How Much Homophony Is Normal?*

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1 Introduction: Contrast Maintenance in Phonology

- Phonological patterns sensitive to the need to maintain contrast
  - Dispersion Theory (Flemming 2002): constraints that require contrast among phonemic categories oppose constraints against expending articulatory effort
  - Phonological patterns sometimes serve to maximize contrasts among potential lexical items (Padgett 2003; Padgett and Tabain 2005)
  - Some patterns seem especially prone to avoiding neutralization (e.g., lenition, Gurevich (2004))
- This sensitivity usually modeled at level of *potential* lexical items, not *actual* ones
  - Don't want to predict unattested phonological patterns:
    * Dispersed inventories only for lexical items in minimal pairs
    * Rules that apply only where they don't create homophones

      "These questions arise when we take the domain of explanation to be the set of actual lexical items in a language. But this is in fact not the practice in generative phonology. Instead, theories model the set of *possible* words of a language...." (Padgett 2003, 78-79)
  - Could there be other types of homophony avoidance?

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- Silverman (to appear) argues that phonological patterns avoid creating homophones among *actual* words
  - Korean has many neutralizing phonological alternations
  - But these alternations result in only a relative handful of homophones
  - Homophony avoidance in lexical statistics rather than formalization of phonological pattern

- Remaining question: how can we be sure number of homophones in Korean is really unexpectedly low?

  ⇒ Perhaps *any* set of neutralizations would create very few homophones

- To establish a 'baseline' level of expected homophony, count homophones produced by alternative phonological rules and compare to actual rule; at least two ways to do this:

  1. Hand-select a few alternative rules for comparison
     - Silverman's method; alternatives produce more homophony than actual rules
     - Pro: can select phonologically plausible rules that are similar to actual rules
     - Con: results highly dependent on which alternatives we happen to pick
  2. Compute homophony for large number of alternative rules ('brute-force' method)
     - Method used for this talk
     - Pro: cover a lot more ground than hand-selection approach
     - Con: hard to filter out implausible rules

2 Method

2.1 Korean

- Why Korean?
  - Large number of neutralizing phonological alternations

(1) a. (i) /nɑʧ-i/ → [nɑʧi] 'day.NOM'
(ii) /nɑʧ-k'wɑ/ → [nɑtk'wɑ] 'day and'
b. (i) /nɑʧʰ-i/ → [nɑʧʰi] 'face.NOM'
(ii) /nɑʧʰ-k'wɑ/ → [nɑtk'wɑ] 'face and'

  - Writing system roughly morphophonemic: orthography can be used to approximate underlying forms

Table 1: Surface realizations of underlying coda-onset sequences in Korean

<table>
<tr><th></th><th>p^h</th><th>p</th><th>p’</th><th>t^h</th><th>t</th><th>t’</th><th>s</th><th>s’</th><th>ʧ^h</th><th>ʧ</th><th>ʧ’</th><th>k^h</th><th>k</th><th>k’</th><th>m</th><th>n</th><th>l</th><th>h</th><th>∅</th></tr>
<tr><td>p</td><td rowspan="12">p^h</td><td rowspan="12" colspan="2">p’</td><td rowspan="5">pt^h</td><td rowspan="5" colspan="2">pt’</td><td rowspan="5" colspan="2">ps’</td><td rowspan="5">pʧ^h</td><td rowspan="5" colspan="2">pʧ’</td><td rowspan="5">pk^h</td><td rowspan="5" colspan="2">pk’</td><td rowspan="12">pm</td><td rowspan="5">pn</td><td rowspan="5">pl</td><td>p^h</td><td>p</td></tr>
<tr><td>p^h</td><td>p^{h}h</td><td>p^h</td></tr>
<tr><td>ps</td><td>ps’h</td><td>ps’</td></tr>
<tr><td>lp</td><td>lp^h</td><td>lp</td></tr>
<tr><td>lp^h</td><td>lp^{h}h</td><td>lp^h</td></tr>
<tr><td>h</td><td rowspan="7">t^h</td><td rowspan="7" colspan="2">t’</td><td rowspan="7" colspan="2">s’</td><td rowspan="7">ʧ^h</td><td rowspan="7" colspan="2">ʧ’</td><td rowspan="12">k^h</td><td rowspan="12" colspan="2">k’</td><td rowspan="7">tn</td><td rowspan="7">tl</td><td>hh</td><td>∅</td></tr>
<tr><td>t</td><td>t^h</td><td>t</td></tr>
<tr><td>t^h</td><td>t^{h}h</td><td>t^h</td></tr>
<tr><td>s</td><td>sh</td><td>s</td></tr>
<tr><td>s’</td><td>s’h</td><td>s’</td></tr>
<tr><td>ʧ</td><td>ʧ^h</td><td>ʧ</td></tr>
<tr><td>ʧ^h</td><td>ʧ^{h}h</td><td>ʧ^h</td></tr>
<tr><td>k</td><td rowspan="5">kp^h</td><td rowspan="5" colspan="2">kp’</td><td rowspan="5">kt^h</td><td rowspan="5" colspan="2">kt’</td><td rowspan="5" colspan="2">ks’</td><td rowspan="5">kʧ^h</td><td rowspan="5" colspan="2">kʧ’</td><td rowspan="5">km</td><td rowspan="5">kn</td><td rowspan="5">kl</td><td rowspan="2">k^h</td><td>k</td></tr>
<tr><td>k’</td><td>k’</td></tr>
<tr><td>k^h</td><td>k^{h}h</td><td>k^h</td></tr>
<tr><td>ks</td><td>ksh</td><td>ks’</td></tr>
<tr><td>lk</td><td>lk^h</td><td>lk</td></tr>
<tr><td>m</td><td>mp^h</td><td>mp</td><td>mp’</td><td>mt^h</td><td>mt</td><td>mt’</td><td>ms</td><td>ms’</td><td>mʧ^h</td><td>mʧ</td><td>mʧ’</td><td>mk^h</td><td>mk</td><td>mk’</td><td>mm</td><td>mn</td><td>ml</td><td colspan="2">m</td></tr>
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<tr><td>nʧ</td><td>nʧ^h</td><td>nʧ</td></tr>
<tr><td>ŋ</td><td>ŋp^h</td><td>ŋp</td><td>ŋp’</td><td>ŋt^h</td><td>ŋt</td><td>ŋt’</td><td>ŋs</td><td>ŋs’</td><td>ŋʧ^h</td><td>ŋʧ</td><td>ŋʧ’</td><td>ŋk^h</td><td>ŋk</td><td>ŋk’</td><td>ŋm</td><td>ŋn</td><td>ŋl</td><td colspan="2">ŋ</td></tr>
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<tr><td>ls</td><td>lsh</td><td>ls</td></tr>
<tr><td>∅</td><td>p^h</td><td>p</td><td>p’</td><td>t^h</td><td>t</td><td>t’</td><td>s</td><td>s’</td><td>ʧ^h</td><td>ʧ</td><td>ʧ’</td><td>k^h</td><td>k</td><td>k’</td><td>m</td><td>n</td><td>l</td><td colspan="2">∅</td></tr>
</table>

- Table 1 shows surface realizations of underlying coda-onset sequences
  - Reflect nine ordered rules from descriptions in Sohn (1994): resyllabification, [h]-aspiration, coda neutralization, sibilation, tensification, consonant cluster simplification, decoronization, [h]-weakening, reduction
  - Some other rules suppressed:
    - Non-neutralizing alternations (e.g., intervocalic voicing)
    - Morphologically conditioned alternations (e.g., lateralization)
- Data on Korean lexicon
  - Data from Korean National Database (Lee 2006) (uninflected stems in Korean orthography; no morpheme boundaries)
  - Phonological rules applied via Java scripts (collaboration w/ Paul Willis)
  - Rules applied only stem-internally: application to codas may be bled by vowel-initial suffixes, of which there are many (Albright and Kang 2009)

2.2 Procedure

- Same procedure for each rule; illustrated here with data for overall neutralization pattern

2.2.1 Step 1: Count Homophones Created by Rule

- Measures of homophony

  Homophones Number of words in lexicon w/ at least one homophone

  Weighted Homophones Sum of frequencies of words w/ at least one homophone

  Homophone Pairs Number of pairs of homophones in lexicon

  Homophone Sets Number of (maximal) sets of words in lexicon that all neutralize to the same thing

- Table 2 shows levels of homophony underlyingly and after all rules have applied

  ⇒ 'New': number of homophones added by rules

- For results of simulations, only 'homophones' and 'weighted homophones' shown

  ⇒ 'Homophone pairs' and 'homophone sets' very similar to 'homophones'

Table 2: Homophony in Korean lexicon

Measure	**Underlying**	**Surface**	**New**
Homophones	6201	6646	445
Weighted Homophones	291681	319835	28154
Homophone Pairs	4308	4692	384
Homophone Sets	2794	2975	181

2.2.2 Step 2: Simulate Alternative Rules

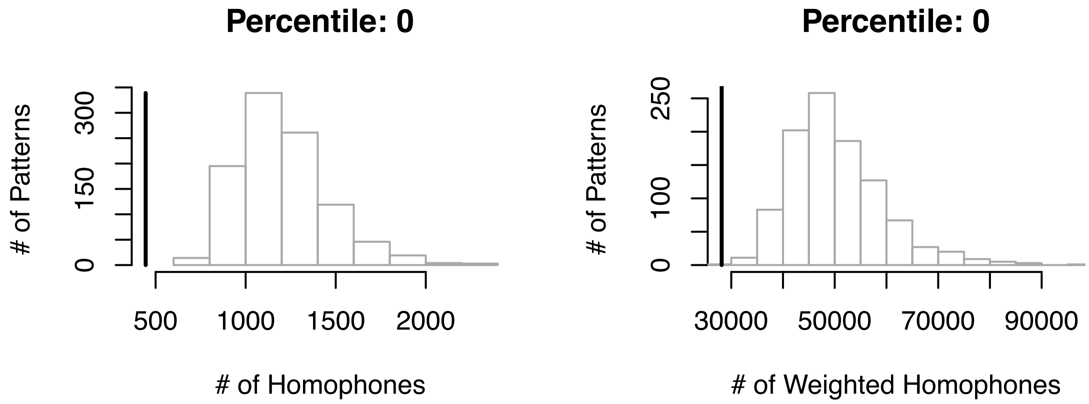
- Three simulations; each creates 1000 random patterns w/ same number of neutralizations as actual rule
- ‘a’-series simulation: neutralize random sets of coda-onset sequences
  - Table 3 illustrates this for overall neutralization pattern
  - Randomly distribute onset-coda sequences in table; superimpose grid from actual pattern
  - All sequences in same box neutralize with each other
  - (Some cells neutralize w/ nothing – left blank; sequences here don’t matter)
  - Figure 1 shows results for overall pattern
    - Histograms show level of homophony across simulated patterns
    - Vertical lines show actual number of homophones
    - Title gives percentile rank of actual number of homophones among simulated patterns: smaller percentile → actual level of homophony surprisingly low

  ⇒ For both measures, every simulated pattern resulted in *more* homophony than actual pattern

Table 3: Example of neutralization patterns in an ‘a’-series simulation

ʧʧ’	hʧ	np’	lkh	ls	pp	tp’	ʧl	lhk^h	t^{h}ʧ’	s’s’	t^{h}s’	nʧp^h	lp^{h}t^h	lst^h	k’p	t^{h}t’	lp^{h}t	mʧ^h
ʧ^{h}l	ls’	nhh	psn	nʧs	ksp	kt^h	lkp^h	ʧ^{h}m	sl	t^{h}t’	k’k^h	mn	ʧk^h	lmp’	ksp’	ʧ^{h}k’		mm
pk’	kss’	nk^h	lmʧ	k’s’	ll	ksk^h	psʧ’	p^h∅	st^h	lhp^h	ʧt’	k’ʧ’	ʧn	tʧ^h	∅ʧ^h	pk		pk^h
nʧl	ŋʧ^h	∅t	kp^h	nʧp’	hk’	mh	nl	lkn	s’m	k^{h}p^h	ŋh	lkm	ŋt	hp’	p^{h}p^h	ʧp	kʧ^h	nt’
ks	pss’	hs’	ls∅	psk^h	lpʧ^h	k^{h}s’	pl	hs	lk∅	s’t^h	lt^{h}k’	ŋʧ’	lkʧ	ms’	ŋk^h	lʧ^h		
lp∅	lp^{h}s	ŋp’	lmt^h	pp^h	s’ʧ	mk’	s’p’	lhs’	kst’	lt^{h}l	ʧ^{h}ʧ^h	lt^h∅	lkʧ^h	k’t	ps∅	lpp		∅∅
k’p’	lk^h	lsn	p^{h}m	∅s’	lhʧ^h	lkk^h	s’k	lʧ	mt	s’l	lpn	m∅	lss’	kst	s’t’	h∅	ss	nm
kʧ’	k^{h}p’	lsʧ^h	pʧ’	k’∅	lsk^h	pst	nhp	lpp’	mt’	ʧ∅	lmk	tn	sp	sm	lp^{h}ʧ^h	k^{h}ʧ		lp^{h}l
ht	s’∅	lt’	k’p’	lmt’	∅s	ʧ^{h}ʧ	psk	p^{h}ʧ’	ksʧ	p^{h}p	kk	kp	p^{h}k	k^{h}ʧ^h	ʧ^{h}t’	ss’		t∅
psk’	lsʧ	lt^{h}k	lht’	ks∅	nht^h	∅ʧ	lmʧ^h	sp^h	ŋn	lm	nhs	tp	p^{h}t^h	∅k’	nn	hh		t^{h}s
∅ʧ’	nʧk’	lpt’	psp	lh	lmh	lt^{h}p’	nʧ’	np	k’m	mk	mp	hm	psh	lms	∅n	kh	nʧh	lpl
kk’	k^h∅	ʧ^{h}k	lpʧ	k’k	ksk’	lp^{h}k^h	nhʧ	lsl	p^{h}n	nʧs’	ht^h	t^h∅	lhs	hʧ^h	k^{h}t’	lkt^h		nʧʧ’
lp^{h}ʧ’	k’t^h	p^{h}h	sk	nhʧ^h	nhk’	ʧs	pt’	nhp^h	ʧ^h∅	lt^{h}ʧ’	t^{h}l	tk	lps	ŋt’	th	nk	∅k^h	lsk
t^{h}ʧ^h	nk’	lt^h	kst^h	lt^{h}ʧ	s’t	ʧʧ^h	lks	tʧ’	nʧk^h	lhl	tʧ	ʧʧ	∅l	nʧp	ʧk	nh	k’k’	lpt
lsp	kʧ	k’s	ʧ^{h}s	lsk’	ʧk’	s’p^h	sʧ	psm	t^{h}h	kt	sp’	nʧk	lp^{h}n	ps	np^h	t^{h}k^h		nʧt
st’	nt^h	t^{h}p	ʧt	ŋl	lp^{h}k’	ksʧ’	ʧp’	lt^{h}k^h	ʧ^{h}ʧ’	lmp	lsʧ	s’k^h	∅k	ʧ^{h}p’	lpm	ksm		nh∅
ksn	s’n	∅t^h	lhm	k^{h}s	ŋs’	lss	k’ʧ^h	lhʧ’	nhl	lp^{h}k	∅p’	nhk	hp	ksh	nhn	lkʧ’	ph	lsm
																	psp^h	lm∅
lt^{h}h		t^{h}k’	∅h		lsp’		lpt^h	∅m		lmt	np		ʧ^{h}p	s’ʧ’	nhk^h	sk’	n∅	nʧm
ŋp^h	ms	lhp’	s’ʧ^h	p^{h}ʧ^h	hk	lp	nʧʧ^h	lt^{h}m	nt	hn	ml	t^{h}m	∅p^h	s’p	lt^{h}s’	pʧ	p^{h}t’	ʧm
mʧ’	pn	lt^{h}t’	lp’	hʧ’	lh∅	∅p	lkp’	nʧ∅	hk^h	k^{h}k	sk^h	ps’	tt’	lst’	psl	st	k’∅	tm
																	lps’	k^{h}t^h
nht	lpʧ’	t^{h}p^h	lp^{h}s’	p^{h}ʧ	lmp^h	k^{h}t	lpp^h	k’l	s’k’	tk^h	tk’	ŋt^h	mp^h	psp’	k^{h}k^h	lsp^h	lt	ts
mt^h	k^{h}l	nʧt’	lms’	ŋk	p^{h}s’	ns’	∅t’	lhn	k^{h}ʧ’	ʧ^{h}k^h	lp^{h}ʧ	lp^h	sn	ʧ^{h}s’	nhm	k’p^h	lkl	lkt’
ʧ^{h}h	nhʧ’	s’s	k’h	nhs’	mʧ	k^{h}k’	lt^{h}t	t^{h}ʧ	pst^h	p^{h}k^h	p^{h}p’	lp^{h}m	lml	pp’	nʧ	hp^h	kk^h	ksk
lmʧ’	tl	ʧs’	pt	p∅	k’ʧ	pst’	k^{h}p	nʧʧ	p^{h}k’	lp^{h}p’	nʧ^h	ŋʧ	s∅	ŋk’	lhh	ʧ^{h}p^h		ts’
kl	t^{h}ʧ^h	lk’	pss	ʧ^{h}t	ns	nʧt^h	ht	tp^h	lp^h∅	psʧ^h	s’h	k^{h}h	km	ksʧ^h	ln	t^{h}n		kn
lt^{h}s	t^{h}p’	lmm	lhk	ʧ^{h}n	lph	pm	kss	lp^{h}p	sʧ’	lkt	lt^{h}ʧ^h	ksl	kn	lht^h	psʧ	lt^{h}t^h	lp^{h}h	lt^{h}n

Figure 1: Amount of homophony in simulation a



- ‘b’-series simulation: randomly shuffle onsets, codas separately
  - Table 4 illustrates for overall pattern
  - Neutralized sequences more similar than in ‘a’-series: more phonologically plausible
  - Figure 2 shows results
    - ⇒ Almost every simulated pattern results in more homophony than actual pattern

Figure 2: Amount of homophony in simulation b

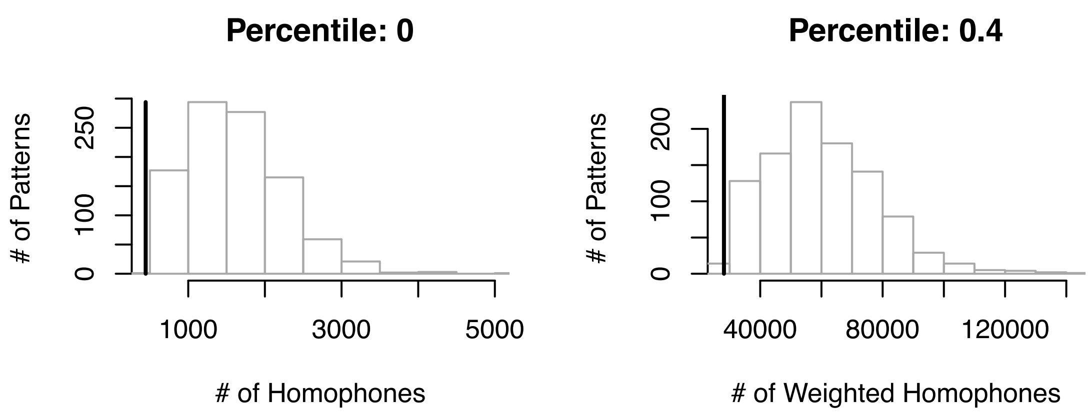


Table 4: Example of neutralization patterns in a ‘b’-series simulation

	p	**s’**	**l**	**∅**	**ʧ^h**	**p^h**	**n**	**k**	**ʧ’**	**t’**	**k^h**	**s**	**k’**	**h**	**t**	**p’**	**ʧ**	**t^h**	**m**
p	pp	ps’	pl	p∅	pʧ^h	pp^h	pn	pk	pʧ’	pt’	pk^h	ps	pk’	ph	pt	pp’	pʧ	pt^h	pm
n	np	ns’	nl	n∅	nʧ^h	np^h	nn	nk	nʧ’	nt’	nk^h	ns	nk’	nh	nt	np’	nʧ	nt^h	nm
lk	lkp	lks’	lkl	lk∅	lkʧ^h	lkp^h	lkn	lkk	lkʧ’	lkt’	lkk^h	lks	lkk’	lkh	lkt	lkp’	lkʧ	lkt^h	lkm
p^h	p^{h}p	p^{h}s’	p^{h}l	p^h∅	p^{h}ʧ^h	p^{h}p^h	p^{h}n	p^{h}k	p^{h}ʧ’	p^{h}t’	p^{h}k^h	p^{h}s	p^{h}k’	p^{h}h	p^{h}t	p^{h}p’	p^{h}ʧ	p^{h}t^h	p^{h}m
lm	lmp	lms’	lml	lm∅	lmʧ^h	lmp^h	lmn	lmk	lmʧ’	lmt’	lmk^h	lms	lmk’	lmh	lmt	lmp’	lmʧ	lmt^h	lmm
m	mp	ms’	ml	m∅	mʧ^h	mp^h	mn	mk	mʧ’	mt’	mk^h	ms	mk’	mh	mt	mp’	mʧ	mt^h	mm
ŋ	ŋp	ŋs’	ŋl	ŋ∅	ŋʧ^h	ŋp^h	ŋn	ŋk	ŋʧ’	ŋt’	ŋk^h	ŋs	ŋk’	ŋh	ŋt	ŋp’	ŋʧ	ŋt^h	ŋm
k	kp	ks’	kl	k∅	kʧ^h	kp^h	kn	kk	kʧ’	kt’	kk^h	ks	kk’	kh	kt	kp’	kʧ	kt^h	km
h	hp	hs’	hl	h∅	hʧ^h	hp^h	hn	hk	hʧ’	ht’	hk^h	hs	hk’	hh	ht	hp’	hʧ	ht^h	hm
ks	ksp	kss’	ksl	ks∅	ksʧ^h	ksp^h	ksn	ksk	ksʧ’	kst’	ksk^h	kss	ksk’	ksh	kst	ksp’	ksʧ	kst^h	ksm
lh	lhp	lhs’	lhl	lh∅	lhʧ^h	lhp^h	lhn	lhk	lhʧ’	lht’	lhk^h	lhs	lhk’	lhh	lht	lhp’	lhʧ	lht^h	lhm
k^h	k^{h}p	k^{h}s’	k^{h}l	k^h∅	k^{h}ʧ^h	k^{h}p^h	k^{h}n	k^{h}k	k^{h}ʧ’	k^{h}t’	k^{h}k^h	k^{h}s	k^{h}k’	k^{h}h	k^{h}t	k^{h}p’	k^{h}ʧ	k^{h}t^h	k^{h}m
ʧ^h	ʧ^{h}p	ʧ^{h}s’	ʧ^{h}l	ʧ^h∅	ʧ^{h}ʧ^h	ʧ^{h}p^h	ʧ^{h}n	ʧ^{h}k	ʧ^{h}ʧ’	ʧ^{h}t’	ʧ^{h}k^h	ʧ^{h}s	ʧ^{h}k’	ʧ^{h}h	ʧ^{h}t	ʧ^{h}p’	ʧ^{h}ʧ	ʧ^{h}t^h	ʧ^{h}m
s	sp	ss’	sl	s∅	sʧ^h	sp^h	sn	sk	sʧ’	st’	sk^h	ss	sk’	sh	st	sp’	sʧ	st^h	sm
t	tp	ts’	tl	t∅	tʧ^h	tp^h	tn	tk	tʧ’	tt’	tk^h	ts	tk’	th	tt	tp’	tʧ	tt^h	tm
nʧ	nʧp	nʧs’	nʧl	nʧ∅	nʧʧ^h	nʧp^h	nʧn	nʧk	nʧʧ’	nʧt’	nʧk^h	nʧs	nʧk’	nʧh	nʧt	lnʧp’	nʧʧ	nʧt^h	nʧm
lp^h	lp^{h}p	lp^{h}s’	lp^{h}l	lp^h∅	lp^{h}ʧ^h	lp^{h}p^h	lp^{h}n	lp^{h}k	lp^{h}ʧ’	lp^{h}t’	lp^{h}k^h	lp^{h}s	lp^{h}k’	lp^{h}h	lp^{h}t	lp^{h}p’	lp^{h}ʧ	lp^{h}t^h	lp^{h}m
lt^h	lt^{h}p	lt^{h}s’	lt^{h}l	lt^h∅	lt^{h}ʧ^h	lt^{h}p^h	lt^{h}n	lt^{h}k	lt^{h}ʧ’	lt^{h}t’	lt^{h}k^h	lt^{h}s	lt^{h}k’	lt^{h}h	lt^{h}t	lt^{h}p’	lt^{h}ʧ	lt^{h}t^h	lt^{h}m
l	lp	ls’	ll	l∅	lʧ^h	lp^h	ln	lk	lʧ’	lt’	lk^h	ls	lk’	lh	lt	lp’	lʧ	lt^h	lm
∅	∅p	∅s’	∅l	∅∅	∅ʧ^h	∅p^h	∅n	∅k	∅ʧ’	∅t’	∅k^h	∅s	∅k’	∅h	∅t	∅p’	∅ʧ	∅t^h	∅m
ps	psp	pss’	psl	ps∅	psʧ^h	psp^h	psn	psk	psʧ’	pst’	psk^h	pss	psk’	psh	pst	psp’	psʧ	pst^h	psm
ls	lsp	lss’	lsl	ls∅	lsʧ^h	lsp^h	lsn	lsk	lsʧ’	lst’	lsk^h	lss	lsk’	lsh	lst	lsp’	lsʧ	lst^h	lsm
s’	s’p	s’s’	s’l	s’∅	s’ʧ^h	s’p^h	s’n	s’k	s’ʧ’	s’t’	s’k^h	s’s	s’k’	s’h	s’t	s’p’	spʧ	s’t^h	s’m
k’	k’p	k’s’	k’l	k’∅	k’ʧ^h	k’p^h	k’n	k’k	k’ʧ’	k’t’	k’k^h	k’s	k’k’	k’h	k’t	k’p’	k’ʧ	k’t^h	k’m
t^h	t^{h}p	t^{h}s’	t^{h}l	t^h∅	t^{h}ʧ^h	t^{h}p^h	t^{h}n	t^{h}k	t^{h}ʧ’	t^{h}t’	t^{h}k^h	t^{h}s	t^{h}k’	t^{h}h	t^{h}t	t^{h}p’	t^{h}ʧ	t^{h}t^h	t^{h}m
ʧ	ʧp	ʧs’	ʧl	ʧ∅	ʧʧ^h	ʧp^h	ʧn	ʧk	ʧʧ’	ʧt’	ʧt^h	ʧs	ʧk’	ʧh	ʧt	ʧp’	ʧʧ	ʧt^h	ʧm
lp	lpp	lps’	lpl	lp∅	lpʧ^h	lpp^h	lpn	lpk	kpʧ’	lpt’	lpt^h	lps	lpk’	lph	lpt	lpp’	lpʧ	lpt^h	lpm
nh	nhp	nhs’	nhl	nh∅	nhʧ^h	nhp^h	nhn	nhk	nhʧ’	nht’	nht^h	nhs	nhk’	nhh	nht	nhp’	nhʧ	nht^h	nhm

- 'c'-series simulation: randomly shuffle segments; combine according to neutralization 'template' for rule
  - Template: specification of which coda-onset sequences neutralize with each other
  - Example from tensification rule: for each ordered pair in set B, first member preceded by anything from set A neutralizes with second member preceded by same thing

    ⇒ So, neutralizing pairs include {k+k, k+k'}, {t+k, t+k'}, {k+t, k+t'}, etc.

Figure 3: Template for tensification

{/A + B_1/, /A + B_2/}	A = {k, t, p, s, kt, nt, lk, lp, lt, pt, ks, ns, ls, ps} B = {⟨k, k'⟩, ⟨t, t'⟩, ⟨p, p'⟩, ⟨s, s'⟩, ⟨ʧ, ʧ'⟩, ⟨sh, s'h⟩}

  - In 'c'-series simulation: randomly assign new segments to sets A and B (and C and so on, if template has more sets); restrictions:
    - Identical segments across sets stay that way (i.e., every [k] in figure 3 becomes [s] in figure 4)
    - Segments that appear as codas in template must be possible codas, those as onsets must be possible onsets (i.e., every member of set A must be a possible coda)
  - Example given in figure 4

    ⇒ New neutralizing pairs include {s+s, s+k^h}, {n+s, n+k^h}, {s+n, s+s'h}

Figure 4: Example of new sets for tensification template in a 'c'-series simulation

A = {s, n, t, k, ns, ∅, ŋ, p, m, ps, ls, lt, pt, lk}

B = {⟨s, k^h⟩, ⟨n, s'h⟩, ⟨t, k^hh⟩, ⟨k, t^h⟩, ⟨t, ŋh⟩, ⟨mh, p^hh⟩}

- In theory, 'b'-series simulations phonologically more plausible than 'a'-series, 'c'-series more plausible than 'b'-series

3 Results

- For each rule, I give:
  - Description of rule
  - Template for rule
  - Homophony produced by rule
  - Results of three simulations
- Display of simulation results
  - Two graphs: homophones measure on left, weighted homophones on right
  - Density curves ($\sim$ smoothed histograms) show distribution of homophony in 1000 patterns run in each simulation
  - Three curves, one for each simulation ('a', 'b', 'c')
  - Vertical bar: actual level of homophony
  - Legend notes percentile rank of actual level in each simulation
- Note:
  - Rules apply in ordered fashion, each rule to output of previous rule
  - Possible onsets and codas at each stage differ accordingly
  - 'Total' homophones listed for each rule are total homophones in lexicon after rule applies

3.1 Rule 1: Resyllabification

- Resyllabify single coda consonant into following onsetless syllable or syllable with initial [h] (Sohn 1994, 164)
- Almost all simulations produce far less homophony than actual rule; most produce none at all!
- Small additional peak in histograms for ‘c’-series near actual pattern
  - ⇒ Suggests a single pair of neutralized coda-onset sequences responsible for most of homophony produced by resyllabification

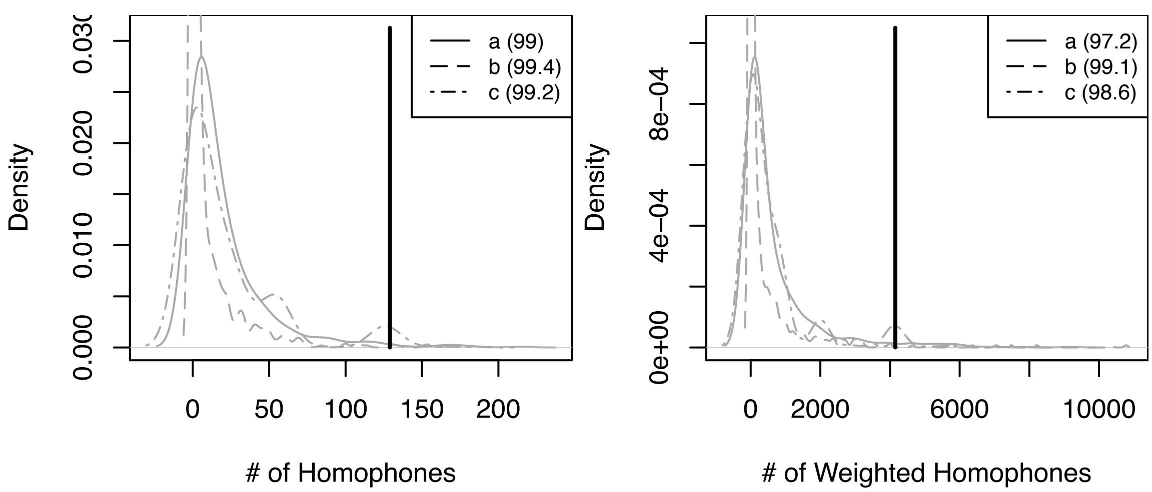
Figure 5: Homophony after resyllabification

Measure	Total	New
Homophones	6330	129
Weighted	295832	4151
Pairs	4417	109
Sets	2847	53

Figure 6: Template for resyllabification

	A = {k, n, t, l, m, p, s, ʧ, ʧ^{h}, k^{h}, t^{h}, p^{h}, h, k’, s’}
{/A + B/, /B + A/}	B = {∅}
{/C_1 + B/, /C_2 + C_3/}	C = {⟨ks, k, s⟩, ⟨nʧ, n, ʧ⟩, ⟨nh, n, h⟩, ⟨lk, l, k⟩, ⟨lm, l, m⟩, ⟨lp, l, p⟩, ⟨ls, l, s⟩, ⟨lt^{h}, l, t^{h}⟩, ⟨lp^{h}, l, p^{h}⟩, ⟨lh, l, h⟩, ⟨ps, p, s⟩}

Figure 7: Amount of homophony in simulation series 1



3.2 Rule 2: [h]-Aspiration

- Fuse plain noncontinuant obstruent with adjacent [h] into homorganic aspirated obstruent (Sohn 1994, 166)
- In ‘a’-series, most simulations yield less homophony than actual pattern: over half of ‘a’-series simulations yield none
- In ‘b’- and ‘c’-series, actual level of homophony in lower half of simulations
- Note that the more phonologically plausible the simulation, the more homophony it tends to produce (c > b > a)

Figure 8: Homophony after [h]-aspiration

Measure	**Total**	**New**
Homophones	6340	10
Weighted	296460	628
Pairs	4425	8
Sets	2851	4

Figure 9: Template for [h]-aspiration

{/A_1 + B/, /B + A_1/, /C + A_2/, /C + A_3/}

{/D + A_2/, /D + A_3/}

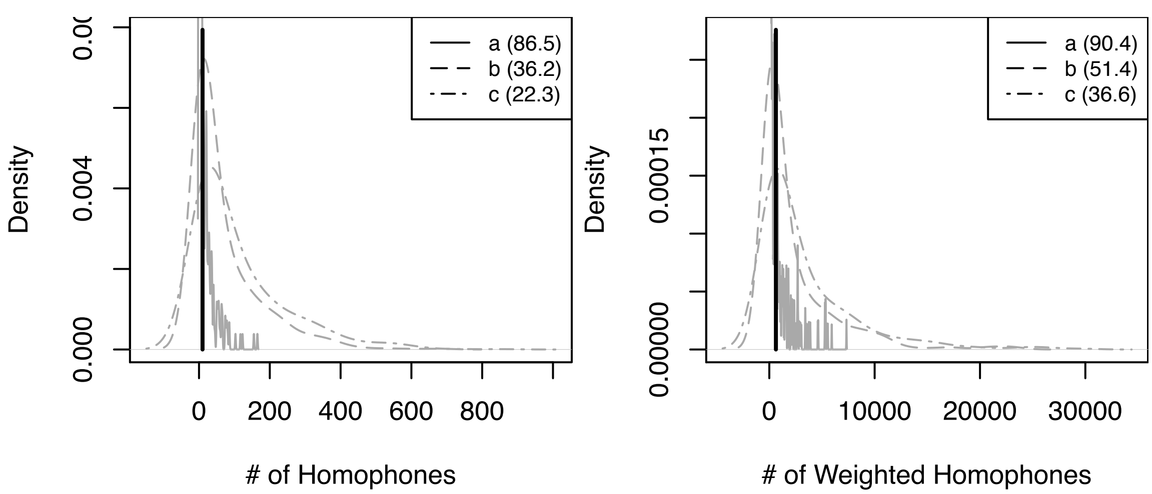
A = {⟨k, kh, k^h⟩, ⟨t, th, t^h⟩, ⟨p, ph, p^h⟩, ⟨ʧ, ʧh, $ʧ^h$⟩}

B = {h}

C = {∅}

D = {k, n, t, l, m, p, s, ŋ, ʧ, $ʧ^h$, k^h, t^h, p^h, k’, s’}

Figure 10: Amount of homophony in simulation series 2



3.3 Rule 3: Coda Neutralization

- Syllable-final obstruents become plain stops; /h/, /s/ → [t] (Sohn 1994, 165)
- Simulated patterns yield more homophony than actual pattern; less concentrated at low end of scale
- Exception: weighted homophones measure for ‘a’-series
- Note that percentile rank of actual level of homophony is generally greater for weighted homophones measure

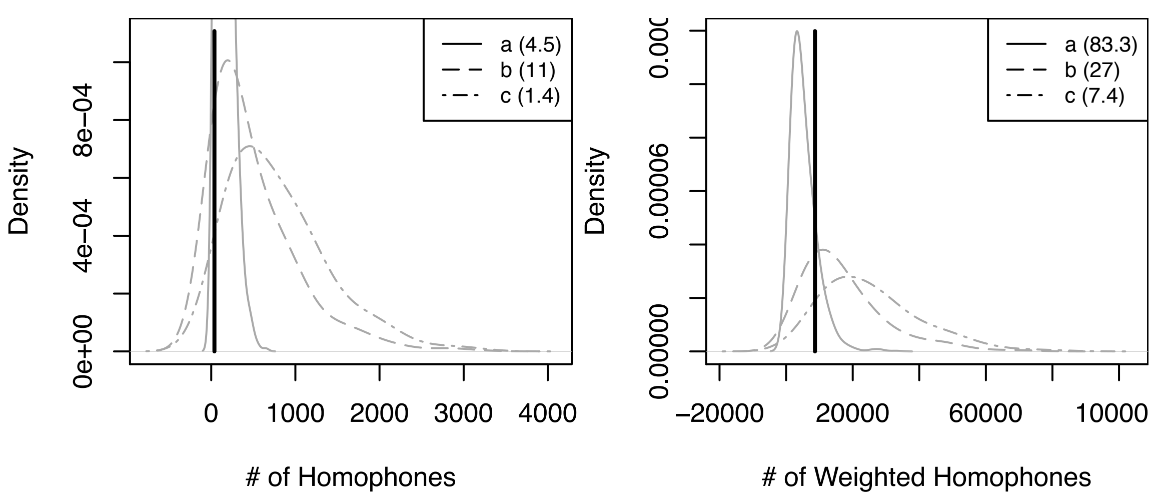
Figure 11: Homophony after coda neutralization

Measure	**Total**	**New**
Homophones	6378	38
Weighted	305133	8673
Pairs	4475	50
Sets	2863	12

Figure 12: Template for coda neutralization

	A = {⟨k, k’, k^{h}⟩, ⟨ls, lt^{h}, lh⟩}
{/A_1 + B/, /A_2 + B/, /A_3 + B}	B = {k, n, t, l, m, p, s, ŋ, ∅, ʧ, ʧ^{h}, k^{h}, t^{h}, p^{h}, k’, t’, p’, s’, ʧ’, nh, lh, mh, sh, ʧ^{h}h, k^{h}h, t^{h}h, p^{h}h, hh, k’h, s’h}
{/C_1 + B/, /C_2 + B/, /C_3 + B/, /C_4 + B/, /C_5 + B/, /C_6 + B/, /C_7 + B/}	C = {⟨t, s, ʧ, ʧ^{h}, t^{h}, h, s’⟩}
{/D_1 + B/, /D_2 + B/}	D = {⟨p, p^{h}⟩, ⟨nʧ, nh⟩, ⟨lp, lp^{h}⟩}

Figure 13: Amount of homophony in simulation series 3



3.4 Rule 4: Sibilation

- /t/ becomes [s] before [s] or [s'] (Sohn 1994, 165)
- Since all /s/s became [t]s in Coda Neutralization, this rule is non-neutralizing

3.5 Rule 5: Tensification

- Plain obstruents become tense after obstruents (Sohn 1994, 173)
- Most simulated patterns produce more homophony than actual rule
- Again, more plausible simulations tend to yield more homophony (c > b > a)

Figure 14: Homophony after tensification

Measure	**Total**	**New**
Homophones	6382	4
Weighted	305140	7
Pairs	4477	2
Sets	2865	2

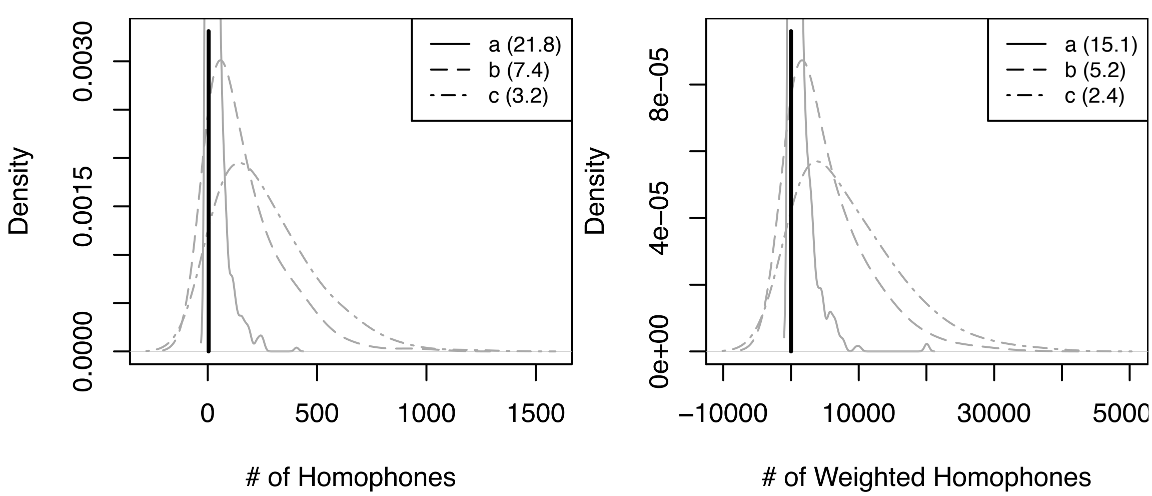
Figure 15: Template for tensification

{/A + B_1/, /A + B_2/}

A = {k, t, p, s, kt, nt, lk, lp, lt, pt, ks, ns, ls, ps}

B = {⟨k, k'⟩, ⟨t, t'⟩, ⟨p, p'⟩, ⟨s, s'⟩, ⟨ʧ, ʧ'⟩, ⟨sh, s'h⟩}

Figure 16: Amount of homophony in simulation series 5



3.6 Rule 6: Consonant Cluster Simplification

- Delete one consonant from all coda clusters (Sohn 1994, 170)
  - If first consonant in cluster is /l/ and second is non-coronal stop, delete /l/ (this simplifies the facts somewhat)
  - Otherwise, delete second consonant
- Most simulated patterns produce far more homophony than actual rule
- Again, note that percentile rank for actual rule is greater for weighted homophones measure

Figure 17: Homophony after consonant cluster simplification

Measure	Total	New
Homophones	6399	17
Weighted	308910	3770
Pairs	4499	22
Sets	2871	6

Figure 18: Template for simplification

{/A_1 + B/, /A_2 + B/, /A_3 + B/, /A_4 + B/}

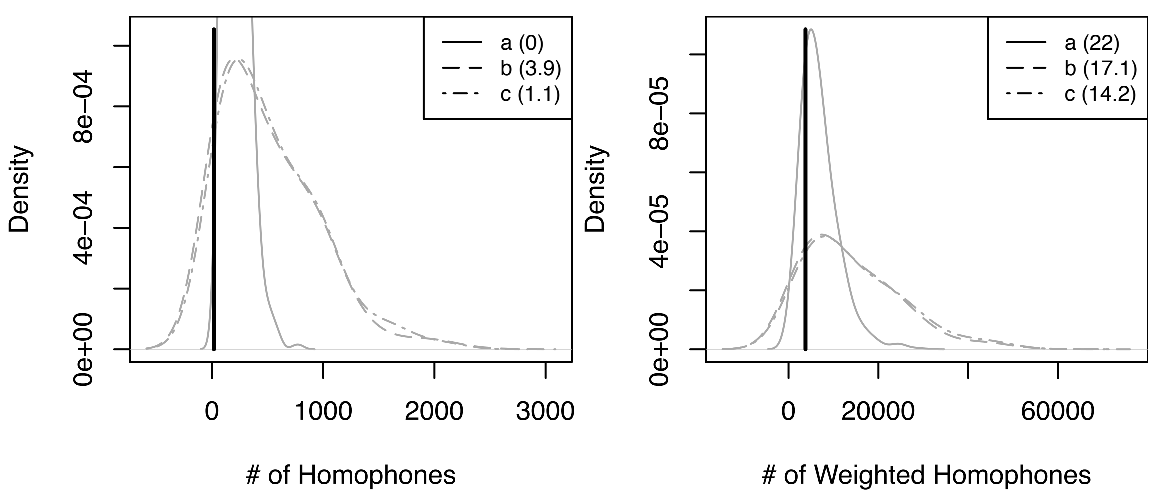
{/C_1 + B/, /C_2 + B/, /C_3 + B/}

A = {⟨k, kt, lk, ks⟩, ⟨l, lm, lt, ls⟩, ⟨p, lp, pt, ps⟩}

B = {k, n, t, l, m, p, s, ŋ, ∅, ʧ, $ʧ^h$, k^h, t^h, p^h, h, k', t', p', s', ʧ', nh, lh, mh, ŋh, sh, $ʧ^h$h, k^hh, t^hh, p^hh, hh, k'h, s'h}

C = {⟨n, nt, ns⟩}

Figure 19: Amount of homophony in simulation series 6



3.7 Rule 7: Decoronization

- /t/ assimilates in place to a following stop (Sohn 1994, 175)
- Decoronization creates practically no homophony (just one pair of words)
- Seems to be a lower limit: no simulation produced *no* homophones

Figure 20: Homophony after decoronization

Measure	**Total**	**New**
Homophones	6401	2
Weighted	308923	13
Pairs	4500	1
Sets	2872	1

Figure 21: Template for decoronization

$\{/A_1 + B/, /A_2 + B/\}$

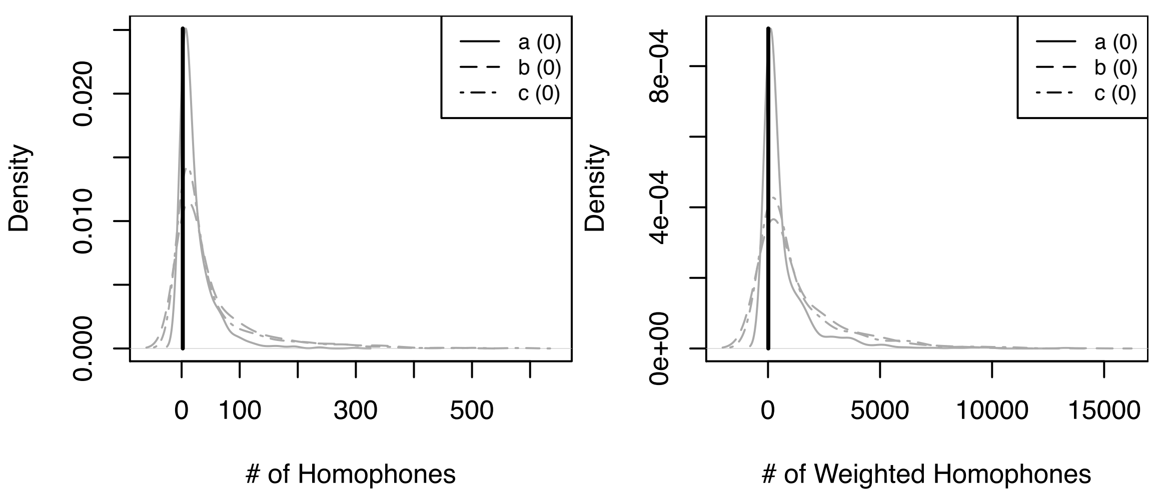
$\{/A_1 + C/, /A_3 + C/\}$

A = {⟨t, k, p⟩}

B = {k, ŋ, k^h, k', ŋh, k^hh, k'h}

C = {m, p, p^h, p', mh, p^hh}

Figure 22: Amount of homophony in simulation series 7



3.8 Rule 8: [h]-Weakening

- Delete /h/ between sonorants
- This rule creates more homophones than any other
- Actual level of homophony always in top half of simulations
- Recurrence of two patterns
  - Phonologically more plausible simulations yield more homophony
  - Percentile rank of actual homophony greater for weighted homophones measure

Figure 23: Homophony after [h]-weakening

Measure	**Total**	**New**
Homophones	6628	227
Weighted	319453	10530
Pairs	4677	177
Sets	2967	95

Figure 24: Template for [h]-weakening

{/A + C_1/, /A + C_2/}

{/B + C_1/, /B + C_2/}

{/B + D_1/, /B + D_2/}

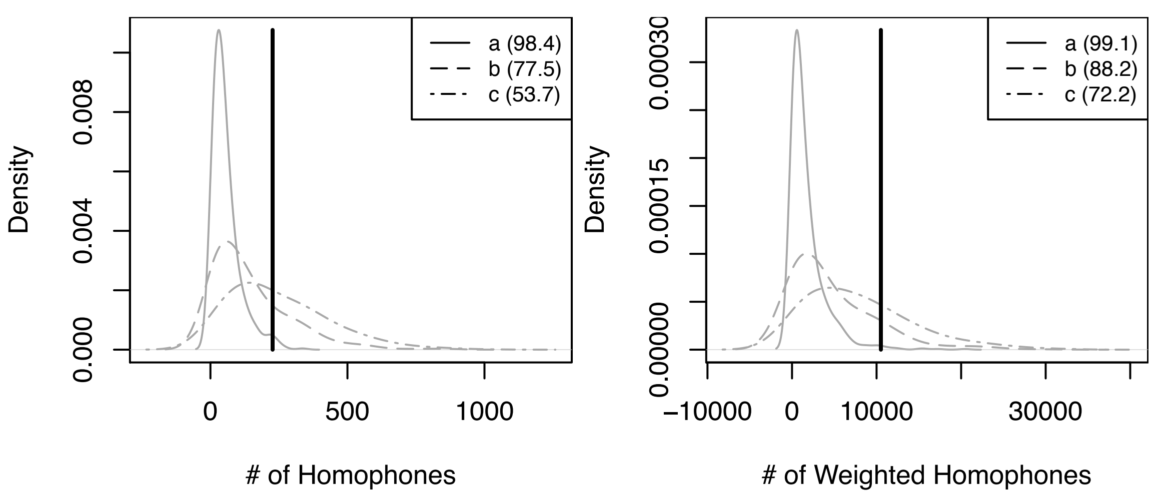
A = {k, t, p, s, n, l, m, ŋ}

B = {∅}

C = {⟨n, nh⟩, ⟨ŋ, ŋh⟩, ⟨l, lh⟩, ⟨m, mh⟩}

D = {⟨∅, h⟩}

Figure 25: Amount of homophony in simulation series 8



3.9 Rule 9: Pre-Tense/Aspirate Reduction

- Delete plain obstruents before homorganic tense or aspirated obstruents (Sohn 1994, 175)
- Actual level of homophony seems to fall in about the middle of simulated patterns
- Many simulations create no homophony
- Again, note greater percentile rank for actual level for weighted homophones measure

Figure 26: Homophony after pre-tense/aspirate reduction

Measure	**Total**	**New**
Homophones	6646	18
Weighted	319835	400
Pairs	4692	15
Sets	2975	8

Figure 27: Template for pre-tense/aspirate reduction

{/A + B/, /C + B/}

{/D + E/, /C + E/}

{/F + G/, /C + G/}

A = {k}

B = {k^h, k', k^hh, k'h}

C = {∅}

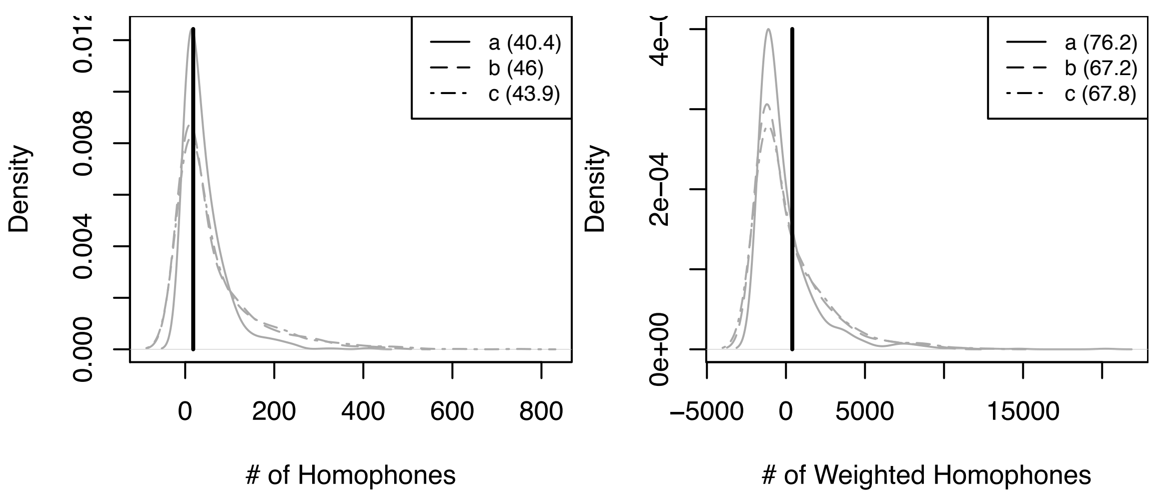
D = {t, s}

E = {$ʧ^h$, t^h, t', s', ʧ', $ʧ^h$h, t^hh, s'h}

F = {p}

G = {p^h, p', p^hh}

Figure 28: Amount of homophony in simulation series 9



4 Discussion

4.1 Does Korean Have Low Homophony?

- Rules 2, 3, 5, 6, and 7 produce less homophony than simulated patterns, as does overall pattern
- But rules 1, 8, and 9 produce more
- To assess overall results across simulations: linear mixed-effects model predicting percentile rank of actual level of homophony for each rule/measure
  - Predictors: measure of homophony, simulation series
  - Random effect of rule
- Two models: one for raw percentiles, one for arcsin-transformed percentiles

  ⇒ Similar results; only raw percentiles presented here

- Results
  - Intercept: 40

    ⇒ Below 50: suggests rules yield less homophony than the median, but not significantly different from 50

  - Weighted homophones measure associated with significantly greater percentiles than other measures ($p = .011$)
  - Percentile rank for 'b'-series simulations significantly less than for 'a'-series ($p = .0014$), for 'c'-series significantly less than for 'b'-series ($p = .0000014$)
- Tentative conclusion: actual level of homophony is indeed low
  - Low intercept in model
  - More rules yield less homophony than their simulations than yield more
  - Overall pattern has less homophony than simulations

4.2 Possible Mechanisms of Homophony Avoidance

- As discussed above, we don't want to build homophony avoidance (as opposed to neutralization avoidance) into formal phonological patterns
- These results suggest only a gradient avoidance of homophony
- How might this situation come about? Possibilities:

1. Given phonetic precursor to a rule, the less homophony the rule would create, the more likely the precursor is to be phonologized
2. Rules tend to neutralize contrasts that are already perceptually suboptimal; lexicon is already optimized to avoid homophones based on hard-to-perceive contrasts
3. Words in dense neighborhoods tend to resist alternation (Ussishkin and Wedel 2009)

4.3 Other Patterns in the Data

- The more phonologically plausible the rule, the more homophony it creates
  - If true, this trend might argue against explanation 2 above
  - Caveat: most simulated rules still not very plausible
  - Future research: how to better filter rules for phonological plausibility?
- Level of actual homophony looks less surprisingly low when homophones are weighted by frequency
  - In other words, few words are homophonized, but they tend to be especially frequent
  - Possible explanation: short words more likely both to be homophonized *and* to be frequent
    - ⇒ Unlikely: should be just as true of simulated patterns as of actual patterns
  - Looks like an anti-functional tendency

5 Conclusion

- Neutralizing alternations in Korean appear to produce less homophony than expected
- Thus, phonological rules may be sensitive to contrast among actual words, not just potential ones

References

Adam Albright and Yoonjung Kang. Predicting innovative alternations in Korean verb paradigms. In *Current Issues in Unity and Diversity of Languages: Collection of the Papers Selected from the CIL 18, Held at Korea University in Seoul*, pages 1–20, Seoul, Korea, 2009. Linguistic Society of Korea.

Edward S. Flemming. *Auditory Representations in Phonology.* Outstanding Dissertations in Linguistics. Routledge, New York, NY, 2002.

Naomi Gurevich. *Lenition and Contrast: The Functional Consequences of Certain Phonologically Conditioned Sound Changes*. Outstanding Dissertations in Linguistics. Garland Publishing, New York, NY, 2004.

Yongeun Lee. *Sub-Syllabic Constituency in Korean and English*. PhD thesis, Northwestern University, 2006.

Jaye Padgett. Contrast and post-velar fronting in Russian. *Natural Language and Linguistic Theory*, 21(1):39–87, 2003.

Jaye Padgett and Marija Tabain. Adaptive dispersion theory and phonological vowel reduction in Russian. *Phonetica*, 62:14–54, 2005.

Daniel Silverman. Neutralzation and anti-homophony in Korean. *Journal of Linguistics*, to appear.

Ho-Min Sohn. *Korean*. Descriptive Grammars. Routledge, New York, NY, 1994.

Adam Ussishkin and Andrew Wedel. Lexical access, effective contrast, and patterns in the lexicon. Ms., University of Arizona, 2009.