Classes 4.1-4.2: Introduction to autosegmental theory[1]

1.0 Administrative

(1) Agenda/leftovers

a. Notes from Problem Set 1: Mandarin tone

b. Notes on Grassfields Bantu examples for stability

c. Notes on Shona exercise from last week

d. Hakha Lai tonotactics (previous handout)

e. Intro to autosegmental theory

(2) Assignments

a. Reading: Gussenhoven (2004) reading Post comments/questions in Box document by 11:59PM (EST) 02/20, including a response to a classmate.

1.1 Notes on Mandarin tone exercise

(3) The variety of Mandarin I speak is sort of a Taiwan-influenced variety with influences from American English. The Taiwan influence can be seen in mergers involving onset retroflexes and mergers involving coda nasals.

(4) The limitations of humming: hum comes from estimated f0 track (blue line), will not capture places where f0 is not defined (by algorithm). (example: leg)

(5) Entering IPA in Praat. With a TextGrid open (or both a TextGrid and a Sound open together), go to `Help` in the top right corner of the editor window and take a look at `Phonetic Symbols`

(6) Is *sky* one or two syllables?

(7) Segmental perturbation of f0 contours, pitch tracking errors: take a look at Gussenhoven (2004) excerpt in `[further-reading/3/gussenhoven2004-phon-tone-inton-pg1-10.pdf]`. (Example: arm)

(8) How much of a difference in f0 "matters"? (example: sky)

(9) Tone 3 vs. Tone 5 (neutral tone) examples: fire, arm

(10) Tone 3 vs. Tone 2, example: marker, answer2, fire

[1] **This set of class notes and the Goldsmith reading questions borrow heavily from material by Kie Zuraw; thank you Kie!**

1.2 Notes on Bamileke Dschang

(11) Example: alternation in /sáŋ è sáŋ/ 'bird of bird' (Hyman, 1985, fn. 4)

a. /sáŋ è sáŋ/

b. /sáŋŋ́ ˡsáŋ/ (assimilation)

c. /sáŋ ˡsáŋ/ (deletion)

> [4] The associative marker /e/, whether with H or L tone, usually drops out in running speech, though it is possible for it to be heard in slower pronunciations. There is some variation in this area which appears to be related to tempo. Thus, underlying /sáŋ + è + sáŋ/ 'bird of bird' may be realised with the AM vowel intact, i.e. [sáŋ é ˡsáŋ], with the vowel assimilating to a preceding nasal, i.e. [sáŋŋ́ ˡsáŋ], or with the vowel being elided, i.e. [sáŋ ˡsáŋ]. The vowel /a/ is more stable, though it often assimilates to a preceding vowel, e.g. /à–pú + á + sáŋ/ 'arm of bird' is realised [àˡpú sáŋ]. Assimilation of the vowels /e/ and /a/ results in a long vowel if the two TBUs are realised on different tones, e.g. /ǹdzà + è + sáŋ/ 'axe of bird' is realised [ǹdzàˡà sáŋ], but /nà + è + sáŋ/ 'animal of bird' is realised [nà sáŋ] ~ [nàà sáŋ] with the vowel length being unclear and probably non-contrastive. I shall transcribe these cases as short in all of the relevant examples.

a. Vowel assimilated as nasal? Note from John Kingston:

> I think it's important/essential that the nasal is velar, as the spectrum of a nasal at that place and a nasalized vowel are very similar to one another, because the side cavity is so short in a velar nasal that it doesn't convey clear acoustic information about its place. Thus, N V N where the V is nasalized by the surrounding nasals, would be hard to distinguish from N N N. This change wouldn't necessarily affect the V's ability to bear tone.

(12) Why a high tone on the nasal? Because alternations in tone for associative marker, and then H tone spread rule. Note from Larry Hyman:

> The H is ultimately from séN, of course. The question is whether you want to spread it onto /è/ and then assimilate the [e] to the nasal, or whether you want to assimilate the [e] to the preceding nasal first and then spread. Since H tone spreading is general, affecting also vowels that don't delete (e.g. when you get H tone [é] as an alternative), I just assume that that's the order. It can of course all be done at once in this case. Does this clarify things?

> **1.3 The tone rules: first approximation**
>
> With these data we are now in a position to consider a first statement of the tone rules. The first tone rule to be considered is H-spreading, formulated as in (3):
>
> (3) (X) X
>
> H L
>
> This rule spreads the H of the class 7 associative marker /á/ in examples 17–32 in Table I and is most transparently observed on the surface in examples 1.25–32. In fact, it is the only rule that applies in 1.29 and 1.32, whose derivations are given in (4):
>
> (4) a. a–saŋ + a + mən–dzwi 'tail of leopards'
>
> L H H L L
>
> b. a–saŋ + a + mə–tsɔŋ 'tail of thieves'
>
> L H H L H

1.3 Notes on Shona exercise from last week

mbwá	'dog'	né-mbwà	'with dog'
hóvé	'fish'	né-hòvè	'with fish'
mbúndúdzí	'army worms'	né-mbùndùdzì	'with army worms'
hákátá	'diviner's bones'	né-hàkàtà	'with diviner's bones'
bénzíbvùnzá	'inquisitive fool'	né-bènzìbvùnzá	'with inquisitive fool

Table 1.1: Tonal assignment in Shona for noun stems and with cliticized elements.

(13) **Task: Describe the phonological process that occurs upon cliticization of *né*. What is the target of the tonal alternation?**

(14) Recall the three proposed hypotheses (note that I have named these transparently, rather than, e.g., H1, H2, H3., and that these may not faitfully represent exactly what was originally proposed). I have also stated the hypotheses to specify what happens to every single syllable (even if a syllable has the same tone as it does in isolation). Are all of these hypotheses falsifiable?

a. **Ternary window hypothesis**: When a word w is prefixed by *né*, then up to the first three syllables of w (what determines how many?) surface as low tones, and following syllables surface with the tone they surface with when w is in isolation.

b. **Morphosyntactic domain hypothesis**: When a word w is prefixed by *né-*, all syllables in the morphosyntactic domain (of some kind) immediately following *né-* surface with low tones (do we have independent evidence to define what this domain is?). Following syllables surface with the tone they surface with when w is in isolation.

c. **Low tone blocking hypothesis**: When a word w is prefixed by *né-*, all following syllables in w surface with low tones—up through a syllable that, in unprefixed w, surfaces as a low tone. Following syllables surface with the tone they surface with when w is in isolation.

(15) Note, first task upon being confronted with phonological data is to **describe** what is observed.

a. A hypothesis stating that there is a floating L tone that comes with *né* which then associates to the root/stem is *not a description, that's an analysis*. Analyses involve assumptions, and assumptions can trap you into a particular analysis of the data (and prevent you from seeing others) without you even realizing it. We'll see an example of this later in the course when we discuss intonational phonology.

b. When we describe a phonological process (or more generally, a relation), there's three things to describe: what the thing started out as (input), what the thing came out as (output), and then how you get from the input to the output (some algorithm). You can't define the algorithm(s) (is there a unique one?) clearly without first defining the input and output clearly. Don't jump to the algorithm first!

1.1 Algorithms

Informally, an ***algorithm*** is any well-defined computational procedure that takes some value, or set of values, as ***input*** and produces some value, or set of values, as ***output***. An algorithm is thus a sequence of computational steps that transform the input into the output.

We can also view an algorithm as a tool for solving a well-specified ***computational problem***. The statement of the problem specifies in general terms the desired input/output relationship. The algorithm describes a specific computational procedure for achieving that input/output relationship.

For example, we might need to sort a sequence of numbers into nondecreasing order. This problem arises frequently in practice and provides fertile ground for introducing many standard design techniques and analysis tools. Here is how we formally define the ***sorting problem***:

Input: A sequence of n numbers $\langle a_1, a_2, \ldots, a_n \rangle$.

Output: A permutation (reordering) $\langle a'_1, a'_2, \ldots, a'_n \rangle$ of the input sequence such that $a'_1 \leq a'_2 \leq \cdots \leq a'_n$.

Figure 1.1: Definition of algorithm from Cormen et al. (2009)

1.4 Introduction to autosegmental theory

1.4.1 The idea of tiers

Exercise 1.1 ***(A linear representation).*** Write a linear representation for [mãj̃ãb̃]. For the purpose of the exercise, just worry about the following features: nasal, consonantal, labial, high, low.

□

Exercise 1.2 ***(A nonlinear representation).*** Now, what if we made sub-matrices, e.g. a 1-row matrix just for nasality? What if we made every row its own matrix? Why might we want to do this?

□

Articulatory phonology

1. INTRODUCTION

We have recently begun a research program with the goal of providing explicit, formal representations of articulatory organization appropriate for use as phonological representations (Browman & Goldstein, 1986; Goldstein & Browman, 1986). The basic assumption underlying this research program is that much phonological organization arises from constraints imposed by physical systems. This is of course a common assumption with respect to the *elements*—features—used in phonological description; it is not such a common assumption, at least in recent years, with respect to the *organization* of phonological structures.

In our view, phonological structure is an interaction of acoustic, articulatory, and other (e.g., psychological and/or purely linguistic) organizations. We are focussing on articulatory organization because we believe that the inherently multi-dimensional nature of articulation can explain a number of phonological phenomena, particularly those that involve overlapping articulatory gestures. Thus, we represent linguistic structures in terms of coordinated articulatory movements, called *gestures*, that are themselves organized into a *gestural score* that resembles an autosegmental representation.

Figure 1.2: The roots of articulatory phonology, from Browman and Goldstein (1987)

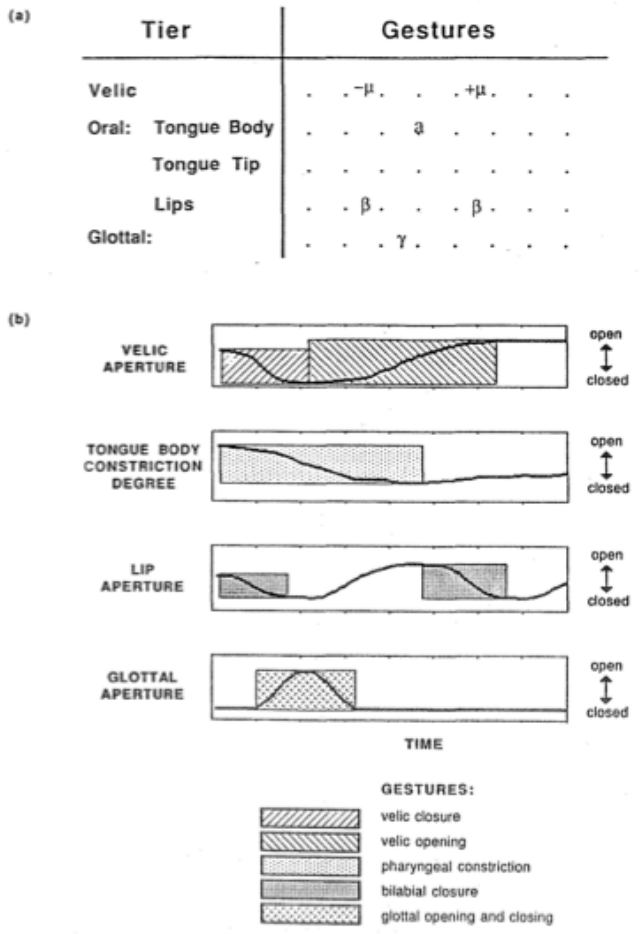

Figure 3. Hypothetical gestural representation for "palm." (a) Symbolic gestural score. (b) Hypothetical trajectories. (Closure is indicated by lowering.)

Figure 1.3: A gestural score in articulatory phonology (Browman and Goldstein, 1987)

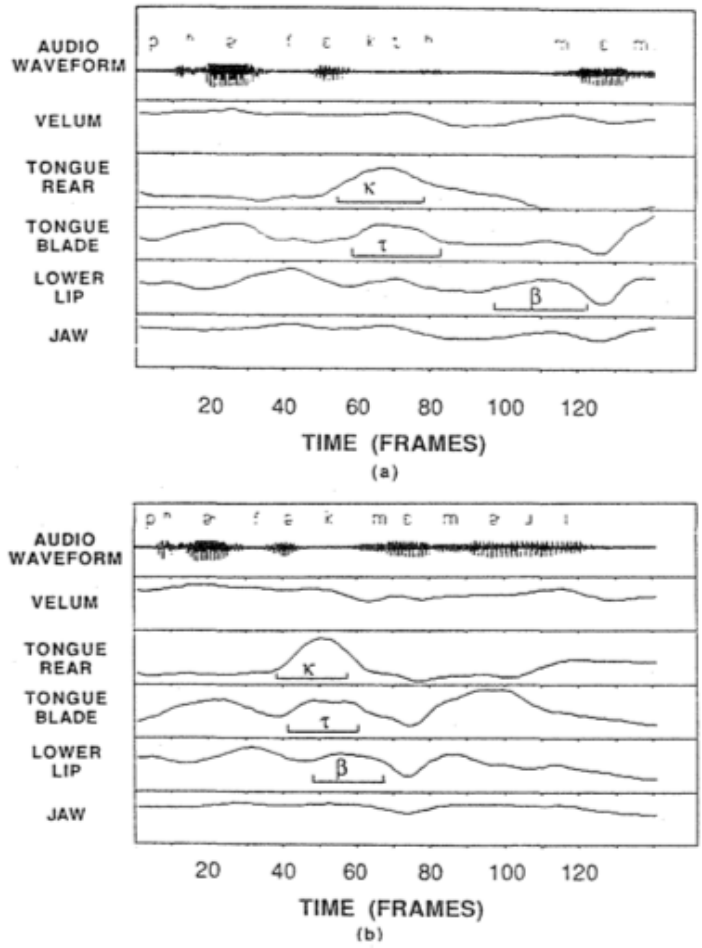

Figure 13. X-ray pellet trajectories for "perfect memory." (a) Spoken in a word list ([pəɹfɛkt#ˈmɛm...]). (b) Spoken in a phrase ([pəɹfɛkˈmɛm...]).

Figure 1.4: Deletion or not? Overlap of velar and alveolar gestures (Browman and Goldstein, 1987)

Discussion 1.1 ***(Gestural scores).*** *What is a gestural score for [mãj̃ãb̃]?* □

	m	ã	j̃	ã	b
lips	closed				closed
tongue tip/blade					
tongue body	low front		hi front	low front	
velum	down				up
glottis	voicing				

Figure 1.5: A gestural score for [mãj̃ãb̃] from Kie Zuraw.

1.4.2 Kikuyu tone assignment

(16) Kikuyu (Clements and Ford, 1979; Goldsmith, 1990)

Subject 'to'		Subject 'ma'	
tò **rɔ̀r** ìré	'*we* **looked at**'	*má* **rór** ìré	'*they* **looked at**'
tò mò **rɔ̀r** ìré	'*we* **looked at** him'	*má* mó **rɔ̀r** ìré	'*they* **looked at** him'
tò mà **rór** ìré	'*we* **looked at** them'	*má* má **rór** ìré	'*they* **looked at** them'
tò **tɔ̀m** íré	'*we* **sent**'	*má* **tɔ́m** íré	'*they* **sent**'
tò mò **tɔ̀m** íré	'*we* **sent** him'	*má* mó **tɔ̀m** íré	'*they* **sent** him'
tò mà **tɔ́m** íré	'*we* **sent** them'	*má* má **tɔ́m** íré	'*they* **sent** them'

Table 1.2: Paradigm for Kikuyu tonal assignment (Goldsmith, 1990, p. 12)

Exercise 1.3 ***(Kikuyu).*** On what does the tone of the tense suffix *irɛ* depend? On what do the tones of the two verb roots (in **bold**) depend? On what do the tones of the object suffixes (underlined) depend?

□

L **L** L H	*H* **H** L H
L L **L** L H	*H* H **L** L H
L L **H** L H	*H* H **H** L H
L **L** H H	*H* **H** H H
L L **L** H H	*H* H **L** H H
L L **H** H H	*H* H **H** H H

Table 1.3: Tone sequences for Kikuyu tonal assignment (Goldsmith, 1990, p. 12)

(17) Inductive generalizations:

a. The tense suffix irɛ is LH iff the root is **rɔr** and HH iff the root is **tɔm**.

b. If an object is present, the **root** is **H** iff it is preceded by the object ma and **L** iff it is preceded by the object mo. If no object is present, the **root** tone is the same as the tone of the subject (which immediately precedes the root).

c. The object tone is the same as the tone of the subject (which immediately precedes the object).

d. The *subject* tone is *L* for *to* and *H* for *ma*.

e. In sum, the tone of the tense suffix is determined by the tone of the root, the tone of the root by the object if present, otherwise by the subject; the tone of the object is determined by the tone of the subject, and the tone of the subject appears to be lexically specified.

f. That is, **within some prosodic and/or syntactic domain, the tone of each morpheme is determined by the preceding morpheme except for the tone of the domain-initial morpheme.**

(18) Derivation with rules acting on autosegmental representations:

Rule 1.1 (Peninitial association)**.** *Associate the word-initial tone T to the peninitial vowel in the word.*

$$\begin{bmatrix} C_0\ V\ C_0\ V \\ \\ T \end{bmatrix}$$

Rule 1.2 (Association convention)**.** *When unassociated vowels and tones appear on the same side of an association line, they will be automatically associated in a one-to-one fashion, radiating outward from the association line. (Goldsmith, 1990, (11)) This rule can operate only on autosegmental representations with at least one association line.*

$$\begin{bmatrix} V\ C_0\ V \\ |\quad \cdots \\ T\ \ T \end{bmatrix}$$

Rule 1.3 (Association of toneless vowels)**.** *Associate a toneless vowel to the tone in the same timing slot in the tone tier.*

$$\begin{bmatrix} \textcircled{V} \\ \vdots \\ T \end{bmatrix}$$

a. Note that peninitial and toneless association are language-specific while the association convention is universal.

b. Notation:

i. Dashed association line indicates structural change

ii. Circle is an element in the structural description, indicating that a segment is not associated to anything in the "facing" tier.

Exercise 1.4 ***(Derivation of 'we looked at them').***

UR

$$\begin{bmatrix} to & ma & ror & ire \\ \\ — & — & — & — \end{bmatrix}$$

Application of Rule 1.1: Peninitial association

$$\begin{bmatrix} to & ma & ror & ire \\ \\ — & — & — & — \end{bmatrix}$$

Application of Rule 1.2: Association convention

$$\begin{bmatrix} to & ma & ror & ire \\ \\ — & — & — & — \end{bmatrix}$$

Application of Rule 1.3: Association of toneless vowels

$$\begin{bmatrix} to & ma & ror & ire \\ \\ — & — & — & — \end{bmatrix}$$

□ □

(19) This analysis is based on Clements and Ford (1979), "Kikuyu Tone Shift and Its Synchronic Consequences".

> Kikuyu bears a close relationship to a number of other Bantu languages spoken in central Kenya, including Kikamba (also known as Kamba), Embu, Mbeere, Cuka, Mūthambī, Mīītīne, Mwīmbī, Imenti, Tharaka, and Tigania. All are mutually intelligible to a high degree except for Kikamba.
>
> Languages of this group are characterized by what Guthrie (1967–1971) terms "clear tone", that is, clear, regular lexical correspondences to the tones of reconstructed Proto-Bantu. However, Kikuyu presents some difficulties. First, it is the only member of the group known at present to employ phonologically distinctive ("nonautomatic") downstep in its phonological system. Second, its tonal correspondences to the other members of the group (and to Guthrie's Proto-Bantu) are not totally straightforward, as the items in Table 1 demonstrate. We represent high tone as [ˊ], low tone as [ˉ], extra-high tone as [ˣ], extra-low tone as [ˋ]. Contour tones, consisting of sequences of these level tones, are represented as joined digraphs, e.g. [ᶕ] = a low-high rising tone, [ᶺ] = a high-to-extra-low falling tone, [ᶯ] = an extra-high-to-extra-low falling tone, etc. The raised exclamation point [ꜜ] represents downstep.

(20) Demo: The Great Ngamo Tone Shift (Russ Schuh)

Discussion 1.2 ***(Directionality of tone shift).*** *Is Ngamo tone shift rightward or leftward? Kikuyu tone shift? See Hyman and Schuh (1974, p. 88).* □

	Proto-Bantu	*Tharaka*	*Kikamba*	*Mwīmbī*	*Kikuyu*
1. 'belonging to someone else'	*-yéné	-éné	-éné	-éné	-ēné
2. 'neck'	*-kíŋgō	ŋkíŋgó	ŋgíŋgó	ŋkíŋgó	ŋgīŋgó
3. 'way of releasing oneself quickly'	(*-dēk- 'to leave')	moe̋rē-káŋgérié	moélē-káŋgélié	moe̋lé-káŋgélié	moēré-kāŋgérié
4. 'tree'	*-tí	mōté	mōté	mōté	mōte̋
5. 'bush land'	*-cāká	kēðāká	kēðēká	kēðāká	ɣēðāka̋
6. 'bamboo'	*-dāŋgí	mōrāŋgí	mōāŋgí	mōlāŋgí	mōrāŋgī́
7. 'charcoal'	*-kádā	ēkárā	ēkǎ̋ǎ̋ /ēkáà/	ēkálà	īkārá¹
8. 'big'	*-nénē	-nénē	-nɛ̌nɛ̂ /-nénè/	-nénè	-nēné¹
9. 'teardrop'	*-yícōdī	rɛ́:ðórī	yé:ðɔ̀ì	yɛ́:ðɔ̀lì	reīðórī¹
10. 'firewood'	*-kúnī	rōkó	ōkǒ /ōkô/	rōkó	rōkó¹

Table 1: Some lexical correspondences among Proto-Bantu, Tharaka, Kikamba, Mwīmbī, and Kikuyu

Figure 1.6: Evidence for diachronic Kikuyu tone shift from Clements and Ford (1979, p. 187)

Discussion 1.3 ***(Why autosegmental representations?).*** *Assume a tonal feature [hi tone]. How might you account for Kikuyu tone assignment with linear representations and rules? How does this analysis compare to the autosegmental analysis? Do the autosegmental rules look "simple" wrt other possible autosegmental rules? Do the linear rules look "simple" wrt other possible linear rules?*

□

Discussion 1.4 ***(Autosegmental representations in OT).*** *How might you account for Kikuyu tonal assignment in OT? What might be a markedness constraint you would propose?*

□

1.4.3 Constraints and autosegmental representations

From Yip (2002, p. 82-83):

(21) Some striking properties of tonal morpho-phonology

a. Tones are usually associated with syllables, but not always (cf. floating tones)

b. Syllables are usually associated with tones, but not always (cf. toneless syllables)

c. Association is preferably one-to-one, but not always (cf. contour tones, spreading)

d. Tone (especially H tone) is attracted to prominent positions (beginnings of things, edges, accented or stressed syllables), but not always.

Here are some OT constraints for tone (and autosegmental representations) from Yip (2002, p. 83-84):

(22) Casting these generalizations as violable constraints:

a. *Float: A tone must be associated with a TBU.

b. Specify T: A TBU must be associated with a tone.

c. NoContour: A TBU may be associated with at most one tone.

d. NoLongT: A tone may be associated with at most one TBU.

e. AlignTone: Align the specified edge (L/R) of a tone span with the head or edge (L/R) of a prosodic or morphological unit. (A tone span is a string of TBUs associated with a single tone.)

(23) Faithfulness constraints

a. Dep-T: No insertion of tones.

b. Max-T: No deletion of tones.

c. Associate: No new association lines.

d. Dissociate: No removal of association lines.

e. NoFusion: Separate underlying tones must stay separate.

f. Ident-T: Correspondent tones are the same.

g. Linearity: Preserve underlying linear order.

(24) Markedness

a. OCP: Adjacent identical elements are prohibited.

b. NoGap: Multiply linked tones cannot skip TBUs.

c. Local: Spread only to the adjacent element

d. General markedness: *H » * L, etc.

(25) Alignment

a. Align-L: Each T should align with the left edge of the domain. (Left-to-right association)

b. Align-R Contour: Contour tones should align with the right edge of the domain. (Preference for contours to appear domain-finally)

1.4.4 Tonal morphemes in Igbo

Subordinate clauses are preceded by a complementizer morpheme which is simply a floating H tone!

ọ̀nù	'yam'	ọ̀nū[rèré èré]	'the yam [that is rotten]'
ọ́zụ̀	'fish'	ọ́zū[rèré èré]	'the fish [that is rotten]'
ọ̀nú	'meat'	ànú[rèré èré]	'the meat [that is rotten]'
ákwhá	'eggs'	ákwhá[rèré èré]	'the eggs [that is rotten]'

Exercise 1.5 ***(OT with autosegmental representations practice: Igbo).***

	/ aʒ̃ụ + + rere + ere/ $H_1\ L_2\ H_3\ L_4\ H_5\ L_6\ H_7$	NO UNATTACHED TONES	DEP-V	MAX-TONE	*>1TONE PERTBU	IDENT(tone)/ first syll of word	UNIFORMITY-TONE
a	a ʒ̃ ụ r e r e e r e $H_1\ L_2\ H_3\ L_4\ H_5\ L_6\ H_7$						
b	a ʒ̃ ụ r e r e e r e $H_1\ L_2\ H_3\ L_4\ H_5\ L_6\ H_7$						
☞ *c*	a ʒ̃ ụ r e r e e r e $H_1\ M_{2,3}\ L_4\ H_5\ L_6\ H_7$						
d	a ʒ̃ ụ r e r e e r e $H_1\ L_2\ M_{3,4}\ H_5\ L_6\ H_7$						
e	a ʒ̃ ụ a r e r e e r e $H_1\ L_2\ H_3\ L_4\ H_5\ L_6\ H_7$						
f	a ʒ̃ ụ r e r e e r e $H_1\ L_2\ L_4\ H_5\ L_6\ H_7$						

□

1.4.5 Revisiting Shona associative lowering

(26) Odden (1980)[further-reading/2/odden1980-shona-multiple-tone-association.pdf] on "Associative Lowering" in Shona (Bantu, Zimbabwe, sna)

(27) Prefix né 'with' (and two other prefixes) cause the following alternations in tone of the following noun stem:

Exercise 1.6 ***(Shona tone-segment mapping).***

1. Draw autosegmental representations for the data.
2. Fill in the tableau for ne hove:

mbwá	‘dog’	né-mbwà	‘with dog’
hóvé	‘fish’	né-hòvè	‘with fish’
mbúndúdzí	‘army worms’	né-mbùndùdzì	‘with army worms’
hákátá	‘diviner’s bones’	né-hàkàtà	‘with diviner’s bones’
bénzíbvùnzá	‘inquisitive fool’	né-bènzìbvùnzá	‘with inquisitive fool

Table 1.4: Tonal assignment in Shona for noun stems and with cliticized elements.

ne hove | \ / H H_1	
a ne hove | | | H L_1 L_1	
b ne hove | \ / H L_1	
c ne hove | | | H L_1 H_1	

3. Make a tableau for né-bènzìbvùnzá

□

1.4.6 Stability

Margi (Marghi, Marghi Central) hiatus resolution (Hoffman 1963, via Kenstowicz 1994), (Afro-Asiatic, Nigeria) in suffixation of the definite suffix *-ari*:

sál	sál-árì	'man'
kùm	kùm-árì	'meat'
ʔímí	ʔímj-árì	'water'
kú	kw-árì	'goat'
tágú	tágw-árì	'horse'
tì	tj-ărì	'morning'
hù	hw-ărì	'grave'
úʔù	úʔw-ărì	'fire'

Table 1.5: Margi hiatus resolution data.

Exercise 1.7 ***(Margi hiatus resolution, linear representations).*** What's the underlying form of the suffix? Describe the tonal alternation with linear rules. Assume tonal features [rise], [hi].

Rule 1.4 (Hiatus resolution)**.**

$[\ +syllabic\ ] \rightarrow [\ \_\_syllabic\ ]\ /\ \_\_\ [\ \_\_syllabic\ ]$

Rule 1.5 (_____)**.**

$$\begin{bmatrix} \_\_syllabic \\ \_\_hi \end{bmatrix} \rightarrow [\ \_\_rise\ ]\ /\ [\ \_\_hi\ ]\ \_\_$$

□

Exercise 1.8 ***(Margi hiatus resolution, nonlinear representations).*** Now try using rules operating on autosegmental representations to describe the tonal alternation for /huari/. Hint: all you need is a delinking rule and a reassociation rule.

Rule 1.6 (Glide formation and delinking)**.**

Rule 1.7 (Stranded tone reassociation)**.**

□

Exercise 1.9 ***(Margi hiatus resolution, nonlinear representations in OT).*** Describe the tonal alternation for huari with constraints. Does it make sense to have MAX and DEP constraints refer to tone? How about IDENT constraints? Hint: Start with an underlying representation /hu + ari/ with unassociated L_1 H_2 L_3. You can use ONSET to help account for hiatus resolution. Your candidates should be syllabified and have tonal association lines.

□

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