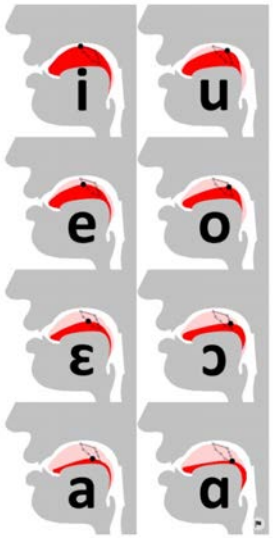


24.901/931, 2026
Introduction to Phonology

Lecture 19

Announcements

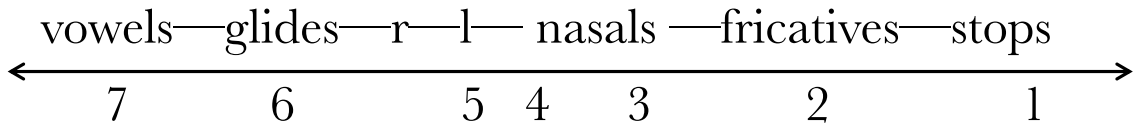
- PS6: Miya (Chadic) syllables. Due 4-28.
- Quiz 2 May 5th
- Recitation today: sonority-based choice of syllabic Cs in Berber, the first in-depth illustration of Eval in Prince and Smolensky's 1993 book.
- The idea: In URs consisting of mostly Cs, Eval selects the least bad nucleus, based on constraint hierarchy: M_1, M_2, M_3 >> *C_1 >> *C_2 >> …*C_n. The sub-hierarchy *C_1>>*C_2…>>*C_n goes from least sonorous C_1 to the most sonorous C_n.
- Highly recommended, for the theory behind the data and for exotic evidence.

Today's class

- Sonority peaks, continued.
- Preliminaries to Amy's lecture
- Stress: what it is, how it is manifested; how we hear it and record it; where finer stress distinctions come from.
- Next week: typology of stress systems.

Review: Sonority and syllables

- The sonority scale is a ranking of segments by relative intensity, from loudest (Vs) to quietest (stops)
- Sonority indices represent the positions of sound classes on this scale



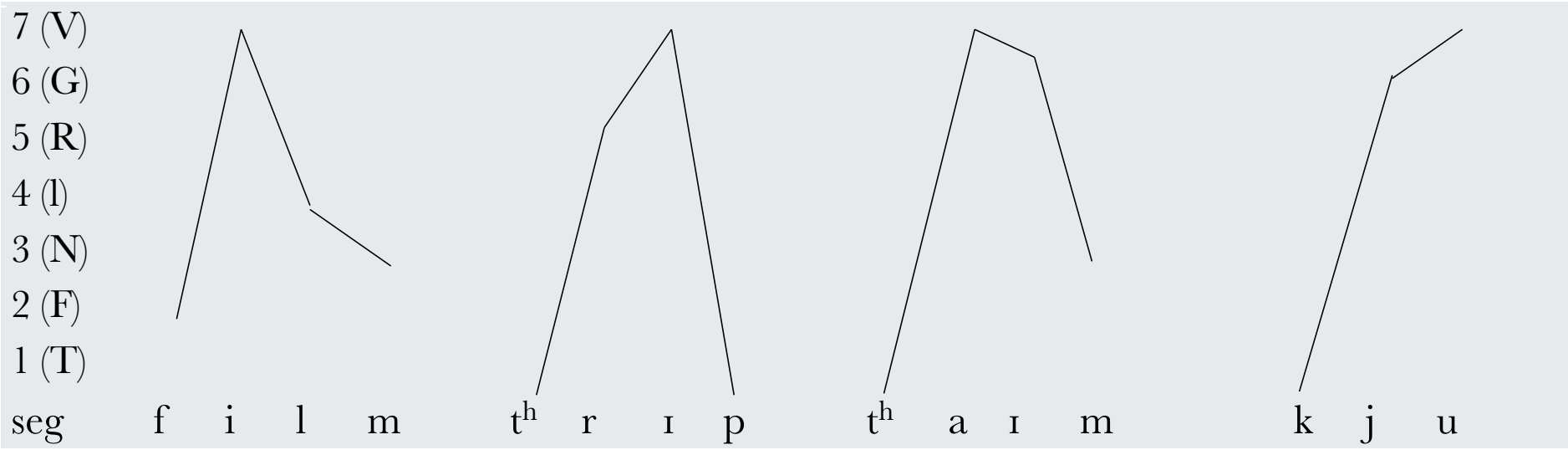
- Sonority Sequencing is a group of constraints that constrain relative sonority in the syllable around sonority peaks: a segment whose sonority exceeds that of adjacent sounds.

  SSC (a): At most one sonority peak/syllable: one * for each extra peak

  SSC (b): This peak is the nucleus: one * for each non-nuclear peak.

Sonority peak =

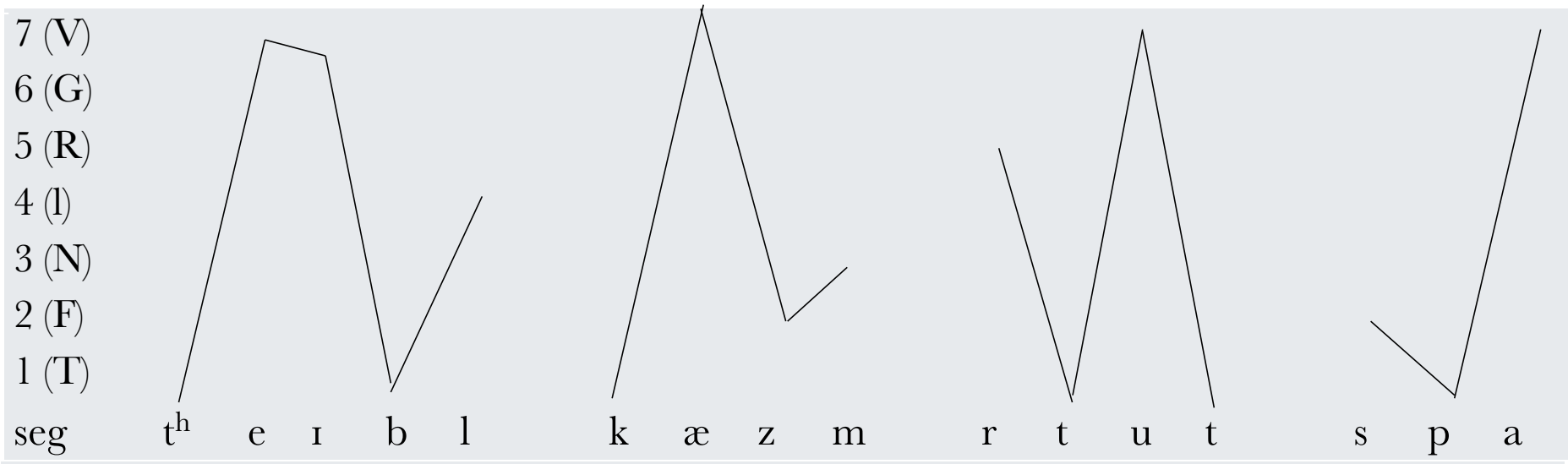
segment more sonorous than any adjacent segment



Above, the sonority peak is the same as the Nucleus of each syllable

Sonority peak

Below, each string contains two peaks



Upshot: each English syllable contains a single sonority peak; [s] deviates.

The typology of sonority in nuclei

Remember this implicational law

If C_i can be syllabic, then C_j of greater sonority also can.

~~p̩t~~	~~p̩s~~	~~p̩n~~	~~p̩r~~	pa	French
~~p̩t~~	~~p̩s~~	~~p̩n~~	p̩r	pa	Czech
~~p̩t~~	~~p̩s~~	p̩n	p̩r	pa	English
~~p̩t~~	p̩s	p̩n	p̩r	pa	Yavapai
p̩t	p̩s	p̩n	p̩r	pa	Berber
1	2	3	4,5,6	7	
Stop	Fric.	Nasal	Approx	Vowel	

An account of these implications

(Prince and Smolensky 1993; cf. Dell and Elmedlaoui 1985, on Tachelhiyt Berber)

- Take the sonority scale for consonants
- Assume each sound class C on the scale corresponds to a *Ç constraint

  *Ç : One * for each instance of a syllabic instance of class C sounds
- *Stop -- *Friç -- *Naṣ -- *l̩ --*r̩ -- *glidẹ --
- Ranking within this constraint family is determined by sonority level of C.

  The lower the sonority of C, the higher the constraint *Ç
- *Stop >> *Friç >> *Naṣ >> *l̩ >> *r̩ >> *glidẹ
- Abbreviated *Ṭ >> *Ḟ >>*Ṇ …
- Intuition: the lower C's sonority, the worse C is as a nucleus, hence the higher ranked the constraint penalizing Ç

The *Ç hierarchy (Prince and Smolensky1993)

1	***Ṭ (one * for each syllabic stop)**
	↓
2	***Ṣ (one * for each syllabic fric)**
	↓
3	***N (one * for each syllabic nasal)**
	↓
4	***L (one * for each syllabic lateral)**
	↓
5	***R (one * for each syllabic rhotic)**

Fixed ranking reflects the universal dispreference for less sonorous nuclei,
Starting with the least sonorous ones.

Languages that allow only vowel nuclei (French, Spanish...)

1	***Ṭ (one * for each syllabic stop)**
	↓
2	**(one * for each syllabic fric)**
	↓
3	***Ṇ (one * for each syllabic nasal)**
	↓
4	**(one * for each syllabic lateral)**
	↓
5	***Ṛ (one * for each syllabic rhotic)**

conflicting constraints:
Faith, *CODA, *COMPLEX, SSC, others

Practice for PS6 and Quiz2: how does hypothetical /krpta/ surface

- In this broad class of rankings
  All *Ç >> Faith, *CODA, *COMPLEX ONSET/CODA, SSC
- Consider these ranking variants:

  All *Ç >> *CODA, *COMPLEX, SSC >> Max C

  All *Ç >> *CODA, *COMPLEX, SSC >> Dep ə

  All *Ç >> *COMPLEX, SSC >> Dep V >> *CODA
- Mention some candidates that can win under each of these rankings

Languages that allow vowels, liquids, nasals as nuclei (English)

1	***T̩ (one * for each syllabic stop)**
	↓
2	***S̩ (one * for each syllabic fric)**
	↓
3	***N̩ (one * for each syllabic nasal)**
	↓
4	***L̩ (one * for each syllabic lateral)**
	↓
5	***R̩ (one * for each syllabic rhotic)**

Some conflicting constraints
(MAX, DEP, SSC: e.g. fæks, vs. *fæ.ks̩)

Other conflicting constraints
(*COMPLEXCODA: e.g. fɪlm, *fɪ.lm̩)

Low-sonority peaks in English

- *fax* (1σ) in English compared to *rythm* (2 σ)

UR /rɪðm/	SSC (a)	*N	UR /fæks/	*F	SSC(a)
rɪðm			☞fæks		
☞ rɪðm			fæks		

- In Romanian, Russian *no Ç's* are ok, so more violations of SSC

UR /rɪtm/	*N	SSC (a)	UR /fæks/	*F	SSC(a)
☞rɪtm			☞fæks		
rɪtm			fæks		

SSC explains σ count in English:
SSC vs. *Ç in systems with undominated MAX / DEP

- *rhythm* (2σ) vs. *film, arm, aim* [e̯im] (1σ), in English

UR /rɪðm/	SSC (a)	*C
rɪðm		
☞ rɪðm		

UR /film/	SSC (a)	*C
☞film		
film		

UR /rɪðm-ɪk/	SSC (a)	*C
☞ rɪðmɪk		
rɪðmɪk		

The SSC is violable
Violated if *Ç, MAX, DEP >> SSC

- *ritm* (1σ) and *film* (1σ), in Romanian (perhaps also Polish, Russian)

UR /ritm/	*C	SSC (a)
☞ ritm		
ritm		

UR /film/	*C	SSC (a)
☞film		
film		

SSC explains aspects of σ division

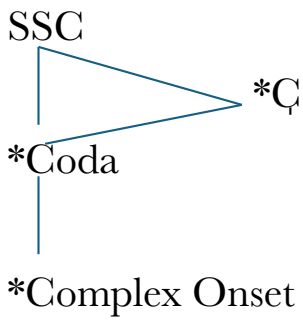
- *algebra* (3σ) in English: the SSC replaces some uses of *Bad Onset

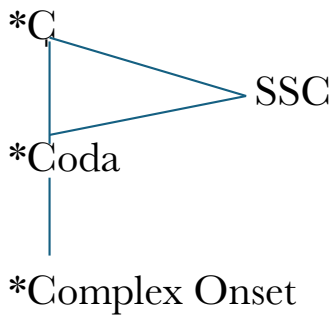
UR /algebra/	SSC (a)	*C	*Coda	*Complex
☞ al.ge.bra				
a.lge.bra				
a.l.ge.bra				
al.geb.ra				

SSC explains σ division:

- *algebra* in English *and* in Romanian

UR /algebra/	SSC (a)	*C	*Coda	*Complex
☞ al.ge.bra				
a.lge.bra				
a.l.ge.bra				
al.geb.ra				





Introduction to stress as a form of linguistic rhythm

(Marc Liberman and Alan Prince 1977 *On stress and linguistic rhythm*, LI)

Rhythm is

- … succession of distinct perceptual events repeating at regular intervals; over time, or space.

  E.g. the periodic succession of different auditory events

- Typically, alternation of prominent with less prominent events

  e.g. beat, silence, beat, silence…

- Prominent events in the auditory domain are marked by

  greater loudness, duration, higher or more complex pitch.

Rhythmic expectations

- Humans can form rhythmic *expectations*: anticipate, without much training, the next occurrence of a periodic event.

  Perceiving a beat can be same as predicting the beat.
- A few other species: songbirds (but not pigeons); cockatoos (but not monkeys)
- These species are *vocal learners:* can learn new, complex vocalization systems.
- Species programmed with a finite set of vocalizations can't.
- Ani Patel's cockatoo
- https://www.youtube.com/watch?v=CykfMAuPCL0&t=521s

Rhythm in spoken language

- Most obvious spoken language rhythms occur in verbal art:
  metrical verse and *text-setting* (setting words to music).
- Verse manipulates *rhythms naturally occurring in speech* to produce regular rhythms.

a. iambic (period is an *iamb*: σ**σ̲**; English lines contain typically 5 iambs)

That **time** | of **year** | thou **mayst** | in **me** | be**hold**

b. trochaic (*trochee*: **σ̲**σ; lines have typically 4 trochees)

Tell me | **not** in | **mourn**ful **|** **num**bers

c. anapestic (*anapest*: σσ**σ̲**; lines of variable length)

And the **sound** | of a **voice** | that is **still**

d. dactylic (*dactyl*: **σ̲**σσ; typically 6 dactyls/line)

This is the|**for**est pri|**me**val, the|**mur**muring |**pine** and the|**hem**locks

e. amphibrachic (*amphibrach*: σ**σ̲**σ; here, 4 amphibrachs per line)

O **where** are| you **go**ing?| said **rea**der| to **ri**der

A bridge engineer, Mister Crumpett,
Built a bridge for the good River Bumpett.
A mistake in the plan
Left a gap in the span,
But he said, "Well, they'll just have to jump it"

_ A **bridge|** engi**neer|**, Mister **Crum|**pett,
Built a **bridge|** for the **good|** River **Bump|**ett.
A mis**take|** in the **plan|**
Left a **gap|** in the **span|**,
But he **said|**, "Well, they'll **just|** have to **jump|** it.

Anapests + final extra σ

Micro rhythms embedded within a macro rhythm
(LongLine/Short/Short/LongLine, in each stanza)

Facts about these rhythms

1. Not specific to spoken language.
2. Rhythm of a line matches rhythm of corresponding 'prose' utterance.

   Extensive mismatch → bad poetry:

   a. That **time** | of **year** | thou **mayst** | in **me** | be**hold**

   b. Tell **me** | not **in** | mourn**ful** | num**bers,** | Mas**ter**

3. Spoken *utterances* have inherent rhythm.

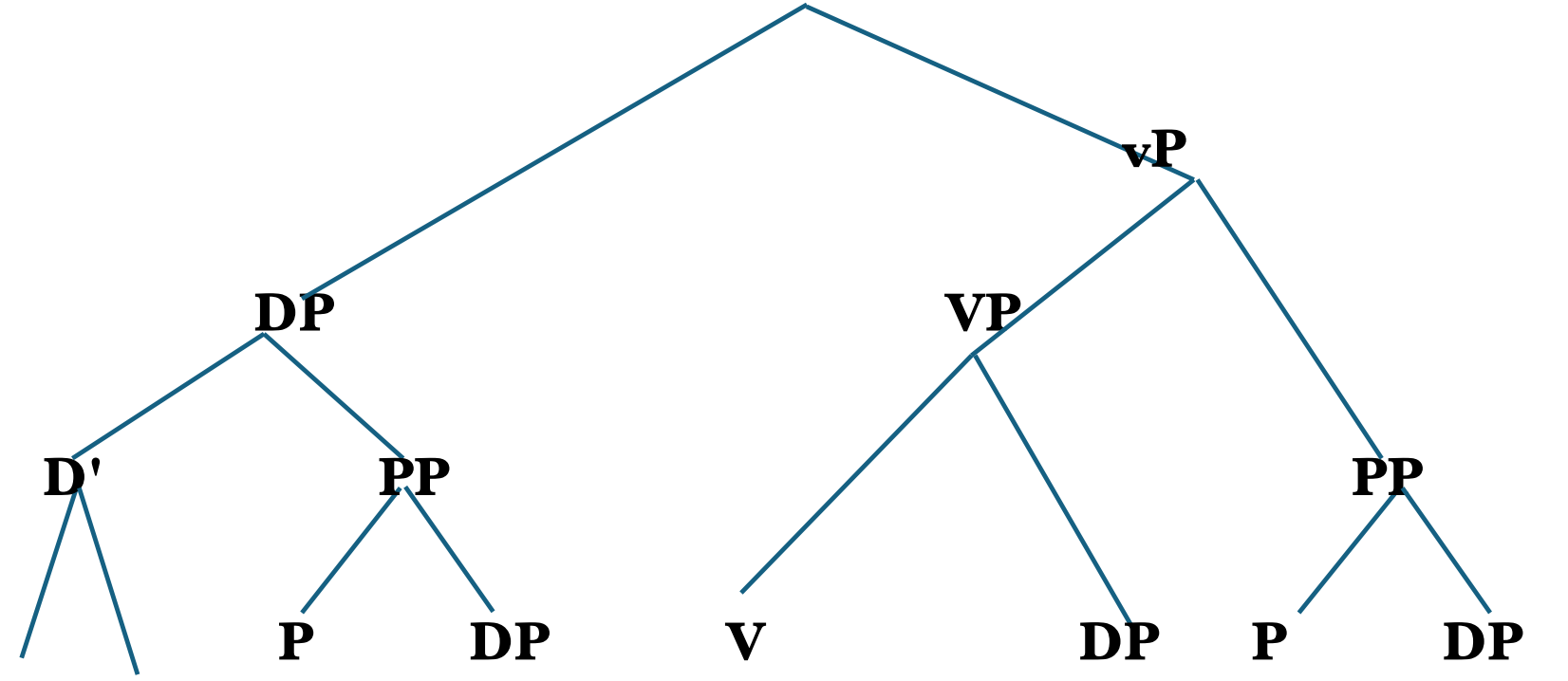
   If you replace Ns and Vs in (a) by any identically sized Ns and Vs

   That **kind** | of **thing** | we **find** | in **us** | all **days**

   the rhythm stays the same. Bec. it's dictated by the syntactic structure:

   most 2-unit phrases in English get a stronger beat on their second unit.

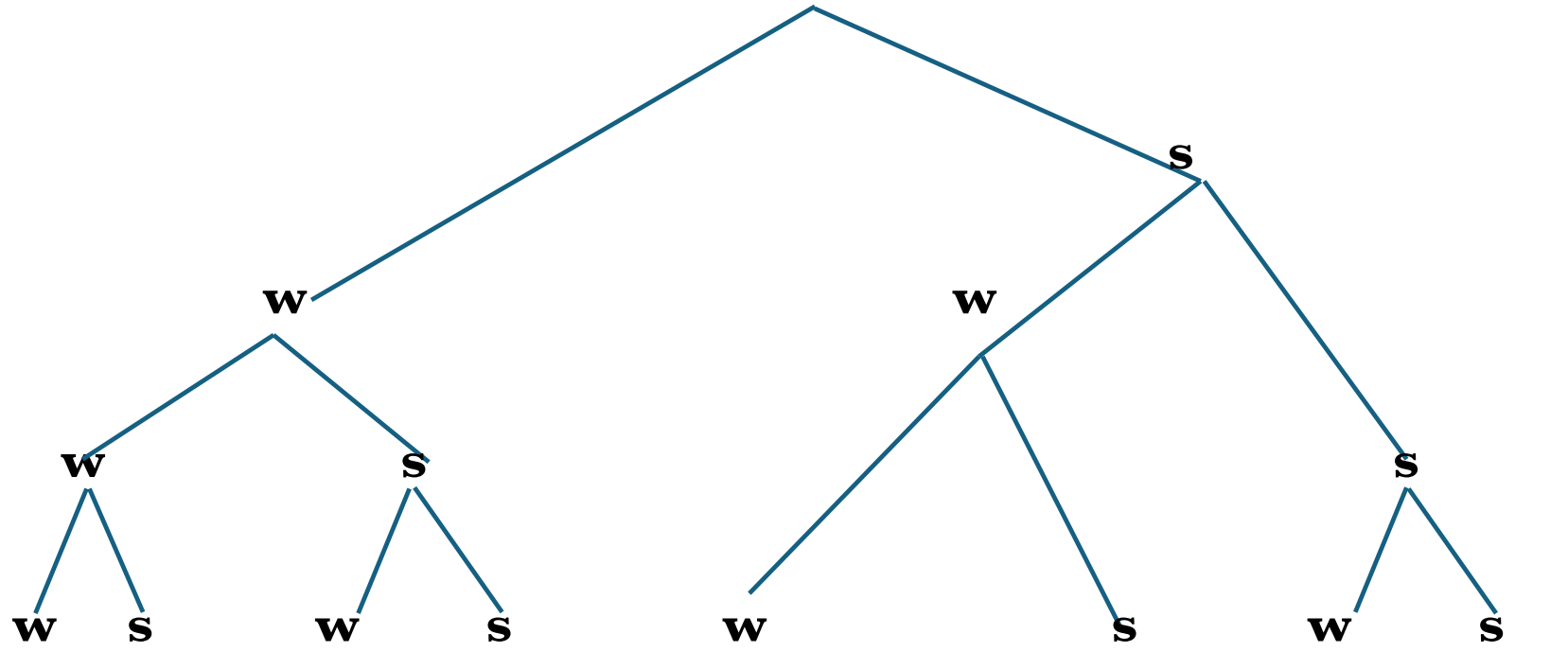
Right sister in each phrase is more prominent



3 Representations of linguistic rhythm

- a *relation* of relative prominence within constituents
  weak-strong (**ws**) or strong-weak (**sw**), or weak-weak-strong (**wws**)…
- numerical *degrees* of relative prominence
- a binary *feature*, [±stress].

ws prominence relations between phrasal units



Prominence relations

- Each expression contains rhythmic sub-groups:

  phrases, words, groups of 2-3 syllables (aka *feet*) within words

- Components of each such group stand in prominence *relations*:

  sw, ws; s = *stronger, more prominent, than*; **w** = *weaker than*

  M. Liberman and A. Prince 1977

Grids record finer degrees of relative prominence, because prominence comparisons involve all syllables in the domain

					x						x
					x			x			x
		x			x	x		x			x
x	x	x	x	x	x	x	x	x	x	x	x
a	mis	take	in	the	plan	left	a	gap	in	the	span

Each potential stress bearer (here, each σ) has a corresponding *grid column*.
Each pair σ_1-σ_2, s.t. σ_1 is more prominent than σ_2, differs in height of their grid columns: |column (σ_1)| > |column (σ_2)|.

Basic principle in prominence determination:
prominent (strong) status is inherited top-down.

Stress numbers correspond to grid columns
(if in a perverse way)

					x						x
					x			x			x
		x			x	x		x			x
x	x	x	x	x	x	x	x	x	x	x	x
a	mis	take	in	the	plan	left	a	gap	in	the	span
0	0	4	0	0	2	4	0	3	0	0	1

Tallest grid column: 1, or *main* stress. One-x columns: 0, *no* stress
More than one x, but less than main, so in-between: *subsidiary* stresses.
2-stress (secondary) > 3-stress (tertiary) > 4-stress (quaternary)….

Stress numbers and IPA notation

- 1 = main stress

  IPA ['ba], alternatively [bá], as if primary stress is a H tone
- 0 = stressless
- 2, 3, 4... = subsidiary stresses, in decreasing order order of prominence.

  IPA [ˌba], alternatively written [bà], as if secondary stress is L tone
- So, ordered by prominence, the stress numbers are: 1 > 2 > 3...n...> 0

A binary feature [±stress]

- 0 = [-stress]
- 1, 2, 3,..., any n >0 = [+stress]
- E.g. *a mistake in the plan* = 002001, 00n00n
- How do I hear stress?

  Listen for F0 excursions (1 stress) and unreduced Vs (some non-0 stress).

  More below.

Some stress regularities

Word-internal rhythms

V , ˈσ = main, most prominent stress
V, ˌσ = subsidiary, less prominent stress

- Completely predictable in most lgs:

  Latin, French, Finnish, Mongolian, Hungarian...

- Less clearly so, but still predictable in others:

  Spanish, Italian, Romanian, Turkish ....

- Degrees of overall predictability.
- English word rhythm seems unpredictable, 'phonemic':

Pámela, Maníla	[ˈpæmələ], [məˈnɪlə]
cómedy, spaghétti	[ˈkɔmədɹi], [spəˈgɛɾi]
cátamaràn, Guàtemálan	[ˈkæɾəməˌɹæn], [ˌgwaɾəˈmalən]

Different word rhythms in different languages

➡Binary **sw** rhythm: English, with some lawful deviations from binarity

Àpalàchicóla, sùpercàlifràgilìstic|èxpiàlidócious

➡Ternary **sww** rhythm: Cayuvava (Bolivia), counting vowels

ikitàparerépeha, ʧàadiròboβurúpuʧe

➡Unary rhythm, one beat per word: Hungarian (Blaho and Szeredi 2011; debate)

fɛ́lɛkɛzɛtijɛke:, ʃí:tot:ɔlɔni:tot:a:tok

English stress, i.e. distribution of [±stress] syllables in words

- Looks unpredictable
- In fact, rules predict most attested patterns (Chomsky and Halle 1968).
  Stress contrasts limited to a few contexts, e.g. choice between …010# and …100#.
- Resulting generalizations include:
  (a) at least one of the last 3 σ has some stress: *América, Mìnnesóta, Kàlamazóo, cátamaràn*
  (b) stress penult if heavy: *Dakóta* [koʊ], *Missóuri* [zu:]; *Aláska* [læs]
  if penult is light, stress antepenult: *América, Connécticut, Minneápolis*
  (c) in nouns, don't stress C_0VC_0 finals: e.g. *América, Connécticut, Minneápolis* vs. *Detróit, Illinóis*
  (irregular: *Vermónt, Háckensàck:* both borrowings, from French and Unami-Lenape)
  (d) stress all heavy non-final syllables: *Tìcònderóga*.
  (e) stress the initial (*Ìllinóis, Háckensàck* [ˈhæ.kn̩.ˌsæk]), but avoid stress clashes (*Connécticut, Aláska)*
  (f) subject to all of the above, stress every other syllable (rhythm!) counting from last stress:
  Àpalàchicóla, Pòtawátomi, hàmamèlidánthemum, sùpercàlifràgilìsticèxpiàlidócious

Speaker knowledge of English stress

- Do speakers know these rules, in spite of the exceptions?
  E.g. do they know rules for 3σ nonce words:
  (penult iff heavy; antepenult otherwise; despite exceptions?)
- Loan words suggest they do:
  Russian [bábuʃkə] restressed as English [bəbʊ́ʃkə]
  Spanish <cañon> [kaɲón] restressed as [kǽɲən]
  French <rococco> [ʁɔkɔkó] restressed as [ròʊkóʊkòʊ]~[róʊkəkòʊ]
- English speakers aren't *stress-deaf* (unlike French, Hungarian speakers).
  Can distinguish σ́σ from σσ́ as well as or better than segmental contrasts.
- Tendency to restress loans suggests speakers apply in their speech the stress rules of English, w. resulting changes in the stress of L2 words.

Moore-Cantwell 2018

- Checks if speakers' productions match rules describing lexical data despite irregularities
- Rule: stress penult iff heavy, antepenult otherwise
- Lexical proportions in attested words:

  96% of 3σ with Heavy penults get penult stress.

  79% of 3σ with Light penults get antepenult stress.

Moore-Cantwell 2018

- Stimuli are 3σ nonce words: e.g. *palaka, palazka, pamalta, palastra…*
- Task: choose the better pronunciation: *pálaka* vs. *paláka, pálazka vs. palázka*

  Stressless <a> = schwa
- Results mirror lexical proportions, approximately.
- Speakers have learned a general rule, not just the stress of individual words.
- Reflect exceptions too

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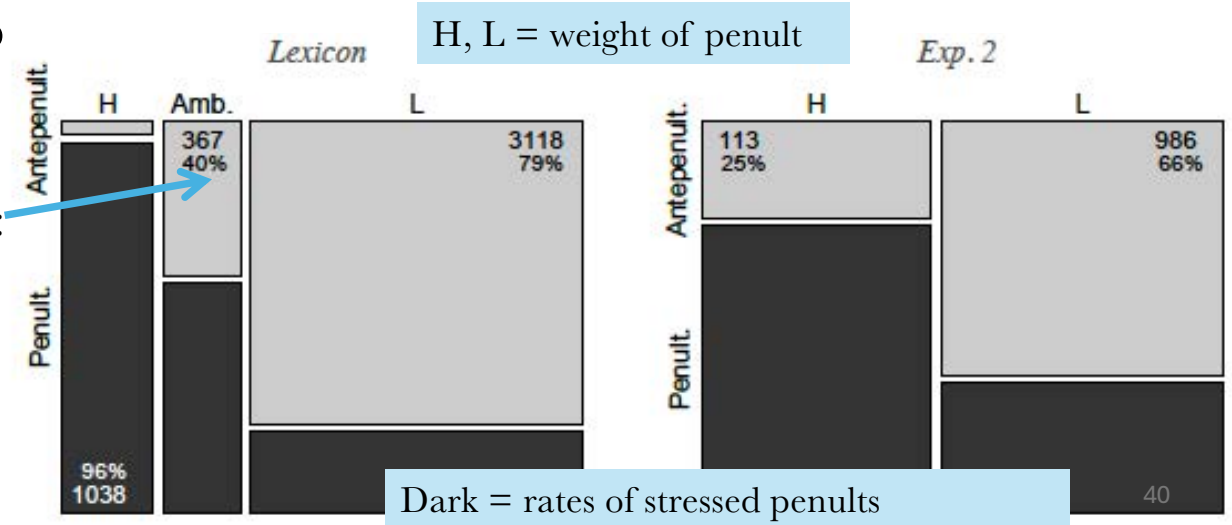
- Reflect exceptions too

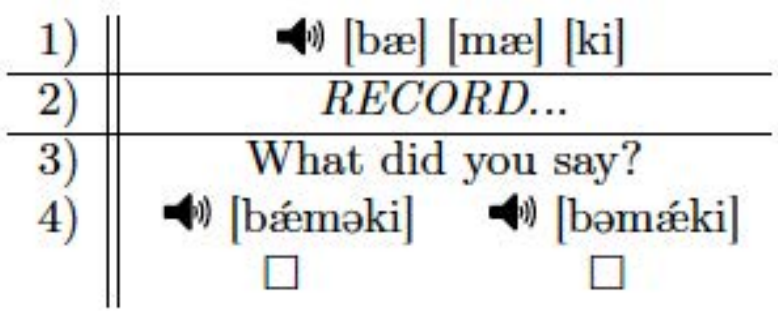
Graphically ambiguous penults:
Heavy, when stressed: *agénda*
Light CC̩, if not: *ágency*
[ə.ʤɛ́n.də] vs. [éɪ.ʤn̩.si]



Experiment procedure:

subjects string together into 1 word 3 individually presented syllables

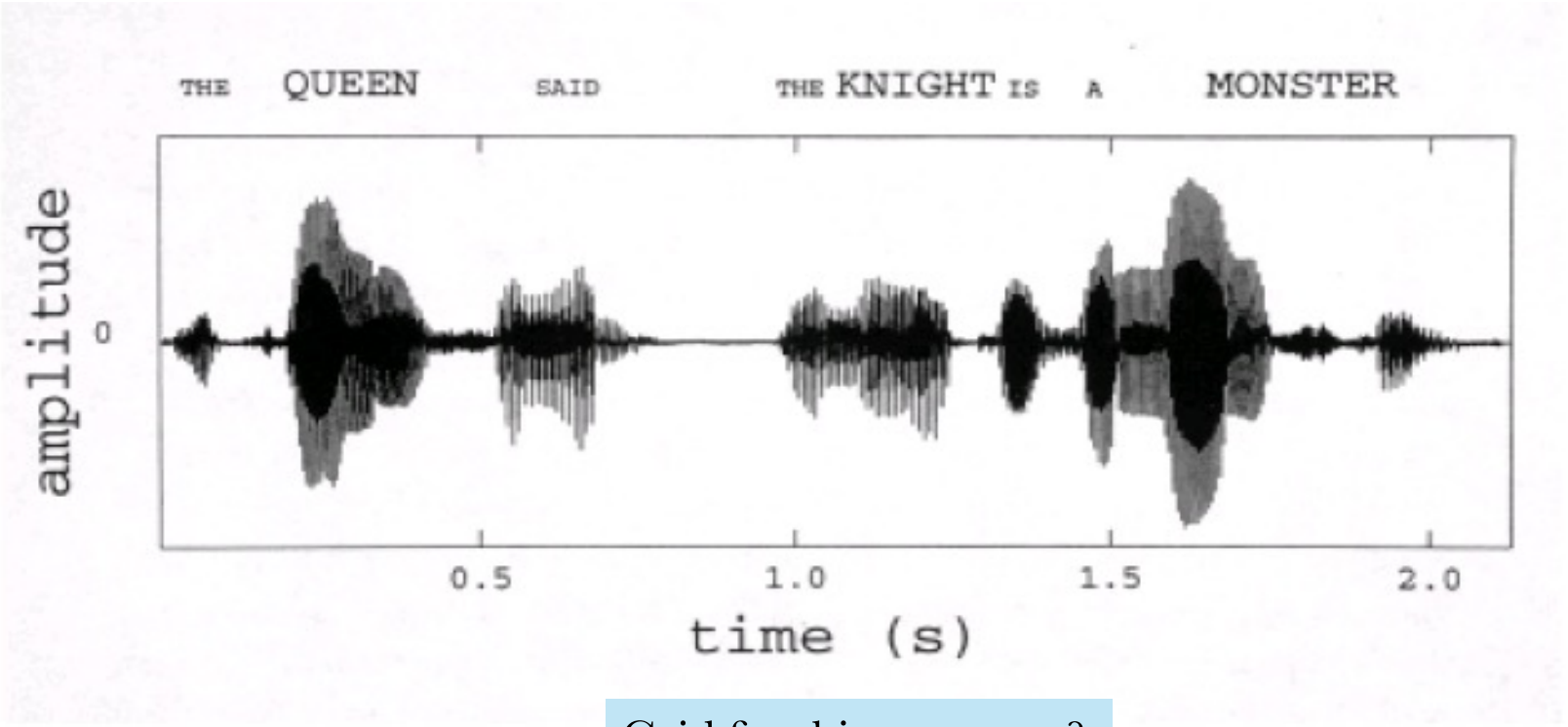
Figure 5: Example item in four stages. All presentation was auditory.



This procedure seeks to solve problems of relying on written stimuli, or on a model spoken utterance

Finding and hearing stresses

Realization of stress: amplitude and duration



Grid for this utterance?

Where *main* stress is

(a) Say the utterance with emphasis and look for the biggest F0 excursion (= sharpest F0 peak or trough)

(b) Turn the utterance into an exaggerated, incredulous question. Look for a point when the F0 goes sharply down then up.

• *Gèorgia* ***Sé****cretàry*	20 1030
• *Gèorgia Sècretàry of* ***Státe***	30 2030 0 1
• *Gèneral* ***Sér****vices*	300 100
• *Gèneral Sèrvices Admìnis****trá****tion*	300 200 030010
• ***lá****bor ùnion leàder*	10 300 20

Where the other stresses are

(a) Look for unreduced vowels (¬(ə, ɪ/_velars)): if non-final they're likely stressed

(b) Look for non-initial syllables w/aspirated stops or h in onset: they're stressed

véhicle, vehícular, cóhòrt	[ˈviəkl̩] [vəˈhɪkjələ˞] [ˈkʰoʊˌhɔɹt]
100 0100 12	
átom, atómic, àtomístic	[ˈæɾəm] [əˈtʰɔmɪk] [ˌæɾəˈmɪstɪk]
10 010 2010	
occúlt, òccultátion	[əˈkʰʌlt] [ˌɔkl̩ˈtʰeɪʃən]
01 2010	

(c) Look for Vs preceded by flaps (*á̠tom* [ˈæɾəm]): they're likely stressless.

Why are *these* the cues to [±stress]?

- All forms of rhythm, not just stress, are periodic sequences of prominent & non-prominent events
- Prominent *auditory* events: longer and/or louder than less prominent ones.
- Stress, as spoken language rhythm, is no different:
  - stressed syllables are longer and louder in all 'stress' languages (‘tone/accent' lgs differ)
  - Increase in loudness is produced by increased subglottal pressure
- The cues to [±stress] *in English* are consequences of these facts

  (a) increased duration of stressed σ: longer Vs less likely to reduce

  (b) increased subglottal pressure generates higher airflow volume ➡ aspiration

  (c) increased subglottal pressure generates higher F0 (Giavazzi 2010, MIT diss)

Cues to [±stress] follow from how prominence in general is manifested

Where do subsidiary stresses (> 0, <1) come from? Many come from syntactic embedding

- Each utterance has *one* main (1) stress. ("Stress is *culminative*.")
- When word/phrase is embedded in a bigger unit, its main (1) stress either becomes the 1 stress of the new phrase, or its 1 stress it *demoted* to 2 or less.

  isolation *a mistake* 001
  embedded *a mistake in the plan* 001 001→ 002 001 (ws)
- The *relative prominence* relations of the embedded unit are generally preserved:

  isolation *a mistake in the plan* 002001
  embedded *a mistake in the plan left a gap in the span*
  <u>002001</u> 302001 → <u>003002</u> 302001, <u>*002002</u> 302001
- Simplified view of phrasal stress. More in Wagner 2005 diss. MIT
  https://dspace.mit.edu/handle/1721.1/33713

Preserving relative prominence under embedding