Currently available data on English *t/d*-deletion fail to refute the classical modular feedforward architecture of phonology.

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INTRODUCTION

> The fundamental philosophical questions like the continuous versus the discrete or the limits of knowledge are **never** definitively solved.
>
> Gregory Chaitin, *Metamaths*, 2.

§1 In classical modular feedforward architectures of grammar (Pierrehumbert 2002, Bermúdez-Otero 2007), there is no direct communication between morphology and phonetics;

morphology can affect the application of gradient processes of phonetic implementation only indirectly, through categorical properties of the surface phonological representation.

§2 So-called English /t,d/-deletion appears to challenge the classical architecture (Myers 1995,[1] Coetzee and Pater forthcoming):

- *morphological sensitivity* (e.g. Labov et al. 1968; Guy 1980, 1994)

  /t,d/ are deleted more often when affiliated to a stem *mis**t***
  than when affiliated to a regular inflectional suffix *miss-**ed***

- *phonetic gradience* (Browman and Goldstein 1989, 1990)

  in at least some instances, the tongue-tip gesture of the allegedly deleted /t,d/ is not removed, but merely hidden by adjacent overlapping gestures (and also possibly reduced).

§3 The rate of complete (categorical) vs incomplete (gradient) /t,d/-deletion is currently unknown.

In any case, the classical architecture can describe the facts in §2 by means of a two-step derivation (cf. Scobbie 1995):

(1) *phonology:*	variable,	categorical,	morphologically sensitive	featural or prosodic change
(2) *phonetics:*	variable,	gradient,	morphologically insensitive	gestural adjustment.

§4 Two-step derivations along the lines of §3 should not be regarded as contrived; they are the natural and expected result of the highly prevalent diachronic process of rule scattering.

> RULE SCATTERING (after Robinson 1976):
> Diachronic change often introduces a new avatar of an existing pattern into a higher component of the grammar by reanalysis, while the old avatar remains *in situ*.

[1] **Note added on 17 Dec 2010.** A few months after this paper was presented at 18mfm, it was brought to my attention that J. Myers had reached very similar conclusions about English /t,d/-deletion in an entirely independent study, reported in Myers (1995). I have added references to Myers's manuscript, highlighted in red, at relevant points in this handout.

MORPHOLOGY AND PHONETICS IN THE CLASSICAL ARCHITECTURE

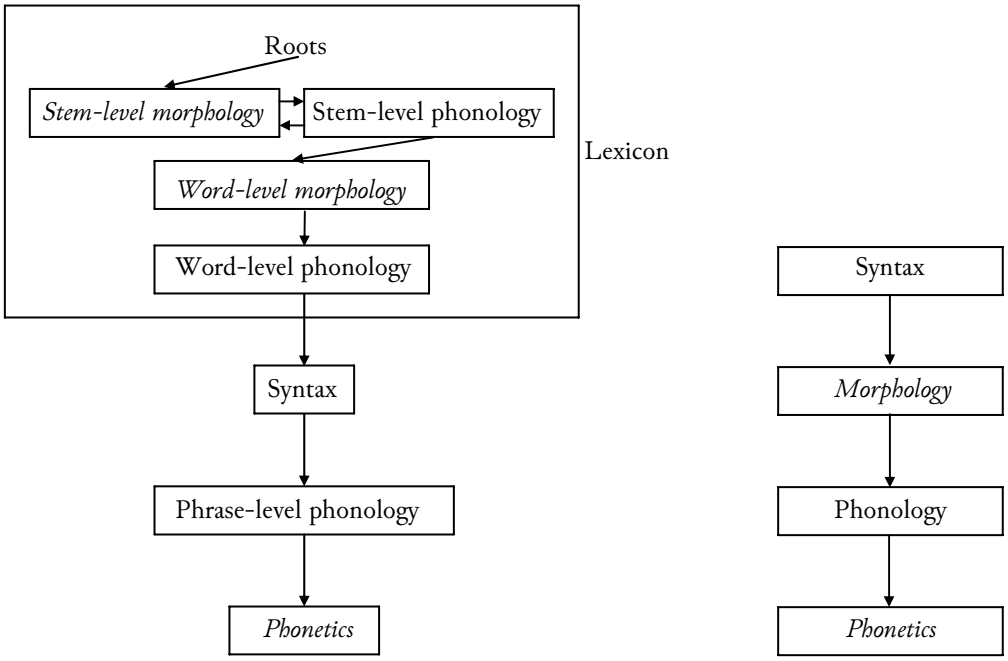
No morphological conditioning in phonetics

§5 In classical architectures, there cannot be direct communication between morphology and phonetics

because morphology and phonetics do not share an interface;
the (categorical) phonology always mediates between the two.

§6 (a) *Late 1980s interactionist architecture*
(Kiparsky 1985, Booij and Rubach 1987)

(b) *Late 1980s noninteractionist architecture*
(Halle and Vergnaud 1987, Odden 1993)



§7 A long-standing principle (see Scheer 2010):

- Structuralism (e.g. Z. S. Harris 1951, ch. 8):
  morphosyntax controls the distribution of juncture phonemes;
  allophony rules refer to juncture phonemes, not to morphosyntax.
- *SPE* (Chomsky and Halle 1968): a variant of §6(b).
- Bidirectional Phonology and Phonetics (Boersma 2009):
  parallel, rather than feedforward, architecture;
  but, still, no constraints directly evaluating the relationship between Morphemes and Auditory Form or Articulatory Form.

Empirical challenges

§8 Allegations of direct morphological conditioning of gradient phonetic processes (see also Kawahara forthcoming: §2.3.3):

phenomenon	reference	this paper
• English /t,d/-deletion	Myers (1995), Coetzee and Pater (forthc.)	§22ff
• English /l/-darkening	Sproat and Fujimura (1993)	†
• The Withgott Effect	Steriade (2000)	§9-§13
• Korean gestural timing	Cho (2001)	§18-§21
• Dutch final devoicing	Ernestus and Baayen (2006, 2007)	
• Dutch *-igheid*	Pluymaekers et al. (2010)	

† I assume that the approach to /t,d/-deletion defended in this paper is also appropriate for /l/-darkening: see Hayes (2000: 93), Bermúdez-Otero (2007: note 6), Bermúdez-Otero and Trousdale (2011: 17).

Prosodic solutions (I): the Withgott Effect

§9 The Withgott effect (Withgott 1982):

cápi[ɾ]*al* ⇨ *càpi*[ɾ]*alístic*
míli[tʰ]*àry* ⇨ *mìli*[tʰ]*arístic* The effect is subject to variation (Riehl 2003).

§10 Steriade's (2000) claims:

- Flapping is a gradient phonetic process (shortening of stop closure); cf. §11 below.
- The Withgott effect requires analogical transfer (via output-output correspondence) of gradient phonetic properties; cf. §12 below.

§11 In fact, flapping is a variable but categorical phrase-level process creating discrete stop vs flap allophones:

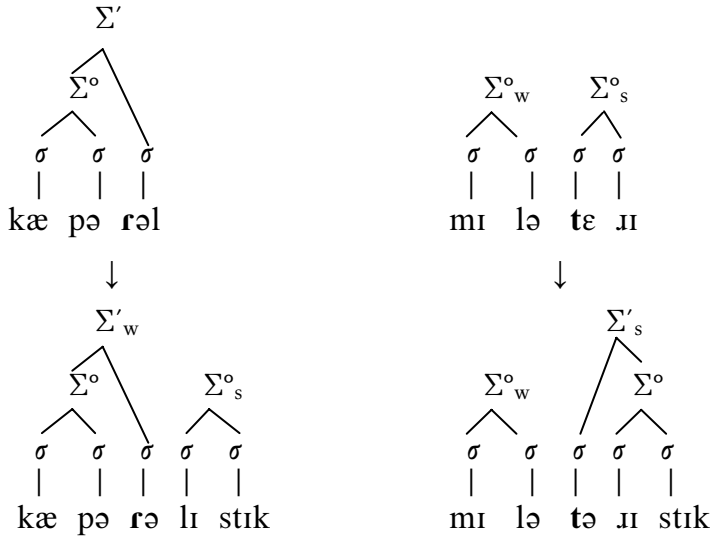
- Stop and flap allophones are distinguished by several interacting acoustic cues (Riehl 2003).
- Stop and flap allophones create a bimodal distribution in duration (Herd et al. 2010: 508).
- /t/-flaps and /d/-flaps are phonetically indistinguishable: e.g. same mean duration (Zue and Laferriere 1979: 1043-44, Kwong and Stevens 1999: 3, Herd et al. 2010: 511, Braver 2010).

  The underlying /t/-/d/ contrast is reflected only in the preceding vowel, notably in its duration. This effect is entirely expected since prefortis clipping (vowel shortening before voiceless obstruents) can be independently shown to apply at the stem level and so to precede phrase-level flapping (Bermúdez-Otero 2004: §14-§22).

§12 In fact, morphological structure affects flapping not directly, but indirectly via prosody:
foot structure is built cyclically
and an intervocalic /t/ resists flapping if it is initial in some foot-projection at the word level.

See Kiparsky (1998), Jensen (2000: 208-11), Davis (2005), Bermúdez-Otero and McMahon (2006: 403-04).

§13



Prosodic solutions (II): durational effects of suffixation

§14 Sugahara and Turk (2009) on durational effects of word-level suffixation in Scottish English:

phonetic realization of the string /ɹeːz/
- ⇨ shorter duration in *raisin* [ɹeːzn̩]
- ⇨ longer duration in *rais-ing* [ɹeːzɪŋ]

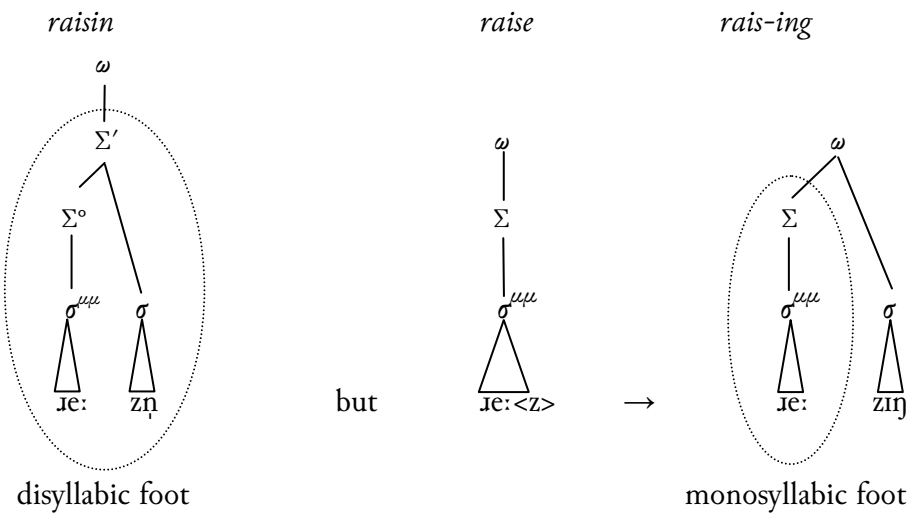
The effect is relatively small:

- it was not detected at all in Sproat and Fujimura (1993)
- not statistically significant at 'normal' speech rates (Sugahara and Turk 2009: 496)
- 6.6% difference (mean of 23ms) at 'slow' speech rates (Sugahara and Turk 2009: 496)
- 9.6% difference (mean of 42ms) at 'extra-slow' speech rates (Sugahara and Turk 2009: 499).

§15 A prosodic solution (Bermúdez-Otero 2011: §4):

- stem level (stress-affecting affixation) ⇨ exhaustive footing
- word level (stress-neutral affixation) ⇨ stray syllables attached directly to *ω*

§16



§17 Sugahara and Turkel propose the prosodification [ˌɹ [ˌɹ ɹeːz] ɪŋ] for *rais-ing*, but this incorrectly predicts that the stem will behave durationally like the first member of a compound (*pace* Sugahara and Turkel 2009: 488; cf. Sproat 1993: 178).

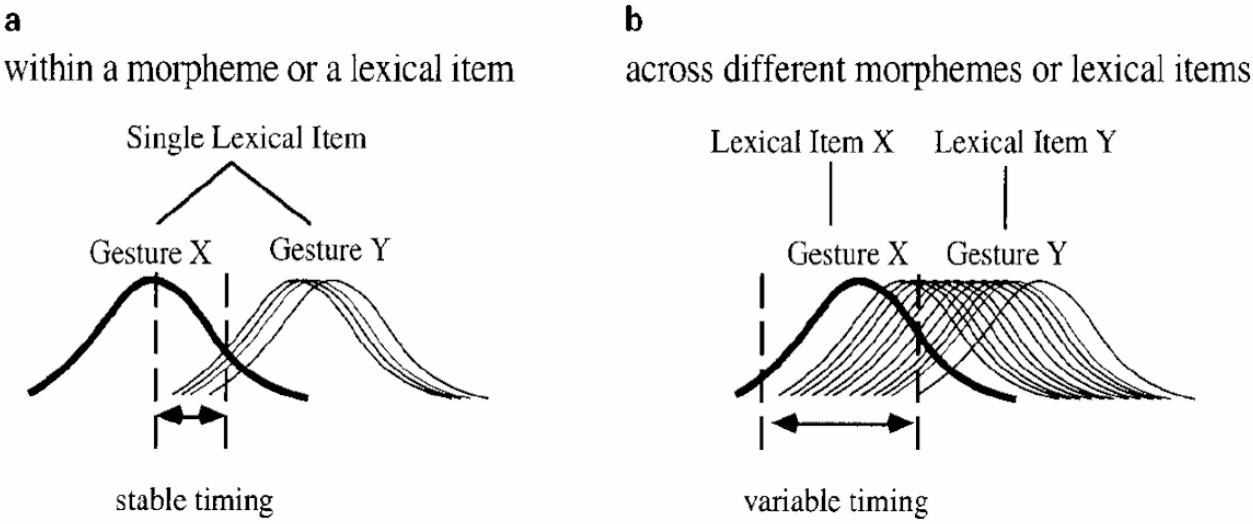
Processing solutions? A speculative suggestion

§18 Cho (2001) on gestural timing in Korean:

- tautomorphemic segments ⇨ low variability in gestural timing /na**pi**/ 'butterfly'
- heteromorphemic segments ⇨ high variability in gestural timing /na**p-i**/ 'lead-NOM'

I assume that Cho is right in treating Korean nominal inflections as belonging in the same morphological and prosodic word as the stem: cf. Yoon (2005) for a phrasal-affix analysis, but see Bermúdez-Otero and Payne (2011).

§19



(Cho 2001: 131, Figure 1)

‼ In this case, the effect of morpheme boundaries is <u>symmetrical</u>: both more extreme overlap and more extreme nonoverlap; cf. §14.

§20 Cho's analysis:

'[...T]he phonological structure of a lexical entry forms a "constellation" of gestures, a stable organization among gestures <u>whose timing is specified in the lexicon</u>' (p. 153, my emphasis).

Cf. Articulatory Phonology (Browman and Goldstein 1989, 1990); see also Bradley (2007).

§21 A speculative suggestion: cascading activation.

Processing models with cascading activation allow competing representations at processing stage *s* to <u>pass on activation to subsequent processing stages even before selection is complete at stage *s*</u>.

- In such models, competiting morphs can pass on activation downwards to phonological representations and thence to articulatory planning even before morph selection is complete.
- If that happens, we expect higher amounts of articulatory 'jitter' near points of morph selection (morphological boundaries) than inside morphs.
- In this scenario, articulatory jitter is an artifact of processing:
  phonological representations *can* be more or less activated in processing,
  but phonological representations *do not* contain fine-grained detail about gestural timing.

(See Rapp and Goldrick 2000, Goldrick 2006, Goldrick and Blumstein 2006, Baese-Berk and Goldrick 2008).

A TWO-STAGE DERIVATION OF ENGLISH *t/d*-DELETION

Morphological sensitivity

§22

Morphological affiliation	Examples	Surface forms	% deleted (Guy 1991a: 5)
stem	*mist, pact*	[mɪs(t), pæk(t)]	38.1
regular inflectional suffix	*miss-ed, pack-ed*		16.0

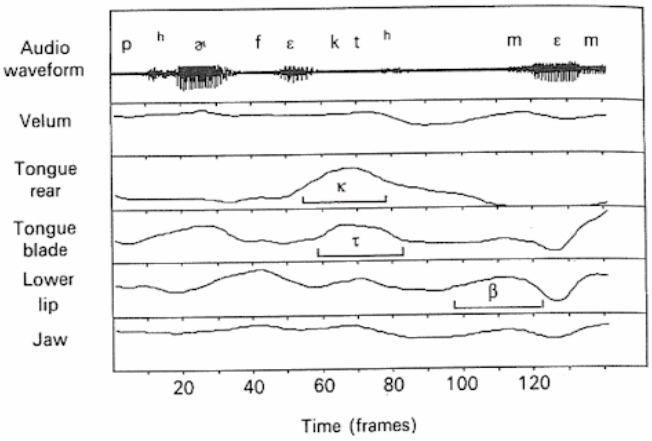
This correlation between the morphological affiliation of the stop and deletion rate has been replicated in various dialects (e.g. Guy 1994: 140), but at least two studies have warned of possible confounding variables: the preceding consonant (Tagliamonte and Temple 2005: 295-96) and lexical frequency (Guy et al. 2008).

§23 Irregular weak verbs (e.g. *lef-t, tol-d*) display an intermediate average rate of deletion in corpora: e.g. 33.9% in Guy (1991a: 5). This does not reflect a third type of morphological structure (*pace* Guy 1991a,b), but is rather an effect of age grading (Guy and Boyd 1990, Guy 2010: 255):

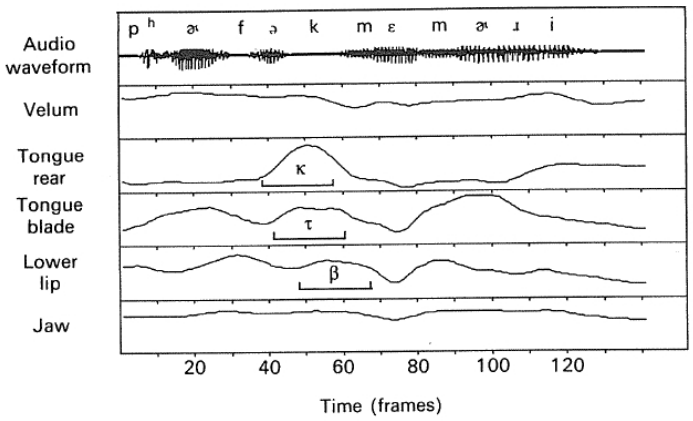
- *lef-t, tol-d* behave like *mist, pact* for younger speakers
- *lef-t, tol-d* behave like *miss-ed, pack-ed* for older speakers.

Phonetic gradience

§24 Audibly released /t/ in *perfect memory* **(Browman and Goldstein 1990: 364, figure 19.13(a))**



§25 Inaudible /t/ with hidden tongue-blade gesture (τ) in *perfect memory* **(Browman and Goldstein 1990: 364, figure 19.13(b))**



§26
- How many of the instances of /t,d/-deletion reported in the sociolinguistic literature are actually incomplete, like §25?

  We just don't know.

- Can we assume that /t,d/-deletion is always incomplete (see e.g. Temple 2009)?

  No! Lichtman (2010) examined the Wisconsin Microbeam Database and conducted an additional electromagnetic articulography study, and found that all speakers produced at least some instances of deleted /t/ without residual linguoalveolar gestures.

- Cf. the following cautionary tale:

  Early reports of gradient coarticulation in assimilatory external sandhi led to the belief that categorical feature delinking and spreading did not operate across word-boundaries

  (e.g. Barry 1985, Wright and Kerswill 1989, Nolan 1992, Hardcastle 1995, Zsiga 1995);

  but this belief has proved false: categorical assimilatory external sandhi does exist

  (e.g. Nolan et al. 1996, Ellis and Hardcastle 2002, Kochetov and Pouplier 2008: 414).

Two-step derivations

§27 Assume the worst-case scenario: morphologically-sensitive incomplete /t,d/-deletion is prevalent.

Can this be accommodated within the classical architecture?

Yes, by means of two step-derivations:

(1) *phonology:*	variable,	categorical,	morphologically sensitive	featural or prosodic change
(2) *phonetics:*	variable,	gradient,	morphologically insensitive	gestural adjustment.

See Myers (1995) for a similar view.

§28 *Scobbie's Caveat* (after Scobbie 1995):

If,	as commonly assumed, phonological processes need not be neutralizing (i.e. need not be 'structure-preserving' in the sense of Kiparsky 1985),
then	evidence of gradience is not evidence of absence of a categorical effect.

§29 Key question:

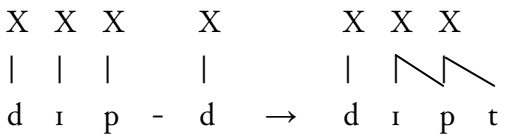
Is there an independently motivated way of categorically representing /t,d/-reduction in the phonology?

§30 • Option 1: represent the absence of audible release

e.g. in Element Theory, delete the h° element (noise component)
(e.g. J. Harris and Lindsey 1995)

• Option 2: represent concurrent articulation

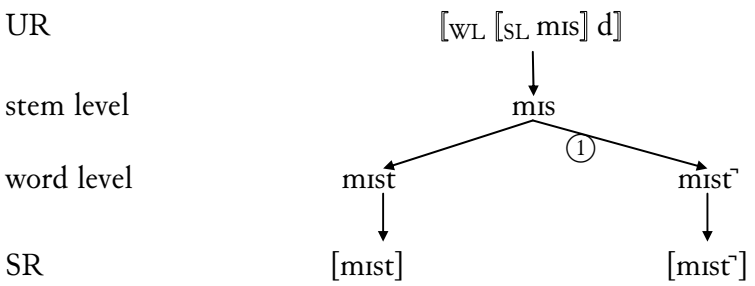
e.g. tuck the underlying /t,d/ under the timing slot of the preceding consonant



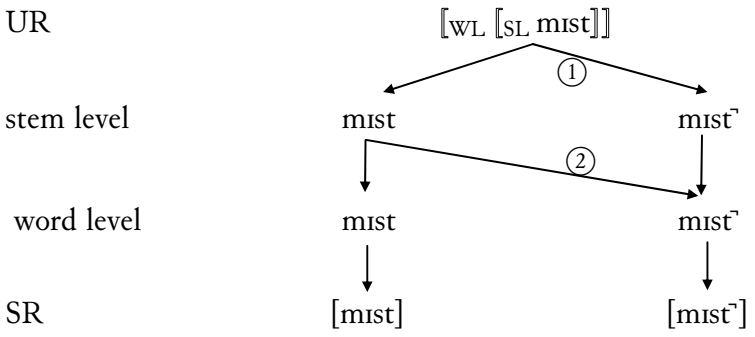
This autosegmental chart iconically represents
- prefortis clipping (reduced duration of /ɪ/ before longer fortis /p/)
- overlap of /p/ and /d/.

Deriving the effect of morphology on frequency cyclically (Guy 1991a, 1991b)

§31 One round of variable reduction in *miss-ed* ⇨ low reduction rate



§32 Two rounds of variable reduction in *mist* ⇨ high reduction rate



§33 *Pace* Guy (1991a, 1991b), I do not assume that the rate of reduction must be the same in every cycle.

On the contrary:

- In their normal diachronic life cycle (Bermúdez-Otero 2007, 2011; Bermúdez-Otero and Trousdale 2011), phonological processes enter the grammar from below and climb up to progressively higher levels.
- This predicts the possibility that a process may display higher rates of application at lower levels, where it has been active the longest (e.g. Turton 2011 on /l/-darkening).

TWO-STAGE DERIVATIONS ARE NATURAL: DIACHRONIC RULE-SCATTERING

A doctrine is not judged at all until it is judged in its best form.
John Rawls, 'Some remarks about my teaching', improving (by misquotation) on John Stuart Mill.

Diachronic rule-scattering gives rise to two-step derivations

§34 A perfectly ordinary stage of affairs:

two cognate rules, one gradient, one categorical, representing different stages in the diachronic life cycle of the same sound pattern, coexist within the same grammar.

Examples:	• Philadelphia *æ*-tensing	(Labov 1994)	§36–§37 below
	• Pre-yod /s/-palatalization	(Zsiga 1995)	§38–§40 below
	• The Scottish Vowel Length Rule	(McMahon 1991, 2000)	Myers (1995: §1)

§35 Why is this stage of affairs common? Presumably because of the mechanics of *stabilization* (i.e. of the diachronic process of reanalysis whereby tokens of a gradient rule of phonetic implementation are reinterpreted as involving a categorical distinction):

the reanalysed tokens give rise to a new categorical rule, whilst the nonreanalysed tokens preserve the gradient rule *in situ* (Bermúdez-Otero 2007: 506; Bermúdez-Otero and Trousdale 2011: 4, 17–18).

☞ Just a special case of rule scattering: see §4.

Philadelphia *æ*-tensing

§36 *A categorical default stem-level rule…*

- categorical opposition between lax [æ] and tense [æː]
- the phonetic realizations of [æ] and [æː] occupy largely nonoverlapping regions in auditory space (Labov 1989: 8-10)
- default pattern: *æ* is normally tense before coda /m, n, f, θ, s/ (Labov 1994: 430)
- counterbled by resyllabification before word-level suffixes:
  e.g. *m*[æː]*n, m*[æ]*nner*, *m*[æː]*nn-ing* (Labov 1994; 430-31)
- outright lexical exceptions: [æː] in mad, bad, glad; but [æ] in *sad*, *fad*, *lad*
  [æ] in strong verbs like *began*, *ran*, *swam*

§37 *…overlaid with a gradient phonetic process*

the precise formant values of the acoustic realization of [æː] are exquisitely sensitive to the phonetic environment

	effect on height
following nasal	158
preceding nasal	99
preceding obstruent plus /l/	–210
two following syllables	–410
etc.	

(coefficients in Labov 1994: 466)

Pre-yod /s/-palatalization

§38 *A neutralizing stem-level morphophonological process…*

confe/s/+/j/*on* → *confe*[ʃ]*on* [ʃ] realized with same pattern of linguopalatal consonant as underlying /ʃ/

§39 *…coexisting with gradient gestural overlap across word-boundaries*

pre/s/ # /j/*ou* → *pre*[s͡j]*ou* [s͡j] arises from the superposition of the patterns of linguopalatal contact for /s/ and /j/

§40 But the same diachronic origin! cf. Chaucer's *confe*/si.uːn/.

METHODOLOGICAL CONSIDERATIONS

The insufficiency of conceptual arguments

§41 *Implications of the evidence for rule-scattering* (§34-§40)

☞ Criteria of elegance or simplicity (e.g. Ockham's Razor) do not suffice to dismiss the two-step solution to the problem that English *t/d*-deletion raises for classical architectures.

Two-step derivations may look synchronically complex, but they are diachronically natural.

Of course, the evidence from rule scattering does not *prove* that two-step derivations are right for English *t/d*-deletion.

§42 *Conceptual arguments against direct communication between morphology and phonetics*

Grotesquely nonclassical behaviours become conceivable:

e.g.
- 'Mark dual number by adding /-no/ and increasing gestural overlap by 20%.'
- 'Form eventive nominalizations by adding /-ti/ and lengthening VOT by 30%.'

Of course, usage-based models need not predict such aberrant behaviour:

e.g. Bybee's line (2001: 54):
Speakers are driven by efficiency requirements to constantly reuse a finite set of highly practised neuromotor programmes in speech. Presumably, this prevents morphological categories from drifting apart in phonetic space.

However, in the absence of equations or computer simulations, isn't this just a promissory note?

> "This family of theories [sc. exemplar-based theories—RBO] holds that the lexicon consists of a massive number of stored phonetic (or auditory) events, with or without category labels. Those subtheories that touch on category creation can do so because they include no category labels, but those subtheories that make interesting linguistic generalizations [...] do require the presence of category labels." (Boersma forthcoming: §10.2.7)

Empirical problems

§43 *Limitations of the data currently available*

- sociolinguistic studies: impressionistic coding
  no way of controlling for the presence of hidden gestures
- articulatory studies: few speakers
  few tokens
  lack of control of relevant morphological and phonological factors

§44 *Analytical challenges*

A bimodal distributions on some phonetic dimension is usually treated as the clearest indication of a categorical distinction (e.g. §11 above):

Problem: suppose that the realizations of two categories create two normal densities on some phonetic dimension;

the mixture of these two densities may be unimodal or very weakly bimodal under a wide range of conditions.

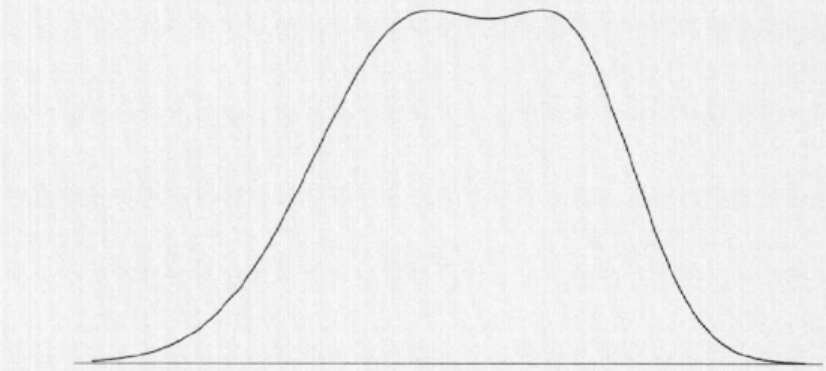


Figure 6. Mixture of two normal densities with $\sigma_1 = 0.6\sigma_2$, $|\mu_2 - \mu_1| = \sigma_1 + \sigma_2$, $p = .288$. This density has the most pronounced dip of any mixture in which $0.6 \leq \sigma_1/\sigma_2 \leq 1$ and $|\mu_2 - \mu_1| \leq \sigma_1 + \sigma_2$.

(Schilling et al. 2002: 225, figure 6)

See Myers (1995) for discussion with particular reference to the problem of *t/d*-deletion.

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