

24.901/931, 2026

Introduction to Phonology

Lecture 10

For next week

- Problem set 3 due
Tues.
- Readings:

Mascaró 2010 Rule ordering, in *Features, Processes*

McCarthy 2008 Chapter 1, in *OT Basics*

(1) A harmony exercise

(2) Rule ordering

- rule ordering conventions
- why they're helpful
- types of rule interactions
- their consequences for learning a grammar

The grammar as a sequence of ordered rules

- $R_1 > R_2 > \dots R_n$
- $R_1 > R_2$ means: the input to R_2 is the immediate output of R_1
or the output of any R_n ordered between R_1 and R_2
or, if neither R_1 nor R_n are applicable, then the input to R_2 is the UR
= the input to R_2 is whatever the grammar has generated up to R_2
- If $R_1 > R_2$, then R_1 **can't** re-apply after R_2
even if its only chance is to apply to some string Σ was *after* R_2

Rule ordering can simplify the grammar

Margi (Chadic; Nigeria, Cameroon, Chad)

Indefinite	Definite	gloss
sal	salari	man
katsakar	katsakari	sword
ɕimi	ɕimjari	water
ku	kwari	goat
ɟere	ɟereri	court
toro	torori	threepence
ghafə	ghafari	arrow
latə	latari	time
məla	məlari	well

Margi vowel sequences

UR	ia	ua	aa	əa	ea	oa
SR	ja	wa	Øa	Øa	eØ	oØ
R1	[+hi] → [-syll] / _ [+syll]					
R2	[+syll, -front, -round] → Ø / _ [+syll]					
R3	[+syll] → Ø / [+syll] _					

R1 > R2 > R3

More complex rules, if applied simultaneously

UR	ia	ua	aa	əa	ea	oa
SR	ja	wa	Øa	Øa	eØ	oØ
Rules	[+hi]→[-syll]/_[+syll] [+syll -front, -round]→Ø/_[+syll] [+syll, -high, αba, αrd]→Ø/[+syll]_					

In the ordered-rule grammar, each rule *removes potential inputs* from later rules, it *bleeds* them. Then statements of later rules need not explicitly exclude these potential inputs.

In the no-order (simultaneous application) grammar above, some rule statements become more complex.

-t	-d	-əd	
packed [kt]	bagged [gd]	cited [saɪtəd]	
mopped [pt]	mobbed [bd]	elided [əlaɪdəd]	
laughed [ft]	loved [vd]	feasted [fɪstəd]	
missed [st]	buzzed [zd]	minded [maɪndəd]	
rushed [ʃt]	rouged [ʒd]	welded. [wɛldəd]	
fetched [ʃt]	edged [dʒd]		
	lined [nd]		
	filled [ld]		
	barred [ɹd]		
	sighed [aɪd]		

Similar rule interactions in the analysis of t/d/əd s/z/əz alternations

-t	-d	-əd	
packed [kt]	bagged [gd]	cited	[təd]
mopped [pt]	mobbed [bd]	elided	[dəd]
laughed [ft]	loved [vd]	feasted	[stəd]
missed [st]	buzzed [zd]	minded	[ndəd]
rushed [ʃt]	rouged [ʒd]	welded.	[ldəd]
fetched [ʃt]	edged [dʒd]		
	lined [nd]		
	filled [ld]		
	barred [ɹd]		
	sighed [aɪd]		
after [-voice]	after [+voice]	after t/d	

UR /-d/

after [-voice], -t

after [+voice], -d

after t, d, -əd

voicing assimilation in obstr.

$[-\text{son}] \rightarrow [\alpha \text{voice}] / [-\text{son}, \alpha \text{ voice}] _$

or

$[-\text{son}] \rightarrow [-\text{voice}] / [-\text{voice}] _$

epenthesis

$\emptyset \rightarrow \text{ə} / [\text{stop, alveolar}] - [\text{stop, alveolar}]$

stop = [-son, -cont]

Why choose UR /d/, not /t/ or /əd/ or /ət/

- rules needed under the /d/ hypothesis (devoicing, ə-epenth.) are general
- alternative hypotheses require different rules (voicing /t/ after voiced, ə-deletion) which must be restricted to certain morphemes (cf. *tenth*, **ten*[ð]; *san*[ə]ty, **santy*)

-S		-Z		-əZ	
packs	[ks]	bags	[gz]	misses	[səz]
mops	[ps]	mobs	[bz]	rushes	[ʃəz]
laughs	[fs]	loves	[vz]	buzzes	[zəz]
cites	[ts]	minds	[ndz]	rouges	[ʒəz]
feasts	[sts]	welds	[ldz]	edges	[dʒəz]
		elides	[aɪdz]	fetches	[tʃəz]
		lines	[nz]		
		fills	[lz]		
		barres	[ɹz]		
		sighes	[aɪz]		

UR /-z/

after [-voice, -son]:-s

after [+voice]_: -z

after s, z, ʃ, ʒ, tʃ, dʒ: -əz

voicing assimilation

epenthesis

$\emptyset \rightarrow \text{ə} / [\text{strident}] - [\text{strident}]$

Why choose UR /z/, not /s/ or /əz/:

- rules needed under the /z/ hypothesis (devoicing, ə-epenth.) are general
- under /s/, /əz/ hypotheses, rules needed (voicing /s/, ə-deletion) must be restricted to certain morphemes (cf. *lens*, **len*[z])

Derivations (arrows = necessary order)

UR	pæk-d	pæk-z	sait-d	sait-z	mɪs-d	mɪs-z
Epenthesis (T//D)			təd			
Epenthesis (Strid)						səz
Voicing assim	kt	ks		ts	st	
SR	pækt	pæks	saitəd	saits	mɪst	mɪsəz

(Alternatively, a single epenthesis rule, triggered by the OCP; with details TBD
That would explain why the order wrt Voicing Assim is the same.)

Failed derivations under different order:

(Voicing Assim. > Epenthesis)

UR	pæk-d	pæk-z	sait-d	sait-z	mis-d	mis-z
Voicing Assim.	t	s	sait-t	s	t	mis-s
Epenthesis (T//D)			tət			
Epenthesis (Strid)						səs
SR	pækt	pæks	*saitət	saits	mist	*misəs

Ordering can be avoided here too, if the rules are made more complex:

e.g. Voicing Assimilation is stated to *not* apply to *alveolar stop clusters*; and to not apply if both Cs *are strident*):

[-son] → [a voice] / [-son, a voice] _—, unless (i) both Cs are [-cont, +coronal, +anterior],
(ii) both Cs are [+strident]

Another process: Flapping

(flap [ɾ] = stop involving a very brief contact; á[ɾ]om, a[t^h]ómic)

-t	-d	-əd, careful		-əd, standard
packed [kt]	bagged [gd]	cited	[sáɪtəd]	[sáɪrəd]
mopped [pt]	mobbed [bd]	elided	[əláɪdəd]	[əláɪrəd]
laughed [ft]	loved [vd]	feasted	[fɪstəd]	
missed [st]	buzzed [zd]	minded	[maɪndəd]	
fetches [tʃt]	edged [dʒd]			
	lined [nd]			
	filled [ld]			
	barred [ɹd]			
	sighed [aɪd]			

packed [kt]	bagged [gd]	cited [saɪtəd]	[saɪrəd]
mopped [pt]	mobbed [bd]	elided [əlaɪdəd]	[əlaɪrəd]
laughed [ft]	loved [vd]	feasted [fɪstəd]	
missed [st]	buzzed [zd]	minded [maɪndəd]	
rushed [ʃt]	rouged [ʒd]	welded. [wɛldəd]	
fetchd [tʃt]	edged [dʒd]		r = [+son, +flap]
	lined [nd]		[-cont, +alv] → [+flap] / 'V_V
	filled [ld]		
	barred [ɹd]		
	sighed [aɪd]		

Derivations (arrows = necessary order)

UR	pæk-d	pæk-z	sair-d	sair-z	mis-d	mis-z
Epenthesis (T//D)			əd			
Epenthesis (Strid)						əz
Voicing assim	t	s		s	t	
Flapping			sairəd			
SR	pækt	pæks	sairəd	sairts	mɪst	mɪsəz



Must Flapping follow Epenthesis (T)? Try the opposite.



This ordering argument, and the alternative

- Epenthesis creates a new context for Flapping to apply to UR /VCd/.
- And Flapping *does* apply in this new context.
- If Flapping > Epenthesis, Flapping will not apply to UR /VCd/.
- And will *not be able to try again, post-Epenthesis*, under usual ordering conventions.
- But we can avoid the order, if we complicate the rule of Flapping:
- Instead of this:

$[-\text{cont}, +\text{alv}] \rightarrow [+ \text{flap}] / 'V_V$

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- Instead of this:

$[-\text{cont}, +\text{alv}] \rightarrow [+ \text{flap}] / 'V_V$

- We can write this:

$[-\text{cont}, +\text{alv}] \rightarrow [+ \text{flap}] / 'V _ \left\{ \begin{array}{l} V \\ [\text{cont}, -\text{son}, +\text{alv}] \end{array} \right\}$

$\{x, y\} = \text{either } x \text{ or } y$

If $R_1 > R_2$, then R_1 **can't** re-apply after R_2

Catalan final nasals

t					
a. unsuffixed		b. V-initial suffix			
[den]	‘tooth’	[dənt-ál]	‘dental’		
[kam]	‘field’	[kəmp-əról]	‘peasant’		
[saŋ]	‘blood’	[səŋg-unós]	‘bloody’		
t					
c. unsuffixed	d. V-initial suffix	e. C-initial suffix			
[kuzí]	‘cousin’	[kuzin-ét]	‘cousin-DIM’	[kuzín-s]	‘cousin-PL’
[pla]	‘even’	[plən-ísim]	‘very even’	[plan-s]	‘even-PL’
[upurtú]	‘opportune’	[upurtun-idád]		[upurtún-s]	‘opportune-PL’

UR	kuzín	kuzin-ét	dént	dent-ál
Delete n#				
[+alv, +nas] → Ø / _#	kuzí	-	-	-
Delete stop#				
[-cont, αplace] → Ø / [+nas, αplace] _#	-	-	den	-
Other rules	-	-	-	dəntál
SR	kuzí	kuzinét		dəntál

[n] in /dent/ has one chance to delete in _#: after [t] deletes.

But by then it's too late: its turn has passed under Delete n# > Delete stop#

Each rule has one chance to apply: when its turn in the rule sequence comes.

Types of rule interactions

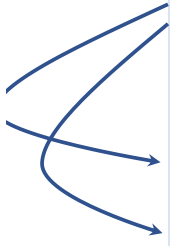
Structural description and structural change

- SD = structural description of a rule
- SC = structural change of the rule
- In the rule $A \rightarrow B / C_D$,
CAD is the SD
 $A \rightarrow B$ is the SC
- A rule may create the SD for another rule = may *feed* that other R
- A rule may eliminate the SD of another rule = may *bleed* that R

Types of rule interactions based on their order

- Two rules, R_1 and R_2
- If $R_1 > R_2$ and R_1 creates new inputs (SDs) for R_2 : **R_1 feeds R_2**
- If $R_1 > R_2$ and R_1 eliminates earlier inputs for R_2 : **R_1 bleeds R_2**

E.g. under the order Epenthesis > Flapping, Voic Assim
Epenthesis feeds Flapping: $\text{sait-d} \rightarrow \text{saitəd} \rightarrow \text{sairəd}$
Epenthesis bleeds Voic Assim: $*\text{saitət}$, $*\text{sairət}$



UR	fist-d	sart-d	əlaɪd-d	pæs-d
(i) Epenthesis	fɪstəd	sartəd	əlaɪdəd	
(ii) VoicAssim				pæs-t
(iii) Flapping	n/a	sairəd	əlaɪrəd	
SR	fɪstəd	sairəd	əlaɪrəd	

- i. Epenthesis $\emptyset \rightarrow \text{ə} / [-\text{son}, -\text{cont}, +\text{alv}]_ - [-\text{son}, -\text{cont}, +\text{alv}]$
- ii. VoicAssim $[-\text{son}] \rightarrow [\alpha \text{ voice}] / [\alpha \text{ voice}, -\text{son}]_ \#$
- iii. Flapping $[+\text{alv}, -\text{sont}, -\text{son}] \rightarrow [+ \text{flap}] / \text{V_V (prelim).}$

A different case of feeding+bleeding

(based on Karok (California Indian) and Bantu patterns, modified)

SR	badutʃi	galiku	baduk-a	badutʃ-i	galik-a	galitʃ-i
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No VV sequence on surface

No ki, gi, no tʃu, tʃa

UR	baduki	galiku	baduki-a	baduki-i	galiku-a	galiku-i
R1	-	-	baduka	baduki	galika	galiki
R2	badutʃi	-	-	badutʃi	-	galitʃi
SR	badutʃi	galiku	baduka	badutʃi	galika	galitʃi

Derivations

(based on Karok and Bantu data, modified)

SR	badutʃi	galiku	baduk-a	badutʃ-i	galik-a	galitʃ-i
UR	baduki	galiku	baduki-a	baduki-i	galiku-a	galiku-i
R1	-	-	baduka	baduki	galika	galiki
R2	badutʃi	-	-	badutʃi	-	galitʃi
SR	badutʃi	galiku	baduka	badutʃi	galika	galitʃi
R1: V-Elision: *V ₁ V ₂			R2: Velar Palatalization: *k i			
↓			↓			
Ø			tʃ			

Rules and derivations

- R_1 V-Elision: $V \rightarrow \emptyset / _V$ SD: $V_1 V_2$
- R_2 Velar Palatalization: $k \rightarrow tʃ / _i$ SD: ki
- $R_1 > R_2$ The rule order itself is not feeding or bleeding, it's the interaction of the ordered rules with a given string that is one or the other.

UR	baduki	galiku	baduki-a	baduki-i	galiku-a	galiku-i
R1	-	-	baduka	baduki	galika	galiki
R2	badutʃi	-	-	badutʃi	-	galitʃi
SR	badutʃi	galiku	baduka	badutʃi	galika	galitʃi
			↓ R ₁ bleeds R ₂			↓ R ₁ feeds R ₂ ³¹

Two more types of rule interactions

- If $R_1 > R_2$,
and if R_2 *could* create new inputs (SDs) for R_1 , but the order $R_1 > R_2$ prevents this,
then R_2 counterfeeds R_1
- If $R_1 > R_2$,
and if R_2 *could* eliminate earlier R_1 inputs, but the order $R_1 > R_2$ prevents this,
then R_2 counterbleeds R_1

Different system; same rules as before, opposite order

- R_1 Elision: $V \rightarrow \emptyset / _V$
- R_2 Palatalization: $k \rightarrow tʃ / _i$
- But, in this system, $R_2 > R_1$

UR	baduki	galiku	baduki-a	baduki-i	galiku-a	galiku-i
R2	baduʃi	-	baduʃia	baduʃii	-	-
R1	-	-	baduʃa	baduʃi	galika	galiki
SR	baduʃi	galiku	baduʃa	baduʃi	galika	galiki

↓
 R_1 counterbleeds R_2

↓
 R_1 counterfeeds R_2

Kinyarwandan (Bantu, Ruanda):

$k, g \rightarrow c, j / _i, e$; and $V_1 \rightarrow \emptyset / _V_2$

Word internal c, j occur only before i, e

Phrase final	Before #C...	Before #V...	
Xci	Xci C...	Xc a...	_Back V
Xko	Xko C...	Xk i...	_Front V
Xji	Xji C...	Xj a...	_Back V
Xgo	Xgo C...	Xg i...	_Front V

Derivations

UR	...ki-a...	...ko i...	
Velar Pal	...ci-a...		Velar Pal counterfed and counterbled by V-Del
V-Del	...ca...	...ki...	
SR	...ca...	...ki...	

Kinyarwanda data (Myers and Crowhurst)

(http://www.laits.utexas.edu/phonology/kinyarwanda/kin_interaction.html)

Phrase-final	Before a C-initial	Before a V-initial
<i>umugi</i> [umuɟí ^h] "town"	<i>umugi-munini</i> [umuɟímuníni ^h] "a big town"	<i>umugi-ukomeye</i> [umuɟúkome ^h] "a strong town"
<i>ubwenge</i> [ubgê:ɲje] "intelligence"	<i>ubwenge-bwinshi</i> [ubgê:ɲjebgĩ:ɲʃĩ] "a lot of intelligence"	<i>ubwenge-ashaka</i> [ubgê:ɲjaʃa:ká] "intelligence 3sg is looking"
<i>itariki</i> [itáricí] "date"	<i>itariki-nziza</i> [táricínzî:zá] "a good date"	<i>itariki-atifuza</i> [táricáfufuzá] "a date he/she doesn't wait"
<i>amaboko</i> [amaβóko ^h] "arms"	<i>amaboko-maremare</i> [amaβókomare:mare] "long arms"	<i>amaboko-akomeye</i> [amaβókakome ^h] "strong arms"
<i>imbogo</i> [imbogó ^h] "water buffalo"	<i>imbogo-zicaye</i> [imboɣózî:tʃajé] "sitting water buffaloes"	<i>imbogo-iryamye</i> [imbogírjá:mje ^h] "a sleeping water buffalo"

ju, ja, cu, ca and ki, gi
occur only when a V was
deleted;

they alternate with
ji, je, ci, ce and ku, ka gu ga

Significance of rule orders: Part 1

- When an order produces **counterfeeding, counterbleeding** interactions, the resulting grammar tends to be historically unstable.
- Perhaps these interactions make it harder to learn the rules.
E.g. [galiki] < /galiku-i/: it seems to contradict Palatalization.
E.g. [badutʃa] < /baduki-a/ vs. [galuka]: suggests [tʃ] is part of UR, as it's not followed by [i]: that also makes Palatalization harder to learn.
- Counterfeeding/-bleeding interactions are said to be **opaque**, because they make the underlying lexicon and the grammar harder to learn.
- Most feeding and bleeding are **transparent**.

Significance of rule orders: Part 2

- Optimality Theory (Prince and Smolensky 1993), in its original version, can model all feeding and bleeding interactions (with 1 exception.)
- Some counterfeeding and some counterbleeding interactions can be modeled indirectly, with new constraint types and representations.
- Some counterfeeding, counterbleeding interactions can't be modeled.
- Possible disadvantage for OT analyses
- Not if the opaque interactions are not learned at all.

Surface-true and surface-apparent (Kiparsky 1973)

- A rule R is *surface-true* if R's SD is not contained in any SR

English ə-Epenthesis (no t-d, d-d, t-t, no zz, sz...)

English voicing assimilation (no tz, pz, gs in final position)

- A rule R is *surface-apparent* if a factor F is responsible for R's application, and this F is observable in every SR where R is known to have applied.

English ə-Epenthesis is surface-apparent between stridents

But English ə-Epenthesis is not surface-apparent betw. alveolars (r_d)

Palatalization in Pseudo-Karok is (every tʃ occurs before –i)

But not Palatalization in Kinyarwanda (there are tʃa strings, < kia)

Transparency and opacity

- Interactions that preserve the surface-true and surface-apparent property of rules are *transparent*
- Other interactions – those resulting in rules being not-surface true or not surface apparent – are *opaque*.
- Different formula:
 - ➡ R is transparent if its SD never surfaces (= R is surface-true), *and* if undoing R's every application reveals the SD, i.e. explains why R should have applied (= R is surface-apparent)
 - ➡ Otherwise, R is opaque.

Connection between (counter)feeding/bleeding and opaque/transparent

- Counter-feeding/-bleeding interactions are opaque; and feeding/bleeding interactions are frequently transparent.
- Most counterfeeding $R1 > R2$ will result in $R1$'s SD appearing in SR, so $R1$ will not be surface true
- All counterbleeding $R1 > R2$ will result in the $R1$ being non-surface apparent: $R2$ removes a factor that has conditioned $R1$.
- (But there are also *feeding* orders $R1 > R2$ that result in $R1$ being made non-surface apparent
- And there are opaque/transparent interactions that don't correspond to (counter) feeding/bleeding)

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