A New Way of Analyzing Vowels:
Comparing Formant Contours Using Smoothing Spline ANOVA

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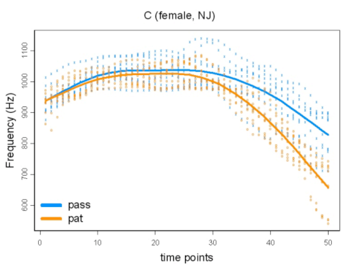
1. Introduction

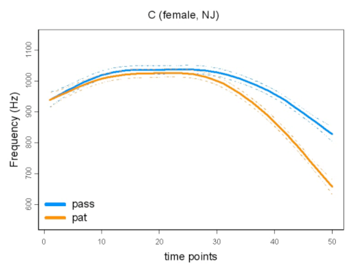
- Formant values are typically measured at 1 or more single points.
- BUT: Vowels are dynamic, time-varying acoustic events.
- Formant **trajectories** may be important for conveying/perceiving contrast (e.g. Lindblom & Studdert-Kennedy 1967, Hillenbrand & Nearey 1999) or sociolinguistic info (Thomas 2000), and could factor into changes in progress (Majors 2005).

Smoothing Spline Analysis of Variance (SS ANOVA)

- method for statistical comparison of curves (Gu 2002; see Davidson 2006 for use of this technique in linguistic ultrasound research)
- tells you **whether** two curves are significantly different; confidence intervals indicate **where** the differences are



Individual F1 contours and smoothing splines for *pass* and *pat.*



Smoothing splines & confidence intervals for *pass* and *pat*

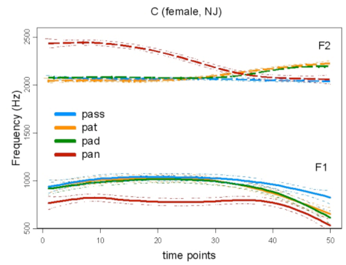
Smoothing splines are functions that best fit the data. The SS ANOVA compares values for the smoothing parameters of splines; a comparison of the smoothing parameters tells you whether curves are different (see handout for more detail!)

2. Procedures

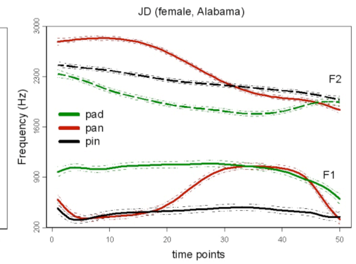
- 8 speakers (6 from NJ, 1 Canadian, 1 Alabamian) produce 10 tokens each of several words containing vowels of interest: *cot/caught, don/dawn; pan/pass/pad/pat; pin/pen.* (each word embedded within a carrier phrase, *Say ___ very loudly.*)
- 50 point formant contours (F1,F2,F3) for each vowel extracted from sound files in Praat (Boersma & Weenink 2006).
- ANOVAs run on onset, midpoint, offset formant values for each vowel.
- Splines generated for each word and SS ANOVA run in S-PLUS.

3. Demonstration: Ash allophony

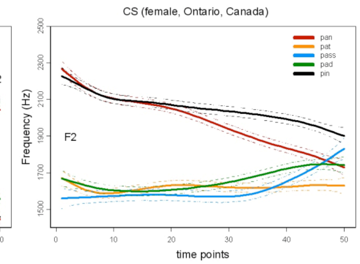
Allophones of [æ] may differ in nasality, lingual height/backness, and/or dynamic qualities (e.g. Labov 1994, Plichta 2002, De Decker & Nycz 2005).



C has a "nasal system" typical of many NJ speakers (Ash 2002), though examination of trajectories reveal differences between *pass* and *pad/pat.*

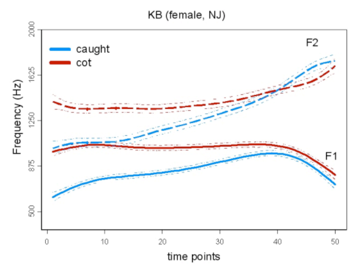


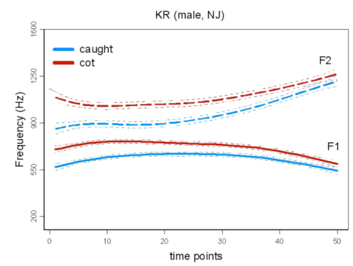
JD also shows pre-nasal [æ] "tensing"; the diphthongal quality of her vowel in *pan* is compared here to *pad* and *pin.*



Another nasal system, though CS's pre-nasal [æ] does not show the extreme movement of JD's.

4. Demonstration: Low back vowel contrast





Based on point measurements at the onset and midpoint, both KB and KR show significant F1 and F2 differences between *cot* and *caught.* However, while KR's formant trajectories for the two vowels are quite similar, KB's low back vowels are not: her *caught* formants slope upward at a greater rate than those of her *cot.*

Future research: What role do trajectories have in low back merger? (Majors 2005)

5. Conclusions & Future Research

- smoothing splines enable us to compare average formant curves, instead of inspecting individual tokens (which may or may not be representative).
- Formant trajectories may differentiate allophones that are grouped together under certain single point analyses.
- SS analyses can inform single point measurements by identifying potentially important acoustic landmarks

Future research: To what extent are trajectory differences relevant to perception? (lots of conflicting work on this topic) How can these methods be used to analyze vowel-liquid and other difficult-to-segment sequences?

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