Allophony and Contrast without Features: Laryngeal Development in Early Grammars*

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SUMMARY

This paper examines the development of laryngeal allophony and contrast in Amahl's grammar of English (Smith 1973). It is shown that, before contrast has been established, laryngeal allophones display unexpected distributions: marked allophones appear in 'weak' positions, whether defined in prosodic, articulatory or perceptual terms; unmarked allophones appear in 'strong' positions. Further, when laryngeal contrasts begin to emerge, they initially develop in non-optimal positions. The solution proposed lies in the formal expression of allophony and contrast: certain phonological relations among segments arise without the features seemingly involved being employed by the grammar; allophony and early contrast are expressed solely in structural terms. Once laryngeal features are projected, at later stages in development, a less surprising pattern of behaviour emerges, one that is more consistent with perceptual and articulatory considerations on optimal positions for contrast.

RÉSUMÉ

Cet article considère le développement des allophones et contrastes laryngiens dans la grammaire d'Amahl, un enfant anglophone (Smith 1973). On montre que, avant que les contrastes soient établis, les allophones laryngiens observent des distributions inattendues : les allophones marqués se trouvent dans les positions «faibles» si les positions sont déterminées en termes prosodiques, articulatoires ou perceptuels ; les allophones non-marqués se trouvent dans les positions «fortes». De plus, quand les contrastes laryngiens commencent à apparaître, initialement ils se développent dans les positions non-optimales. On propose que la solution à ce problème se trouve dans l'expression formelle d'allophonie et de contraste : certaines relations phonologiques entre les segments émergent sans les traits qui semblent être utilisés par la grammaire ; l'allophonie et les premiers contrastes sont exprimés uniquement en termes structurels. Une fois que les traits laryngiens sont projetés, aux étapes subséquentes du développement, un patron de comportement moins surprenant émerge, un patron qui est plus en accord avec les considérations perceptuelles et articulatoires sur les positions optimales pour les contrastes.

* Thanks to the audiences at Phonology in the 21st Century: In Honour of Glyne Piggott and Réseau Français de Phonologie for questions and comments, to Élise Rivard for research assistance, and to SSHRC and FQRSC for funding. I would especially like to thank Glyne for his encouragement and feedback over the years. The analysis in this paper has been heavily influenced by his work on the syllabification of word-final consonants.

McGill Working Papers in Linguistics, Volume 22.1, Winter 2012

1 INTRODUCTION

In perhaps all theories of phonology, allophony and contrast are formally expressed in featural terms. In allophony, the features under focus are active in the grammar, but their distribution is limited due to positional constraints of some sort or other: marked features typically occur in prosodically strong positions or in positions that are perceptually or articulatorily favoured, while unmarked features are often confined to prosodically weak positions or to positions that are perceptually or articulatorily compromised. Contrast is similarly feature-based: contrasts are optimally licensed in prosodically strong positions or in positions that are perceptually more robust or articulatorily advantageous. This is not meant to imply that prosodic and phonetic factors always align in determining the distribution of allophones or positions of contrast (Steriade 1999), nor that contrast and allophony are the only relations that segments engage in (Hall 2009). The point is that, regardless of the factors that regulate their distribution, the phonological relations that segments enter into are formally expressed in terms of features.

This paper examines a case of allophony and contrast in language acquisition that is problematic when viewed from a featural perspective: laryngeal development in Amahl's grammar of English (Smith 1973). The problem is twofold. First, at early stages, before contrast has been established, laryngeal allophones show unexpected distributions: marked allophones appear in 'weak' positions, that is, positions that are prosodically weak as well as perceptually and articulatorily compromised; unmarked allophones appear in 'strong' positions. Second, when laryngeal contrasts begin to emerge, they initially develop in positions that are non-optimal: in prosodically weak as well as perceptually and articulatorily disfavoured positions. I propose that the solution to these surprising patterns of behaviour lies in the formal expression of allophony and contrast: certain phonological relations among segments arise without the features seemingly involved being employed by the grammar. In the absence of features, what formal mechanism could be responsible for expressing allophony and contrast? I propose that the answer is hierarchical structure: if a significant burden is placed on structure, both internal to the segment and at the level of the syllable, an analysis of the surprising behaviour emerges straightforwardly. I will refer to this as *structure-based* allophony and contrast. Once laryngeal features are projected, at later stages in Amahl's development, a less surprising pattern of behaviour emerges, one that is more consistent with perceptual and articulatory considerations on optimal positions for contrast. I will refer to this as *feature-based* contrast.

2 ALLOPHONY: PATTERNS AND PROBLEMS

In Amahl's Stage 1 grammar (age 2.60), voicing contrasts are neutralized. Allophones are distributed as follows (Smith 1973: 37).

(1) a. Voiceless unaspirated lenis in initial position: [b̥ d̥ ġ]
    b. Voiced lenis in medial position: [b d g]
    c. Voiceless fortis (aspirated or unaspirated) in final position: [p' t' k'][1]

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[1] Smith transcribes voiceless fortis as [p t k]. The reason for departing from his transcription will become evident in section 4.1. Fortis allophones are principally confined to utterance-final position.

Representative examples are provided in (2).

(2) a. Voiceless unaspirated lenis:

[ḅɛn]	‘pen’	[ḍəːn]	‘turn’	[ġʌm]	‘come’
[ḅɔː]	‘ball’	[ḍɔː]	‘door’	[ġeip']	‘grape’

b. Voiced lenis:

[ubuː]	‘open’	[nɔːdiː]	‘naughty’	[ġigiː]	‘sticky’
[ɛbuː]	‘elbow’	[ġiːdiː]	‘greedy’	[ġɛgu]	‘lego’

c. Voiceless fortis:

[ḅʌp']	‘bump’	[nʌt']	‘nut’	[mik']	‘milk’
[ġuːp']	‘cube’	[aːt']	‘hard’	[ɛk']	‘egg’

Smith’s formulation of voicing allophony makes reference to linear position. Because syllable structure will play an important role in the analysis to follow, we begin by reformulating (1) in prosodic terms:

(3) Prosodic reformulation of (1):
a. Voiceless unaspirated lenis in word-initial onset position: [ḅ ḍ ġ]
b. Voiced lenis in word-medial onset position: [b d g]
c. Voiceless fortis (aspirated or unaspirated) in word-final coda position: [p' t' k']

Due to limits on the prosodic shape of children’s early productions, that words around age two are typically maximally one foot in length, we might consider formulating (3a) as: Voiceless unaspirated lenis in the onset of stressed syllables (foot-initial position); and (3b) as: Voiced lenis in the onset of unstressed syllables (foot-medial position). Although the number of forms that can arbitrate between the formulations that make reference to stress and those in (3a-b) is small, the few forms available are generally consistent with (3). For example, although initial unstressed syllables are typically deleted in Amahl’s outputs (e.g. [ḅaːnə] ‘banana’), the few that survive are realized with voiceless unaspirated lenis allophones (e.g. [ḍəˈmaːḍo], *[dəˈmaːḍo] ‘tomato’[2]), consistent with (3a). And consistent with (3b), word-medial stops in the onset of stressed syllables are generally realized as voiced lenis (e.g. [ḍɛwiːbuːn], *[ḍɛwiːḅuːn] ‘telephone’). Note finally that Amahl has no word-medial codas at Stage 1, so medial in (1b) is effectively word-medial onset position in (3b).

The voiced/voiceless values observed in (1)/(3) are as expected on articulatory grounds. Voicing is favoured in intervocalic position and is disfavoured initially and finally due to lower subglottal pressure in the latter positions (Westbury & Keating 1986). The fortis/lenis values are unexpected on prosodic as well as articulatory and perceptual grounds. Since word-initial onset position is strong (cf. Beckman 1997, Becker, Nevins & Levine to appear; see also Harris 1997), this position should not attract lenis allophones; since codas are weak (e.g. Itô 1986, Steriade 1999), this position should not favour fortis allophones.

[2] This example comes from Stage 2 but the pattern for initial position in (1a)/(3a) holds for Amahl’s grammar through Stage 8 (see section 4.3).

3 ANALYSIS FOR ALLOPHONY

In the following sections, we provide an analysis for Amahl's Stage 1 allophony. It will be shown that a structure-based approach to allophony leads straightforwardly to the patterns of behaviour observed, in contrast to a feature-baded approach.

3.1 WORD-MEDIAL ONSET POSITION

We begin with word-medial onset position, as this position is the most straightforward to formally capture, when viewed from the perspective of end-state grammars, as intervocalic voicing is cross-linguistically well-attested in languages as diverse Korean (e.g. Jun 1993) and Plains Cree (Wolfart & Carroll 1973). Plains Cree provides a particularly close comparison with Amahl's Stage 1 grammar because this language lacks laryngeal contrasts: voiced stops and affricates ([b d g dz dʒ]) are limited to intervocalic position, whereas their voiceless counterparts are found at word edges and after voiceless fricatives ([s h]) (Wolfart & Carroll 1973). It is highly unlikely that intervocalic voicing in Plains Cree is due to the presence of a [voice] feature: since voicing is not contrastive in this language, there is little motivation for [voice] to be projected. Where then does voicing come from? To answer this question, we briefly consider cross-linguistic observations on weakening. First, intervocalic position is a favoured context for weakening, precisely the context where voicing takes place in Plains Cree. Second, Lass (1984: 177-178) has proposed that weakening involves sonorantization. Weakening manifests itself in a variety of ways across languages, for example as flapping in English, as spirantization in Spanish and, arguably, as voicing in Plains Cree. All of these cases can be unified if the process formally involves sonorantization where the source of the sonorant feature is the adjacent vowels.[3]

For the case of Plains Cree, as well as English, this analysis requires that oral stops be able to bear a sonorant feature and still maintain their status as oral. This is permitted in the literature on SV, where it is proposed that SV replace the traditional feature [sonorant] (SV abbreviates sonorant voicing or spontaneous voicing) (Piggott 1992, Rice 1993, Avery 1996). In this framework, languages vary as to whether voicing contrasts are expressed through laryngeal voicing or SV voicing. Following from this, voiced stops are 'sonorant obstruents' in languages with SV voicing.

With this background, let us return to Amahl's grammar. The allophones that appear in word-medial onset position are voiced lenis. The *voicing* observed is exactly parallel to what was described above for Plains Cree. Concerning their realization as *lenis*, it has been observed that in languages with SV voicing, sonorant obstruents often surface as lenis (Rice 1993, Avery 1996).

The analysis is thus as follows. Amahl's Stage 1 productions lack laryngeal features ([voice], [SG]) altogether. Accordingly, voiced lenis stops (3b) are not specified for laryngeal voicing; instead, they are specified for SV where SV has been acquired from the adjacent vowels. This is illustrated in (4) for target voiceless and voiced stops respectively:

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[3] On English flap as a sonorant, see Chomsky & Halle (1968) and Avery (1996); on Spanish voiced obstruents as bearing the same voicing feature as sonorants, see Avery (1996).

(4) Medial voiced lenis stops in Amahl's Stage 1 grammar:

a. /p/ [ú b uː] 'open'
SV SV

b. /b/ [ɛ́ b uː] 'elbow'
SV SV

In short, voiced lenis stops are derived sonorant obstruents in Amahl's grammar. Viewed from this perspective, their appearance in medial position is not surprising. We turn next to word-initial onset position.

3.2 Word-initial Onset Position

As mentioned earlier, word-initial position is strong, which can be motivated on prosodic, articulatory or perceptual grounds. The target English grammar provides evidence for this: voiceless stops surface as aspirated in this position, e.g. [kʰ]ábin, [kʰ]abána. The prosodically strong position licenses aspiration; aspiration serves to enhance the contrast between voiced and voiceless.

If word-initial position is strong, why do stops surface as lenis in this context in Amahl's grammar instead of as fortis (i.e. as aspirated when prevocalic in an English-type language)? The ingredients for the analysis of this seemingly unexpected finding are as follows. In adult languages, voiceless unaspirated lenis is the unmarked value of voicing. In theories that assume positionally-determined underspecification (e.g. Steriade 1995), this type of segment would be underspecified for laryngeal features. Since Amahl's outputs lacks laryngeal features altogether, the underspecified representation arises for free. Word-initial voiceless stops do not surface as fortis (unlike in the adult grammar for voiceless targets) because they cannot bear [SG], or any other laryngeal feature. Representations are in (5).

(5) Initial stops in the adult grammar and in Amahl's Stage 1 grammar:

a. Target grammar:

Voiceless aspirated: 'pen'
O
|
pʰɛn
-vce +SG

Voiced: 'ball'
O
|
bɔːl
|
+vce

b. Amahl's productions:

Voiceless unaspirated lenis: 'pen'
O
|
b̥ɛn

Voiceless unaspirated lenis: 'ball'
O
|
b̥ɔː

In short, the appearance of voiceless lenis allophones in initial position in Amahl's Stage 1 grammar is not surprising, when viewed from the perspective of a grammar lacking laryngeal features. We turn next to word-final position.

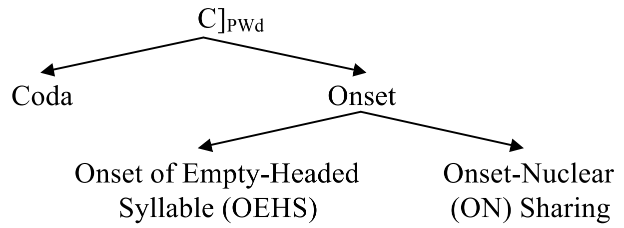
3.3 WORD-FINAL POSITION

There is significant cross-linguistic evidence that codas are weak positions, which can be motivated on prosodic, articulatory and perceptual grounds. In view of this, it is surprising that word-final position attracts fortis instead of lenis allophones. In section 3.3.1, we provide the necessary ingredients for the analysis of this pattern, through an examination of adult grammar typology. We then consider the consequences for Amahl's grammar in section 3.3.2.

3.3.1 SYLLABIFICATION OF FINAL CONSONANTS IN ADULT GRAMMARS

The typology in (6) reveals that, in adult grammars, consonants at the right edge of the prosodic word (PWd) have been shown to display two broad types of behaviour: in some languages, final consonants pattern as codas, while in others, they pattern as onsets (Piggott 1991, 1999, Rice 1992, Goad 2002, Goad & Brannen 2003; cf. Kaye 1990 and Government Phonology more generally where final consonants are always analysed as onsets). In earlier work, I have argued that final onsets are of two types: languages where final consonants are syllabified as onsets of empty-headed syllables (OEHS), which is the standard view for final consonants when they are analysed as onsets, and languages where final consonants are syllabified through onset-nuclear (ON) sharing (Goad 2002, Goad & Brannen 2003; cf. Hoard 1978).[4] In the latter, the features of the final onset have spread into the following empty nucleus, yielding fortis release.

(6) Typology for the syllabification of word-final consonants:



There are two main arguments that divide languages into those with final codas versus those with final onsets: 'rhyme' size and segmental profile (the following discussion draws heavily from Piggott 1999). We begin with 'rhyme' size where 'rhyme' refers to the final overtly-realized vowel and any consonants that follow it, regardless of whether these consonants are syllabified as coda, onset or coda-onset sequences.

In languages with final codas, the number of segments permitted in word-final 'rhymes' is the same as that permitted in word-internal rhymes. For example, (7a) shows that, in Selayarese, word-internal rhymes are maximally binary (VC); word-final 'rhymes' are also maximally binary, indicating that these strings are indeed structured as rhymes. In languages with final onsets, one additional consonant is permitted when compared to the constraints that hold of word-internal rhymes, indicating that word final 'rhymes' are, instead, rhyme + extra consonant, where the latter consonant is analysed as an onset. (7b) shows that, in Diola-Fogny word-internal rhymes are maximally binary (VV, VC), whereas word-finally, one extra consonant is permitted; in Yapese, a language without word-internal codas, word-internal rhymes are maximally binary (VV), whereas word-finally, an extra consonant is permitted.

[4] Scheer proposes ON sharing for trapped consonants (2008) and, in later work, for syllabic consonants (2009).

(7) 'Rhyme' size:

a. Final coda languages:
Selayarese (Mithun & Basri 1986):
i. Word-internally:
Rhymes maximally binary (VC)
ii. Word-finally:
Same as observed word-internally (VC)

b. Final onset languages:
Diola-Fogny (Sapir 1965):
i. Word-internally:
Rhymes maximally binary (VV, VC)
ii. Word-finally:
One extra consonant permitted (VVC, VCC)

Yapese (Jensen 1977):
i. Word-internally:
Rhymes maximally binary (VV)
ii. Word-finally:
One extra consonant permitted (VVC)

Turning to segmental profile, in coda languages, final consonants have a coda profile, as determined through a comparison of the constraints that hold of word-internal codas and those that hold of word-final consonants. In Selayarese (8a), for example, word-internal codas are limited to the first half of a geminate, to place-sharing nasals and to glottal stop. Word-final consonants are similarly constrained, to placeless nasals and glottal stop. In the final onset languages in (8b), we see a different profile. In Diola-Fogny, word-internal codas are a small subset of the range of consonants that can occur word-finally: in final position, any consonant from the inventory of onsets is permitted. In Yapese, word-internal codas are absent altogether; and, as expected, word-final consonants have an onset profile.

(8) Segmental profile:

a. Final coda languages:
Selayarese (Mithun & Basri 1986):
i. Word-internal codas: First half of geminate, place-sharing nasal, [ʔ]:

ʔuppa	'find'	ʔandeŋka	'throw'
allonni	'this day'	seʔla	'salt'

ii. Word-final consonants: Placeless nasal, [ʔ]:

pekaŋ	'hook'	sassaʔ	'lizard'

b. Final onset languages:
Diola-Fogny (Sapir 1965):
i. Word-internal codas: Place-sharing nasal, place-sharing liquid:

niŋaŋŋan	'I cried'	jɛnsʊ	'undershirt'
saltɛ	'be dirty'	na-laŋ-laŋ → nalalaŋ	'he returned'

ii. Word-final consonants: Any consonant from the inventory of onsets:

jawac	'to swim'	famb	'annoy'
ufeːgir	'three'	wopuːs	'green caterpillar'

Yapese (Jensen 1977):
i. Word-internal codas: none
ii. Word-final consonants: Any possible onset consonant except [h]:

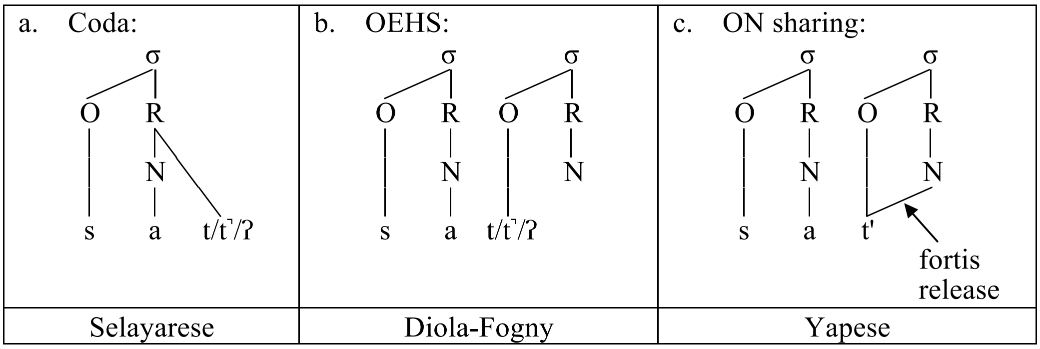
fɑrɑf	'floor'	dɑnoop	'the world'	tɑɑŋ	'song'
gɑrik	'stinging jellyfish'	pilig	'to take down'	lik'	'its root'

Turning to the difference between types of onsets at the right edge, this is tied to the release properties of the final consonant (at least before pause). In OEHS languages, there is no fortis release; indeed, final consonants can even be unreleased. In ON sharing languages, by contrast, there is fortis release. Compare Diola-Fogny and Yapese in (9), two languages with word-final onsets.[5]

(9) Release properties of final consonants (before pause):
a. OEHS languages: No fortis release:
Diola-Fogny: Voiceless stops optionally unreleased (Sapir 1965)

b. ON sharing languages: Fortis release:
Yapese: Voiceless stops 'aspirated' (Jensen 1977)

The representations in (10) illustrate the three-way typology for word-final consonants in adult grammars.

(10)


As can be seen from a comparison of (10a) and (10b), the release properties of final consonants in coda and OEHS languages can be the same. However, the difference between these two types of languages is nonetheless straightforwardly motivated: we have seen that they differ in terms of the segmental profile of final consonants and the number of segments permitted in word-final 'rhymes'. The difference between final onsets syllabified as onsets of

[5] Although no phonetic detail on final 'aspirated' consonants appears to be available for Yapase, Wagner (2002) provides phonetic evidence to show that PWd-final 'aspirated' (fortis) stops in German, even those resulting from laryngeal neutralization, have closure durations of approximately 160ms, like geminates. A similar situation is observed in Kayardild (Tangkic) (E. Round p.c.). All words end in vowels in this language, but in utterance-final position, /a/ deletes, yielding a final consonant with an onset profile. When the consonant is a stop, is has a 'long heavy release' with duration equivalent to utterance-final stop+vowel sequences. The German and Kayardild findings are consistent with final stops being syllabified through ON sharing in these languages – i.e. they span two syllable constituents – but they also indicate that the phonetic properties of consonants syllabified through ON sharing go beyond release. See below on Northern East Cree as well.

empty-headed syllables versus through ON sharing is more difficult to motivate. Indeed, one might question whether this difference is truly representational, as proposed here, or whether it is instead a question of timing that does not need to be phonologically encoded. In the following lines, I argue that the difference between (10b) and (10c) is truly representational, drawing on data from Northern East Cree, a language that requires both OEHS and ON sharing.[6]

The relevant aspects of Northern East Cree syllables are given in (11): word internal codas are quite limited in what they can license, whereas word-final consonants have an onset profile (Dyck, Brittain, MacKenzie & Rose 2008, Dyck p.c.).

(11) Northern East Cree syllables:
  a. Word-internal codas: [s, ʃ, h] and first half of geminate (derived only);
  b. Word-final consonants (and word-medial consonants derived through syncope): onset profile

(11b) suggests that word-final consonants are syllabified as onsets; an examination of inanimate plural constructions is revealing in determining whether these consonants are syllabified as OEHS or through ON sharing. The inanimate plural morpheme is underlyingly /-^{h}/; it additionally triggers accent shift (Dyck, Brittain & MacKenzie 2006, Dyck et al. 2008). This morpheme is phonetically realized as follows:

–as aspiration after word final stops ([p^h, t^h, k^h, n^h, m^h]);
–as duration after word-final fricatives and affricates ([ss, ʃʃ, tʃʃ]); and
–as heavy aspiration after vowels.

Examples are provided in (12) (data from Dyck et al. 2006, 2008).

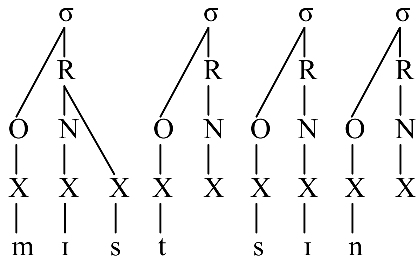
(12)	a.	[ˈmɪs.t.sɪ.n] ~ [ˈmɪs.t.ʃɪ.n]	‘shoe’
		[mɪs.t.ˈsɪ.n^h] ~ [mɪs.t.ˈʃɪ.n^h]	‘shoes’
	b.	[ˈwi.yæ.s]	‘meat’
		[wi.ˈyæ.ss]	‘meat’ (pl)
	c.	[ˈgæ.n.dʒiː]	‘sweater’
		[gæ.n.ˈdʒih]	‘sweaters’

How do we accommodate the observation that word-final consonants in Northern East Cree have an onset profile, (11b), with the inanimate plural data in (12)? Dyck et al. (2006: 13) provide the following answer: “Northern East Cree…requires two types of word-final empty-headed syllable[s]: a non-metrically-relevant, ‘invisible’ type that will support a word-final onset while not affecting accent assignment; and a metrically-relevant, ‘visible’ one that can affect accent assignment.” Under the current proposal, where there are two types of final onsets, there is nothing unusual about Northern East Cree. Non-metrically relevant final onsets are OEHS: the final nucleus remains empty and is therefore invisible for accent assignment, as shown in (13a). Metrically-relevant final onsets are syllabified through ON sharing, as in (13b): the final nucleus is melodically filled and is thereby visible, as shown in (13b).

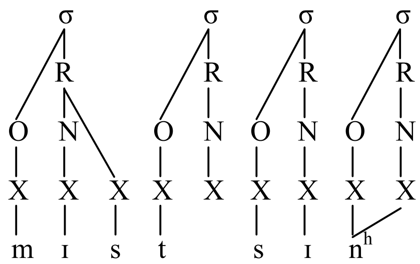
[6] Thanks to Carrie Dyck for bringing the Northern East Cree data to my attention.

(13) Current proposal:

a. ['mɪs.t.sɪ.n] ‘shoe’



b. [mɪs.t.'sɪ.n^h] ‘shoes’



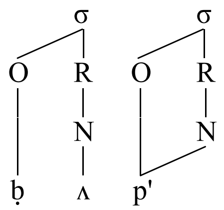
3.3.2 FINAL CONSONANTS IN AMAHL’S GRAMMAR

The three-way typology for the analysis of word-final consonants in section 3.3.1 provides us with a solution for the analysis of Amahl’s Stage 1 grammar. Recall that Smith observes that Amahl’s final consonants are voiceless *fortis* (aspirated or unaspirated), which is surprising if these consonants are analysed as codas. I will argue that this indicates that Amahl’s word-final consonants are instead onsets, syllabified through ON sharing. The nucleus serves to host the fortis release of the consonant. Fortis output thus arises not from particular laryngeal features but rather from a particular prosodic representation.[7]

Output representations for Amahl’s target ‘bump’ and ‘cube’ are in (14). (On the reduction of right-edge clusters in words like ‘bump’, see below.)

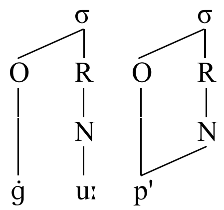
(14) Final voiceless fortis stops in Amahl’s Stage 1 grammar:

a. Target voiceless:



‘bump’

b. Target voiced:



‘cube’

In view of this analysis, the prosodic reformulation of (1), given in (3), must be reformulated yet again as in (3'):

[7] ON sharing is not peculiar to Amahl’s grammar. Goad (2002) and Goad & Brannen (2003) motivate this representation for final obstruents in the grammars of other children learning English, as well as children learning Québec French and German.

(3') Prosodic reformulation of (1) – Revised from (3):

a. Voiceless unaspirated lenis in word-initial onset position: [ḅ ḍ ġ]
b. Voiced lenis in word-medial onset position: [b d g]
c. Voiceless fortis (aspirated or unaspirated) in word-final onset position: [p' t' k']

If the analysis proposed above is along the right lines, we should find other evidence for final onsets in Amahl's grammar. In the following lines, we consider 'rhyme' size and segmental profile, the two diagnostics of onset versus coda status of final consonants examined for adult grammars in section 3.3.1. Recall that in adult languages where final consonants are analysed as onsets, an extra consonant is permitted in word-final position, in contrast to what is observed in word-medial rhymes. The data in (15) show that this also holds of Amahl's grammar. At Stage 1 (age 2.60), his grammar resembles Yapese: word-internal rhymes are maximally binary and there are no codas; word-finally, though, a post-vocalic consonant is permitted. By Stages 2-3 (age 2.115-2.130), word-internal codas have emerged; as expected, word-final VCC is now permitted.

(15) 'Rhyme' size:

a. Stage 1 (age 2.60):

i. Word-internally: Rhymes maximally binary; no codas (VV, *VC)

VV]$_\sigma$ targets:		VC]$_\sigma$ targets:	
[ḅaːnə]	'banana'	[ɛŋiː]	'angry'
[peːbiː]	'baby'	[ḅigiː]	'biscuit'

ii. Word-finally: One extra consonant is permitted (VVC, *VCC)

VVC# targets:		VCC# targets:	
[ġiːm]	'scream'	[mɛn]	'mend'
[ḅɔːt']	'bolt'	[ɛt']	'ant'

b. Stages 2-3 (age 2.115-2.130):

i. Word-internally: Rhymes maximally binary (VV, VC)

VV]$_\sigma$ targets:		VC]$_\sigma$ targets:	
[ġuːgu]	'Dougal'	[æŋgiː]	'angry'
[ġaigə]	'tiger'	[ġɔktə]	'doctor'

ii. Word-finally: One extra consonant is permitted (VVC, VCC)

VVC# targets:		VCC# targets:	
[ġeːp']	'grape'	[wɛnd]	'friend'
[maut']	'mouth'	[wɛpt']	'left'

We consider next segmental profile, although it is less revealing, as Amahl's inventory of initial and medial onset consonants at this stage is limited to nasals, stops, [w] and a handful of liquids. The important point to observe about the data in (16) is that if we combine the word-internal codas from Stages 2-3 with the word-final consonants from Stage 1, we arrive at the final cluster profiles for Stages 2-3 (aside from nasal+nasal, which is also not attested in the adult grammar).

(16) Segmental profile:

a. Stage 1:
Word-internal coda: none
Word-final C: nasal, stop

b. Stages 2-3:
Word-internal coda: nasal, stop
Word-final C: nasal+stop, stop+stop

To sum up thus far, we have shown that Amahl's patterns of laryngeal allophony at Stage 1 are entirely unexpected when viewed from a featural perspective. They are much less surprising if Amahl's grammar lacks laryngeal features at this stage in development, if voicing in medial stops can arise from SV rather than [voice], and if final consonants are analysed as onsets syllabified through ON sharing, rather than as codas.

4 DEVELOPMENT OF LARYNGEAL CONTRASTS (IN STOPS)

We turn now to examine the development of laryngeal contrasts in Amahl's grammar. The predictions of various approaches are outlined in (17). A prosodic approach predicts that laryngeal contrasts should develop in prosodically-strong positions before weak positions: strong positions are positions of contrast and weak positions are positions of neutralization. If we consider syllable position only and leave stress aside, we expect contrasts to emerge in word-initial onsets first, followed by word-medial onsets, followed by final position, if the latter are analysed as codas; see (17a). (Alternatively, contrasts should emerge in initial and medial onsets together before final position.) An articulatory approach predicts that voicing contrasts should be disfavoured in initial and final position because voicing is harder to maintain in these positions due to lower subglottal pressure (Westbury & Keating 1986). Contrasts should thus emerge in medial position first; see (17b). A perceptual approach (Steriade 1999, Wright 2004) predicts that voicing contrasts should emerge first in positions where perception of the contrast is optimized. In the case of voicing, this will be pre-vocalically because the cues are more robust in this position, for example, VOT lag, aspiration noise and release burst amplitude; and, in addition, for intervocalic stops, closure duration and preceding vowel duration. The prediction is thus the development of contrast in medial position first, followed by initial position, followed by final position; see (17c).

(17) Predictions for the development of laryngeal contrasts:

a. Prosodic:
word-initial onset > word-medial onset > final position

b. Articulatory:
medial position > initial and final positions

c. Perceptual:
medial position > initial position > final position

The problem is that laryngeal contrasts *appear* to develop in final position first, starting as early as Stage 1. The solution I propose is the following. Early development in final position, as well as the earliest development observed in medial position, does not involve laryngeal features but, instead, the presence versus absence of a link in the structures posited in (14) and (4) respectively: the presence/absence of a link between the final consonant and nucleus in the case of (14), and the presence/absence of links between the vowels and medial consonant in the case of (4). Later development (in medial position, followed by other positions) involves projection of actual laryngeal features. We address each position in turn.

4.1 FINAL POSITION

(18) charts the course of development for Amahl's production of stops in final position. For this and all tables that follow, robustly-attested patterns are in bold; minor patterns are shaded and will not be discussed. Adjacent stages are collapsed when there was no change in behaviour for a particular target (voiced or voiceless) in a particular position in the word (initial, medial or final).[8]

The allophonic rules we provided earlier had both /b d g/ and /p t k/ being realized as [p' t' k'] (voiceless fortis) in final position at Stage 1. As can be seen in (18), though, a contrast in voicing, in fact, starts to emerge as early at Stage 1. Voiced targets are variably realized as [ḅ ḍ ġ] and [p' t' k'] at Stages 1-4, meaning that the contrast between voiced and voiceless is starting to emerge: /b d g/ → [ḅ ḍ ġ] versus /p t k/ → [p' t' k']. The contrast is well established by Stage 5. It is important to observe, however, that target /b d g/ are not realized in target fashion in this window of time. Rather, they are realized as voiceless unaspirated lenis, [ḅ ḍ ġ]. The target voiced sounds do not emerge until Stage 10. Indeed, at this point, there is an abrupt change in Amahl's behaviour and [b d g] appear almost categorically.

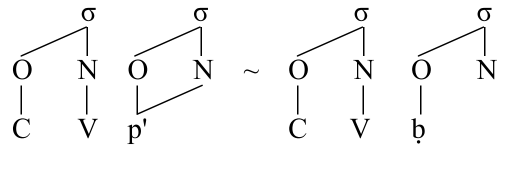
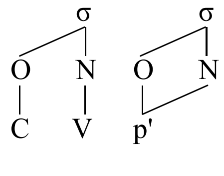
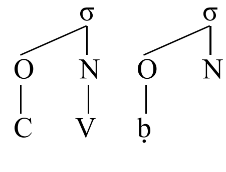
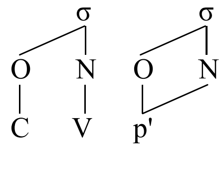
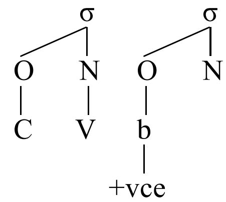
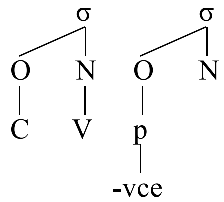
(18) Stop targets in final position:

Target	Output	St 1-4 (2.60-2.137) (n=41)	St 5-9 (2.139-2.196) (n=54)	St 10-29 (2.198-3.355) (n=164)
b d g	p' t' k'	**51.2**	11.1	0.6
	ḅ ḍ ġ	**46.3**	**81.5**	3.0
	b d g	2.4	7.4	**96.3**
Target	Output	St 1-29 (2.198-3.355) (n=793)		
p t k	p' t' k'	**99.4**		
	ḅ ḍ ġ	0.5		
	b d g	0.1		

There are two critical points about (18) that bear on the question of the formal status of the voicing contrast in Amahl's grammar. One, the contrast first involves introduction of non-target voiceless unaspirated lenis and, two, the change to target behaviour occurs abruptly, suggesting a radical modification to the character of his grammar. Both of these observations are captured in the representations in (19).

8 It should be pointed out in this context that Smith's (1973) study of Amahl is comprehensive, covering most aspects of Amahl's phonological development. Whenever there was any change in Amahl's grammar, Smith placed the data in a new stage. As most of these changes are not relevant for voicing, many of Smith's stages are collapsed in the present work.

(19) Representations for final position:

	Voiced targets:	Voiceless targets:
Stages 1-4: Contrast emerging without features		
Stages 5-9: Contrast established without features		
Stages 10-29: [vce] is projected; adult contrast established		

At Stages 1-9, Amahl is trying to represent the adult voicing contrast but he has no features available to do it. He does, however, have complex syllable structures that can be manipulated. Recall from (14) and (5) respectively that voiceless fortis was represented through ON sharing and voiceless unaspirated lenis through a segment being linked solely to onset position. If, for target /p t k/, Amahl thus simply removes the link between [p' t' k'] and the final nucleus, this will yield voiceless unaspirated lenis [ḅ ḍ ġ]. The result is contrast without features, as shown in the first two rows in (19).

At Stage 10, there is an abrupt change, suggesting that [voice] has now been projected. As a result, /b d g/ are realized in target fashion, as shown in the last row of (19). Note from the representations provided that I have assumed that the link between target /p t k/ and the final nucleus is also removed at this stage, because once these segments are represented as [-vce], it is no longer needed. Without the link to the final nucleus, these segments would no longer be realized as fortis. Smith provides no discussion of the point when the fortis allophones for voiceless targets leave Amahl’s grammar; it could very well be later than Stage 10 (which would mean that there is an intermediate period during which the contrast is realized both structurally and featurally). This cannot be resolved from the data available, but it does not significantly impact the analysis provided here.

In sum, we see an early period in Amahl’s development during which the voicing contrast in final position is realized through structure. Since the contrast involves the presence or absence of a link between stops and final nuclei, rather than the licensing of features in a particular position, it is not surprising that it emerges first in final position. Indeed, the contrast is initially not one of voicing at all – both [p t k] and [ḅ ḍ ġ] are voiceless – but one of fortis-lenis which, under the proposal here, can be expressed in final position in structural terms.

4.2 MEDIAL POSITION

(20) charts the course of development for voicing in medial position. The allophonic rules provided earlier, where both /b d g/ and /p t k/ are realized as [b d g] (voiced lenis), robustly holds of Stage 1. At Stage 2, Amahl starts to establish a contrast. However, just as we obseved earlier for final position, the contrast does not involve target-like productions; instead, /p t k/ variably surface as [b d g] and [ḅ ḍ ġ], so that the contrast is variably realized as /b d g/ → [b d g] versus /p t k/ → [ḅ ḍ ġ]. At Stage 3, target-like productions for /p t k/ emerge, and the contrast is fully established at Stage 10.

(20) Stop targets in medial position:

Target	Output	Stages 1-29 (2.60-3.355) (n=259)			
b d g	b d g	**97.7**			
	ḅ ḍ ġ	1.1			
	p t k	0.8			
	p^h t^h k^h	0.4			
Target	Output	Stage 1 (2.60) (n=30)	Stage 2 (2.115) (n=26)	St 3-9 (2.130-2.196) (n=92)	Stages 10-29 (2.198-3.355) (n=297)
p t k	b d g	**91.0**	**50.0**	**36.9**	1.3
	ḅ ḍ ġ	4.5	**40.0**	**19.6**	1.7
	p t k	4.5	10.0	**43.5**	**97.0**
	p^h t^h k^h	0	0	0	0

The important point to highlight, just as with final position, is that the contrast first involves the introduction of voiceless unaspirated lenis; and as was proposed for final position, this similarly does not involve the introduction of [voice]. Before we detail the analysis, let us examine the representations for Stage 1 in the first row of (21). Recall from (4) that voiced lenis was argued to arise from the sharing of the SV specification of adjacent vowels with the medial stop. The representation for [ḅ ḍ ġ], as we saw immediately above in (19), involves the consonant being linked only to onset position. Thus, the contrast that starts to emerge at Stage 2 can simply involve the presence or absence of links between SV and the consonant, as shown in the second row in (21). At Stages 3-9, /p t k/ begins to appear as target-like [p t k]. There is no way to derive a voiceless production through structure in this position; it must be that the feature [voice] has been projected. The new representation is unstable until Stage 10, however, when the adult contrast is firmly established. Concerning voiced targets at Stages 3-9, [+voice] will also be available but its presence or absence will not impact how these segments sound, as can be seen from the alternative representations provided for target /b d g/.

(21) Representations for medial position:

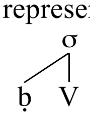
	Voiced targets:	Voiceless targets:
Stage 1: No contrast	'C V b V SV SV	'C V b V SV SV
Stage 2: Contrast emerging without features	'C V b V SV SV	'C V b V SV SV ~ 'C V b̥ V SV SV
Stages 3-9: [vce] projected but unstable	'C V b V SV SV ~ 'C V b V SV SV (+vce)	' C V b V SV SV ~ 'C V b̥ V SV SV ~ 'C V p V SV SV (-vce)
Stages 10-29: Adult contrast established	'C V b V SV SV +vce	'C V p V SV SV -vce

In sum, as with final position, for medial position, we see an early period in Amahl's development when the voicing contrast is realized through structure rather than with features. The difference between final and medial position is the point at which the feature [voice] becomes available. Consistent with all of the predictions in (17), feature-based contrast emerges in medial position before final position; for medial position, it emerges at Stage 3 and becomes well-established at Stage 10; for final position, it both emerges and is established at Stage 10. In short, it is only when the contrast has been established in medial position that the feature becomes available to final position.

4.3 INITIAL POSITION

We consider, finally, development in initial position. Recall from (5) that Amahl's representation of voiceless unaspirated lenis stops is that in (22).

(22) Amahl's representation of voiceless unaspirated lenis:



With no change in structure available, unlike in (19) and (21), no contrast can emerge until the necessary features are available. It is thus predicted that there should be no asymmetry between voiced and voiceless targets concerning the development of contrast, unlike in the case of medial and final position where we observed that changes in the structure of one member of the pair leads to emergence of contrast without features: change in the structure of voiced targets for final position, and change in the structure of voiceless targets for medial position. (23) shows that this prediction is supported: the voicing contrast starts to emerge for both voiced and voiceless targets at Stage 9 and is fully established by Stage 13. Further, when the contrast begins to emerge at Stage 9, the new productions that result are target-like for voicing (though not yet for aspiration) – [b d g] and [p t k] – thereby implicating the feature [voice]. At the point when the voicing contrast is established, at Stage 13, aspirated productions also appear for /p t k/, and the feature [SG] seems to be fully established by Stage 19.[9]

(23) Stop targets in initial position:

Target	Output	St 1-8 (2.60-2.175) (n=186)	St 9-12 (2.189-2.227) (n=155)	St 13-29 (2.233-3.355) (n=323)
b d g	ḅ ḍ ġ	**99.5**	**51.0**	0.6
	b d g	0.5	**46.5**	**99.4**
	p t k	0	2.5	0

Target	Output	St 1-8 (2.60-2.175) (n=274)	St 9-12 (2.189-2.227) (n=169)	St 13-18 (2.233-2.312) (n=211)	St 19-29 (2.317-3.355) (n=189)
p t k	ḅ ḍ ġ	**92.0**	**68.0**	0.5	0
	p t k	6.2	**28.4**	**52.6**	0?
	p^h t^h k^h	1.8	3.6	**46.9**	**100?**
	b d g	0	0	0	0

Representations for initial position are provided in (24). The first row shows that, at Stages 1-8, no [voice] feature is available, even though it is licensed in medial position as early as Stage 3. This is consistent with the predictions of the articulatory and perceptual positions, that the contrast should emerge in medial position first (see (17b-c)). Just as we observed earlier for final position, the feature does not appear in initial position (see the second row in (24)) until it has been established for medial position (at Stage 10; see (21)) (note that the onsets of Stages 9 and 10 are only nine days apart). What is surprising, in view of what we observed for final position, is that it takes some time – until Stage 13 – for the feature to be established in initial position.

Returning to the column for voiceless targets in (24), we observe that [SG] starts to emerge only when [voice] is well-established. Indeed, a glance at (23) shows that the point when voiceless unaspirated lenis allophones [ḅ ḍ ġ] all but disappear is the same point at which [p^h t^h k^h] appear (beginning of Stage 13). What we must determine is whether we truly have evidence for projection of the feature [SG] at Stage 13, as shown in (24), or whether this instead only reflects improvement in Amahl's timing of the closure-to-release gestures and onset of voicing. We address this question next.

[9] Smith does not transcribe aspiration after Stage 19. On the basis of the following, I assume that this indicates that aspiration is now target-like: "At [stage 13] A[mahl] (usually) had the correct allophones of the voiced and voiceless segments; for instance, voiceless plosives were aspirated initially, etc." (p. 118).

(24) Representations for initial position:

Voiced targets:	Voiceless targets:
Stages 1-8: [b] → [b̥] σ b̥ V	Stages 1-8: [pʰ] → [b̥] σ b̥ V
Stages 9-12: [b] → [b̥]~[b] σ b̥/b V (+vce)	Stages 9-12: [b] → [b̥]~[p] σ b̥/p V (-vce)
Stages 13-29: [b] → [b] σ b V +vce	Stages 13-18: [pʰ] → [p]~[pʰ] σ p'/pʰ V -vce (+SG)
	Stages 19-29: [pʰ] → [pʰ] σ pʰ V -vce +SG

4.4 FURTHER EVIDENCE FOR PROJECTION OF [SG]

As mentioned, (24) shows that I assume that the appearance of aspirated allophones of /p t k/ at Stage 13 reflects projection of [SG]. Evidence that the change we are observing at Stages 13 and 19 is truly feature-based comes from a comparison of Amahl's acquisition of /h/ and aspiration.

The data in (25) reveal that [h] and aspiration have the same distribution in English (Jensen 1993, Davis & Cho 2003); both are restricted to onset position. The forms in (25a) show that [h] and aspiration are licensed at the beginning of words, regardless of whether or not the syllable is stressed. (25b) shows that, in medial contexts, their occurrence is tied to stress: [h] and aspiration are only licensed at the beginning of stressed syllables.

(25) Distribution of [h] and aspiration in English:

a.	[h]ábit	[kʰ]ábin	b.	ve[h]ícular	ra[pʰ]ídity
	[h]abítual	[kʰ]abána		vé~~h~~icle	rá[p]id

I adopt Davis & Cho's (2003) analysis that the parallels in (25) reveal that both [h] and aspirated stops are specified for [SG]. Their distribution is captured by alignment of [SG] with positions of prominence (word-initial, foot-initial).

The link between English [h] and aspiration may appear to be subtle, but the time course in (26) compared to that in (23) indicates that Amahl has no difficulty working this out. [h] is deleted from Stages 1-13, parallel to the absence of aspiration until Stage 13. At Stage 14, [h] is produced 46.4% of the time, similar to what is observed for aspiration of voiceless stops in (23): 46.9% target-like from Stage 13 (note that the onsets of Stages 13 and 14 are fourteen days apart). From Stage 16, [h] appears virtually all the time, relatively similar to what is observed for aspiration in (23) from Stage 19 (although the onsets of Stages 16 and 19 are further apart, 42 days).

(26) Emergence of [h] in Amahl's grammar:

Target	Amahl	St 1-13 (2.60-2.242) (n=82)	St 14-15 (2.247-2.271) (n=28)	St 16-29 (2.275-3.355) (n=82)
h	Ø	97.6	53.6	2.5
	h	0	46.4	96.3
	other	2.4	0	1.2

In sum, the nearly parallel developmental path for [h] and aspiration in Amahl's outputs suggests that both involve the same formal analysis, projection of SV.

4.5 INTERIM SUMMARY

The table in (27) summarizes Amahl's development of voicing contrasts. What is striking is that the paths observed for structure-based contrast and for feature-based contrast are entirely different.

(27) Summary of the development of voicing contrasts in Amahl's grammar:

	Stage:	1	2	3	5	9	10	13	19
	Age:	2.60	2.115	2.130	2.139	2.189	2.198	2.233	2.317
Structure-based contrast	final	emerg			estab				
	medial		emerg						
	initial								
Feature-based contrast	medial [vce]			emerg			estab		
	initial [vce]					emerg		estab	
	final [vce]						emerg/ estab		
	initial [SG]							emerg	estab

We have seen that a structure-based contrast for voicing emerges in final position first, inconsistent with all of the predictions in (17). Yet, when viewed from the perspective of highly-articulated representations, this is not surprising: in final position, as well as in medial position, the structures proposed can be manipulated to capture contrast in the absence of features (see (14) and (4) respectively). This is not, however, an option for initial position (see (5)/(22)) and, thus, development of contrast in this position must await the projection of [voice].

For feature-based contrast, the path followed is less surprising from articulatory and perceptual perspectives (see (17b-c)): [voice] starts to emerge in medial position a full 59 days before initial position; and the feature is established in medial position at roughly the same point that it emerges in initial and final position. What remains a mystery from any of the perspectives in (17) is why it takes much longer for [voice] to be established in initial positon than final position (35 days). We leave further examination of this problem to future research.

5 CONCLUSION

To conclude, I have shown that the Stage 1 distribution of laryngeal allophones in Amahl's grammar is cross-linguistically unexpected when viewed in featural terms. An analysis based on laryngeal features cannot yield a principled account for the surprising distribution of allophones in Amahl's outputs, both the presence of unexpected allophones in certain contexts and the absence of expected allophones in other contexts. The distribution is less surprising if Amahl's Stage 1 grammar lacks laryngeal features and if allophony is viewed solely in structural terms.

Early in development, contrasts emerge in an order which is prosodically, perceptually and articulatorily surprising but the order follows from a purely structure-based perspective of contrast, i.e. one which does not involve features. Later in development, when contrast is featurally-based, contrasts emerge in an order which is more consistent with perceptual and articulatory considerations.

The structural account of Amahl's allophony and early contrast has relied on a formal difference being drawn between final consonants syllabified through ON sharing and as onsets of empty-headed syllables. The difference between these two has been motivated for adult languages and both types of final onsets have been shown to function contrastively in the grammar of Northern East Cree.

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