Never Surfacing Underlying Representations in Klamath

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In Klamath (Barker, 1963, 1964) an alternation is seen between [i] and [∅].

This alternation cannot be caused by i-deletion or i-epenthesiis.

However, this alternation is in complementary distribution with /e/.

This alternation can be represented underlyingly with /e/.

Though /e/ is an abstract UR for such alternations, these forms are learnable due to emergent properties of MaxEnt learners.
Phonemic Inventory of Klamath

- Klamath was a Plateau Penutian language spoken in south-central Oregon.
- There are no living native speakers.
- This searchable representation is available on my website. (https://dornsife.usc.edu/ohara/klamathdictionary/)

Vowels of Klamath (Adapted from Blevins (1993))

<table>
<thead>
<tr>
<th>Vowels +front</th>
<th>+long</th>
<th>+front</th>
</tr>
</thead>
<tbody>
<tr>
<td>+hi</td>
<td>i u</td>
<td>+hi i: u:</td>
</tr>
<tr>
<td></td>
<td>e a</td>
<td>e: a:</td>
</tr>
</tbody>
</table>
Around 50 stems show [i] before the /-tkʰ/ morpheme, but appear consonant final before the indicative /-a/ suffix.

a) [ʔeːwə] ‘is deep’ (D: 31)
b) [ʔeːwɪtkʰ] ‘deep’

Suffixes like that in (c) show that this is not (just) a hiatus resolution effect.

a) [nᵗʰeːw’a] ‘breaks with a round instrument’ (D: 403)
b) [nᵗʰeːwɪtkʰ] ‘broken’
c) [nᵗʰewlʲi] ‘breaks into’
Possible Concrete URs

- The two possible concrete URs for a form like [ʔeːwa]-[ʔeːwitkʰ] are /ʔeːw/ and /ʔeːwi/.  
- If /ʔeːw/ was the underlying form, we would need to see [i]-epenthesis to break up the word-final [ʔitkʰ] cluster.  
- If /ʔeːwi/ was the underlying form, we would need to see stem final /i/ deletion when not phonotactically necessary.
Concrete URs

Epenthesis

[a] is the default epenthetic vowel in Klamath.

/\text{snak’l-a}/  \quad [\text{snak’la}]  \quad ‘has spots on the face’  \quad (D: 379)

/\text{snak’l-s}/  \quad [\text{snak’als}]  \quad ‘pregnancy spots’

/\text{pʰipʰi:k’-tkʰ}/  \quad [\text{pʰipʰi:k’atkʰ}]  \quad ‘wearing a bracelet’  \quad (D: 301)

/\text{pʰipʰi:k’-s}/  \quad [\text{pʰipʰi:ks}]  \quad ‘bracelet’

/\text{taq’-ni}/  \quad [\text{taqni}]  \quad ‘Sharp One’  \quad (D: 109)

/\text{taq’-tkʰ}/  \quad [\text{taq’atkʰ}]  \quad ‘sharp-edged

\text{Pe:w˚}-a/ should show [a]-epenthesis, contrary to the observed forms.

\text{Pe:w˚}-tkʰ/ should show [a]-epenthesis, contrary to the observed forms.

/\text{ʔe:w˚}/-[\text{ʔe:wa}]

*/\text{ʔe:w˚-tkʰ}/-[\text{ʔe:watkʰ}]*
Concrete URs

Non-Alternating [i]

Underlying /i/ drives deletion of /a/ in hiatus resolution.

/stupwǐ-a/  [stupwǐ]  ‘has first menstruation’ (D: 358)
/stupwǐ-tkʰ/  [stupwǐtkʰ]  ‘woman’
/slaːm’i-a/  [slaːm’i]  ‘becomes a widower’  (D:373)
/slaːm’i-tkʰ/  [slaːm’itkʰ]  ‘widower’
/sn’eːwli-a/  [sn’eːwli]  ‘gets a cold’  (D: 381)
/sn’eːwli-tkʰ/  [sn’eːwilitkʰ]  ‘one having a cold’

*/eːwi/ should not show /i/-deletion, contrary to the observed forms.

*/eːwi-a/*-/eːwi/
*/eːwi-tkʰ/*-/eːwitkʰ/
What about /e/?

Distribution of [e]

- While all other vowels have a thorough distribution, [e] is relatively restricted in Klamath.
- Short [e] only appears in initial syllables of verb stems.
  /tejuːw-a/  [tejuːwa] ‘dares someone to do’ (D: 113)
- Short [e] appears in any syllable of nouns.
  /sqʰul’e/  [sqʰul’e] ‘meadowlark’ (D: 390)
- Long [eː] appears in any syllable, but only if its deletion would create an illicit cluster.
  /nt’useː-tkʰ/  [nt’useːtkʰ] ‘swollen’ (D: 272)
What about /e/?

Complementary Distribution

- The distribution of [e],
  - (nouns, initial syllables, or long vowels)
  is complementary with the distribution of the [i]-[∅] alternation
  - (final syllables of verb stems).
- /ʔeːwe/ can represent [ʔeːwa]-[ʔeːwɪθkʰ]
  - If phonotactically allowed, /e/ deletes.
  - If not, it raises.
Phonological contrasts are more likely to be maintained in privileged positions. (Beckman, 1998)

- Long vowels are privileged over short vowels. (Steriade, 1995; Beckman, 1998)
- Stem-initial syllables are privileged over other syllables. (ibid, Walker 2011; Trubetzkoy 1969)
- Nouns show privilege over verbs. (Smith, 1997; Jesney & Tessier, 2011)

- Mid-vowels ([e]) are more marked than the corner vowels ([i a u]), and many languages show /e/-[i] raising in unprivileged positions. (Crosswhite, 2004)
Harmonic Grammar

- Following work in the phonological learning literature\(^1\), I use weighted rather than ranked constraints, as in Harmonic Grammar (Legendre *et al.*, 1990, 2006).
- Here, I use Positional Faithfulness constraints.
- Marked structures are only allowed in privileged positions with the constraint ranking:
  - Positional Faithfulness $\gg$ Markedness $\gg$ General Faithfulness
- In HG, multiple low-weighted constraints can cumulatively interact to outweigh a higher-weighted constraint.
  - $\text{PosFaith} + \text{GenFaith} > \text{Markedness} > \text{GenFaith}$

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\(^1\)Goldwater & Johnson (2003); Wilson (2006); Hayes & Wilson (2008); Hayes *et al.* (2009); Potts *et al.* (2010); Jesney & Tessier (2011) among others.
## Distribution of [e]

- In order to find that [e] is protected in initial syllables, $w(F) + w(F/\sigma_1) > w(\text{*MIDV})$

<table>
<thead>
<tr>
<th></th>
<th>$w = 3$</th>
<th>$w = 2$</th>
<th>$w = 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>/teju:wa/</td>
<td>*MIDV</td>
<td>ID[HI]</td>
<td>ID[HI]/$\sigma_1$</td>
</tr>
<tr>
<td>a. te.ju:.wa</td>
<td>-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. ti.ju:.wa</td>
<td></td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>$w = 3$</td>
<td>$w = 2$</td>
<td>$w = 2$</td>
</tr>
<tr>
<td>/teju:wa/</td>
<td>*MIDV</td>
<td>MAX-V</td>
<td>MAX-V/$\sigma_1$</td>
</tr>
<tr>
<td>c. te.ju:.wa</td>
<td>-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. tju:.wa</td>
<td></td>
<td>-1</td>
<td>-1</td>
</tr>
</tbody>
</table>
Distribution of [e] II

- In order to find that [e] is protected in nouns, 
  \( w(F) + w(F_{\text{NOUN}}) > w(*\text{MIDV}) \)

<table>
<thead>
<tr>
<th></th>
<th>/sq^hul’e_{\text{Noun}}/</th>
<th>*\text{MIDV}</th>
<th>\text{ID}[\text{HI}]</th>
<th>\text{ID}[\text{HI}]_{\text{NOUN}}</th>
<th>\text{H}</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>sq^hul’e</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-3</td>
</tr>
<tr>
<td>b.</td>
<td>sq^hul’i</td>
<td>*\text{MIDV}</td>
<td>\text{MAX-V}</td>
<td>\text{MAX-V}_{\text{NOUN}}</td>
<td>\text{H}</td>
</tr>
<tr>
<td>c.</td>
<td>sq^hul’e</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-3</td>
</tr>
<tr>
<td>d.</td>
<td>sq^hul’</td>
<td>*\text{MIDV}</td>
<td>\text{ID}[\text{HI}]</td>
<td>\text{ID}[\text{HI}]_{\text{NOUN}}</td>
<td>\text{H}</td>
</tr>
</tbody>
</table>
Distribution of [e] III

- Since long [e:] does surface in noninitial syllables of verbs, 
  \[ w(\text{ID[HI]}) + w(\text{ID[HI]}/V:) > w(*\text{MIDV}). \]

<table>
<thead>
<tr>
<th>/nt’use:tk^h/</th>
<th>*\text{MIDV}</th>
<th>\text{ID[HI]}</th>
<th>\text{ID[HI]}/V:</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. nt’use:tk^h</td>
<td>-1</td>
<td></td>
<td></td>
<td>-3</td>
</tr>
<tr>
<td>b. nt’usi:tk^h</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-4</td>
</tr>
</tbody>
</table>
Driving the [i]-[∅] Alternation

- In order to get [e] deleting by default,
  \(w(*\text{MidV}), w(\text{ID[HI]}) > w(\text{Max-V})\)

<table>
<thead>
<tr>
<th>/\text{?eːwe-ta/}</th>
<th>*\text{MidV}</th>
<th>\text{ID[HI]}</th>
<th>\text{Max-V}</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>/\text{?eːwta}</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-4</td>
</tr>
<tr>
<td>/\text{?eːwit}</td>
<td>-1</td>
<td>-1</td>
<td>-5</td>
<td></td>
</tr>
<tr>
<td>/\text{?eːweta}</td>
<td>-2</td>
<td>-1</td>
<td>-6</td>
<td></td>
</tr>
</tbody>
</table>

- So that [e] raises when it cannot delete,
  \(w(\text{PhTAC}) + w(\text{Max-V}), w(*\text{MidV}) > w(\text{ID[HI]})\)

<table>
<thead>
<tr>
<th>/\text{?eːwe-tkʰ/}</th>
<th>*\text{MidV}</th>
<th>\text{ID[HI]}</th>
<th>\text{PhTAC}</th>
<th>\text{Max-V}</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>/\text{?eːwtkʰ}</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-6</td>
</tr>
<tr>
<td>/\text{?eːwitkʰ}</td>
<td>-1</td>
<td>-1</td>
<td>-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/\text{?eːwetkʰ}</td>
<td>-2</td>
<td>-1</td>
<td>-6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary of Analysis

- By using /e/ in the underlying forms for verbs with the [i]∼[∅], we gain several theoretical benefits:
  - The same constraints needed to restrict [e]’s surface distribution can be used to drive this alternation.
  - A large class of verb stems do not need to be marked overtly as exceptional.
  - There is additional evidence from the behavior of long /e:/ and the interaction with glottalization to back this up.

- However, a UR with a segment that does not occur on the surface anywhere is abstract, and some question the learnability of abstract URs.
Abstractness

An *abstract* UR is any UR such that some feature or component of the UR never appears in any of its surface exponents. (Following Kentstowicz & Kisseberth 1979; Baković 2009)

In Klamath, /ʔeːwe/ is an abstract UR, because the /e/ does not surface in any of the surface exponents of the morpheme.
Questions

- Are abstract URs learnable?
- And if so, why do we prefer /ʔeːwe/ to any other abstract UR.
  - The original morphophonemic account given in Barker (1964) uses an abstract UR similar to /ʔeːwɪ/, where /ɪ/ only appears in the words showing the [i]-[∅] alternation.

CLAIM

Using a set of assumptions common in the phonological learning literature, not only are abstract URs learnable, but /ʔeːwe/ is preferred to /ʔeːwɪ/
MaxLex

- My learning algorithm, MaxLex (A Maximum Entropy learner of Lexicons and Grammars), is based on several assumptions made by many different phonological learners.
  - MaxLex uses a Maximum Entropy grammar following Goldwater & Johnson (2003); Wilson (2006); Hayes & Wilson (2008); Jäger & Rosenbach (2006); Jäger (2007); Hayes et al. (2009) and many others.
  - MaxLex first learns a phonotactic grammar at one stage and then becomes morphologically aware,
    - (Hayes, 2004; Jarosz, 2006; Tessier, 2007; Jesney & Tessier, 2011; Tesar, 2014; Alderete et al., 2005; Merchant, 2008)
  - To find the most restrictive grammar, faithfulness constraints are biased low (as close to 0), and markedness constraints are biased high (as close to 100).
    - (Jesney & Tessier, 2011)
  - In order to learn the lexicon, MaxLex assigns a probability distribution across a set of possible URs.
    - (Jarosz, 2006)
The phonotactic grammar must learn the surface distributions of /e/ and /i/.

Thus, \( w(F) + w(\text{Pos Faith}(F, P)) > w(*\text{Mid}) \), for each faithfulness Constraint \( F \), and each position where /e/ surfaces, or else /e/ would repair somehow in that position.

- \( w(\text{ID(HI)}) + w(\text{ID(HI)}/\text{NOUN}) > w(*\text{Mid}) \)
- \( w(\text{ID(HI)}) + w(\text{ID(HI)}/\sigma_1) > w(*\text{Mid}) \)
- \( w(\text{ID(HI)}) + w(\text{ID(HI)}/V:) > w(*\text{Mid}) \)

In order for /i/ to surface nowhere in Klamath, \( w(*-\text{ATR}) > w(F) + \sum_P w(\text{Pos Faith}(F, P)) \).

To ensure restrictiveness, the learner minimizes the sum of the squares of the faithfulness constraints.

- \( \text{ID[HI]} \) must be weighted above \( \frac{n}{n+1} w(*\text{Mid V}) \), where \( n \) is the number of specific constraints violated with it (here 3).
- \( \text{ID[HI]}/V:, \text{ID[HI]}/\sigma_1, \text{ID[HI]}_\text{NOUN} \) all must be weighted near \( \frac{1}{n+1} w(*\text{Mid V}) \).
- \( \text{ID[ATR]} \) is weighted 0 since it never has to outweigh anything, alone or with other constraints.
I ran simulations of the phonotactic learner looking just at verbs without noninitial long e.

- I biased faithfulness constraints near 0 and markedness constraints near 100.
- (I did not use the constraints $\text{ID[HI]}/V$: or $\text{ID[HI]}_{\text{NOUN}}$ in the sim)

Since my simulation uses MaxEnt rather than HG, the weights of the constraints must be more extreme than they need to be in HG.

However the distribution of weight between general and specific constraints will remain the same.

- For this sim, $n = 1$ so $w(\text{ID[HI]}) \sim w(\text{ID[HI]}/\sigma_1) > \frac{w(\text{*MIDV})}{2}$
**Constraint Weights Learned by Phonotactic Grammar**

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Learned Weight</th>
<th>Constraint</th>
<th>Learned Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID[HI]</td>
<td>40.1280662622</td>
<td>ID[ATR]</td>
<td>0</td>
</tr>
<tr>
<td>ID[HI]/σ₁</td>
<td>40.1280662622</td>
<td>ID[ATR]/σ₁</td>
<td>0</td>
</tr>
<tr>
<td>Max-V</td>
<td>40.1050314302</td>
<td>Dep-V</td>
<td>8.25610961151</td>
</tr>
<tr>
<td>Max-V/σ₁</td>
<td>40.1050314302</td>
<td>*[−ATR]</td>
<td>100.000031978</td>
</tr>
<tr>
<td>*MidV</td>
<td>74.4312330447</td>
<td>PhTAC</td>
<td>100.000031978</td>
</tr>
</tbody>
</table>

- We see that the ID[HI] and ID[HI]\_\text{NOUN} share equal distribution of the weight.

- On the other hand since ATR contrasts are never maintained in Klamath, ID[ATR] never dominates anything and gets 0 weight.
Morphologically aware learning

- I consider the possible URs /\textipa{\textipa{\v{e}}:\v{e}}/ and /\textipa{\textipa{\v{e}}:\v{u}}/, along with the concrete URs.

- For /\textipa{\v{e}}/ in unprivileged positions to show the [i]∼[\emptyset] alternation:
  - \( w(\text{ID(\text{Hi}))} > w(\text{Max-V}) \)
  - Both must be outweighed by \(*\text{Mid}.*\)
  - \( w(\text{Max-V})+w(\text{PhTAC}) > w(\text{ID(\text{Hi}))} \)

- For /\textipa{\v{u}}/ to show the alternation:
  - \( w(\text{ID(\text{ATR})}) > w(\text{Max-V}) \)
  - Both must be outweighed by \(*[-\text{ATR}].*\)
  - \( w(\text{Max-V})+w(\text{PhTAC}) > w(\text{ID(\text{ATR})}) \)
In order for /?eːwe/ to model the alternation:

\[ w(\text{ID[HI]})^2 + w(\text{MAX-V})^2 + w(\text{ID[ATR]})^2 \sim 3,364 \]

- \*[-ATR] \hspace{1cm} \text{ID[HI]} \hspace{1cm} \text{ID[ATR]} \hspace{1cm} 0

\*MidV

100 \hspace{2cm} \text{MAX-V}

In order for /?eːwɪ/ to model the alternation:

\[ w(\text{ID[HI]})^2 + w(\text{MAX-V})^2 + w(\text{ID[ATR]})^2 \sim 4,733 \]

- \*[-ATR] \hspace{1cm} \text{ID[Hi]} \hspace{1cm} \text{ID[ATR]} \hspace{1cm} 0

\*MidV

100 \hspace{2cm} \text{MAX-V}

The top option does better on the learning bias, and is a more restrictive grammar.
My simulation started with equal distribution across 4 possible URs, /e/ə/w/, /e/ə/wi/, /e/ə/w/, and /e/ə/wi/.

After the simulation runs, the URs with /e/ have each accrued over .999999999 probability.

This confirms that the URs with /e/ are learned over other abstract URs.
Generalization of results

- The more privileged positions a faithfulness constraint is respected in (a contrast is maintained in), the higher weighted it will be.
- The higher weighted a faithfulness constraint is, the more likely an alternate repair is chosen to prevent that contrast from appearing in those positions it doesn’t.
- Thus, the more positions a featural contrast occurs in, the more likely that feature can be used to represent abstract alternations in the positions where it does not occur.
Conclusion

- Analyzing the [i]~[∅] alternation as a loss of vowel contrasts in unprivileged positions simplifies the grammar of Klamath, and is the most restrictive grammar available.
- This analysis not only explains this phenomenon but explains gaps in the distribution of [e].
- This abstract UR is learnable, and easier to learn than any other abstract UR.
Thanks

I would like to thank Karen Jesney, Rachel Walker, Khalil Iskarous, Roumyana Pancheva, Reed Blaylock, Paul de Lacy and Martin Krämer for their insights on this project. Thanks to audiences at USC PhonLunch, OCP12 and SSILA 2015. None of this work would be possible without M.A.R. Barker’s thorough work on the Klamath language. All errors are my own.
Works Cited I


Works Cited II


Crosswhite, Katherine. 2004. Vowel Reduction. *Chap. 7 of: Hayes, Bruce, Kirchner, Robert, & Steriade, Donca* (eds), *Phonetically Based Phonology*. Pearson Education.

Works Cited III


Works Cited VI


Works Cited VII


Constraints

- **ID[hi]** - Violated by changing the [hi] feature of a segment. 
  \( /e/ \rightarrow [i] \)

- **Max-V** - Violated by deleting a vowel. 
  \( /e/ \rightarrow [\emptyset] \)

- ***MidV** - Violated by mid vowels in output. 
  \([e]\)

- **PhTAc** - Violated by illicit clusters. 
  \([Ctk^h]\)

- **F/P** - Violated by violations of a faithfulness constraint \( F \) in a position \( P \).
However, most of the verb stems in Barker (1963) with noninitial long /e/ have allomorphs where the /e:/ deletes.

An investigation of this allomorphy shows that these /e:/-less forms surface in the same environments where short /e/ deletes.

/nt’use:-tkʰ/ → [nt’use:tkʰ], but
/nt’use:-a/ → [nt’us?a]
Long /e/s in verbs are not totally protected

<table>
<thead>
<tr>
<th>PhTAC, ID[hi]/V: ≫ *MidV ≫ Max-V/V:</th>
<th>/nt’use:?-tkʰ/</th>
<th>PhTAC</th>
<th>ID[hi]/V:</th>
<th>*MidV</th>
<th>Max-V/V:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. nt’u:se:tkʰ</td>
<td></td>
<td></td>
<td></td>
<td>*e:</td>
<td></td>
</tr>
<tr>
<td>b. nt’u:si:tkʰ</td>
<td></td>
<td></td>
<td></td>
<td>*i: W</td>
<td>L</td>
</tr>
<tr>
<td>c. nt’ustk</td>
<td></td>
<td>*stk W</td>
<td></td>
<td>L</td>
<td>*e: W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>/nt’use:?-a/</th>
<th>PhTAC</th>
<th>ID[hi]/V:</th>
<th>*MidV</th>
<th>Max-V/V:</th>
</tr>
</thead>
<tbody>
<tr>
<td>d. nt’us?a</td>
<td></td>
<td></td>
<td></td>
<td>*e:</td>
</tr>
<tr>
<td>e. nt’u:si:?a</td>
<td></td>
<td></td>
<td>*i: W</td>
<td>L</td>
</tr>
<tr>
<td>f. nt’use:?a</td>
<td></td>
<td></td>
<td>*e: W</td>
<td>L</td>
</tr>
</tbody>
</table>
Glottalization Effects

- The glottal stop in Klamath tends to coalesce with the previous consonant when in a C?V context.  
  /pʰetʃ-aːk'#/ [pʰetʃ'aːk] ‘little foot’ (Barker, 1964, p. 54)
- The [constricted glottis] node usually deletes when not in syllable onset.  
  /n-tʰit'-tqi/ [ntʰittqi] ‘defecates’ (Barker, 1963, p. 408)
[i] Epentheses?

- In order to get [ʧiːmaːʔas], [a]-epenthesis must bleed [cg] deletion.
  
<table>
<thead>
<tr>
<th>U.R.</th>
<th>/ʧiːmaːʔas/</th>
<th>/ntʰeːw’-tkʰ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>[a]-Epen</td>
<td>ʧiːmaːʔas</td>
<td>ntʰeːw’atkʰ</td>
</tr>
<tr>
<td>[cg]-Del</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>S.R.</td>
<td>[ʧiːmaːʔas]</td>
<td>[ntʰeːw’atkʰ]</td>
</tr>
</tbody>
</table>

- But in order to get [ntʰeːwtkʰ], through [i]-epenthesis, [i]-epenthesis must counter-bleed [cg]-deletion.
  
<table>
<thead>
<tr>
<th>U.R.</th>
<th>/ʧiːmaːʔas/</th>
<th>/ntʰeːw’-tkʰ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>[cg]-Del</td>
<td>ʧiːmaːs</td>
<td>ntʰeːwtkʰ</td>
</tr>
<tr>
<td>[i]-Epen</td>
<td>—</td>
<td>ntʰeːwtkʰ</td>
</tr>
<tr>
<td>S.R.</td>
<td>[ʧiːmaːs]</td>
<td>[ntʰeːwtkʰ]</td>
</tr>
</tbody>
</table>
[i] Epenthesis?

- However, if we assume this ordering, [a]-Epenthesis should bleed [i]-Epenthesis, since [i]-Epenthesis occurs in contexts where we expect to see [a]-Epenthesis.
- Without some sort of abstract feature preventing [a]-epenthesis, we cannot get [ntʰeːwitkʰ]

<table>
<thead>
<tr>
<th>U.R.</th>
<th>/ʧimaː?-s/</th>
<th>/ntʰeːw’-tkʰ/</th>
<th>/ntʰeːw’-tkʰ/</th>
<th>No a-epen</th>
</tr>
</thead>
<tbody>
<tr>
<td>[a]-Epen</td>
<td>tfimaː?as</td>
<td>ntʰeːw’atkʰ</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>[cg]-Del</td>
<td>—</td>
<td>—</td>
<td>ntʰeːwtkʰ</td>
<td></td>
</tr>
<tr>
<td>[i]-Epen</td>
<td>—</td>
<td>—</td>
<td>ntʰeːwitkʰ</td>
<td></td>
</tr>
<tr>
<td>S.R.</td>
<td>tfimaː?as</td>
<td>ntʰeːw’atkʰ</td>
<td>ntʰeːwtkʰ</td>
<td></td>
</tr>
</tbody>
</table>

- Thus, this analysis is just as abstract as the /i/ analysis, since all the same stems must be marked.
Richness of the Base

- Under this analysis, verbs with /e/ in non-initial positions have either /e/ raising or /e/ deletion.
  - Typically, non-initial /e/ deletes.
  - If deletion would create a phonotactically illicit cluster, /e/ raises instead.
- [Ctkʰ] is an illicit coda in Klamath.
- If the /e/ is morpheme final, we see the [i]∼[∅] alternation, because /e/ must raise to avoid [Ctkʰ].
  - /...Ce-a/ → [...Ca]
  - /...Ce-tkʰ/ → [...Citkʰ], *[...Ctkʰ]
Richness of the Base II

- If a glottal stop intervenes between /e/ and the end of the stem, the glottal stop will delete in order to avoid the [ʔtkʰ] coda, so /e/ will raise before /-tkʰ/.
  - /...Ceʔ-a/ → [...C’a]
  - /...Ceʔ-tkʰ/ → [...Citkʰ], *[...Ctkʰ]
- If any other consonant intervenes between /e/ and the end of the stem, this alternation will not appear, because epenthesis will break up the [Ctkʰ] cluster.
  - /...CeC-a/ → [...CCa]
  - /...CeC-tkʰ/ → [...CCatkʰ]
- These stems will be lexicalized as having no /e/, since this /e/ deletes in all contexts.
- If an /e/ exists stem internally breaking up a large cluster, it should always raise, no matter what suffixes are applied.
  - /...CCeCC-a/ → [...CCiCCa], *[...CCCCCa]
  - /...CCeCC-tkʰ/ → [...CCiCCatkʰ]
- These stems will always be lexicalized as containing /i/. 
Richness of the Base III

- With this analysis, any gaps in the distribution of /e/ throughout the lexicon are caused by total neutralization with /i/ or /∅/.
- No abstract phonemes have highly specific distributions in the lexicon.