

24.901/931, 2026

Introduction to Phonology

Lecture 11

Work this week

- One more reading on ordering rules
Hayes 2009 Chapters 7 (and 8) in *Features, Processes, Inventories*
(in addition to Mascaró 2010 Rule ordering
and to McCarthy 2008 Chapter 1, in *OT Basics*)
- A solution to Quiz1 is posted under *Features, Processes, Inventories*.

Re Quiz 1

- Korean nasal assimilation can generate sounds that aren't phonemes in Korean: ᆞ , n^{h} , ɲ , ɲ^{h} etc, depending on how we state the rule.
- ᆞ , n^{h} , ɲ , ɲ^{h} etc result from rule that spreads nasality onto a voiceless, aspirated or palatoalveolar C.
- These Cs never surface in Korean, no matter the source. Why not? Maybe because ᆞ , n^{h} , ɲ , ɲ^{h} etc $\rightarrow$ n by rules distinct from nasal assim.
- The grammar can let the same rule(s) that exclude ᆞ , n^{h} , ɲ , ɲ^{h} from the phonemic inventory of Korean apply to the output of nasal assimilation.
- Some quiz answers proposed that ᆞ , n^{h} , ɲ , ɲ^{h} don't have to be considered at all, because they are not phonemes of Korean.
- But flap is not a phoneme of English, yet an English rule generates it. Same for aspirated and glottalized stops.

Derivations

		Real inputs			Hypothetical inputs		
	Inputs →	apna	ap ^h na	atʃna	other N̥	other N ^h	other ɲ
Nasal assimilation		am̥na	am ^h na	aɲna			
[+nasal] → [+voice]		amna		aɲna	N		
[+nasal] → [- aspir.]			amna			N	
[+nasal, +cor] → [+ anterior]				anna			n

Last class: using rule ordering to simplify grammars

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

Catalan final Cs

†		
a. unsuffixed		b. V-initial suffix
[den]	‘tooth’	[dənt-ál] ‘dental’
[kam]	‘field’	[kəmp-əról] ‘peasant’
[saŋ]	‘blood’	[səŋg-unós] ‘bloody’
†		
c. unsuffixed	d. V-initial suffix	e. C-initial suffix
[kuzí]	‘cousin’	[kuzín-s] ‘cousin-PL’
[pla]	‘even’	[plan-s] ‘even-PL’
[upurtú]	‘opportune’	[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 if the order is

Delete n# > Delete stop#

By assuming that each rule has just one chance to apply we can describe Catalan.

Alternative description: a language avoid losing strings longer than 1C.

Not expressible with rules, but in grammar types that control extent of changes.

Types of rule orders and 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

Feding and bleeding

- 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 English 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	fistəd	sartəd	əlaɪdəd	pæs-t
(ii) VoicAssim				
(iii) Flapping	n/a	sairəd	əlaɪrəd	
SR	fistəd	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
	‘owl’	‘chicken’	DIMIN	PLURAL	DIMIN	PLURAL

No ki, gi. No tʃ except/_i

No VV sequence on surface

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

Feeding and bleeding here

- 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 ¹³ R ₂	

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 URs, same rules, 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

Kinyarwanda (Bantu, Rwanda):

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

Word internally: c, j occur only before i, e ; and no ki, gi occur.

In word combinations, c, j occur before any V . No VV sequences occur.

Phrase final	Before #C...	Before #V...
Xci, *ki	Xci, *ki C...	Xc a, i, u... _Back or front V
Xko, *co	Xko, *co C...	Xk a, i, u... _Front or back V

Derivations

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

Actual 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> [umu ɟú kome ^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:ɲ ja ʃa:ká] "intelligence 3sg is looking"
<i>itariki</i> [itáricí] "date"	<i>itariki-nziza</i> [táricínzî:zá] "a good date"	<i>itariki-atifuza</i> [táric á tifuzá] "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> [imbog ír já:mje ^h] "a sleeping water buffalo"

ju, ja, cu, ca and ki, gi
occur only when a V₁ was
deleted in UR /V₁V₂/;

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

Summary of this classification of rule interactions

	Rule A > Rule B	Rule B > Rule A
If Rule A can create extra inputs to B	<i>A feeds B</i>	<i>A counterfeeds B</i>
If Rule A can eliminate inputs to B:	<i>A bleeds B</i>	<i>A counterbleeds B</i>

Feeding: English Epenthesis precedes and feeds Flapping: əlaɪd-d → əlaɪd-ə-d → əlaɪr-ə-d

Bleeding: English Epenthesis precedes & bleeds Voicing Assimilation: bʊʃ-z → bʊʃ-ə-z, *bʊʃ-ə-s

Counter-bleeding: Kinyarwanda V-Elision follows & counterbleeds Velar Palatalization:
baluki-a → baluci-a (Pal) → baluc-a (V-Elis)

Counter-feeding: Kinyarwanda V-Elision follows & counterfeeds Velar Palatalization
galiku-i → Pal (n/a) → galik-i (V-Elis) *galic-i

Learning consequences of different rule orders

- When an order produces **counterfeeding or 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/: this output seems to contradict Palatalization.
E.g. [badutʃa] < /baduki-a/ vs. [galuka]: this suggests [tʃ] is part of UR, because it seems to contrast with [k]. But there is no k/tʃ contrast here.
- Counter-feeding/-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**.

Surface-true and surface-apparent (Kiparsky 1973)

- A rule **R** is *surface-true* if **R**'s SD is not found 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)
 - Palatalization in Kinyarwanda is not surface true (ki strings from kV#i)
- 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.
 - 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 ca strings, < kia)

Transparency and opacity

- Interactions that preserve the surface-true and surface-apparent properties of rules are *transparent*
- Other interactions – those resulting in rules becoming 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 every application of R 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)

Non-surface apparent epenthesis in Turkish from a feeding order

- Epenthesis into final Cn clusters:
oda-n ‘your room’; ip ‘rope’, ip-n → ip-in ‘your rope’
- [k]-deletion in V_V position:
ajak ‘foot’, /ayak-i, ayak-a/ → ayai, ayaa ‘foot-Acc’, ‘foot-Dat’
- Interaction: epenthesis feeds [k]-deletion
/ajak-n/ → ayak-in → aja-in ‘your foot’, not *aja-n.
/bebek-n/ → bebek-in → bebe-in ‘your baby’, not *bebe-n.
- Epenthesis *feeds* [k]-Deletion. But Epenthesis is not surface-apparent.

Not all rule interactions fit a (counter)feeding/bleeding classification. But all can be classified as transparent/opaque

- Swahili (Bantu): penultimate stress ($V \rightarrow V[+\text{stress}] / _C_0V\#$)

jíko ‘kitchen’

jikó-ni ‘in the kitchen’

nilimpíga ‘I hit him’

nitakupíga ‘I shall hit him’

- There is epenthesis in loanwords. Result also gets penultimate stress:

tíket ~ *tikéti* ‘ticket’

rátli ~ *ratíli* ‘pound’

- SD of Swahili stress CVCV# - the last two syllables, neither of them stressed.
- Stress applies whether epenthesis does or doesn’t. So feeding not involved

But stress would *apply differently* depending on whether epenthesis precedes stress or follows: *tikéti* (surface true and surface apparent) vs. **tíkети* (neither).

Transparent/opaque in non-feeding/bleeding cases

- Yimas (Papua New Guinea)

[a], [u] underlying vowels	[i] is inserted: #C _C, C _CC, C _C#)
<i>wáŋkaŋ</i> ‘bird’	/pkam/ → <i>píkám</i> ‘skin of back’
<i>kálaŋaŋ</i> ‘walk’	/tmi/ → <i>tímí</i> ‘say’
<i>wúratàkay</i> ‘turtle’	/kcakk/ → <i>kícákik</i>
<i>mámantùkarman</i> ‘land crab’	/nmpanmara/ → <i>nimpánmara</i> ‘stomach’

- SD of Yimas 1st stress: #CV
- Stress applies whether epenthesis does or does not. So no feeding/bleeding involved.
- But stress applies differently depending on whether epenthesis precedes stress or follows:

píkám, **píkám*.

Yimas stress is not surface true, nor surface apparent.

Opaque stress systems, like Yimas

- Are very, very common, but historically unstable
- Varieties of Arabic (Lebanese vs. Palestinian), Mohawk, Austronesian languages, Spanish
have Stress > Epenthesis, with patterns comparable to Yimas
- But some change the order to Epenthesis > Stress
- In this case, it's not the counterfeeding/counterbleeding property that causes instability in the stress system: the original order was neither counterfeeding nor counterbleeding.
- Rather, the change is from a stress pattern that's non-surface true/apparent to one that is both.

A closer look at 2 systems with opaque interactions, to illustrate that some opaque interactions are not successfully learned, and could be eliminated for that reason.

Canadian (and North Eastern US) Raising

aɪD		ʌɪT	
tribe	[t ^h raɪb]	tripe	[t ^h rʌɪp]
ride	[ɹaɪd]	right	[rʌɪt]
live	[laɪv]	life	[lʌɪf]
rival	[ɹaɪvəl]	rifle	[ɹʌɪfəl]
tiger	[t ^h aɪgə]	hiker	[hʌɪkə]
pie	[p ^h aɪ]	pipe	[p ^h ʌɪp]

T = [-son, -voice], D = [-son, +voice]
 ʌ = [-low, -high, +back, -round]
 a = [+low, -high, -back, -round]
 ɪ, ʊ = [+syll, +high]

Pig Latin (one dialect):

pie → [ʌɪpeɪ]

buy → [aɪbeɪ]

More data in Hayes 2009 Phonological Alternations II
 Much more data on US dialects in Vance 1987.

Canadian Raising Rule?

[+syll] → [-low] / _[+high] [-voice]

Note: [+high] [-voice] (2 segments) vs. [+high, -voice] (1 segment).

Stress effects: *cíte* [Λit], vs. *citátion* [ait]; *bíceycle* [Λis] vs. *bicúspid* [aik]

Low frequency inhibits rule: *colítis*, *nítrate* [Λit] ~ [ait], some US speakers

Interaction of Flapping and CR

1. write	[rʌɪt]	writing	[rʌɪrɪŋ]	writer	[rʌɪrə]
2. ride	[raɪd]	riding	[raɪrɪŋ]	rider	[raɪrə]
3. cite	[saɪt]	citing	[saɪrɪŋ]		
4. side	[saɪd]	siding	[saɪrɪŋ]		
5. white	[waɪt]	whiter	[waɪrə]		
6. wide	[waɪd]	wider	[waɪrə]		

Flaps are [+voice]. What is the order wrt CR?

Is the interaction transparent or opaque?

Is either rule not surface true/not surface apparent?

Order

UR	raid-ə	rait-ə
CR Flap SR		

- Flapping counterbleeds CR.
- CR is not surface-apparent:
no apparent justification for $[\Delta I]$ in $[\Delta I r V]$.
- The interaction is opaque

An alternative analysis

- The analysis of [ɹ] in *writer* could be due to a very different factor than ordering:
writer [ɹɹɪtə] consists of *write-er* [ɹɹɪt] + [ə]
- When a word occurs in both unaffixed and affixed form, the unaffixed form (*the base*) tends to influence the shape of the affixed stem (the stem of *the derivative*) (Class 20), independently of ordered rules.
- This effect (*phonological cycle* –cf. Galab):
Phonological rules apply to simple words: *write* [ɹɹɪt]
Their effects are inherited by complex words created by affixation: *writ-er* [ɹɹɪtə]
Then more rules apply to the newly created word: *writer* [ɹɹɪtə]. Then more affixation...
- The opacity of CR in interactions with Flapping could be attributed to the cycle.

Extensions of [ʌɪ] to other contexts

- How about unsuffixed words like *titan*, *mitre*, *title*, *vital*.
A look at those.
- [ʌɪ] is also found before $r < t$ (*titan*) but also $r < t$ and before b, g, in some CR dialects:
sp[ʌɪ]*der*, *c*[ʌɪ]*der*, *Sn*[ʌɪ]*der*, *c*[ʌɪ]*ber*, *t*[ʌɪ]*ger*, *t*[ʌɪ]*dal*. Mostly -*er*, -*al* words.
- Speculation: [ʌɪ] has been extended from words like *wr*[ʌɪ]*ter*, from *wr*[ʌɪt].
A new rule could be learned: [aɪ] → [ʌɪ] / _CəR (R=liquid)
This rule doesn't interact with Flapping, so it's not opaque.
- This new rule can also derive CR in words like [rʌɪrə]
But it is not conditioned by [-voice].
Rather it can be learned as Raising conditioned by the last CVC string of the word.

‘Canadian’ Raising before voiced Cs.

Philadelphia speakers: Fruehwald 2008; more noise in this data

Word	Speakers
spider	11/11
cider	11/11
beside	6/11
cyber	6/11
tiny	6/11
idol	5/11
tidal	5/11
dinosaur	4/11
Heinz	4/11
nine	4/11
Snyder	4/11
tidy	4/11

Rate of pronunciations with [ʌɪ]
among F’s Philadelphia speakers

Yet more speculation

- It is possible that grammars of Canadian and NE dialects contained an original counterbleeding interaction, CR > Flapping, a result of some sound change. We lack evidence for this, but it's possible.
- However, much of the data available *today* suggests that this possible interaction is no longer learned as a *counterbleeding* interaction
- It is learned as several non-interacting rules:
Raising in monosyllables; Flapping; er-Raising (in *spider, tiger, writer*)
- Maybe all counterbleeding and counterfeeding interactions are eventually mis-learned in this way. We don't know yet.

Opacity and learning in Polish

Evidence for one rule

Singular	Plural	gloss	
trup	trupi	corpse	
klup	klubi	club	Also: snɔp/snɔpi,
kɔp	kɔpe	shuck corn	nɔs/nɔsi,
trut	trudi	labor	kɔʃ/kɔʃe,
kɔt	kɔti	cat	psɔts/psɔtʃe
wuk	wugi	lye	
wuk	wuki	bow	

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

Evidence for another rule

Singular	Plural	gloss	and note these
bur	bɔri	forest	snɔp/snɔpi,
ʒur	ʒuri	soup	nɔs/nɔsi,
vuw	vɔwi	ox	kɔʃ/kɔʃe,
buj	bɔji	fight	psɔts/psɔtʃe
sul	sɔli	salt	kɔp/kɔpe
			kɔt/kɔti
			trup/trupi
			trut/trudi

[+round] → [+high] / __ [+voice] #

Interaction of Devoicing and Raising

Singular	Plural	gloss
rup	rɔbe	do
lut	lɔdi	ice
ʒvup	ʒvɔbi	cib
nuʃ	nɔʒe	knife
ruk	rɔgi	horn

Derivations

UR				
SR	rup	rɔb-e	kɔp	klup

Derivations

UR	rɔb	rɔb-e	kɔp	klub
Raising	rub	n/a	n/a	n/a
Devoicing	rup	n/a	n/a	klup
SR	rup	rɔb-e	kɔp	klup

Counterbleeding: Devoicing could have bled Raising, had Devoicing come first

Loss of ɔ-Raising in loanwords (Sanders 2002)

Singular	Expected	Plural	Gloss
glɔp	*glɔp	glɔbɪ	‘globe’
snɔp	*snɔp	snɔbɪ	‘snob’
ɛpizɔt	*ɛpizɔt	ɛpizɔdɪ	‘episode’
kɔt	*kɔt	kɔdɪ	‘code’
nɛkrɔɔk	*nɛkrɔɔk	nɛkrɔɔgi	‘obituary’
prɔɔk	*prɔɔk	prɔɔgi	‘prologue’
kɔɔr	*kɔɔr	kɔɔrɪ	‘card suit’
xɔl	*xɔl	xɔɛ	‘lobby’
parasɔl	*parasɔl	parasɔɛ	‘umbrella’
kɔvbɔj	*kɔvbɔj	kɔvbɔjɛ	‘cowboy’

ɔ-Raising doesn't apply
Final Devoicing does

Testing Raising rule with nonce (*wug*) words

(Sanders 2002)

- Nonce plurals words presented with ɔ+voiced C+suffix, in context:
Bardzo ładne cztapody [tʃtapod-i] dały Janowi kawę,
‘the very pretty **cztapod-s** gave Janek coffee’
- Responses elicited: corresponding singulars with final C
Jeden bardzo ładny ____ pozyczył Jankowi i pieniądze i koszulę,
‘one very pretty (**cztapod**) lent Janek both money and a shirt’
- Will Voicing and/or Raising apply?
~~—cztap[ut] or cztap[ot]? or cztap[ud] or cztap[od]?—~~
- Devoicing always applies, but not Raising. No Raising responses.

Conclusion and speculation

- Polish Raising doesn't exist as a productive rule any more
- Opaque interaction with Devoicing could have made Raising harder to learn.

Caveat about learning

- Possible reasons why rules like Polish Raising aren't learned.
 1. Maybe because interaction with Devoicing made Polish Raising opaque.
But Raising fails before sonorants too: **parasol**, **kɔvboj**. No opacity here.
 2. Polish ɔ-Raising is unusual: seems to lack a rationale for the change.
No articulatory or perceptual reason to raise ɔ to u before final [+voice].
(Originally, Raising was motivated, but the original motivation was lost.)
- So, failure to learn Polish Raising *might* tell us that learners expect processes to have a functional rationale: to improve perception/production.
Raising contradicts these expectations.
- Then this could be unrelated to opacity. We don't know.

An AL experiment in learning opaque rules

AL = artificial language

Shimakonde (Bantu, Mozambique) VH

Etlinger, Bradlow, Wong 2014, Applied Psycholinguistics

	<u>Stem</u>		<u>Applicative</u>
a.	kú-píít-a ‘to pass’		kú-pít-ííl-a
b.	kú-páát-a ‘to cut’		kú-pát-ííl-a
c.	kú-péét-a ‘to separate’		kú-pét-éél-a

Vowel Harmony

[+high] → [-high] / [-hi, -lo] C₀__ (iterates)
no e(e) beyond 1st root syll except VH contexts

	<u>Stem</u>		<u>Future</u>
a.	kú-píít-a ‘to pass’		vanda-pít-aan-a
b.	kú-páát-a ‘to cut’		vanda-pát-aan-a
c.	kú-péét-a ‘to separate’		vanda-pát-aan-a vanda-péet-a*

Lengthening

[+syll] → [+long] / __σ#

Reduction

[-high, -long] → [+low] / [+low] C₀__

Interaction of Harmony and Reduction

	Stem		Future Applicative	
a.	kú-píít-a 'to pass'		vanda-pít-ííl-a	'will pass for X'
b.	kú-páát-a 'to cut'		vanda-pát-ííl-a	'will cut for X'
c.	kú-péét-a 'to separate'		vanda-pat-éél-a	'will separate for X'

UR	ku-pet-ila	vanda-pet-ila	ku-pat-ila	
Lengthening	kupetiila	vandapetiila	kupatiila	Lengthening bleeds Reduction
Harmony	kupeteela	vandapeteela	-	
Reduction	-	vandapateela	-	Reduction counterbleeds
SR	kupeteela	vandapateela	kupatiila	Harmony

How do Shimakonde speakers learn this system?

- Maybe they successfully learn the URs,, all the rules and their order.
- Or maybe they learn a partial analysis, without understanding why it's *vanda-pat-eela*, and not **vanda-pat-iila*.
Maybe they can't reconstruct intermediate *-pet-eela*.
- Even without mastering the rule order, they could learn inexplicable forms by heart, or by some other mechanism, e.g.

"Roots with /e/ *in any form* cause following *ii* to lower to *ee*."

Then, since 'to separate' is *ku-peet-a* it must be *vanda-pat-eel-a*

- Ettlinger et al. tried to re-create the Shimakonde learning experience in the lab to investigate what learners actually learn.

Artificial language (AL) based on Shimakonde

Base word
fin
mez
vab

Artificial language (AL) based on Shimakonde

Base	Plural
fin	fin-il
mez	m ez-el
vab	vab-il

Artificial language (AL) based on Shimakonde

Base	Plural	Diminutive
fin	fin-il	ka-fin
mez	m ez-el	ka-m az
vab	vab-il	ka-vab

Artificial language (AL) based on Shimakonde

Base	Plural	Diminutive	Plur-Diminutive	Comment
fin	fin-il	ka-fin	ka-fin-il	Nothing happens here
mez	m ez-el	ka-m az	k a-maz-el	VH i → e/eC ₀ _ Reduc. e → a/aC ₀ _
vab	vab-il	ka-vab	ka-vab-il	Nothing happens here

- 3 conditions: each uses different V as trigger of VH + as undergoer of reduction
Only condition 1 is discussed here. All 3 yielded identical results.
- Stress on stem always.
- Recorded by native speaker of English, who attempts fluent English production.
- Stimuli presented aurally; 36 learners, NWU students.

Format of experiment

1. **Training** (10 mins):

- ➡ stimuli presented aurally; paired pictures to indicate meaning
- ➡ 3 repetitions of 12 nouns, each presented in all its 4 forms

2. Break

3. **Test the 48 trained** forms: stimulus is picture; 2 alternative forms Choose the right form for this language. Feedback.

4. **Test 18 untrained** forms: new picture + new word, uninflected Then choose among two options for an inflected form of that word. One follows the grammar implicit in the training data, one doesn't. e.g. Given word *ged*, is it *ka-gad-el* or *ka-gad-il*? (Cond. 1: *ka-gad-el*)

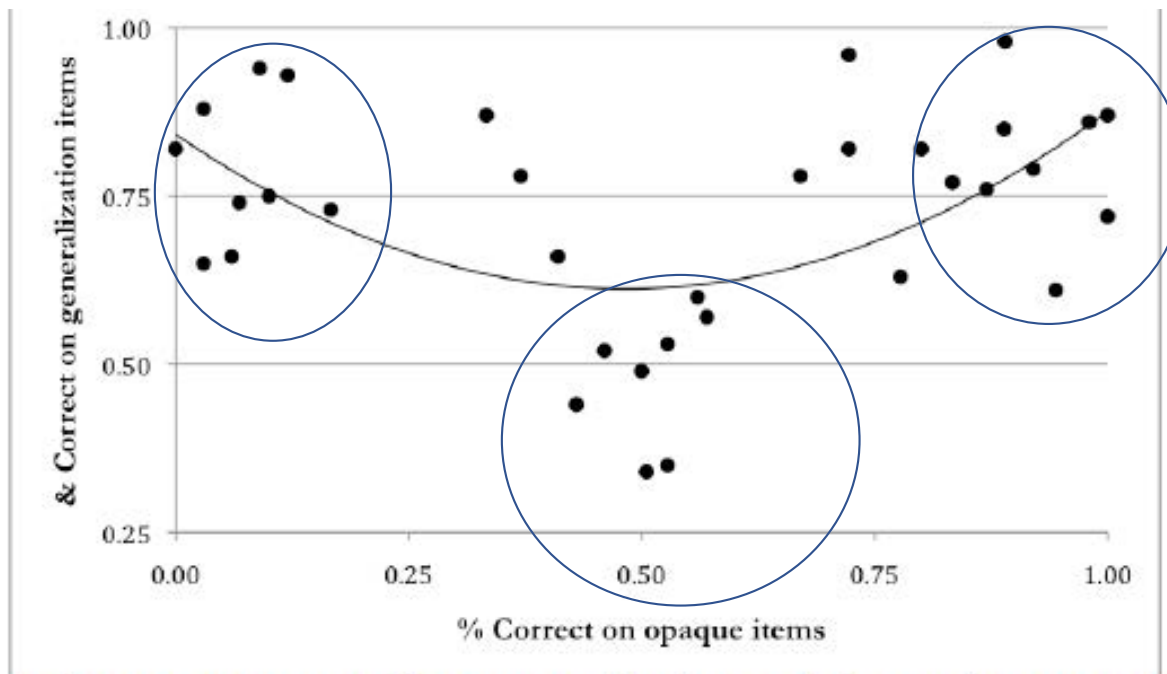
Results (1st of 3 pages saying the same thing in diff. ways)

- Equivalent results across the 3 conditions: didn't matter which V alternates
- All trained items were successfully learned: avg 82% accurate
- Untrained items: accuracy rate for singly affixed items, not involving any process, was 65%. Better than chance.
- Accuracy rate for untrained opaque ka-X-VI items is at chance, 52%.
- But this conflates 3 distinct groups of participants:
 - **learners**: high rates of correct answers to untrained opaque items
E.g. if *ged* then *ka-gad-el*
 - **levellers**: systematic substitution of transparent forms for opaque ones
E.g. if *ged* then incorrect but systematic *ka-gad-il* and correct *ged-el*
 - **non-learners**: unsystematic mistakes on all forms.
E.g. if *ged* then *ka-ged-il*, or *ka-gad-al*, or *ke-ged-el*

Visualizing global results

Trained items		Untrained items	
No process	82% accurate responses	bin, kibin, bin-il, tam, tam-il	65% accurate
Process, transp.		rez, rez-el; rez, ka-raz	[?]
Process, opaque		rez, ka-raz-el	52% accurate

Three groups of participants (each dot = 1 participant)



learners

high accuracy rates on new opaque items
and on all items requiring generalization

levellers

low accuracy rates on new opaque items
high accuracy on all other items

non-learners:

this group is at chance on all new items
requiring any generalization.

Performance on acquiring generalizations relative to the opaque interaction

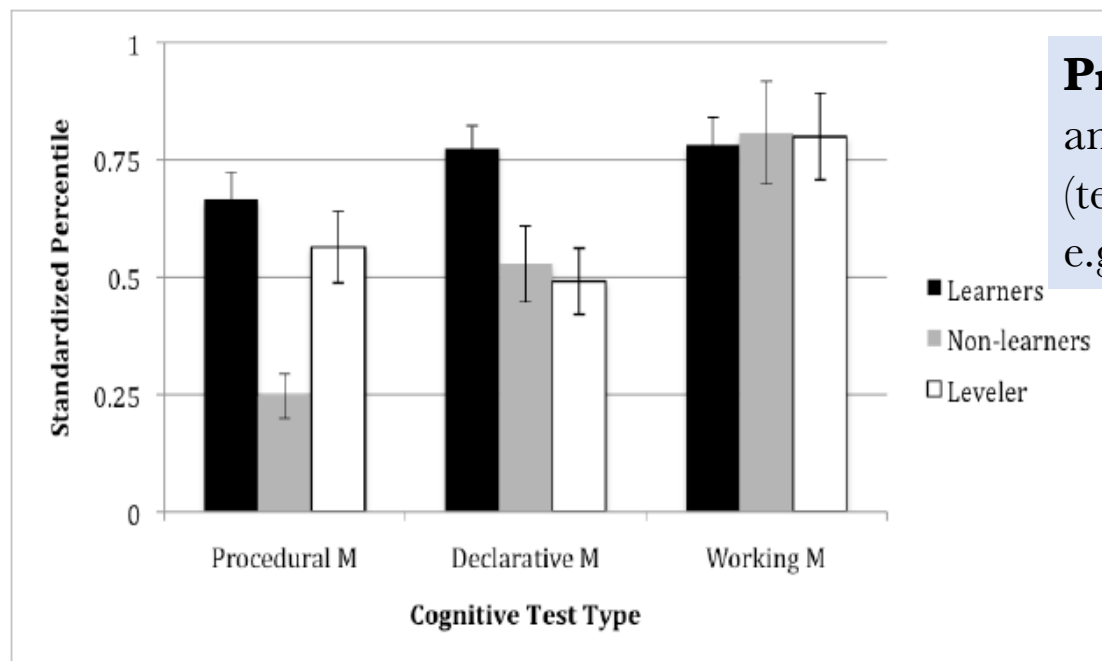
Random choice vs. systematic rejection

- Surprising: levellers do as well as the learners on untrained items requiring generalization, but are *worse than non-learners* on opaque untrained items
- Interpretation: levellers' answers to new opaque items are not random mistakes. Rather, they chose a grammar generating different patterns from those taught in training. Based on the grammar chosen, they reject the opaque pattern, hence very low accuracy scores on those.
- Non-learners are at chance on all new items requiring generalization, including opaque ones. They have higher accuracy rates on opaque items because they answer randomly. They don't systematically reject the opaque pattern, because they haven't learned any pattern.

Possible moral

- There is a claimed instability inherent in opaque systems, over time.
- Possible cause: a subset of the learners reject opaque patterns, like Ettlinger's levellers. Then the question is why.
- No learners reject transparent patterns.

Association of learning style with performance on cognitive tests



Procedural memory: memory and performance on sequential tasks. (test at <https://www.brainiac.com/tol>) e.g. 'Apply VH, then apply Reduction.'

Declarative memory: memory for static data (lexicon) and static generalizations, e.g. 'If Base is *pet*, DimPl is *X-el*' Even if X doesn't contain *e*.

If these associations of learning style with memory tasks are replicated, they suggest that opaque systems are learned as **associative links between the shape of related words**. Not learned as sequential instructions, i.e. **not as rule orders**.

Significance of rule orders

- Optimality Theory (Prince and Smolensky 1993), in its original version, can model most feeding and bleeding interactions.
- Some counterfeeding and some counterbleeding interactions can be modeled indirectly, with new constraint types.
- Some counterfeeding, counterbleeding interactions can't be modeled.
- That's a possible disadvantage for OT analyses.
- But not if the opaque interactions are not learned at all.
- Or if the learning mechanism is different in those cases.

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