LSA.365 | Variation in Optimality Theory, Handout #3
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VARIATION AND OPACITY IN SINGAPORE ENGLISH CONSONANT CLUSTERS

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1. Introduction

(1) Singapore English (SE) exhibits a rich array of consonant cluster processes (Bao 1998, Mohanan 1992, Poedjosoedarmo 2000, Tay 1982; for general background, see Lim and Foley 2004).

(2) Why are SE cluster processes theoretically interesting?
- (a) Simultaneous variation and opacity
- (b) Two kinds of opacity: stratal opacity and variation in the input
- (c) Both input and output variation can be simultaneously modeled using T-orders

(3) The structure of the paper:
- (a) An overview of cluster processes based on Mohanan 1992.
- (b) An elicitation study of /sp/-clusters (56 speakers, 815 cluster tokens).
- (c) A discussion of the opaque interactions among cluster processes.
- (d) An OT analysis of the quantitative variation among cluster processes.

2. Mohanan (1992)

(4) Mohanan (1992) identifies several consonant cluster processes in Educated Singapore English, works out their interactions, and establishes the underlying representations. We start with an overview of Mohanan's analysis.

(5) Plosive Deletion: Delete a plosive in a coda if it is preceded by an obstruent.

(a)	/test/ → [tes]	'test'
(b)	/lisp/ → [lis]	'lisp'
(c)	/lift/ → [lif]	'lift'
(d)	/ækt/ → [æk]	'act'

(6) Voicing Assimilation: An obstruent becomes voiceless when adjacent to a voiceless obstruent in the same syllable.

(a)	/set-z/ → [sets]	'sets'
(b)	/bæg-z/ → [bægz]	'bags'

(7) Epenthesis: Insert a [ə] between tautosyllabic consonants if they share the same manner and primary place of articulation. Note that Voicing Assimilation feeds Epenthesis.

(a) /reiz-z/ → [reizəz] 'raises'
(b) /his-z/ → hiss → [hisəs] 'hisses'

(8) Metathesis: *sp* becomes *ps* in the syllable coda. Mohanan describes two dialects:

	Dialect A	Dialect B	
(a)	/lisp/ → [lips]	/lisp/ → [lips]	'lisp'
(b)	/lisp-iŋ/ → [lispiŋ]	/lisp-iŋ/ → [lipsiŋ]	'lisping'

(9) Degemination: If a consonant is preceded by an identical consonant in the same syllable, delete it. Note that Voicing Assimilation feeds Plosive Deletion and Metathesis which in turn feed Degemination.

(a) /list-z/ → lists → liss → [lis] 'lists'
(b) /lisp-z/ → lisps→ lipss → [lips] 'lisps'

(10) Variation:
(a) Metathesis vs. Plosive Deletion: [lips], [lis]
(b) Metathesis before vowel: [lispiŋ], [lipsiŋ]

(11) Opacity:
(a) Epenthesis counterbleeds Voicing Assimilation
/his-z/ → hiss → [hisəs] (*[hisəz])
(b) Metathesis counterfeeds Epenthesis:
/grasp-z/ → grasps → grapss → [graps] (*[grapsəs])
(c) Deletion counterbleeds Metathesis (some speakers):
/lisp/ → [lips] (*[lis])

(12) Rule ordering: Voicing Assimilation < Epenthesis < Metathesis < Deletion. Adding the transparent Degemination, we arrive at the ordering in (13).

(13) The ordering of cluster processes in Educated Singapore English (Mohanan 1992)

	(a) /list-z/	(b) /his-z/	(c) /grasp-z/	(d) /lisp/	(e) /læps-z/
Assimilation	lists	hiss	grasps	--	læpss
Epenthesis	--	hisəs	--	--	læpsəs
Metathesis	--	--	grapss	lips	--
Deletion	liss	--	--	--	--
Degemination	lis	--	graps	--	--
	[lis]	[hisəs]	[graps]	[lips]	[læpsəs]
	'lists'	'hisses'	'grasps'	'lisp'	'lapses'

(14) Two further opacities between non-adjacent processes are predicted:
  (a) Deletion counterfeeds Epenthesis:
  /list-z/ → *lists* → *liss* → *lis* (**li*[səs])
  (b) Degemination counterbleeds Epenthesis:
  /his-z/ → *hiss* → *hi*[səs] (**his*)

(15) Note that the opacity involves 4 levels, exceeding the 3 levels allowed by Stratal Optimality Theory (Kiparsky 2000, 2003).

3. Quantitative patterns in /sp/-clusters

(16) Why focus on Metathesis?
  (a) Metathesis interacts opaquely with both earlier and later processes.
  (b) Metathesis is rare compared to e.g. plosive deletion (Guy 1991a,b).
  (c) Metathesis is easy to hear and therefore easy to study.

(17) Hypothesis: Based on earlier studies of cluster processes, in particular *t,d*-deletion, we would expect the vowel vs. pause vs. consonant environment to matter.

(18) Procedure:
  (a) Subjects: 56 N.U.S. undergraduates.
  (b) 17 sentences presented as an ordered list (Appendix A).
  (c) The list was read through twice in the same order.
  (d) 8 target examples × 56 speakers × 2 repetitions = 896 tokens. Only 883 obtained.

(19) The target examples:

	NEXT WORD	
NEXT SEGMENT	V-INITIAL	C-INITIAL
#V	*Say* lisping *again*	*Say* lisping *my way*
##	*Say* lisp *again*	*Say* lisp *my way*
#C = /z/	*Say* lisps *again*	*Say* lisps *my way*
#C = /d/	*Say* lisped *again*	*Say* lisped *my way*

(20) Results:
  (a) Transcribed by two individuals using PRAAT (Boersma & Weenink 1996).
  (b) Annotated for phonology, morphology, speaker (Appendix B)
  (b) Excluded tokens:
    - 26 hapaxes (Appendix C)
    - 23 tokens where the two transcribers disagreed
    - 19 uninterpretable tokens
  (c) Result: 815 remaining tokens which cover about 92% of the elicited target data.

(21) How to classify the raw data?
  (a) The focus of this study: segment reordering (metathesis, copy) and epenthesis
  (b) Other processes: lenition (deletion, degemination, changes in place and manner).

(22) Why this choice? Reordering and epenthesis are LEXICAL, lenition POSTLEXICAL.

(23) Data classification

	_#V lisp#iŋ		_## lisp##		_#z lisp#z		_#d lisp#d	
Faithful	*lispiŋ*	146	*lisp*	75	*lisps*	53	*lispt*	37
p-Deletion	--		--		--		*list*	11
t/d-Deletion	--		--		--		*lisp*	10
s-Deletion	--		--		*lisp*	13	--	
Assimilation	--		*list*	3	*lists*	4	--	
p-Deletion	--		*lis*	7	--		--	
p-Deletion + *s*-Deletion	--		--		*lis*	5	--	
s-Stopping	--		--		*lispt*	2	--	
s-Deletion	--		--		--		*lipt*	2
s-Deletion + Assimilation	--		--		--		*lift*	3
No Metathesis		**146**		**85**		**77**		**63**
Metathesis	*lipsiŋ*	27	*lips*	84	*lipss*	18	*lipst*	95
Metathesis + Degemination	--		--		*lips*	68	--	
Metathesis + Assimilation	--		*lits*	7			--	
Metathesis + Assim. + Deg.	--		--		*lits*	10	--	
Metathesis + Fricativization	--		*lifs*	12			*lifst*	9
Metathesis + Fric. + Deg.	--		--		*lifs*	15	--	
Metathesis + *t/d*-Deletion	--		--		--		*lips*	14
Metathesis + *t/d*-Del. + Ass.	--		--		--		*lits*	3
Metathesis		**27**		**103**		**111**		**121**
Metathesis + Epenthesis	--		--		*lipsəs*	9	--	
Metathesis + Epenth. + Fric.	--		--		*lifsəs*	3	--	
Epenthesis						**12**		
p-Copy + no lenition	*lipspiŋ*	22	*lipsp*	2	--		--	
p-Copy + Assimilation	*litspiŋ*	5	*lipst* *litsp*	8 2	*litsps*	2	*litspt*	2
p-Copy + Fricativization	*lipsfiŋ* *lifspiŋ*	4 4	*lifst*	3	--		--	
p-Copy + Fric. + Assim.	*lifstiŋ*	3	--		--		--	
p-Copy + Ass. + *s*-Del.	--		--		*lipst*	3	--	
p-Copy + Fr. + As. + *s*-Del.	--		--		*lifst*	4	--	
***p*-Copy**		**38**		**15**		**9**		**2**
s-Copy	--		--		--		*lispst*	4
s-Copy + t/d-Del.	--		--		--		*lisps*	2
***s*-Copy**								**6**

(24) The classification procedure

1. For each token, strip off the final suffix, i.e. *-ing*, *-s*, *-t*, if present.
2. Classify the tokens by the remaining part of the cluster by applying the following rules, in this order (+ = 'immediately follows'):
   (a) *p*-Copy: Stem vowel + stop or labial fricative + *s* + stop or labial fricative (*lipsp-*, *litsp-*, *lipst-*, *lipsf-*, *lifsp-*, *lifst-*)
   (b) *s*-Copy: Stem vowel + *sps-* (*lisps-*)
   (c) Metathesis: Stem vowel + stop or labial fricative (*lips-, lits-*, *lifs-, lip-, lit-, lif-*)
   (d) Epenthesis: Stem-final *sə-* (*lipsə-, lifsə-*).
   (e) No Metathesis: All other tokens

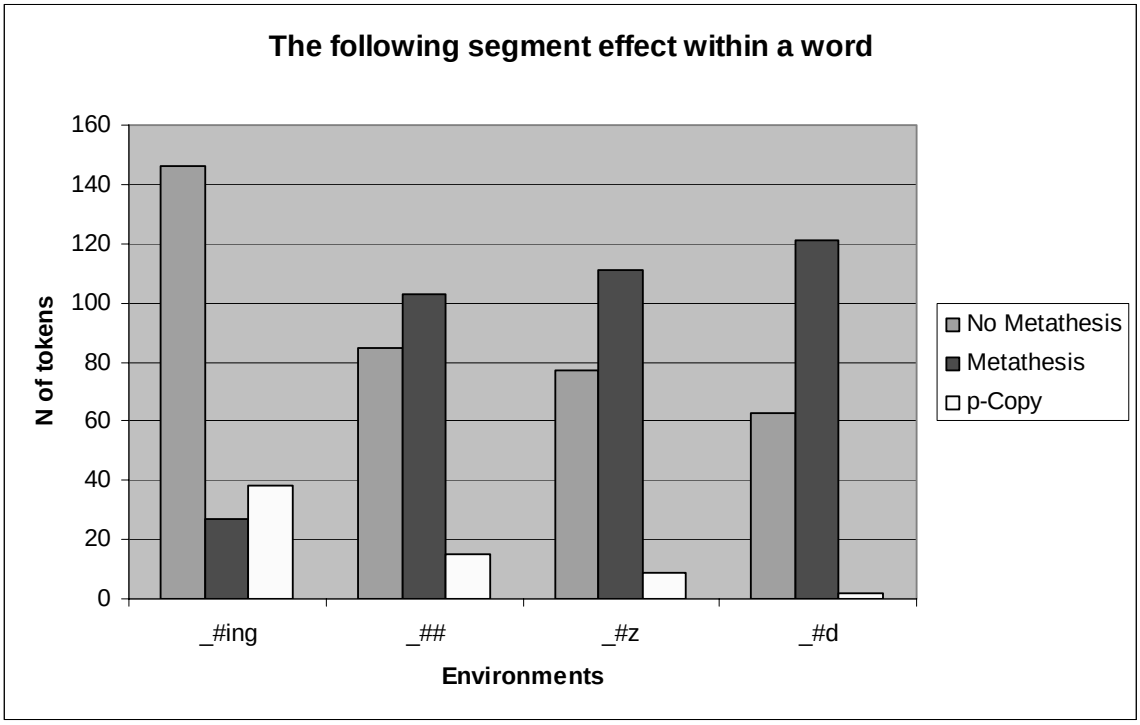
(25) Attested types of segment reordering (abstracting away from lenition):

		_#V	_##	_#z	_#d
(a)	Faithful:	*lispiŋ*	*lisp*	*lisps*	*lispt*
(b)	Metathesis:	*lipsiŋ*	*lips*	*lipss*	*lipst*
(c)	Epenthesis:	--	--	*lipsəs*	--
(d)	*p*-Copy	*lipspiŋ*	*lipsp*	*lipsps*	*lipspt*
(e)	*s*-Copy	--	--	--	*lispst*

(26) The following segment effect within a word (aggregate data)

	_#V lisp#ing	_## lisp##	_#z lisp#z	_#d lisp#d	TOTAL
No Metathesis	69.2% (146)	41.9% (85)	36.8% (77)	32.8% (63)	(371)
Metathesis	12.8% (27)	50.7% (103)	53.1% (111)	63.0% (121)	(362)
p-Copy total	18.0% (38)	7.4% (15)	4.3% (9)	1.0% (2)	(64)
Epenthesis	--	--	5.7% (12)	--	(12)
s-Copy total	--	--	--	3.1% (6)	(6)
TOTAL	100% (211)	100% (203)	100% (209)	100% (192)	(815)

(27) The following segment effect within a word. Epenthesis and *s*-Copy have been omitted. Chi square = 145.06, df = 6, $p \leq 0.001$.



(28) Generalizations:
- (a) Metathesis is common in _#C, less common in _##, least common in _#V.
- (b) Copy is common in _#V, less common in _##, least common in _#C.

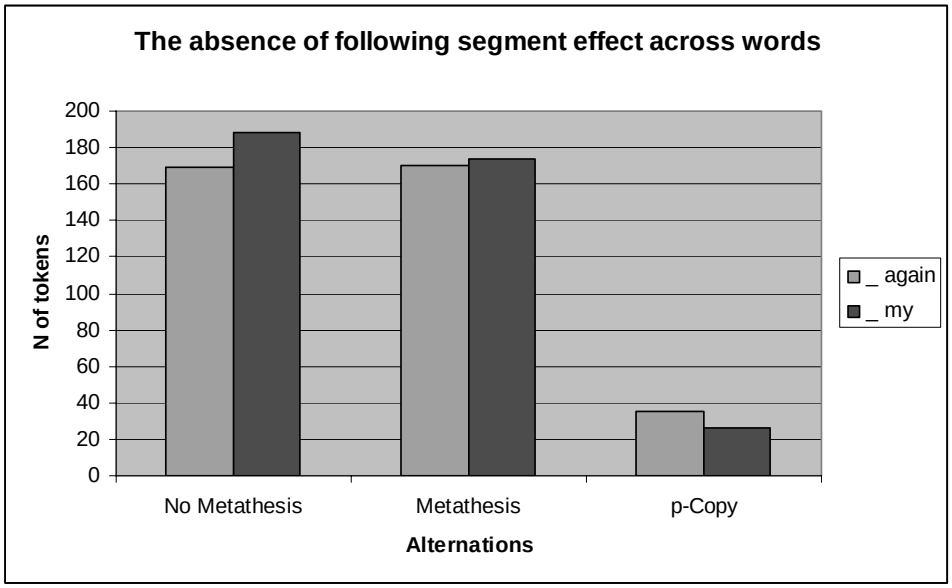
(29) Metathesis is preferred before consonants, much like *t,d*-deletion (see Coetzee 2004:214-329 for a recent summary).

(30) Copy appears to split a stop, perhaps to provide a stop onset in a prevocalic environment.

(31) The absence of the following segment effect across words

		_ again	_my way
_#V lisp#ing	Faithful	63	76
	Metathesis	9	15
	Copy	21	14
_## lisp##	Faithful	37	47
	Metathesis	55	46
	Copy	6	9
_#C lisp#z	Faithful	35	38
	Metathesis	47	54
	Copy	7	2
_#C lisp#d	Faithful	34	27
	Metathesis	59	59
	Copy	1	1

(32) The absence of the following segment effect across words: all environments
Chi square = 2.13, df = 2, $p \leq 1$.



(33) In the environment *lisp##* where you would expect to find an effect, the chi square value is about the same (= 2.51, df = 2, $p \leq 1$).

(34) Conclusion: The first segment of the next word has no effect on segment reordering within the cluster. This suggests that Metathesis is lexical, not postlexical.

(35) Postlexical metathesis appears cross-linguistically unattested. [However, in Leti (Hume 1998b) metathesis apparently arises because phonological phrases must end in a vowel.]

(36) Notes on across-the-word data:
  (a) Only 762 tokens (instead of 797). 35 tokens were unusable because the input and the output failed to match (e.g. 'lisped again' → *lisping my*, 'lisping again' → *lipsping magain* (presumably a blend of *my* and *again*).
  (b) In 74 tokens, the speaker inserted a pause between words, e.g. *lisp ## my way*. These tokens are currently included.

4. Process interaction

4.1 First approximation

(37) Stratal Optimality Theory (e.g. Kiparsky 2000, 2003; see also Anttila 2006, Bermúdez-Otero 1999, Itô & Mester 2002, Kenstowicz 1995, Kiparsky 1982, McCarthy & Prince 1993, Mohanan 1986, Rubach 2000, among others):

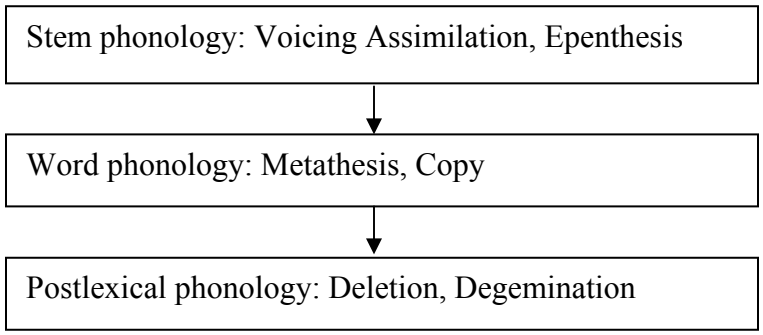
  (a) Morphological and phonological derivations apply in tandem, inside out.
  (b) Three morphosyntactic levels: Stem, Word, Postlexical

(38) Prediction: A process can be sensitive to morphosyntactic material introduced at the same or an earlier level, but not to material introduced at a later level.

(39) Metathesis and Copy belong to the word level:
  (a) Sensitive to the _V vs. _C distinction within a word, but not across words, hence lexical, not postlexical.
  (b) Sensitive to *-ing*, *-z*, *-d*, hence word-level, not stem-level.

(40) Putting this together with Mohanan's (1992) analysis:
  (a) All processes preceding Metathesis must be stem-level
  (b) All processes following Metathesis must be postlexical.

(41) Tentative level ordering for Singapore English



(42) Predictions:
  (a) Voicing Assimilation and Epenthesis should interact transparently and be sensitive only to stem-level morphology.
  (b) Metathesis should be able to opacify Voicing Assimilation and Epenthesis and be sensitive to both stem-level and word-level morphology.
  (c) Deletion and Degemination should interact transparently; they should never be opaque themselves, but should be able to opacify all other processes; they should have no morpholexical conditions; and they should be sensitive to phonological material across word boundaries.

(43) Two problems:
  (a) Epenthesis counterbleeds Voicing Assimilation: *rai*[zəz], *hi*[səs].
  (b) Epenthesis is sensitive to word-level morphology: /-z/.

4.2 Voicing Assimilation and Epenthesis

(44) The empirical generalization is suspect:
  (a) The contrast between voiced and voiceless fricatives and affricates is neutralized word-finally, even in careful speech, e.g. *edge = etch*, *rice = rise*, *leaf = leave = live*, *this = these* (Gupta 1995)
  (b) The opacity is suspect on typological grounds (Kenstowicz & Kisseberth 1977:163): There are no other known cases of Epenthesis counterbleeding Voicing Assimilation, whereas bleeding is common (Lithuanian, Latvian, Hebrew, most Slavic languages); see Schein and Steriade 1986, McCarthy 1986, Hayes 1986 for geminate inalterability; Kiparsky 2006)

(45) Some speakers exhibit the following pattern (Tara Mohanan, p.c.):
  (a) After vowels and voiceless consonants /-z/ is devoiced: *bee*[s], *hi*[səs], *ro*[zəs] (!), *se*[ts]
  (b) After voiced consonants either /-z/ or the entire cluster is optionally devoiced: *do*[gz] ~ *do*[gs] ~ *do*[ks].

(46) Result: *hi*[səs] is transparent.

(47) Conclusion:
  (a) All lenition processes are postlexical. This includes Voicing Assimilation and Fricativization which counterbleeds Metathesis: /lisp/ → lips → [lifs].
  (b) Only Epenthesis, Metathesis, and Copy remain in the lexical phonology.

(48) An analysis suggested by Michael Kenstowicz (p.c.): the plural suffix may have been reanalyzed as /s/. Note that this would require analyzing the variant *do*[gz] as the result of optional progressive voicing assimilation.

(49) Other analytical options (suggested by reviewers):
(a) *hisse*[s] as long-distance voicing agreement (Rose and Walker 2004)
(b) Treat schwa as a transparent vowel, possibly devoiced between two [s]'s.

(50) All these analyses make voicing assimilation a surface phenomenon rather than an early lexical process.

(51) Conclusion: The case for opacity appears weak.

4.3 Epenthesis and Metathesis

(52) Mohanan's (1992) evidence for counterfeeding opacity:

	/læps-z/	/lisp-z/
Epenthesis	læpsəs	--
Metathesis	--	lipss
Degemination	--	lips
	[læpsəs]	[lips] (*[lipsəs])

(53) Could the underlying form be /lips/? That cannot be because Epenthesis applies in [læpsəs], but not in [lips], showing that the former has a word-final underlying sibilant (/læps/), the latter does not (/lisp/). (Mohanan 1992:122)

(54) The counterfeeding problem in Optimality Theory: how to rank *S-S and DEP?

/lisp-z/	*S-S	DEP	LIN
a. lipss	*?		*
b. lipsəs		*?	*
/læps-z/	*S-S	DEP	LIN
a. læpss	*?		
b. læpsəs		* ?	

(55) Note that the opacity argument only goes through if [lips] and [læpsəs] are the only possible outputs. In reality, there is variation.

(56) The variation in 'lisps':
(a) Metathesis (7 types, 120 tokens) = Mohanan's data:
lips (68), *lipss* (18), *lifs* (15), *lits* (10), *lifst* (4), *lipst* (3), *litsps* (2)
(b) No Metathesis (5 types, 77 tokens):
lisps (53), *lisp* (13), *lis* (5), *lists* (4), *lispt* (2)
(c) Epenthesis (2 types, 12 tokens):
lipsos (9), *lifsos* (3)

(57) As for 'lapses', verbal inflections are systematically optional (Fong 2004).

(58) Conclusion:
  (a) Both Epenthesis and Metathesis are word-level processes. The apparent opacity arises from multiple transparent grammars that result in variation, e.g. [lips] ~ [lisps]; [læpsəs] ~ [læps].
  (b) There may be variation in the input as well: both /lisp/ and /lips/ are clearly possible underlying forms since both are common outputs.

(59) Note that [lipsəs] is relatively marginal. How to account for this?

(60) An alternative hypothesis: Could the opacity of *lips* vs *lapses* be a spelling effect (as suggested by two reviewers): schwa is pronounced when it is written.

(61) French: *cette housse* 'this cover' [sɛtʔus] ~ [sɛtœus] vs. *sept housses* 'seven covers' [sɛtʔus] (*[sɛtœus]). Two alternative hypotheses:
  (a) *cette* has a final underlying schwa (Dell 1973)
  (b) The effect is due to spelling (Tranel 1981) [apparently the correct explanation]

(62) However, this cannot be the case in Singapore English:
  (a) If epenthesis was merely a spelling effect, we would expect no epenthesis in *lisps*, but in fact we find 12 tokens: *lipsos* (9 tokens), *lifsos* (3 tokens).
  (b) Conversely, we would expect epenthesis in *lisped*, but in fact we only find one token: *lispot* (1 token). The pattern is thus exactly the opposite of what one would expect if epenthesis were merely a spelling effect.

(63) Conclusion: This suggests that epenthesis is phonologically real.

4.4 The status of Deletion

(64) Prediction: Stop deletion is postlexical. What is the empirical evidence?

(65) Dmitrieva (2006) studied *t*-deletion based on the *test*-examples in our corpus (= the "distractor items"), following the methodology of Myers (1995).

(66) Dmitrieva measured the interval from the offset of the vowel in *test* until the onset of the vowel in *again* or the nasal in *my* (e.g. *Say test again* vs. *Say test my way*).

(67) Hypothesis: The interval should be shorter in preconsonantal environments (_ *my*) than in prevocalic environments (_ *again*), reflecting the higher rate of preconsonantal *t*-deletion.

(68) Result: Impressionistic evidence supported the hypothesis to some extent (18/44 pre-C deletions vs. 11/44 pre-V deletions), but the duration measurements did not show a statistically significant difference between the two environments, thus providing no direct evidence for the postlexical status of *t,d*-deletion.

(69) However, there are reasons for the absence of duration evidence (Dmitrieva 2006):
  (a) The initial consonant [m] in *my* is a nasal sonorant which shares many acoustic qualities with vowels. [Try the same with a following obstruent, e.g. *t, d, z*]
  (b) Deletion may not affect timing: *t,d* may delete more often in *test my* than in *test again*, but what is actually deleted is just the articulatory gesture, not the timing slot, which would resulting in the compensatory lengthening of the preceding [s].
  (c) The participants may have attempted to read the words very clearly, inserting a pause after the test word (74 clear cases).

5. Deriving variation

5.1 The candidate set

(70) Assumptions:
  (a) Reordering respects morpheme boundaries, e.g. a suffix [s] cannot correspond to a root /s/ and inflectional morphemes strictly follow stems.
  (b) Schwa-epenthesis only occurs between morphemes (e.g. **lipes*, **lipse*, …)

(71) Consider all candidates of the form *li*{*s,p*}+. Both can occur multiple times because of Copy. If cluster length is at most 3, we get 14 candidates: *li*{s,p} (2), *li*{s,p}{s,p} (4), *li*{s,p}{s,p}{s,p} (8).

(72) If MAX and IDENT are undominated, then both /p/ and /s/ must be realized at least once, ruling out **lip*, **lis*, **lipp*, **liss*, **lippp*, **lisss*, which leaves 8 candidates.

(73) Epenthesis:
  (a) Relevant for /lisp#z/ and /lisp#d/, e.g. *lips*[ə]*s*, *lisp*[ə]*s*, *lisp*[ə]*d*, *lipsp*[ə]*d*, etc. which doubles the number of candidates for these inputs (= 16).
  (b) Assumption: *lisp*[ə]*ing*, is ruled out by the high-ranked *HIATUS.

(74) Since lenition is postlexical, a single candidate corresponds to several forms:

lisp:	*lisp*, *list*, *lis*
lips:	*lips*, *lits*, *lifs*
lipsp:	*lipsp*, *lipst*, *litsp*, *lifst*
lisp-ing:	*lisping*
lips-ing:	*lipsing*
lipsp-ing:	*lipsping, litsping, lipsfing, lifsping, lifsting*
lisp-s:	*lisps, lisp, lists, lis, lispt*
lips-s:	*lipss, lips, lits, lifs*
lipsp-s	*litsps, lipst, lifst*
lips-es:	*lipsos, lifsos*
lisp-t:	*lispt, list, lisp, lift, lipt*
lips-t:	*lipst, lifst, lips, lits*
lipsp-t:	*litspt*
lisps-t	*lispst, lisps*

5.2 Constraints and rankings

(75) Cluster constraints (see e.g. Côté 2000, Hume 1998a, Steriade 2001)

TV	An underlying stop is realized before a vowel.
TVT	An underlying stop is realized next to a vowel.
*OTO	No inter-obstruent stops.
*S-S	No adjacent sibilants.

(76) Faithfulness constraints:

MAX	No deletion (undominated at the word level)
DEP	No epenthesis.
INT(EGRITY)-IO	Input segments are not split in the output.
LIN(EARITY)-IO	If $S_1 < S_2$ in the input, then $S_1' < S_2'$ in the output.

(77) Our interpretation of the constraint LIN-IO crucially differs from that in McCarthy and Prince 1995:371) Here's the difference:

(78) Defining LINEARITY:

(a) A > B in the input if and only if not B' > A' in the output (McCarthy and Prince 1995)

(b) If A > B in the input, then A' > B' in the output.

(79) Violation patterns

(a) McCarthy and Prince (1995)

/sp/	LINEARITY-IO
sp	
ps	*
psp	*

(b) Our interpretation

/sp/	LINEARITY-IO
sp	
ps	*
psp	

(80) The interpretations are equivalent except in the case of Copy.

(81) Rankings:

(a) Only *S-S can trigger Epenthesis, hence DEP >> { TV, TVT, *OTO}.

(b) *S-S cannot trigger Metathesis, witness the absence of "reverse metathesis" of type /læps#z/ → *[læsps], hence LIN-IO >> *S-S.

(c) TV cannot trigger Metathesis, witness the absence of "reverse metathesis" of type /læps#ing/ → *[læsping], hence LIN-IO >> TV.

(82) The violation profile for /lisp#z/

/lisp-z/	*S-S	DEP	LIN-IO	INT	TV	TVT	*OTO
lisp-s					1	1	1
lips-s	1		1		1		
lipsp-s				1	1		1
lipps-s	1		1	1	1		1
lipss-s	1		1	1	1		
lispp-s				1	1	1	2
lissp-s				1	1	1	1
lisps-s	1			1	1	1	1
lisp-es		1					
lips-es		1	1		1		
lipsp-es		1		1			
lissp-es		1		1			
lipps-es		1	1	1	1		1
lipss-es		1	1	1	1		
lispp-es		1		1			1
lisps-es		1		1	1	1	1

5.3 Variation in the output

(83) Factorial typology computed by OTSoft (Hayes, Tesar & Zuraw 2003). The gray cells mark Metathesis.

```
With 7 constraints, the number of logically possible grammars is 5040.
There were 5 different output patterns.

            Output #1   Output #2   Output #3   Output #4
/lisp/:     lisp        lisp        lips        lipsp
/lisp-ing/: lisp-ing    lisp-ing    lisp-ing    lisp-ing
/lisp-z/:   lisp-s      lips-s      lips-s      lips-s
/lisp-d/:   lisp-t      lips-t      lips-t      lips-t

            Output #5
/lisp/:     lipsp
/lisp-ing/: lisp-ing
/lisp-z/:   lipsp-s
/lisp-d/:   lipsp-t
```

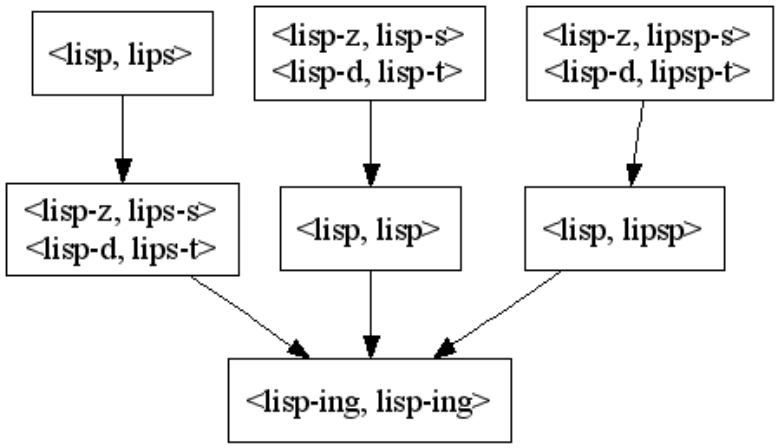
(84) Note that if we consider 3 variants (Faithful, Metathesis, Copy) and 4 environments (*_ing*, *_##*, *_z*, *_d*), pure combinatorics predicts $3^4 = 81$ dialects.

(85) Two implicational universals hidden in the factorial typology:
- (a) Metathesis in /lisp-z/ implies Metathesis in /lisp-d/, and vice versa.
- (b) Metathesis in /lisp/ implies Metathesis in /lisp-z/ (and /lisp-d/).

(86) T-ORDER = the set of all implicational universals in a factorial typology

(87) How to figure out all the implications quickly and easily?

(88) T-order, underlying form /lisp/

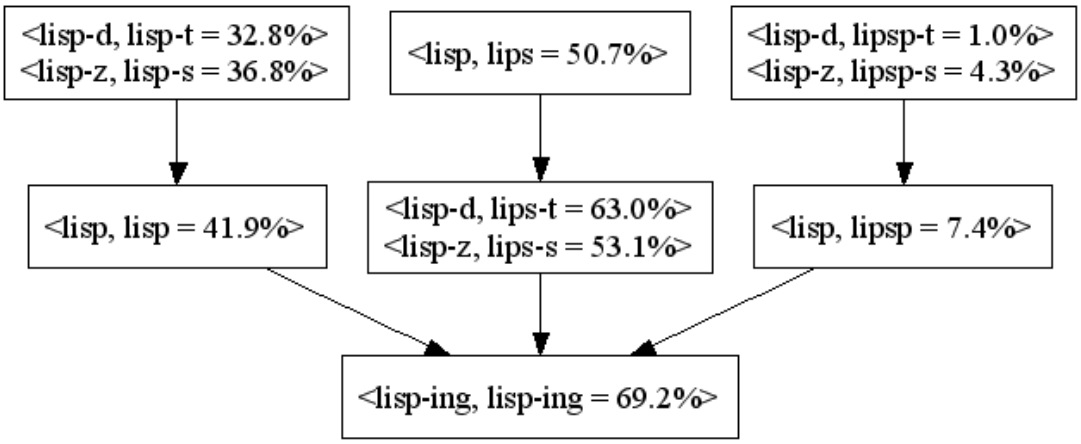


(89) Prose statements
- (a) Metathesis before a pause (*lips*) implies metathesis before a consonant (*lips-s*, *lips-t*).
- (b) If a *sp*-cluster surfaces faithfully before a consonant (*lisp-s, lisp-t*), it surfaces faithfully before a pause (*lisp*); if a *sp*-cluster surfaces faithfully before a pause (*lisp*), it surfaces faithfully before a vowel (*lisp-ing*).
- (b) If a *sp*-cluster undergoes copy before a consonant (*lipsp-s*, *lipsp-t*), it undergoes copy before a pause (*lipsp*).

(90) The variation connection:
- (a) Assume that variation arises from multiple grammars within/across individuals (Kiparsky 1993, Anttila 2007)
- (b) Assume that the number of grammars predicting an output is proportional to the frequency of occurrence of this output (Anttila 1997).

(91) Quantitative predictions:
- (a) /lisp-z/ and /lisp-d/ should undergo Metathesis at the same rate.
- (b) Metathesis in /lisp-z/ and /lisp-d/ should be at least as common as Metathesis /lisp/.
- (c) etc.

(92) T-order annotated with corpus frequencies. Precision = 0.857, Recall = 0.5



(93) The precision errors arise from the 3 cyclic pairs (= boxes). These exist because no constraint distinguishes /-d/ and /-z/. The problematic edges:

```
<lisp-z, lisp-s = 36.8> --> <lisp-d, lisp-t = 32.8>
<lisp-z, lipsp-s = 4.3> --> <lisp-d, lipsp-t = 1.0>
<lisp-d, lips-t = 63.0> --> <lisp-z, lips-s = 53.1>
```

(94) The precision errors are not statistically significant: chi square = 1.788, *df* = 1, *p* = 0.1812 (*p*-Copy omitted).

	/lisp-z/	/lisp-d/
No Metathesis	77	63
Metathesis	111	121
p-Copy	9	2

(95) Problem: Some existing variants are not predicted:

(a)	/lisp-ing/ → *lipsing*	prevocalic Metathesis	(27 tokens)
(b)	/lisp-ing/ → *lipsping*	prevocalic Copy	(38 tokens)
(c)	/lisp-z/ → *lipsəs*	Epenthesis	(12 tokens)

(96) These are all instances of OVERAPPLICATION OPACITY: there is a faithfulness violation that has no apparent surface reason (McCarthy 1999).

(97) If the input is /lisp-ing/, the analysis only predicts the variant *lisping* (Faithful, 146 tokens). This is because *lisping* does not violate any constraints. The variants *lipsing* (Metathesis, 27 tokens) and *lipsping* (Copy, 38 tokens) are harmonically bounded.

(98) The opacity of *lipsing* and *lipsping*

/lisp-ing/	TV	INTEGRITY	LINEARITY-IO
a. lisping (N = 146)			
b. lipsing (N = 27)	*		*
c. lipsping (N = 38)		*	

(99) If the input is /lisp-z/, the analysis predicts three surface variants: *lisp-s* (Faithful, 77 tokens), *lips-s* (Metathesis, 111 tokens), and *lipsp-s* (Copy, 9 tokens). The variant *lips-es* (Epenthesis, 12 tokens) is harmonically bounded:

(100) The opacity of *lips-es*

/lisp-z/	*S-S	DEP	LIN-IO	INT	TV	TVT	*OTO
a. lisp-s (N = 77)					*	*	*
b. lips-s (N = 111)	*		*		*		
c. lipsp-s (N = 9)				*	*		*
d. lips-es (N = 12)		*	*		*		
e. lisp-es (N = 0)		*					

(101) How to derive Metathesis and Copy in prevocalic position (*lipsing*, *lipsping*, *lips*[ə]*s*)?

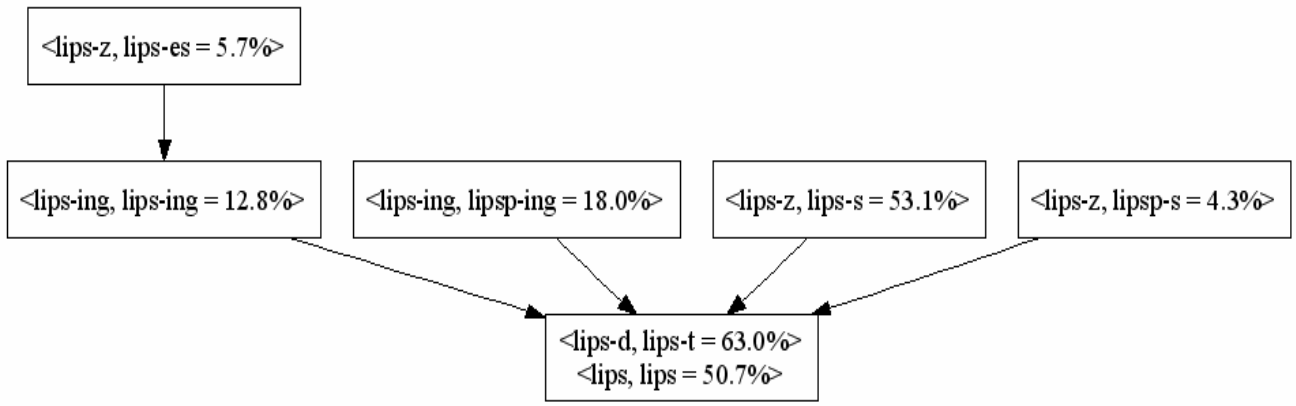
5.4 Variation in the input

(102) Solution: Both /lisp/ and /lips/ are possible underlying forms.

(103) The opacity is thus only apparent and results from the assumption that each output may only have one underlying form, i.e. there can be no variation in the input (= ambiguity).

(104) The possibility of /lips/ in the input must be considered for two reasons:
- (a) Both the transparent *lisp* and the "opaque" *lips* exist in the output. There is thus no reason why the speaker should not store both forms in the lexicon. Mohanan's argument against /lips/ was crucially based on the nonexistence of *lipses*. However, as we have seen, this form occurs 12 times in our corpus.
- (b) An underlying /lips/ is required in any case by Richness of the Base (Prince and Smolensky 1993/2004:225).

(105) T-order for the underlying form /lips/, annotated with corpus frequencies. Precision: 0.846, Recall: 0.647 [+++ Does this take into account ambiguous percentages? +++]



(106) Thus, by assuming an underlying /lips/, *lipsing*, *lipsping* and *lipses* become transparent.

(107) Some existing variants are not predicted. However, all these forms can be derived from an underlying /lisp/:

lisp	No Metathesis before _##
lipsp	Copy before _##
lisping	No Metathesis before _#*ing*
lisps	No Metathesis before _#*z*
lisp	No Metathesis before _##
lipspt	Copy before _#*d*

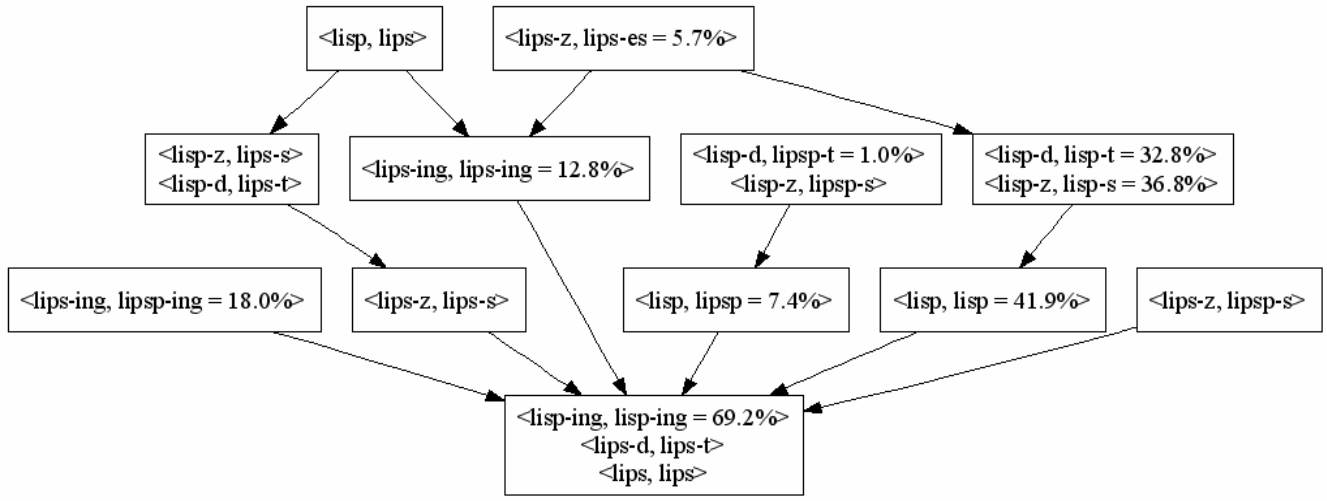
(108) Questions:

(a) How do we know what underlying forms the speakers have? We don't, although naïve spelling might provide evidence (Keith Johnson, p.c.)

(b) Could the same speaker have both /lisp/ and /lips/? That seems entirely possible.

(109) Are quantitative predictions still possible? Yes, compute the T-order for both /lisp/ and /lips/ in parallel.

(110) T-order, underlying form either /lisp/ or /lips/: precision = 0.941, recall = 0.485



(111) One precision problem remains: the analysis predicts that the two preconsonantal environments should not differ. The difference is not statistically significant (see above).

(112) The rare form *lipses* (N = 12, 5.7%) implies that Metathesis should be possible everywhere else, i.e. *lipsing* (12.8%), *lipst*, and *lips*.

(113) The grammar makes predictions about variation and preferences in the input (ambiguity):

	OUTPUT	POSSIBLE INPUTS	PREFERENCES
(a)	lips	lisp, lips	lips > lisp
(b)	lips-s	lips-z, lisp-z	lips-z > lisp-z
(c)	lips-t	lisp-d, lips-d	lips-d > lisp-d
(d)	lipsp-s	lips-z, lisp-z	--

(114) We have now resolved all of Mohanan's (1992) opacities:

	OPACITY	SOLUTION
(a)	Epenthesis counterbleeds Voicing Assimilation: /his-z/ → hiss → [hisəs] (*[hisəz])	Revised generalization: Voicing Assimilation is transparent (Gupta 1995, T. Mohanan, p.c.)
(b)	Metathesis counterfeeds Epenthesis /lisp-z/ → lisps → lipss → [lips] (*[lipsəs])	Revised generalization: [lipsəs] is attested and follows from an underlying /lips-z/.
(c)	Deletion counterbleeds Metathesis (some speakers) /lisp/ → [lips] (*[lis])	Stratal opacity: Metathesis (lexical) precedes Deletion (postlexical).
(d)	Deletion counterfeeds Epenthesis: /list-z/ → *lists* → *liss* → *lis* (**li*[səs])	Stratal opacity: Epenthesis (lexical) precedes Deletion (postlexical)
(e)	Degemination counterbleeds Epenthesis: /his-z/ → *hiss* → *hi*[səs] (**his*)	Stratal opacity: Epenthesis (lexical) precedes Degemination (postlexical)

(115) Spurious opacity: The appearance of opacity resulted from the assumption that each output may only have one underlying form, i.e. no variation in the input (= ambiguity).

(116) However, since both transparent and opaque forms (e.g. *lisp*, *lips*) exist in the output, there is no reason why the speaker should not store both forms in the lexicon.

(117) Note that the present theory goes beyond the "exemplarist" view: whatever is heard is stored as an input. It makes predictions about which of the alternative inputs is preferred. The inputs are thus "weighted" by the grammar.

(118) All this follows from a small set of constraints, with no numerical weighting.

6. Conclusion

(119) Singapore English cluster phonology shows extensive variation and opacity:
- (a) The quantitative variation patterns are entirely systematic and can be derived from a small number of phonological constraints.
- (b) Some of the opacity is real and follows from the stratal hypothesis.
- (c) Some of the opacity is spurious and follows from variation in the input (= ambiguity, multiple underlying forms).

(120) T-orders reveal the intricate (and almost completely unexplored) quantitative structure hidden in OT grammars:
- (a) T-orders impose strict limits on quantitative variation
- (b) T-orders can be easily computed for any OT grammar

(121) "New Englishes" can be phonologically more complex than standard English.

Appendix A: The test script

The following 17 sentences were read by each subject twice in the same order.

1. Say lisping my way.
2. Say lisp again.
3. Say testing again.
4. Say lisped my way.
5. Say tests again.
6. Say dyspnea my way.
7. Say testing my way.
8. Say lisping again.
9. Say tested again.
10. Say lisps my way.
11. Say test again.
12. Say tested my way.
13. Say lisp my way.
14. Say test my way.
15. Say lisps again.
16. Say lisped again.
17. Say tests my way.

Appendix B: Corpus sample

An extract from our annotated corpus is shown below. Key: U = underlying form; T = target cluster; M = morphophonological environment; S = speaker/utterance identifier; P = pause vs. no pause before *my/again*; F = faithful vs. unfaithful output; A = alternation type (F = Faithful, M = Metathesis, C = Copy); H = what the transcribers heard.

U:/lisping my/ T:sp M:#V S:38-1 P:0 F:0 A:F H:lisping my
U:/lisp again/ T:sp M:##V S:38-1 P:0 F:1 A:M H:lips again
U:/lisped my/ T:sp M:#C##C S:38-1 P:0 F:1 A:M H:lipsst my
U:/lisping again/ T:sp M:#V S:38-1 P:1 F:0 A:F H:lisping again
U:/lisps my/ T:sp M:#C##C S:38-1 P:0 F:1 A:M H:lips my
U:/lisp my/ T:sp M:##C S:38-1 P:0 F:1 A:M H:lips my
U:/lisps again/ T:sp M:#C##V S:38-1 P:0 F:1 A:M H:lips again
U:/lisped again/ T:sp M:#C##V S:38-1 P:0 F:1 A:M H:lipst again
U:/lisping my/ T:sp M:#V S:38-2 P:0 F:1 A:C H:lipsfing my
U:/lisp again/ T:sp M:##V S:38-2 P:0 F:1 A:M H:lips again
U:/lisped my/ T:sp M:#C##C S:38-2 P:0 F:1 A:M+Dp H:lits my
U:/lisping again/ T:sp M:#V S:38-2 P:0 F:1 A:C H:lipsping again
U:/lisps my/ T:sp M:#C##C S:38-2 P:0 F:1 A:M H:lips my
U:/lisp my/ T:sp M:##C S:38-2 P:0 F:1 A:M H:lits my
U:/lisps again/ T:sp M:#C##V S:38-2 P:0 F:1 A:M H:lips again
U:/lisped again/ T:sp M:#C##V S:38-2 P:0 F:1 A:M H:lipst again

Appendix C: Hapaxes

/lisp again/:	lipsk again, livs [again], liis again, lispt again, lisps again
/lisping again/:	lisp ?iping again, lifshping again, litsfing again, lispo?ing again
/lisped again/:	lisft again, lifstuh again, lifspt again, litst magain
/lisps again/:	lifss magain, lisfs again
/lisp my/:	lish my, litspt my, lipss my
/lisping my/:	--
/lisped my/:	li?ts my, lifsp my, lipps my, lipsst my, lispot my
/lisps my/:	lifsts my, liss my, lisfss my

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