group comparisons show distinct differences of pattern, and
- Nomograms show model extracts different patterns of articulatory gestures.

Needs:
- Method for quantifying difference between two phones, within and/or across languages,
- Possibly via calculation of area functions?
- Synthesis by model, then panel judgments, to relate articulation and perception?