Class 18, 5/19/2020: Generative Phonetics I

1. Assignments

- Reading:
  - Braver, Aaron (2019) Modeling incomplete neutralization with weighted phonetic constraints. *Phonology* 36:1-36.
  - On course web site.
- Homework #4 (Indonesian) due in a week.
- Feel free to discuss progress/problems with your term project.
  - Office hours W, F at 2.

2. Note on coverage of generative phonetics

- This was a topic in 201A, with readings:
  - Liberman and Pierrehumbert (Aronoff and Oehrle, 2nd Halle festschrift, 1984)
  - Flemming and Cho (*Phonology* 2017)
- I'll give a quick once-over, at a speed you may influence if you wish, then move on to further topics:
  - paradigm uniformity and near-neutralization (Braver)
  - phonetic distributions and MaxEnt (Lefkowitz)

WHAT IS GENERATIVE PHONETICS?

3. Usage

- Caution: the use of this term is non-standard, and reflects a point of view.

4. One possible answer

- A **generative phonetics** would be the portion of a generative grammar that models the phonetic capacities of people.
- It would take the form of a formalized grammar.
- Like other grammars, it would make **predictions**; i.e. …
- Given a surface phonological representation and other factors (like speaking style, speaking rate, word frequency, i.e. our knobs), what is the contour that the speaker will create for:
  - F0
  - formants
  - tongue body coordinates
  - … and durational pattern for all of the above

- I.e. generate a "movie of the mouth", or an acoustic representation affiliated with it.
- … the algorithm for speaking

5. This is enormously challenging

- And so people have:
  - reduced the problem to tiny little corners (legit, but not forever …)
  - Done the usual thing in very hard fields: presented data without theory, or theory without data
  - I have always loved this passage from Kiparsky (1977, *LI*) on meter:

So there have really been two independent lines of metrics, each incomplete by itself: theories without data, never really doing justice to the extensive but systematic diversity within the tradition; and data without theory, unable to find the shared foundation of all English metrics. Had they connected properly, many of the odd but traumatic controversies that have periodically shaken the field of metrics would have been unnecessary

6. Four influential early works in generative phonetics

- *From text to speech; The MITalk system* (1987) Jonathan Allen, M. Sharon Hunnicutt and Dennis Klatt (with Robert C. Armstrong and David Pisoni): Cambridge University Press, Cambridge.
- Pierrehumbert, Janet (1980) The phonology and phonetics of English intonation, MIT diss.
- Liberman, Mark and Janet Pierrehumbert (1984) Intonational invariance under changes in pitch range and length. In Aronoff and Oehrle, *Language sound structure*, MIT Press.
- Pierrehumbert, Janet, and Mary Beckman (1988) *Japanese tone structure*, MIT Press.

7. Methodology I: as generative grammar

- Generative grammars can be altered and improved to achieve better fit to data.
- So can the assumptions about grammar content, theoretical architecture.
- The range of data explored can gradually be expanded.
- An article of faith of generative linguistics is that patient and thoughtful work on these lines will gradually pay off.
- For remarks along these lines, see Pierrehumbert and Beckman (1988: ch. 1).

8. Methodology II: as experimental science

- It is impossible to assess a phonetic grammar without measurement data; either massive corpora or closely controlled experiments.

9. Sources of difficulty in generative phonetics

- **Too many grammars:** Like every branch of generative grammar, it suffers from the fact that there are so many conceivable ways to go about the task — how can we make informed choices?
- **Not even an single decent grammar:** But far more than in phonology, it is extremely hard to find any sort of grammar that works well for a non-trivial set of data.[1]
  - It is startling how bad the speech synthesis of extremely well-funded industrial labs is — *they* clearly have not yet solved the problem of generative phonetics.

10. Some research traditions in or related to[2] generative phonetics

- **Articulatory phonology** (e.g. http://www.haskins.yale.edu/research/gestural.html, and a vast literature.)
- The research program of **Paul Boersma** (http://www.fon.hum.uva.nl/paul/).
- Mainstream phoneticians sometime create generative models. One that I have enjoyed is:
  - Andreas Windmann, Juraj Sˇimko, and Petra Wagner (2015) Optimization -based modeling of speech timing. *Speech Communication* 74:76–92.
- I suspect that there is tons of material I haven't read, and the presentation here is necessarily sketchy and suggestive.

11. Generative phonetics and language acquisition: the Mennian perspective

- The grammar attributed to the parents must be learned mostly (or entirely) with **acoustic/perceptual** data.
- The criterion, "do my own productions match those of my parents?" must be met, I believe, in acoustic terms.
- The child's own production grammar plausibly does involve the control of articulation (as well, perhaps, as monitoring her own outputs).
- Hence, a kind of loop:
  - speak
  - listen to self
  - compare result to expected parental acoustic output
  - modify the rules for speaking
- Again, the Boersmian perspective (child's production grammar eventually evolves into the adult production grammar, separate from perception grammar) is relevant.
- See also the research oeuvre of **Frank Guenther** (Boston University), who has created large-scale simulations of this interaction.

[1] In this respect I think phonetics resembles syntax, where the extreme difficulty of the material means that accurate large-scale grammars are not widely pursued.
[2] You may decide which …

12. Evidence for the idea that children invent the way to create the acoustics

- Cases where multiple choices of articulation are available to the child, any one of which might be chosen, and the arbitrary choice is kept into adulthood.
  - Where to put the "groove" in a sibilant (left, right, center)
  - Making a lateral (left, right, both sides open)
  - Blends of coronal, dorsal, pharyngeal constriction in [ɹ]
  - Startling variation in what is supposed to be "alveolar-retroflex" or "dental-alveolar" — UCLA dissertation of Sarah Dart.[3]
- I conjecture that such differences are not found for labial sounds.

13. The opposing point of view

- "Direct realist" theory of speech perception
  - Catherine T. Best (1995) A dire ct realist view of cross-language speech perception. In *Speech perception and linguistic experience: Theoretical and methodological issues in cross-language speech research*. W. Strange (Ed.)
- We perceive and represent speech gestures.
- Acoustics exists, but humans use it with trivial ease in recovering the speech gestures, which are the object of cognitive computations and theoretical interest.
- Direct Realism is often paired with Articulatory Phonology, which includes only articulation in its cognitive representation of phonology/speech.
- Understandably, this might not be very popular with phonologists who seek to explain phenomena by invoking perceptual principles:
  - Steriadean cue-based licensing theory
  - Constraints banning phonetically extreme alternation (Steriade, Zuraw)

14. A possible consequence of the existence of a "model-the-parents" phonetic grammar

- Unless one accepts Direct Realism, it is legit for theoretical phonetics to conduct studies with nothing but acoustic data — this matches the child's first task and fits a realism criterion.

15. The importance of tone and intonation in generative phonetics

- Pierrehumbert and Beckman emphasize:
  - Mappings from phonological values to articulatory trajectories/formant trajectories are very complicated for vowel and consonant features.[4]
  - I.e. nonlinear, many-to-one/one-to-many for features and measurable values.
- F0 is "sort of" clean by comparison, suffering from

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[3] Dart, Sarah N. (1991) Articulatory and acoustic properties of apical and laminal articulations. Available at our Dissertation Page: https://linguistics.ucla.edu/research/phd-dissertations/.

[4] The lab of Bryan Gick at UBC is a leading center for untangling all this; Gick thinks it may be simpler than this once you have the right theory of movement …

- modest vowel-height effects
- consonant perturbations
- voiceless cutouts
- difficulty of measurement under creak
- need for even more speaker normalization than is usual
- need for expressive range normalization

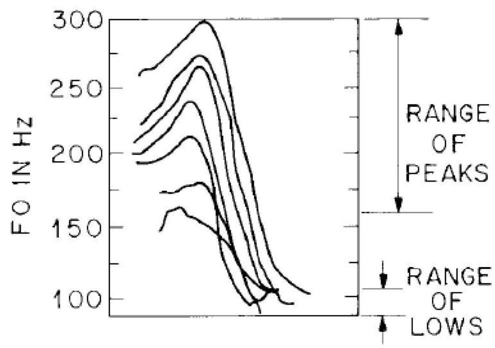


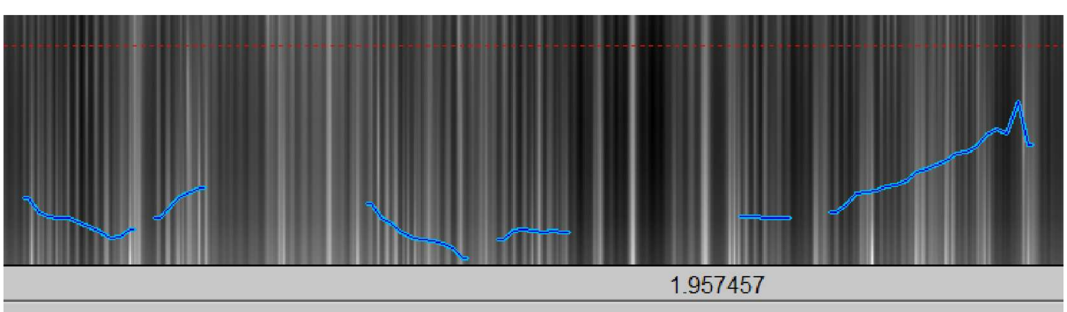
Figure 4
A declarative intonation pattern produced on *Anne* with seven different amounts of overall emphasis.

16. The concept of target

- The approach taken by Pierrehumbert and colleagues is sometimes called "targets-and-interpolation" theory.
- Phonological entities — often autosegments — translate as targets with physical values.

17. Alignment of targets in time

- This traditional advanced beyond traditional autosegmentalism in letting targets actually occur at boundaries.
- Thus in English, if we have a syllable that is post-nuclear with rising question intonation, then the H% tone is likely to create a rise to the very end:



was it Cle- men- tine? H%

INTERPOLATION

18. Interpolation and surface underspecification

- This is how you get phonetic values on regions having no target.
- See P. A. Keating: "Underspecification in phonetics", Phonology 5.2, 275 -292 (1988), who offers this spectrogram of a Persian speaker saying [bihude].

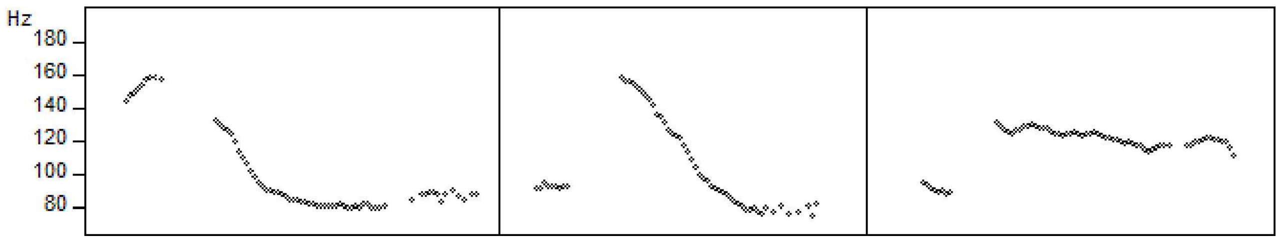
19. Kinds of interpolation

- Liberman/Pierrehumbert (1984), on English, as well as *Japanese Tone Structure*, use basically simple linear interpolation.
- Augmented (for synthesis) with:
  - Smoothing (forward only)
  - insertion of random noise (increasing auditory realism)[5]
- I have seen other forms of interpolation
  - Slight, constrained, droop (Bruce Hayes and Aditi Lahiri (1991) Bengali intonational phonology". *Natural Language and Linguistic Theory* 9: 47-96.). The droop never goes below the horizontal; i.e. one endpoint must be a minimum.
  - I've seen Japanese pitch tracks that look "billowy" to me.

[5] I wonder if real noise is caused, not random, and might sound better?

20. A bit of Japanese phonology we will need

Japanese pitch accent



háʃi-o nuɾu	haʃí-o nuɾu	haʃi-o nuɾu
chopsticks-acc. paint	bridge-acc. paint	end-acc. paint
‘paint chopsticks’	‘paint a bridge’	‘paint the end’

- These illustrate a three-way contrast in disyllables of accent location/existence.
- In the olden days:

háʃi-o nuɾu	haʃí-o nuɾu	haʃi-o nuɾu
H L	L H L	L H

- In the view initiated by Pierrehumbert and Beckman:
  - ➢ Accent is phonemic, and is represented as a H*+L tone (prominent H, immediately falling L), H* linked to the phonemically relevant mora).
  - ➢ Words group into little units called accentual phrases.
  - ➢ There is a final L% boundary tone.

[háʃi-o nuɾu]	[haʃí-o nuɾu]	[haʃi-o nuɾu]
L H*+L L%	L H*+L L%	L H L%

  - ➢ H*+L is a rapid and extensive fall.
  - ➢ Initial L is quite a bit lower when it can dock onto a mora.
  - ➢ Final L% is greatly lowered by a preceding H*+L

21. Proof of interpolation in Japanese

- The required experiment demands that you systematically change that distance (in moras, syllables, or whatever) between a H and a L, then show that the slope changes in response.
- Why? because there can be rival explanations, notably *declination* (a purely mechanical downward drift in tone).
- Here is Pierrehumbert and Beckman’s proof of interpolation between H and L in Japanese.
- Explaining the phonology

- Glossing:

moriya-no	mawari-no	oˈmawarisan
proper name-of	neighborhood-of	policeman

- accentual and higher phrasing:

[[moriya-no   mawari-no] [oˈmawarisan]]

- tones with their ur-affiliations:

```
[ [ moriya-no   mawari-no ] [ oˈmawarisan ] ]
 | |                         |       |           |
LH                           L      H*+L         L%
```

- tones once docking rules have applied:

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[ [ moriya-no   mawari-no ] [ oˈmawarisan ] ]
       | |                  /|       | \         |
       LH                    L      H*+L        L%
```

- Others: substitute shorter or longer words for *moriya*

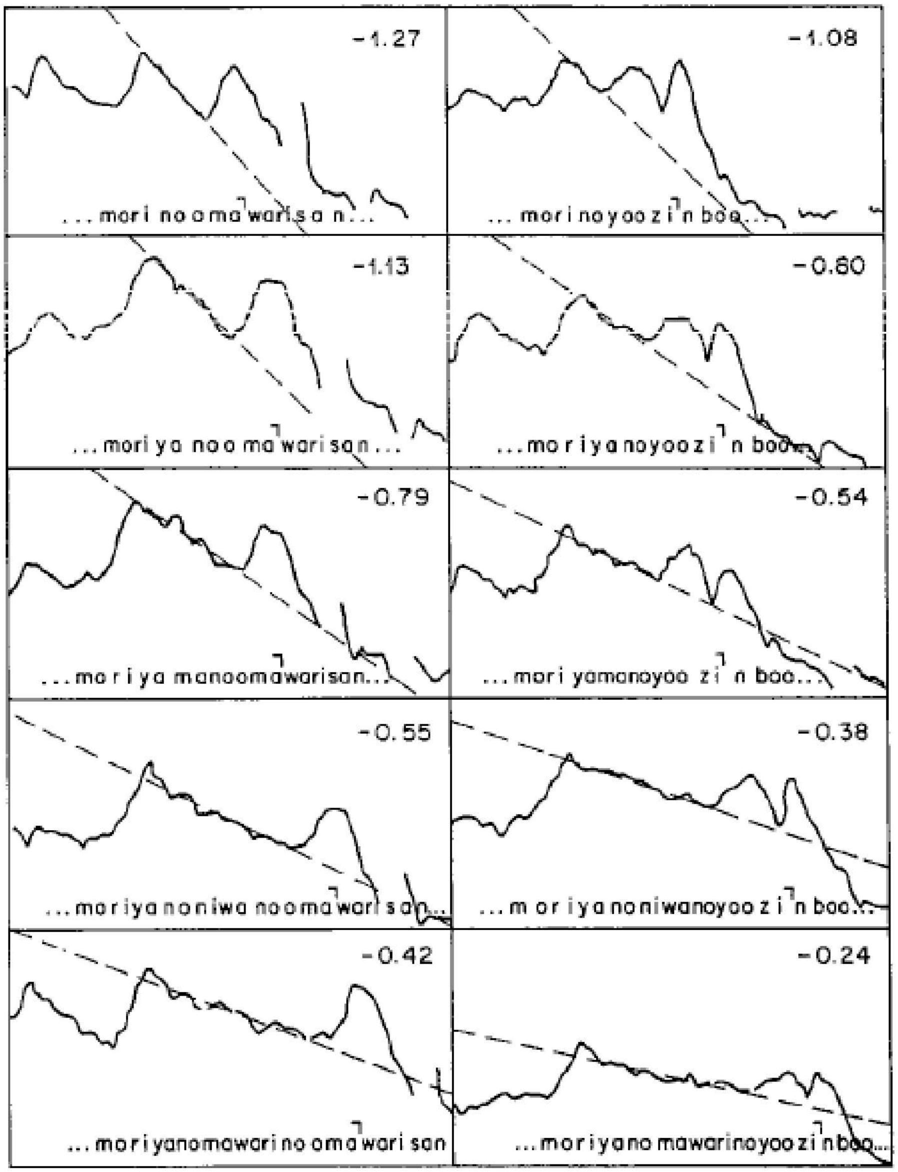


Figure 1.3

Unaccented phrases with 3, 4, 5, 7, and 8 morae before accentual-phrase boundaries with two different allophones of L%. The dashed line in each panel is a regression line fitted to all f_0 values between the peak for the phrasal **H** in the first phrase and the minimum for the interphrasal L%. The number in the upper right-hand corner is the slope of the regression line. Here and in subsequent figures a right corner in the transcription indicates the location of an accent.

22. More general comments on experimentation in generative phonetics

- *Phonological* rigor is crucial.
- I.e. we seek *minimal pairs*, or as close as possible to it given the structure of the language.
- Minimal pairs are the phonological side of sound experimental methodology in general, where we seek causes and effects by varying one thing at a time.

ARITHMETIC IS THE LANGUAGE OF PHONETICS

23. What arithmetic?

- Multiplication
  - ➢ Cleverly designed experiments yield not-so-pudgy snakes of data points, indicating a clear multiplicative relationship.
- Addition
  - ➢ This arises when the pudgy snake, extrapolated, does not pass through the origin.

24. One experiment that created pudgy snakes

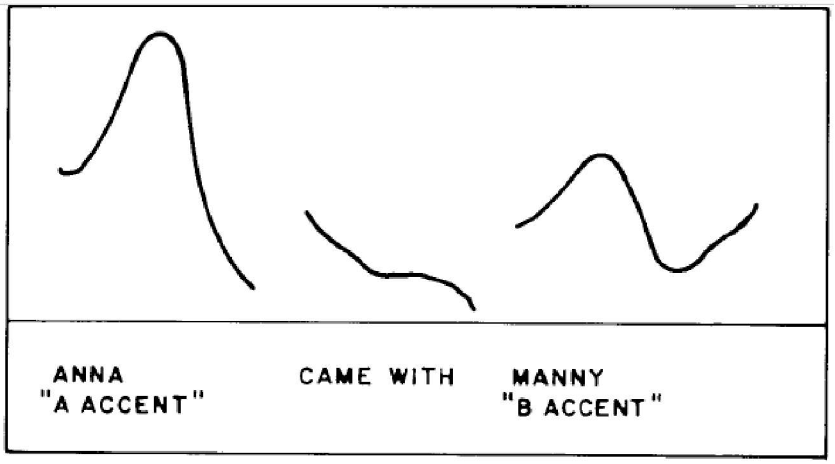


Figure 9
An F0 contour for *Anna came with Manny*, produced as a response to *What about Manny? Who came with him?*

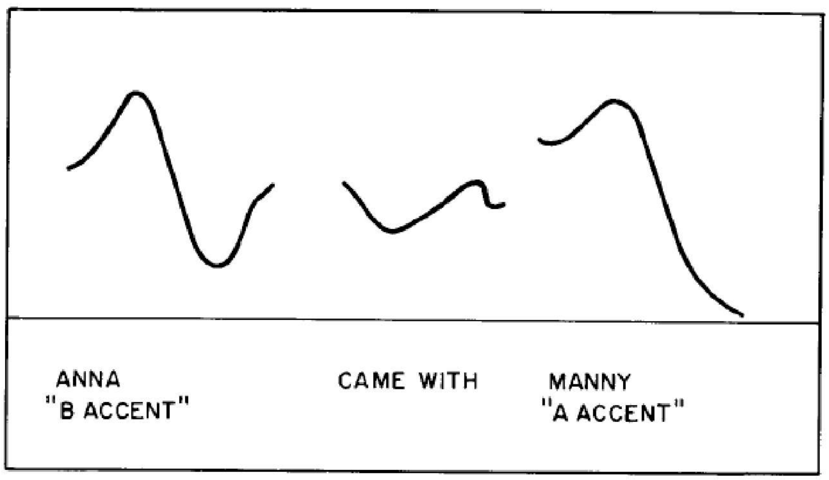


Figure 10
An F0 contour for *Anna came with Manny*, produced as a response to *What about Anna? Who did she come with?*

- ☞ I can tell you roughly what these are tonally; fully-trained ToBI'ists please specify in full.

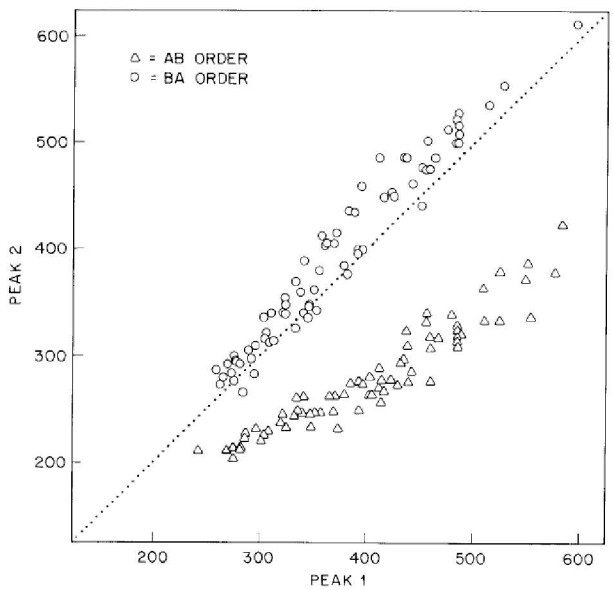
25. Experimental method

- Find incredibly-cooperative-and-sympathetic experimental subjects.
  - ➢ The authors themselves and colleagues at Bell Labs
  - ➢ I'm actually fairly pretty sympathetic on this issue — rendering intonations out of context is very difficult.
- Give them little prompt-cards with emphasis-number from 1-10.

26. A key experimental technique: use your knob

- This will generate your snakes, hence detect lawful patterns
- Large range will lengthen the snake and de-sheep-ify it.
- Knobs that work for phonetics:
  - rate
  - casualness (much harder)
  - emphasis (voice range, "speaking out")
  - lexical frequency

27. Sample pudgy snakes from this experiment (subject JP)



28. More snakes in the berry experiment

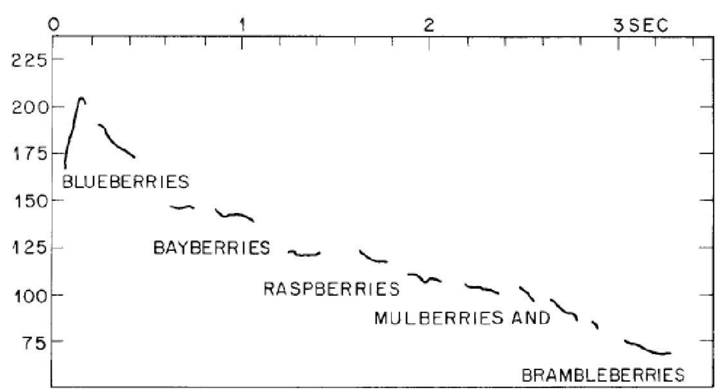


Figure 13
An F0 contour for the berry list *Blueberries, bayberries, raspberries, mulberries, and brambleberries*, produced with a sequence of step accents. Each step is smaller than the one before, so that the step levels appear to trace out an exponential decay.

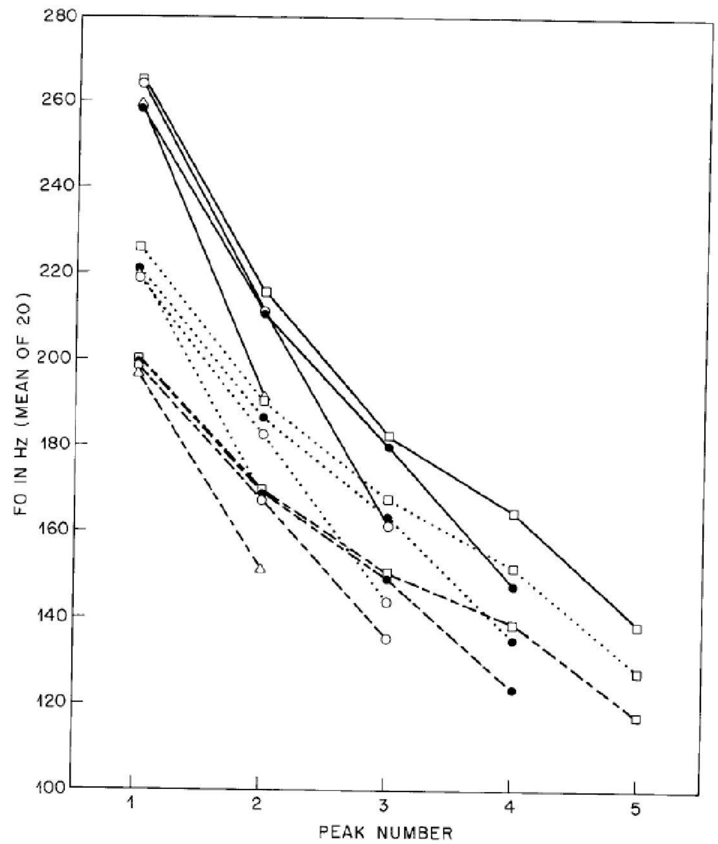


Figure 19
Downstep data (3 pitch ranges, 4 lengths) for subject DWS

29. The informativeness of this experiment

- They obtain an *exponential* relationship of successive pitch accents.
- This relationship is defined not on raw Hertz but on hertz-above-a-floor value.
- There is also a deviation at the end, justifying a phonetic rule of Final Lowering.

30. Regression as the key to developing models

- Put the hypothesized principles, relating {phonological entities, emphasis} to measurements, into arithmetic form.
- Do regression to obtain parameters with best fit.
- Seek areas of systematic error, revise and repeat, possibly doing further experiments.
- This whole method carries over (below) to MaxEnt, which indeed is also regression.

31. The equations developed in Liberman and Pierrehumbert (1984)

- The model is a very simple one in which tone targets are computed from preceding tones.
- It uses fictional units of "high-ness", measured as Hertz above a reference line of height *r*

➢ It is fun to imagine a unit of measure, which Pierrehumbert (1980) facetiously called the Amana.[6]

32. Defining the Amana

$T(P) = P - r$ defining the Amana by subtraction; P is physical pitch

33. The Downstep Rule

$$T(P_i) = s \cdot T(P_{i+1})$$

- Iterated downstep is a constant fraction, when measured in Amanas.

34. Answer-Background Scaling (for *Anna came with Manny*)

$T(P_A) = k * T(P_A)$

- It's the *same* ratio *k* despite difference in order, once the other rules are taken into account.

35. Final Lowering rule

$$P \rightarrow r + l \cdot (P - r) / \_\_\_\_ \$$$

- In some window to be defined near the right edge, a pitch target shrinks down by a factor of *l* when measured in Amanas.

36. Utter (confessed) ad hockery to give us a value of *r* from empirical data

$$r = f \cdot (P_0 - b)^e + d + b$$

where P_0 is the target in Hz of the first pitch accent, and *d*, *e*, *f*, and *b* are constants

- *b* is as low as you are willing to go
- *d* is positive
- they needed a curved function to fit the data and so added an exponent.
- They struggle with this, it emerges as the best fit to their data but is less obviously principle.
- Something like this is needed; it is the seat-of-the-pants theory of emphasis.

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[6] An American brand name for household appliances, consisting entirely of sonorants and useful for intonational work. Amana

CROWDED SYSTEMS; GENERATIVE PHONETICS WITH HARMONIC GRAMMAR

37. Focus

- The classical work of the 1980's deliberately chose *uncrowded* systems, in which the targets are (almost) always attained.
- In OT terms: there is a single candidate that obeys all the phonetic constraints.
- This is hardly the norm in phonetics!

38. Cases of conflict in phonetics

- Two elements inherently articulated in different places receive output values that moves them toward each other (work of Flemming: loci, Mandarin 2nd tone).
- **Duration** of segments reflects a compromise of effects based on
  - inherent duration
  - number of segments in syllable or rhyme
  - phrasal position
  - etc.
  - work of Jonah Katz, Michael Lefkowitz
- Near-neutralization as phonetic paradigm uniformity — Braver, below

39. The appropriateness of Harmonic Grammar

- It is set up to handle conflict.
- It is naturally gradient, as in phonetics.

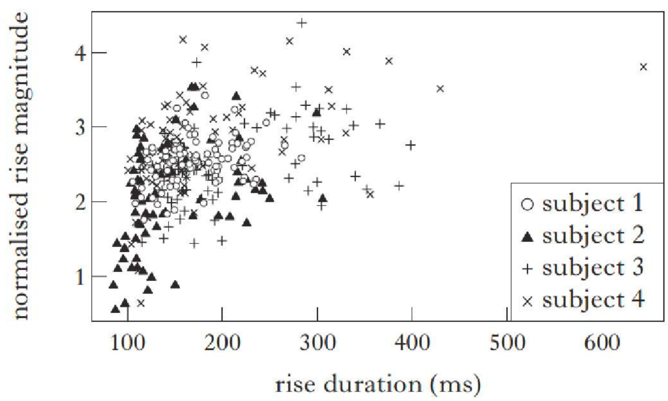
40. Basics of running a phonetic grammar in a Harmonic-Grammar framework

- Constraint violations: these will penalize *quantitative* deviations from a target.
  - Not "how many times", but "how much"
- Violations need not be integers.
  - Nothing in the math of harmonic grammar or maxent would require this.
- Asserting winners: two possibilities
  - a non-stochastic system with a single winner: the most harmonic candidate
  - a stochastic system, using maxent or Noisy Harmonic Grammar, deriving a probability distribution over outputs.

41. A characteristic empirical pattern in crowded systems

- Flemming and Cho 2017 examined the realization of Mandarin Tone 2 in difficult conditions (it is a rise, they put it after H and before L).
- Varying the knob of speaking rate, they obtain clouds of points — pudgy snakes — like their predecessors Liberman and Pierrehumbert's

- However, these clouds are **curved**, not straight.[7]
- This is because one end of the range is constrained by other factors and cannot continue in a straight line.
- Look right-to-left along this plot of Mandarin rising tones (Tone 2): as you shorten, it becomes impossible to rise that much.

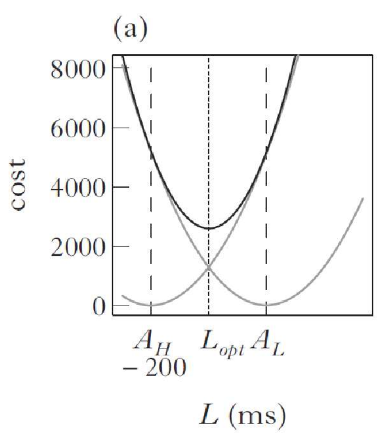


42. The mechanism of compromise in phonetic harmonic grammars (Flemming)

- It is essential that violations *be taken to some power greater than one* (he and others use 2).
- Only in this way do you get
  - compromise outcomes
  - compromise outcomes favoring the stronger constraint

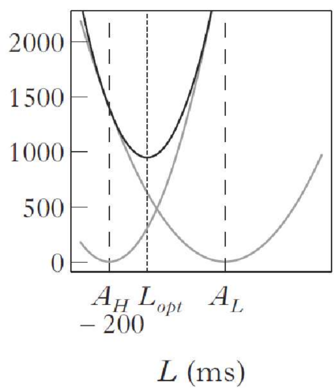
43. Schematic example from Flemming and Cho: An equal compromise

- Vertical axis: Harmony penalty
- Horizontal axis: timing of L target

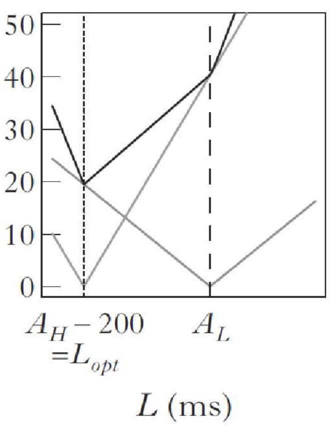


[7] Inevitably, given the complexity of crowded-target phonetics, they are pudgier.

44. An unequal compromise: higher-weighted constraint has stronger influence



45. The bad result with power-of-one rather than power-of-two: winner-take-all



- We will look at this again in MaxEnt when we do Braver.

46. Moving to probability distributions

- Flemming has always simply taken the harmonic-maximum candidate as a single winner.
- Under either MaxEnt or Noisy Harmonic Grammar, we can move to modeling distributions.

47. Lefkowitz's theorem

- Let us play with a *single target* and a *single parabolic constraint*.
- Query: what is the probability distribution under Maxent?
- Play with spreadsheet, then turn the page.

48. Lefkowitz's theorem

- The probability distribution generated from a parabolic violation pattern in MaxEnt is a Gaussian curve.
- The exact formula is given in Lefkowitz's (2017) UCLA dissertation, p. 75:

$$\sqrt{\frac{w}{\pi}}\, e^{-w(x-t)^2}$$

where:
t = the phonetic target of the constraint
w = the weight of the constraint

49. The more general version

- The sum of two parabolic functions is a parabolic function.
  - $y = ax^2 + bx + c$
  - $z = dx^2 + ex + f$
  - $y + z = (a+d)x^2 + (b+e)x + c + f$
- So the probability distribution created by any Flemmingian MaxEnt phonetic grammar (all constraints defined by a parabolic penalty) is a Gaussian curve.
- We will see that Lefkowitz was empirically compelled to visit the trans-Flemmingian regions (hemi-parabolas), where his theorem no longer holds true.

FLEMMING'S EARLY RESULT O N LOCI

50. Source

- Flemming, Edward (2001) Scalar and categorical phenomena in a unified model of phonetics and phonology. *Phonology* 18: 7-44.
- I see this as the urtext of Harmonic Grammar phonetics, though Flemming doesn't call it that.

51. The scheme

- You have a consonant, like /t/, and a vowel, like /a/.
  - /t/ wants F2 to be 1800
  - /a/ wants F2 to be 1100.
- The system wants to avoid a severe, mousetrap-like transition at release.
- It turns out that both the consonant and the vowel contribute to the compromise.

52. The existing findings of experimental phonetics

- The outcome is always a compromise.
- The target for the consonant — unobservable, inferred — is called its *locus*.
- This was worked out, with equations, by phoneticians Bjorn Lindblom, Harvey Sussman and others.
  - Lindblom, Björn (1963). Spectrographic study of vowel reduction. JASA 35:1773-1781.
  - Sussman, H. M., K. A. Hoemeke & F. S. Ahmed (1993). A cross -linguistic investigation of locus equations as a phonetic descriptor for place of articulation. JASA 94.1256-1268.
  - Sussman, H. M., H. A. McCaffrey & S. A. Matthews (1991). An investigation of locus equations as a source of relational invariance for stop place categorization. JASA 90.1309-1325.
- The standard "locus equation" for consonants as expressed by Flemming:

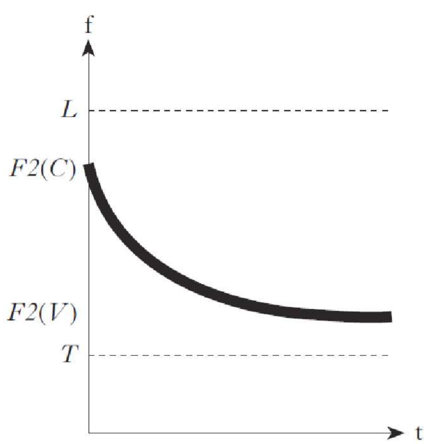
$$F2(C) = k_1(F2(V) - L) + L$$

  - I.e., the F2 of the consonant at release is basically its locus L, but deviating from L by an amount based on how far away the target for the vowel (F2(V)) is.
  - Note that in Flemming's diagram, the vowel itself compromises a bit, deviating from its target.
- Adding in the equation for the vowel:

$$F2(V) = k_2(F2(C) - T) + T$$

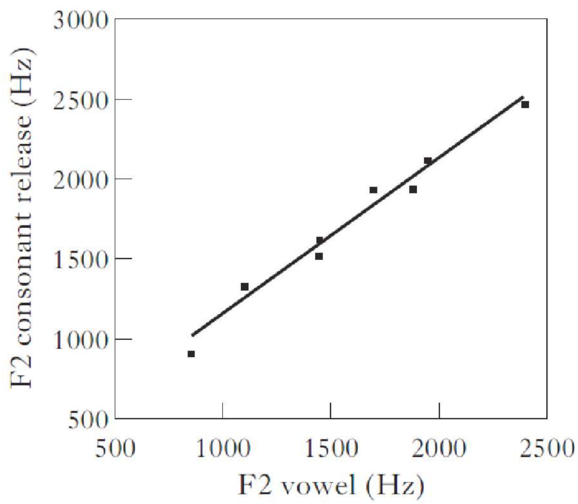
  - which is just the same equation going in the opposite direction.

- Flemming puts the two patterns together in a schematic graph:



53. Locus theory works

- [g] followed by a variety of vowels (Flemming's data):



- ☞ What is the slope of the line and why?

54. Flemming's Harmonic Grammar analysis

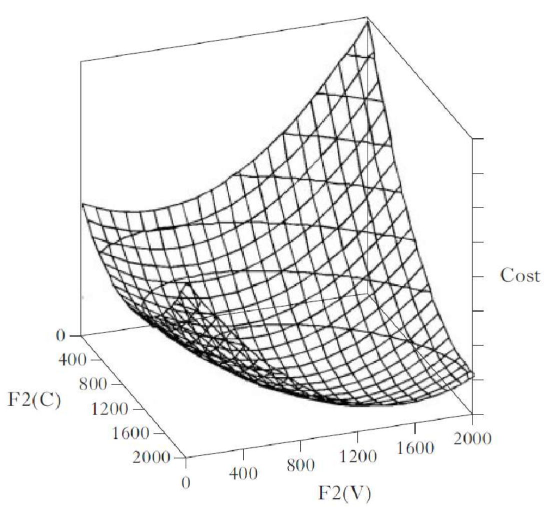
- Constraints (note squared deviation penalty, per above)

	Constraint	*Cost of violation*
IDENT(C)	$F2(C) = L$	$w_c(F2(C) - L)^2$
IDENT(V)	$F2(V) = T$	$w_v(F2(V) - T)^2$
MINIMISEEFFORT	$F2(C) = F2(V)$	$w_e(F2(C) - F2(V))^2$

- Calculating harmony — this is the standard formula, sumproduct() with weights.

$$cost = w_c(F2(C) - L)^2 + w_v(F2(V) - T)^2 + w_e(F2(C) - F2(V))^2$$

- Finding the best candidate.
  - ➢ It is the F2(V) and F2(C) coordinates of the *minimum* of a beautiful parabolic harmony-bowl:



- You don't need the Solver for this! Flemming dredged up his high school calculus; a minimum is where the slope along every axis is zero.
- The answer is:

$$F2(C) = u_c(L - T) + L \quad \text{where} \quad u_c = \frac{w_e w_v}{w_e w_c + w_v w_c + w_e w_v}$$

$$F2(V) = u_v(L - T) + T \quad \text{where} \quad u_v = \frac{w_e w_c}{w_e w_c + w_v w_c + w_e w_v}$$

  - These equations are indeed the Lindblom/Sussmann locus equations, with coefficients derived from the constraint weights. QED!
  - And using the Lefkowitzian math, we could also compute the standard deviations of the Gaussian curves defining the range of variation (are they realistic)?

HARMONIC GRAMMAR IN PHONETICS II:
PARADIGM UNIFORMITY AND NEAR-NEUTRALIZATION

55. Work of Aaron Braver

- Braver, Aaron (2013) Degrees of incompleteness in neutralization: Paradigm uniformity in a phonetics with weighted constraints. Rutgers Ph.D. dissertation.
- *Phonology* article in readings.
- Experimental collaborations with Shigeto Kawahara.

56. Braver's key idea

- Near-neutralization is not capricious.
- In every case, it represents a compromise:
  - Inherent value predict by pure phonetics
  - Influence of a paradigmatic base — at the phonetic level.

57. Braver's Law of Incomplete Neutralization

- All incomplete neutralizations are compromises between the observed values in paradigms.
- Example: there could never be a German′ in which /rad/ surfaces as slightly "more voiceless" than /rat/.

58. The signature case: Japanese vowel length

- Empirical work was in earlier paper with his adviser Kawahara.
- Example:
  - /CV/ → [CVˑ], not quite as long as underlying /CVː/.
  - /fu/ 'gluten' is [fuˑ] alone, [fu ga] with suffix.
  - /fuː/ 'seal' is [fuː] alone.

- Example:
  - /fu/ alone wants to be bimoraic to satisfy a word-minimum.
  - It wants to be shortish to resemble the base form (seen before a suffix, as in *fu ga*)
  - There is further evidence — from pitch accent — that the suffixed form is the base in Japanese.

59. Another example, showing experimental setup

Sample stimulus set (from Braver & Kawahara 2016)

condition	*orthography*	
a. short, with particle	木もなくしたよ。	ki mo nakushita yo tree also lost DISC
b. short, no particle	木なくしたよ。	ki nakushita yo tree lost DISC
c. long	キーなくしたよ。	kii nakushita yo key lost DISC

60. The theory in outline

- Derived forms are tied to their bases by weak, weighted constraints that penalize differences in phonetic parameters.
- This is done with Harmonic Grammar, with Flemmingian squared derivations from constraints TARGETDUR=x, OOFAITH(Dur).

61. Trying this out ourselves

- The simplified phonetic data from Braver's *Phonology* article:

condition	mean	SD	rounded
unlengthened short (with particle)	54.99	21.89	50
lengthened short (without particle)	124.98	34.91	125
underlyingly long (without particle)	157.45	39.21	150

- Let us try this with MaxEnt, to get a distribution.
- How good is the fit?
- If we manipulate the weights by hand, what changes emerge?
- What would have happened if we used not Flemmingian parabolas, but a linear (absolute-value) penalty for deviation from target?