Encoding strength as a unified explanation of two Guébie (Kru) vowel alternations*

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1 Introduction

Phenomena: There are two vowel alternations that apply to the same subset of CVCV roots in Guébie (Kru) [Côte d'Ivoire].

1. **Vowel deletion:** The initial vowel in CVCV roots can optionally be unpronounced.

    (1) /jɪla$^{3.2}$/, 'ask' → [jra^{32}], [jɪla$^{3.2}$]

    – Vowel deletion can only occur in 33% of CVCV roots in Guébie.

2. **Vowel replacement:** Root vowels are replaced with vowels of particular affixes:

    (2) /jɪla$^{3.2}$+ɔ^{2}/ → [jɔlɔ$^{3.2}$], *[jɪla-ɔ$^{3.3.2}$], *[jɪlɔ$^{3.2}$]
    ask+3SG.HUM.OBJ → 'ask him'

- This vowel replacement process is complex in two ways:
    - It only occurs in particular morphosyntactic environments (plural-marked nouns, object-marked verbs).
    - It occurs in the same subset of roots as vowel deletion.

Question 1: Can we account for vowel replacement and vowel deletion with a single, unified explanation?

Solution: Yes! A strength-based representational explanation can differentiate alternating from non-alternating roots in both vowel deletion and vowel replacement contexts.

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- This analysis builds on recent work on phonological activation and encoding strength (Smolensky et al. 2014; Inkelas 2015; Rosen 2016; Vaxman 2016; Moore-Cantwell 2017; Faust and Smolensky 2017; Pycha et al. 2017; Zimmermann 2017).

Question 2: How do we account for the morphosyntactic conditioning of vowel replacement (it only occurs in plural and object-marked contexts)?

Solution:

- Option 1: Differences in phonological encoding strength of *affix* vowels condition different alternations.

- Option 2: Morpheme-specific phonological grammars drive vowel replacement only in particular contexts (Orgun 1996; Anttila 2002; Inkelas and Zoll 2005).

Here I show that allowing for strength-differentiated representations provides a unified explanation of vowel replacement and deletion, and I introduce the problems that arise in determining how to account for morphosyntactic conditioning.

Road map:

§ 1	Introduction
§ 2	Vowel deletion
§ 3	Vowel replacement
§ 4	A unified strength-based approach
§ 5	Potential problems for a strength-only account
§ 6	Implications and remaining questions

2 Vowel deletion

- Certain CVCV roots can surface as CCV in Guébie.

(3) **CVCV reduced to CCV**[1] (syl_20161207)

	CVCV	**CCV**	**Gloss**
a.	bala$^{3.3}$	$\underline{\text{br}}$a^{3}	'hit'
b.	tulu$^{4.4}$	$\underline{\text{tr}}$u^{4}	'chase'
c.	wʊlʊ$^{3.3}$	$\underline{\text{wr}}$ʊ^{3}	'granary'
d.	munu$^{3.3}$	$\underline{\text{mn}}$u^{3}	'bite/sting'
e.	mana$^{3.3}$	$\underline{\text{mn}}$a^{3}	'meat'
f.	jɪla$^{3.3}$	$\underline{\text{jr}}$a^{3}	'ask'
g.	sija$^{2.3}$	$\underline{\text{sj}}$a^{23}	'be defeated'
h.	kuɓə$^{3.1}$	$\underline{\text{kɓ}}$ə^{31}	'yesterday'
i.	ɟʊla$^{3.2}$	*$\underline{\text{ɟr}}$a^{32}	'take, borrow'
j.	ɓolo$^{2.2}$	*$\underline{\text{ɓr}}$o$^{2.2}$	'one'

[1]Guébie has four tone heights, marked with numbers 1-4, where 4 is high. There is also an alternation between [l] and [r] in Guébie, where [r] is typically used in onset clusters (CCV), and [l] is used elsewhere. While all surface [l] and [r] consonants come from underlying /l/, I use [r] in clusters and [l] elsewhere to reflect production patterns.

  - Reduction seems to be conditioned by speech rate and social factors, and does not depend on morphosyntactic environment.

- No set of phonotactic traits exhaustively and exclusively picks out those CVCV roots which undergo deletion.
- However, the set of roots that undergo deletion tends to share certain phonological properties:
  - C2 (consonant) is /l/ (or /m/ in a nasal root)
  - V1 (vowel) and V2 are identical
  - T1 (tone) and T2 are identical
- Not every root with these features is reducible, and not every reducible root has (some subset of) these features.

(4) **Minimal pairs of alternating and non-alternating roots** (syl_20161207)

	CVCV	**CCV**	**Gloss**
a.	$\text{jili}^{2.2}$	jri^{2}	'be fat'
b.	$\text{jili}^{2.2}$	*jri^{2}	'fish'
c.	$\text{gɔlɔ}^{3.3}$	grɔ^{3}	'pain'
d.	$\text{gɔlɔ}^{2.3}$	*grɔ^{23}	'canoe'
e.	$\text{kpolo}^{3.1}$	kpro^{31}	'be clean'
f.	$\text{kpoke}^{2.4}$	*kpke^{24}	'crocodile'
g.	$\text{ɟulu}^{3.3}$	ɟru^{3}	'salt'
h.	$\text{ɟʊla}^{3.2}$	*ɟra^{32}	'take/borrow'

- The more of the above features a given root shows, the more likely it is to be reducible[2].

(5) **Factors influencing reducibility**

	None	**T1=T2**	**C2=l**	**V1=V2**	**T&C2**	**T&V**	**C2&V**	**All**
Reducible	157	269	287	328	145	208	199	127
Total	751	614	536	611	244	339	244	154
Percent	20.9	43.8	53.5	53.7	59.4	61.4	81.6	82.5

- Alternating roots make up only 33% of all CVCV roots.
  - This number is based on a corpus of 3577 distinct morphemes and over 5000 utterances, collected between 2013 and 2017.
  - A total of 1869 disyllabic roots were considered.
- Phonological features like those in (5) tend to cue which roots can alternate.

[2]See Sande (2017) for a MaxEnt model of the distribution of reduction across root types.

- However, the effect is not categorical, thus some information about degree of subjectivity to alternation must be present lexically.
  - I notate this difference in on lexical items with superscripts, follow the Kru literature (Marchese 1979; Zogbo to appear): *b^{a}la*$^{3.3}$, 'hit'.

3 Vowel replacement

- The initial vowel in certain CVCV roots undergoes replacement (full vowel harmony) in the presence of particular affixes or clitics.
  - The set of roots affected is the same set that undergoes deletion, as described in section 2.
  - Alternating vowels are notated as superscripts.
- This process applies in the environment of object enclitics on verbs, and plural suffixes on nouns.
  - I discuss only the object enclitic cases here.
- On monosyllabic roots, it is difficult to see the effect of vowel replacement, because all roots end in vowels, and when a vowel-initial suffix is added, the normal hiatus resolution process of the language is to delete to root-final vowel.
  - Ex: /ɓi^{2}-o^{2}/, *finish*-PASS, is pronounced [ɓo^{2}], *[ɓio$^{2.2}$].
  - For this reason, I use disyllabic examples throughout.
- **Object enclitics on non-alternating verbs**
  - When an object enclitic is present on a non-alternating verb root,
    a. the final vowel of the root fails to surface (hiatus resolution),
    b. the initial root vowel retains its input features.

(6) **Non-replaceable roots in object contexts**

	Root	Root=ɔ^{2}	Gloss
a.	sumu$^{2.2}$	sum=ɔ$^{2.2}$, *sɔmɔ$^{2.2}$	'boil him'
b.	ɟʊla$^{3.2}$	ɟʊl=ɔ$^{3.2.2}$, *ɟɔlɔ$^{3.2}$	'take him'

- **Object enclitics on alternating verbs**
  - When an object enclitic is present on an alternating root,
    a. the final vowel of the root fails to surface (hiatus resolution),
    b. the initial vowel of a root surfaces with the same features as the object enclitic.

(7) **Object enclitics trigger vowel replacement on alternating roots**

	Bare verb	3SG.HUM =ɔ^{2}	3SG =ɛ^{2}	3PL =ɪ^{2}	Gloss
j^{i}li$^{2.3}$	jili$^{2.3}$	jɔl=ɔ$^{2.32}$	jɛl=ɛ$^{2.32}$	jɪl=ɪ$^{2.32}$	'steal'
j^{I}la$^{3.3}$	jɪla$^{3.3}$	jɔl=ɔ$^{3.2}$	jɛl=ɛ$^{3.2}$	jɪl=ɪ$^{3.2}$	'ask'
b^{a}la$^{3.3}$	bala$^{3.3}$	bɔl=ɔ$^{3.2}$	bɛl=ɛ$^{3.2}$	bɪl=ɪ$^{3.2}$	'hit'
w^{U}la$^{3.1}$	wʊra^{31}	wɔl=ɔ$^{3.12}$	wɛl=ɛ$^{3.12}$	wɪl=ɪ$^{3.12}$	'look at'

- Other phonologically identical suffixes do not trigger vowel replacement.

(8) **Passive suffix does not trigger vowel replacement**

	Verb	**Passive**	**Gloss**
a.	j^{i}li$^{2.3}$	jil-o$^{2.32}$, *jol-o$^{2.32}$	'be stolen'
b.	b^{a}la$^{3.3}$	bal-ɔ$^{3.2}$, *bɔl-ɔ$^{3.2}$	'be hit'
c.	j^{I}la$^{3.3}$	jɪl-ɔ$^{3.2}$, *jɪl-ɔ$^{3.2}$	'be asked'

- **Summary:** Vowel replacement occurs in a subset of CVCV roots in object enclitic contexts (and plural contexts), but not elsewhere.

4 A unified strength-based approach

- I propose that the surface differences between alternating and non-alternating roots are due to a difference in phonological encoding strength.
- Roots that undergo replacement have a weakly phonologically encoded initial vowel (cf. Smolensky et al. 2014; Inkelas 2015; Rosen 2016; Vaxman 2016; Moore-Cantwell 2017; Pycha et al. 2017).
  - Weakly encoded vowels have been called *latent, floating, defective* (cf. Zoll 1996).
  - Here, segments notated with superscript are *weakly encoded*.
  - By contrast, those segments not written as superscripts are *strongly encoded*.
- Here I adopt a binary view of phonological encoding strength, where segments can be either weakly or strongly encoded (Inkelas 2015; Vaxman 2016).
  - This process could also be modeled with gradient representations (cf. Smolensky et al. 2014; Zimmermann 2017).
- The following generalizations need to be accounted for:
  - Strong vowels do not alternate.
  - No vowel hiatus is allowed.
  - When vowel hiatus would otherwise occur between root and suffix, the root vowel fails to surface.
  - Weak vowels surface with the same features as object enclitics.
  - Otherwise, all vowels surface with their input features.

The following constraints interact to derive the above generalizations:

- **Ident-Strong**:
  Assign one violation for each output segment that corresponds to a strongly encoded input segment, and whose features differ from that corresponding input segment (cf. Inkelas 2015).
- ***V+V**:
  Assign one violation for every instance of two consecutive output vowels that correspond to two distinct input morphemes.
- **RealizeMorpheme**:
  Assign one violation for each input morpheme that is not phonologically realized in the output (Samek-Lodovici 1993; Rose 1997; Walker 2000; Kurisu 2001).
- *$[\alpha\mathbf{F}][\beta\mathbf{F}]_{[+syllabic]}$ (Harmony):
  A segment with feature value α may not directly precede another segment with feature value $\neg\alpha$ in the ordered set of output segments that are [+syllabic]. Assign one violation for each pair of neighboring segments that meet the criteria (cf. Hansson 2014; Lionnet 2016; Walker 2016 on Agreement-by-Projection).
- **Ident-IO**:
  Assign one violation for each output segment whose features differ from the corresponding input segment (McCarthy and Prince 1995).

(9) **Weak vowels in object contexts**
Realize, *V+V, Id-Strong ≫ Harmony ≫ Id-IO

/b^{a_i}la$_j$=ɔ$_k$/	Realize	*V+V	Id-Strong	Harmony	Id-IO
a. ba$_i$la$_j$	*!				
b. ba$_i$la$_j$ɔ$_k$		*!		*	
c. ba$_i$la$_k$			*!		
d. ba$_i$lɔ$_k$				*!	
e. ☞bɔ$_i$lɔ$_k$					*

(10) **Strong vowels in object contexts**
Realize, *V+V, Id-Strong ≫ Harmony ≫ Id-IO

/ɟʊ$_i$la$_j$=ɔ$_k$/	Realize	*V+V	Id-Strong	Harmony	Id-IO
a. ɟʊ$_i$la$_j$	*!			*	
b. ɟʊ$_i$la$_j$ɔ$_k$		*!		**	
c. ɟʊ$_i$lʊ$_k$			*!		*
d. ɟɔ$_i$lɔ$_k$			*!		*
e. ☞ɟʊ$_i$lɔ$_k$				*	

- The ranking in (10) gets us the correct output for roots with strongly and weakly encoded vowels in the environment of a third-person object enclitic.

- The same Ident-Strong constraint can be used to prevent CVCV reduction to CCV in roots with strongly encoded vowels (i.e. Ident-Strong ≫ Reduce ≫ Ident-IO).

5 Potential problems for a strength-only account

- While the analysis in section 4 accounts for vowel replacement in object enclitic contexts, it is unclear what *prevents* vowel replacement in other contexts.
  - Recall that outside of object markers, other verbal affixes and clitics do not trigger vowel replacement.
  - In the nominal domain only plural suffixes, and not other affixes or clitics, trigger replacement.
- Here I consider whether strength-based representations alone (option 1) can derive the morphosyntactic environment effects, or if we need additional tools such as morpheme-specific grammars or constraints (option 2).
  - Option 1: Differences in phonological encoding strength of root and *affix* vowels condition different alternations.
  - Option 2: Cophonologies, or morpheme-specific phonological grammars, drive vowel replacement only in particular contexts (Orgun 1996; Anttila 2002; Inkelas and Zoll 2005).
- To differentiate between these two options, let us consider data from other affixes in Guébie.
  - Affixes differ not only in whether they trigger vowel replacement on roots, but also in whether they undergo root-triggered ATR harmony.

(11) **Nominalizer: no ATR harmony, no replacement**

	Verb	**Nominalized**	**Gloss**
a.	j^{e}ɓe$^{3.1}$	jeɓe-li$^{3.1.2}$	'knowing'
b.	sumu$^{2.2}$	sumo-li$^{2.2.2}$	'boiling'
c.	gb^{a}la$^{2.4}$	gbala-li$^{2.4.2}$	'climbing'
d.	b^{a}la$^{3.3}$	bala-li$^{3.3.2}$	'hitting'

(12) **Passive: ATR harmony, no replacement**

	Verb	**Passive**	**Gloss**
a.	ɓi^{2}	ɓ-o^{2}	'be finished'
b.	sumu$^{2.2}$	sum-o$^{2.2}$	'be boiled'
c.	j^{i}li$^{2.3}$	jil-o$^{2.32}$	'be stolen'
d.	b^{a}la$^{3.3}$	bal-ɔ$^{3.2}$	'be hit'
e.	j^{I}la$^{3.3}$	jɪl-ɔ$^{3.2}$	'be asked'

(13) **Object enclitics: No harmony, root vowel replacement**

	Verb	**Object**	**Verb+Obj**	**Gloss**
a.	j^{i}li$^{2.3}$	=ɔ^{2}	jɔl=ɔ$^{2.32}$, *jol=o$^{2.32}$	'steal him'
b.	j^{I}la$^{3.3}$	=ɔ^{2}	jɔl=ɔ$^{3.2}$	'ask him'

(14) **Plural: ATR harmony, root vowel replacement**

	Noun	Plural	Plural noun	Gloss
a.	ɓ^{u}li$^{3.3}$	/-I/	ɓil-i$^{3.3}$	'cow'
b.	w^{U}lɪ$^{4.4}$	/-I/	wɪl-ɪ$^{4.4}$	'goat'

– Whether an affix undergoes vowel harmony with the root is independent of whether it triggers root vowel replacement.

(15) **Morphemes by phonological property**

	Harmony	**No Harmony**
No replacement	Sg	Def
	Caus	1/2.acc
	Pass	Nmlz
	Appl	
	Recip	
Replacement	Pl	3.acc

∗ The shaded cells are morphemes that occur in nominal domains, while the other morphemes occur on verb roots.

∗ Vowel replacement occurs in object enclitic and plural contexts, but not elsewhere.

∗ Vowel harmony occurs in passive and plural contexts, but not in all contexts.

- **In a strength-only model**, we could differentiate the object enclitic and plural suffix from other affixes and clitics that do not condition root vowel replacement by assigning the affixes different representational levels of strength.
  - However, we would also need a way to differentiate between those affixes which undergo vowel harmony (plural, passive) and those that do not (OM, nominalizer).
  - There is no combination of strength levels and constraint weights that derives both processes solely with (gradient) representations of strength
    - ∗ See the appendix for an attempted MaxEnt model using Gradient Symbolic Representations (Smolensky et al. 2014; Rosen 2016; Zimmermann 2017).
  - A strength-only model can account for ATR harmony or root vowel replacement, but when presented with both processes in the same language, the model fails.
    - ∗ **Caveat:** The strength-based approach could be saved if we allow for strength to be indexed to particular features of morphemes (i.e. affixes that undergo ATR harmony have a weak ATR feature).
      - · These feature-specific degrees of strength add complexity to the model. Further work is needed to determine whether there is phonological need for psycholinguistic reality behind feature-specific degrees of strength.
- **In a strength+cophonologies model** we can combine encoding strength to derive lexical-specificity effects and cophonologies to derive morphosyntactic conditioning.

  - In this model, we need no additional representational tools to derive ATR harmony and root vowel replacement only in particular contexts.
  - Instead, we see a small set of constraints reranked depending on the construction.

- We must add one constraint to our inventory from section 4, which penalizes consecutive vowels within a word that do not agree in ATR quality.

(16) $*[\alpha\textbf{ATR}][\beta\textbf{ATR}]_{[+syllabic]}$ (ATRHarmony)
A segment with ATR feature value α may not directly precede another segment with ATR value $\neg\alpha$ in the ordered set of output segments that are [+syllabic]. Assign one violation for each pair of neighboring segments that meets the criteria.

- In OM contexts, with replacement but no harmony, we see the same ranking developed in section 4, with the addition of our ATRHarmony constraint.

(17) **OM ranking**
Realize, *V+V, Id-Strong, ≫ Harmony ≫ Id-IO, ATRHarmony

- In plural contexts, where we see both replacement and ATR harmony, both the ATR harmony and general vowel agreement constraints are highly ranked:

(18) **Plural ranking**
Realize, Id-Strong, ATRHarmony ≫ Harmony, *V+V ≫ Id-IO

- In passive contexts, where we see ATR harmony but no replacement, the ATR constraint must be ranked high, but the general vowel agreement constraint low.

(19) **Passive ranking**
Realize, Id-Strong, ATRHarmony, *V+V ≫ Id-IO ≫ Harmony

- In nominalizing contexts, where we see neither ATR harmony nor replacement, both ABP constraints must be ranked below the faithfulness constraints Id-Strong, Id-IO.

(20) **Nominalizing ranking**
Realize, Id-Strong, *V+V, Id-IO ≫ Harmony, ATRHarmony

- Reranking faithfulness constraints Id-Strong, Id-IO with respect to Agreement-by-Projection constraints Harmony, ATRHarmony, results in four surface possibilities all found in Guébie morphophonology:

(21) **The distribution of harmony and replacement in Guébie**

	Harmony	**No harmony**
Replacement	Plural	Objects
No replacement	Passive	Nominalizer

- The lexical specificity of the vowel replacement process is due to strength-based representational differences between alternating and non-alternating root vowels.

6 Implications and remaining questions

- There are two vowel alternations in Guébie that both affect the same subset of roots.
  - A strength of encoding account unifies the explanation of these two alternations
- Vowel replacement of root vowels in Guébie is both lexically and morphosyntactically conditioned.
  - It only occurs in the context of a third-person object enclitic or plural suffix.
  - It only occurs in roots containing weakly phonologically encoded initial vowels.
- Here I explored using a single tool to account for the lexical specificity and morphosyntactic conditioning: encoding strength.
  - Problems arise when relying on encoding strength to account for morphosyntactic conditioning:
    - We expect "strong" suffixes to condition root vowel alternations, while weak suffixes do not.
    - However, some "strong" suffixes also undergo root-conditioned vowel harmony, which suggests that in some sense they are "weak".
    - No combination of degrees of strength and constraint weights can model both processes.
- I propose an alternative account relying on both encoding strength and cophonologies.
  - Strength-based representations account for the lexical specificity of vowel deletion and replacement.
  - Cophonologies account for the morphosyntactic conditioning of vowel replacement and ATR harmony.
- **Remaining questions:**
  1. Is there a modification to encoding-strength approaches like Gradient Symbolic Representations (Smolensky et al. 2014; Rosen 2016) that can account for morphosyntactic conditioning of both root vowel replacement and ATR harmony?
     - Possible solution: strength indexed to particular features (i.e. ATR).
  2. Is there psychological reality to the strength-based differences proposed here for root vowels?
     - Possible solution: Test for representational differences with future psycholinguistic experiments.

Appendix A A MaxEnt-HG model of replacement and harmony with gradient representations

- The following tableaux is a single example of many attempts to model vowel replacement and ATR harmony in Guébie with a strength-only approach using the MaxEnt Grammar Tool (Hayes et al. 2009).
- Note that the predicted variants do not always match the observed variants.
- Strong roots are left out for space, but the model predicts that the correct output for strong roots will appear over 99% of the time.
- Here I limit differences in encoding strength to inputs, so only faithfulness constraints are affected by strength values (though see Zimmermann (2017)).

(22) **MaxEnt-HG tableau**

weight	3.71 ATRHaromny	2.15 FullHarmony	10.4 IdentIO	14.7 Realize	1.11 *V+V	**Obs**	**Pred**
WkRt /jɪ$_{.25}$la$_1$/							
a. jɪla		1				1	.610
b. jɪlɪ			1			0	0
c. jala			.25			0	.389
d. jila	1	1	.25			0	.001
WkRt-Passive /jɪ$_{.25}$la$_1$-O$_{.25}$/							
a. jɪla-o	1	2			1	0	.002
b. jɪla-ɔ		2			1	0	.066
c. jolo-o			1.25		1	0	0
d. jɪl-ɔ		1				1	.57
e. jɪla		1		1		0	0
f. jɪl-ɪ			.25			0	.36
WkRt-Nmlz /jɪ$_{.25}$la$_1$-li$_1$/							
a. jɪla-li	1	2				1	97.5
b. jɪla-lɪ		2	2			0	.001
c. jilə-li		2	1.25			0	0
d. jɪla		1		1		0	0
e. jili-li			1.25			0	.007
f. jɪla-la		1	1			0	.010
g. jala-la			1.25			0	.007
WkRt-OM /jɪ$_{.25}$la$_1$-ɔ$_1$/							
a. jɪla-ɔ		2			1	0	.066
b. jɔlɔ-ɔ			1.25		1	0	0
c. jɪlɔ-ɔ		1	1		1	0	0
d. jɪl-ɔ		1				0	.57
e. jɔl-ɔ			.25			1	.364
f. jɪl-ɪ			1			0	0 0

(23) **MaxEnt-HG tableau (cont.)**

weight	3.71 ATRHaromny	2.15 FullHarmony	10.4 IdentIO	14.7 Realize	1.11 *V+V	**Obs**	**Pred**
WkRt-Pl mɛ$_{.25}$nɛ$_{1}$-a$_{.75}$							
a. mɛnɛ-a	1	1	1		1	0	0
b. mɛnɛ				1		0	0
c. mana-a			1.25		1	0	0
d. man-a			.25			1	.389
e. mɛn-a		1				0	.609
f. mɛn-ə		1	.75			0	0
g. mɛn-ɛ			.75			0	.002

- Light grey cells show where the model makes good predictions, and dark grey cells are where it fails.
- This particular model correctly predicts the most frequent form for bare roots, root+passive, and root+nominalizer, but incorrectly predicts the plural and object marker forms, always favoring forms where the root does not alternate.
- This model makes the right predictions about suffix vowel harmony, but not about root vowel replacement. Each iteration of the model was able to capture one but not both of these effects.
- There is a trade-off, such that either root alternations *or* harmony are correctly predicted, but never both.

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