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On the Foot-based Analysis of Aspiration in American English

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Aspiration environments in American English (Iverson & Salmons 1995, Jensen 2000, Davis & Cho 2003; but also see Vaux & Samuels 2005)

1. The distribution of aspirated stops in American English

What is the environment where voiceless stops (/p/, /t/, /k/) become aspirated?

a. At the beginning of a syllable with primary stress

póny	[p^h]	appéar	[p^h]
térrible	[t^h]	matérial	[t^h]
cándy	[k^h]	accúse	[k^h]
atómic	[t^h]	optícian	[t^h]

b. At the beginning of a syllable with secondary stress

dávenpòrt	[p^h]	Pènnsylvánia	[p^h]
plánetàry	[t^h]	tìtánic	[t^h]
cúcùmber	[k^h]	Càrolína	[k^h]

c. At the beginning of a word-initial stressless syllable

Pacífic	[p^h]	potáto	[p^h]
tomáto	[t^h]	connéct	[k^h]

d. At the beginning of a stressless syllable when immediately preceded by a stressless syllable and followed by a stressed one (3rd syllable of a word-internal dactylic sequence, noted by (Jensen 2000, Pater 2000, Van Dam 2003))

Mèdi**t**erránean	[t^h]	pèri**p**atétic	[p^h]	lòllapalóoza	[p^h]
Nàvra**t**ilóva	[t^h]	àbra**c**adábra	[k^h]		

What are the environments where voiceless stops are not aspirated?

e. In coda position

at.las	[t]	sit	[t]
ac.ne	[k]	sick	[k]
hyp.no.sis	[p]	lapse	[p]

f. At the beginning of a (non-initial) stressless syllable following a stressed one

átom	[ɾ]	Míckey	[k]	rápid	[p]

g. At the beginning of a word final stressless syllable when preceded by a stressless syllable (i.e. at the beginning of the final syllable in a word-final dactylic sequence)

sánity [ɾ] chárity [ɾ] sénator [ɾ]

cánopy [p] mánnequin [k] (Compare with d.)

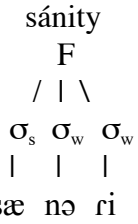
h. As a possible second member of an onset

ský [k] exposítion [p] extínguish [t]

2. Foot Structure (after Davis 2003, Davis & Cho 2003 and Davis 2005)

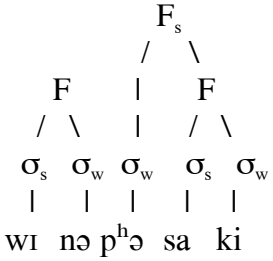
a. English foot structure is essentially trochaic

b. Surface footing of a word final dactylic sequence (1g)



c. Surface footing of a non-final dactylic sequence (1d)

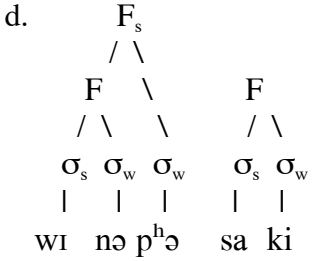
Wìnnepesáukee (F_s = superfoot, F = foot, σ_s = stress syllable, σ_w = stressless syllable; a final syllable is shown incorporated into foot structure, the word tree is not shown)



The foot structure above in (2c) for nonfinal dactylic sequences was originally proposed by Withgott (1982) but was also suggested in a footnote by McCarthy (1982). More recently, this foot structure has been adopted by Jensen (2000), Davis & Cho (2003) and is suggested by Pater (2000). One immediate advantage of this footing is that it makes for a unified statement regarding American English aspiration (as noted by Jensen 2000). Namely, that voiceless stops are aspirated in foot-initial position.

The structure on nonfinal dactyls is not as in (2d) below

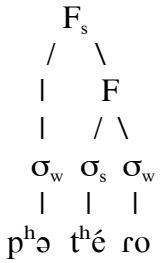
d.



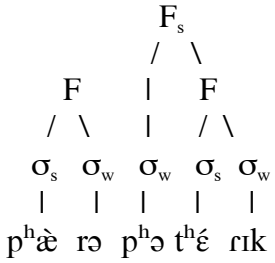
In (2d) above, the initial dactylic sequence comprises a superfoot. This reflects the analysis of English found in Hayes (1981) and McCarthy (1982), and Spencer (1996).

Evidence for (2c) as opposed to (2d) not only comes from aspiration patterns but also from attested word plays such as lollapalooza-palooza and lesbopalooza. The potential reduplication as lollapa-lollapalooza seems ill-formed. Further, McCarthy (1982) observed that words like "Wìnnepesáukee" (and the others in 1d) prefer expletive infixation as Winne-frickin-pesaukee. This is more consistent with the structure in (2c).

e. surface footing of words beginning with stressless syllables (similar to 2c above)
potáto



f. footing of pèripatétic



3. Analysis along the lines of Davis & Cho (2003) assuming underlying [s.g.] following Iverson & Salmons 1995, though the assumption is not essential)

a. AlignL(Ft, [sg]) -- Align the left edge of the foot with the feature [spread glottis].
b. *[sg, +voice] -- The feature [sg] cannot be realized on sounds that are [+voice].
c. Max-[sg] -- The feature [sg] in the input corresponds to the feature [sg] in the output.
d. *sg -- The feature [sg] is not allowed

4. *[sg, +voice] >> AlignL (Ft, [sg]) >> *sg >> Max-[sg]

5. "pie" / pʰay / -- [pʰay]

/pʰay/	*[sg, +voice]	AlignL (Ft, [sg])	*sg	Max-[sg]
a. pay		*!		*
☞ b. pʰay			*	

6. "buy" /bay/ -- [bay]

/bay/	*[sg,+voice]	AlignL (Ft, [sg])	*sg	Max-[sg]
a. b^{h}ay	*!		*	
☞ b. bay		*		

7. "lapse" /læp^{h}s/ -- [læps]

/læp^{h}s/	*[sg, +voice]	AlignL (Ft, [sg])	*sg	Max-[sg]
a. læp^{h}s		*	*!	
☞ b. læps		*		*
c. l^{h}æps	*!		*	*

8. "peripatetic" /p^{h}ɛ̀rɪp^{h}ət^{h}ét^{h}ɪk^{h}/ -- [p^{h}ɛ̀rɪp^{h}ət^{h}érɪk] (brackets = superfoot; parentheses = foot)

/p^{h}ɛ̀rɪp^{h}ət^{h}ét^{h}ɪk^{h}/	*[sg, +voice]	AlignL (Ft, [sg])	*sg	Max-[sg]
☞ a. (p^{h}ɛ̀.rɪ){p^{h}ə (t^{h}é.rɪk)}			***	**
b. (p^{h}ɛ̀.rɪ){pə (t^{h}é.rɪk)}		*!	**	***
c. (p^{h}ɛ̀.rɪ){p^{h}ə (t^{h}é.t^{h}ɪk)}			****!	*

9. "rapid" /ræp^{h}ɪd/ -- [ræpɪd]

/ræp^{h}ɪd/	*[sg, +voice]	AlignL (Ft, [sg])	*sg	Max-[sg]
a. ræp^{h}ɪd		*	*!	
☞ b. ræpɪd		*		*

10. Alternatives to the foot-based approach. Here I will not consider the syllable-based approach to English aspiration (voiceless stops are aspirated in syllable-initial position) such as Kahn (1976) that assumes ambisyllabicity or Selkirk (1982) that assumes resyllabification. Note that such analyses would have a difficult time distinguishing the initial dactylic sequence in (1d) from that in (1g).

11. Enhancement of contrast (Fleming 1995:62) - Given that word-initial voiced stops in English are not fully voiced, aspiration of voiceless stops in word-initial position can be understood in terms of enhancement of contrast. By making a word-initial voiceless stop aspirated it becomes more distinct from a word-initial voiced stop, which is not fully voiced. Thus, aspiration enhances the laryngeal contrast between voiceless and voiced stops. Moreover, intervocalically, aspiration of voiceless stops should be unnecessary given that voiced stops in such environment are fully voiced. Thus, as seen by a pair like rapid-rabid, there is no reason to aspirate the /p/ in 'rapid' since a /b/ in this environment is fully voiced. The problem for such a view, though, is that prosody still needs to be referenced because intervocalically the voiceless stop is aspirated at the beginning of a stress syllable as in rapídity. Intervocalically, aspiration of voiceless stops should be unnecessary given that voiced stops in such environment are fully voiced. Moreover, under an enhancement of contrast view, there is no clear reason why the stop is aspirated in the dactylic sequence in (1d) but not in (1g), unless prosody is also being referenced.

12. Steriade (1997) argues for a cue-based approach to account for the distribution of laryngeal features as opposed to an approach in which laryngeal features are licensed by prosody (Lombardi 1995). In the latter approach the distribution of laryngeal features is controlled by their prosodic position. In the licensing by cue approach, laryngeal features are permitted in positions high on the scale of perceptibility and it is the relevant poverty of cues that induces laryngeal neutralization in certain positions. For example, the position of best perceptibility for the feature [voice] is intervocalic while positions of poor perceptibility of [voice] would include before an obstruent or at the end of a word. With respect to aspiration (i.e. post-aspiration), it would be most perceptible before sonorants (includes vowels) especially in a stress environment. Thus, this string-based approach to phonotactics (see also Blevins 2003) would seem to best explain the occurrence of English aspirated stops in the environments in which it occurs. However, a serious problem for this string/cue-based approach to English aspiration (implicitly recognized by Steriade 2000) is the difference between aspiration aspiration between two stressless vowels in (1d) versus the lack of aspiration between two stressless vowels in (1g). The string environment is identical but the aspiration is different. We suggest that this reflects the different foot structures of the two types of dactylic sequences as shown in (2b) and (2c).

13. The distribution of [h] in American English (Davis & Cho 2003) – Where does /h/ surface?

a. At the beginning of a syllable with primary stress

hábit	[h]	prohíbit	[h]		
héro	[h]	Tahíti	[h]		
hístory	[h]	mahogany	[h]	adhérence	[h]

b. At the beginning of a syllable with secondary stress

álcohòl	[h]	h`ypótenuse	[h]
Ídahò	[h]	Ahàsuérus	[h]
réhàb	[h]	Hàragúchi	[h]

c. At the beginning of a word-initial stressless syllable

horízon	[h]	Hawáii	[h]
habítual	[h]	hypócrisy	[h]

d. At the beginning of a stressless syllable when immediately preceded by a stressless syllable and followed by a stressed one (3rd syllable of a word-internal dactylic sequence)

Tàrahumára [h]

What are the environments where /h/ does not surface?

e. In coda position (~~h~~ indicates a possible /h/ that does not surface)

Te~~h~~.ran	bra~~h~~.min
Ya~~h~~.we~~h~~	Fa~~h~~d

f. At the beginning of a (non-initial) stressless syllable following a stressed one

vé.~~h~~i.cle	prò.~~h~~i.bí.tion
ní.~~h~~i.lism	prè.~~h~~I.stó.ric

g. At the beginning of a word final stressless syllable when preceded by a stressless syllable (i.e. at the beginning of the final syllable in a word-final dactylic sequence)

É.lo.~~h~~ist (vs. È.lo.hím)

h. As a possible second member of an onset

B~~h~~utan	ex~~h~~ibition	ex~~h~~íbit

14. The patterning parallels aspiration and the analysis is the same (that is, /h/ surfaces when in foot-initial position)
15. *[sg, +voice] >> AlignL (Ft, [sg]) >> *sg >> Max-[sg] (same as in 4)
16. "habit" /hæbɪt/ -- [hæbɪt] (Compare these with 5-9)

/hæbɪt/	*[sg, +voice]	AlignL (Ft, [sg])	*sg	Max-[sg]
a. æbɪt		*!		*
☞ b. hæbɪt			*	

17. "véhicle" /víhɪkəl/ -- [ví.ɪ.kəl]

/víhɪkəl/	*[sg, +voice]	AlignL (Ft, [sg])	*sg	Max-[sg]
a. ví.hɪ.kəl		*	*!	
☞ b. ví.ɪ.kəl		*		*

18. "Tàrahumára" /t^{h}ˋærəhumárə/ -- [t^{h}ˋærəhumárə/] (brackets = superfoot; parentheses = foot)

/ t^{h}ˋærəhumárə/	*[sg, +voice]	AlignL (Ft, [sg])	*sg	Max-[sg]
☞ a. (t^{h}ˋæ.rə){hu(má.rə)}		*	**	
b. (t^{h}ˋæ.rə){u(má.rə)}		**!	*	*
c. (t^{h}ˋæ.rə){hu(m^{h}á.rə)}	*!		**	

19. Alternative analyses -- Borowsky (1984, 1986) along with Selkirk (1982) assume stress-based resyllabification. /h/ deletes just in case it resyllabifies in a coda. While this is neat, it completely misses the parallel distribution between /h/ and aspirated stops. They have a rule that aspirates stops at the beginning of syllables and a different rule that deletes /h/ in coda. (Harris 1994, 1997 offers a government phonology analysis that has certain problematic aspects regarding feature representation; See Davis & Cho 2003 for discussion.)
20. It is not clear to me how to account for the distribution of /h/ in American English in an approach that references enhancement of contrast (Fleming 1995) or licensing by cue in a string-based theory of phonotactics (Steriade 1997, Blevins 2003). Further, it is not clear why there should be a close parallel in the distribution of /h/ and aspirated stops. Goldstein (1992) who observes the close parallel between /h/ and aspirated stops also mentions that /h/ and aspiration often has different acoustic manifestations.

21. Pennsylvania D(e)ut(s)chified English (henceforth, PDE)
There is occasional mentioning in the literature of devoicing in German-influenced English that includes intervocalic devoicing in addition to coda devoicing, but studies either do not include such environments (e.g. Purnell et al. 2005) or only mention it in passing (e.g. Knack 1991). The only systematic examination of this is by Anderson 2001, 2002a,b a bidialectal speaker of PDE and Standard English from eastern Pennsylvania. The PDE data presented here and analysis are based on her work. PDE is an English dialect that has obstruent devoicing in a way that seems to be similar to German. On the other hand, a close examination of the devoicing pattern reveals that it is not exactly like what is found in German. While the fact of obstruent devoicing is obviously a German influence, the actual devoicing pattern is best understood in a foot-based approach consistent with American English.

22. The distribution of voiced obstruents in PDE -- Where do voiced obstruents occur?

a. At the beginning of a syllable with primary stress

bless	[b]	habítual	[b]
duck	[d]	addíction	[d]
zoo	[z]	diséase	[z]
go	[g]	lagóon	[g]

b. At the beginning of a syllable with secondary stress

cáribòu	[b]	Péntagòn	[g]
hólidày	[d]	mágazìne	[z]

c. At the beginning of a word-initial stressless syllable

belów	[b]	gorílla	[g]	diséase	[d]

What are the environments where voiced obstruents do not surface?

d. In coda position

tug	[k]	bed	[t]	leave	[f]
Agnes	[k]	admission	[t]	obtuse	[p]
dogs	[ks]	beds	[ts]	leaves	[fs]

f. At the beginning of a (non-initial) stressless syllable following a stressed one

hábit	[p]	dízzy	[s]	bágle	[k]
fábric	[p]			Séagrams	[k]

(Note: compare: *hábit* [p] with *habítual* [b])

23. Note, since PDE is an American dialect of English it has flapping. Flapping takes precedence over devoicing: bedding [ɾ] riding [ɾ]

24. Key observation: Voiced obstruents in PDE only surface in the environments where aspiration appears on voiceless stops. That is, voiced obstruents only appear in foot-initial position. Compare: *hábit* [p] / *habítual* [b] with *rapid* [p] / *rapídity* [p^h] (Note that PDE has typical American English type aspiration in the manner described in the first part of the paper.)

25. The PDE devoicing pattern exemplified in (22) is captured in terms of the foot alignment constraint AlignL(Ft, [+voice])) and not in terms of a licensing by cue approach as developed in the influential work of Steriade (1997) and Blevins (2003). The PDE devoicing pattern can be understood simply as the generalization of the alignment constraint with respect to the laryngeal feature [spread glottis], i.e. AlignL(Ft.[s.g.], to the other laryngeal feature [voice]. (Note the similarity in alternation environments in such pairs as rápid-rap^{h}ídity with "habit" [h´æpIt] - "habítual"). This strongly argues for the the importance of foot-based phonology in American English. PDE devoicing can be understood as the imposition of American English phonology (with the importance of foot-initial position) to German devoicing.

26. The analysis of PDE devoicing is highly problematic in a licensing-by-cue approach. This is because of the devoicing in the intervocalic environment in examples like *habit*.
In the licensing by cue approach (Steriade 1997), the cue-rich intervocalic position is the most favorable environment to maintain the voicing contrast. Moreover, as Kingston and Diehl (1994:428) note, "...intervocalically, it is turning voicing off that's more difficult..." Thus under the licensing by cue approach the pattern of PDE devoicing is unexpected. I would contend instead that devoicing of the intervocalic obstruent occurs because the obstruent is not in foot-initial position.

Acquisitional evidence (Inkelas & Rose 2007, my interpretation of their data)
27. Positional Lateral Gliding
Child E, between 1;8 and 2;9 does not have target /l/; instead target /l/ is typically realized as a glide with the following pattern (p. 712-713) where there is allophony between [j] and [w]

(a) At the beginning of a syllable with primary stress (j=palatal glide)

Target	Actual
lamp	jæmp
like	jɑjk
violín	vajəjín
helló	hajów

(b) At the beginning of a syllable with secondary stress

Target	Actual
Mádelìne	m´ædəjìn
Góldilòcks	gɔ́wdijɔ̀ks

(c) At the beginning of a word-initial stressless syllable

Target	Actual
Liván	jiván

(d) In coda position

Target	Actual
fell	fɛw
Hilda	hiwdə
hold me	how mi

(e) At the beginning of a (non-initial) stressless syllable following a stressed one

Target	Actual
helicopter	h´æwət^{h}ʌ̀əkə˞
alligator	´æwədɛ̀ɾə˞
necklace	nɛ́kwəs
Stellaluna	stɛ̀wəjú^{w}nə

(f) As a possible second member of an onset (realized as [w] (common after labials) or deleted)

Target	Actual
flakes	fwejks
please	pi:z
slip	sɪp
glasses	dæsəs

28. Velar fronting in acquisition, a common process according to Inkelas & Rose (2007) [see Bills & Golston 2002] Data from E between 1 and 2 years of age (Inkelas & Rose 2007:710-711)

(a) At the beginning of a syllable with primary stress (j=palatal glide)

Target	Actual
cup	t^{h}ʌp
go	do:
again	ədín

(b) At the beginning of a syllable with secondary stress

Target	Actual
helicopter	h˝æwət^{h}ʌ̀əkə˝
alligator	˝æwədɛ̀rə˝

(c) At the beginning of a word-initial stressless syllable (sometimes deleted)

Target	Actual
conductor	[tʌndʌ́ktə] (note: aspiration isn't consistently indicated in Inkelas & Rose)
caboose	[ʌbuəs̩]

(d) In coda position

Target	Actual
big	bɪg
octopus	ɑktəpʊs

(e) At the beginning of a (non-initial) stressless syllable following a stressed one

Target	Actual
bagel	béjgu
bucket	bʌ́kɨt
monkey	mɑ́ŋki

29. Inkelas & Rose (2007) cite other examples from the acquisition literature of similar patterning, such as the stopping of fricatives as in Rvachew & Andrews (2002:193)

a. Word-initial onset (stressed): *sádly* [dɑdi]; *fish* [pɪs]
b. Word-medial onset (stressed): *casíno* [kətino]; *únifòrm* [jubo]
c. Word-medial onset (unstressed): *glásses* [wæsəs]; *múffin* [mʌfɪn]
d. Word-final (coda) position: *yes* [jɛs]; *giraffe* [dəwæf]

30. In trying to explain why processes like velar fronting occur in acquisition Inkelas & Rose do not mention the similar patterning found with aspiration (and /h/) in the ambient language, nor do they couch an explanation referencing foot structure nor the obvious importance of these patterns in helping to parse words and constituents. They do note that the type of phenomena that are shown above for child acquisition do not occur in adult languages. Given this, focusing on velar fronting as in (28), they prefer a largely phonetic explanation. The following is a synopsis of Inkelas & Rose's (2007) explanation (p. 723-724) for positional velar fronting (PVF)"

"…in young children, the size of the tongue is much bigger, relative to the rest of the vocal tract, than it is in adults, while the palate is proportionally larger…children have a 'relatively anterior tongue mass, a closely approximating velum and epiglottis, and a relatively high larynx'…These facts generally imply that velar consonants should be articulated closer to the front area of the palate across young children, even those not exhibiting (P)VF…In the context of imperfect articulatory control [of young children], bigger tongue size, when combined with a relatively shorter palate, implies that even a slight increase of vertical tongue movement, required in the enhanced articulations in prosodically strong positions, will have direct consequences for the child's production of target velars. The greater emphasis on the dorsal articulator expands tongue contact into the coronal region, yielding the coronal release that characterizes fronted velars."

31. Inkelas & Rose (2007:726-727) go on to explain the lateral gliding data (27) as not being phonetically motivated but as a case of phonological analogy with velar fronting. There is no reference to the aspiration/spread glottis pattern in the ambient language which the child E apparently has target-appropriately and that would provide a natural hypothesis for the child in trying to acquire appropriately other variants.

Psycholinguistic evidence for the importance of foot in English (and for a foot-based analysis to English phonological processes)

32. Speech Errors (Shattuck-Hufnagel 2008) – Speech errors in English tend to target two types of syllables: word-initial syllables and stressed syllables. In other words, speech errors target foot-initial syllables. This is suggestive of the salience of the foot (especially foot-initial position) in speech production planning, and not really the salience of the syllable independent of the foot.

33. Speech processing evidence for the foot -- The well-known experiments of Cutler et al. (1986) and elaborated on further in Cutler (1986) argue against a syllable-based view of speech processing in English, but may be consistent with a foot-based view [my intepretation].

The processing experiment: balance vs. balcony in English and French (balance vs. balcon)

In a reaction time experiment French speakers are quicker at identifying the sequence 'bal' in *balcon* where it constitutes a single syllable than in *balance* where it falls over a syllable boundary. This suggests that French speakers process words in terms of syllables. Interestingly, Cutler et al. found no such advantage for English: there was no quicker reaction time for English speakers at identifying the 'bal' sequence in *balcony* where it constitutes a single syllable as opposed to *balance*. Some have found this result for English surprising, but it is actually expected given that in both words 'bal' is a foot-internal sequence comprising the first three phonemes of the foot. The syllable boundary is not relevant. Where a difference might be expected is with the reaction time of a word like "balloon" where there is a foot boundary between the second and third phoneme. The expectation is that because there is a foot boundary in the 'bal' sequence of *balloon* speakers would have a slower reaction time in identifying the 'bal' sequence in that word than in words like *balcony* and *balance* controlling for word frequency and word familiarity effects.

34. Conclusion -- If one just considers aspiration alone, the foot-based analysis of it may not seem to be convincing, but when one considers the larger picture, as I have tried to do here, the foot-based analysis is compelling. One can speculate that the foot has an important functional role in American English in terms of parsing words and constituents. This is clearly seen with aspiration, which demarcates a constituent (foot) boundary within a word or the beginning of a lexical word. Once this is understood, the difference in aspiration or lack of it in resyllabified environments as shown below becomes clear.

a. planet [t] -- plánetàry [t^h] -- hit Ike [t] or [ɾ] [Gussenhoven & Jacobs 1998:168]
b. up [p] -- appénded [p^h] -- up ended [p]

35. References

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