**Multilevel MaxEnt grammars for probabilistic morphologically-conditioned tonotactics**

Stephanie S Shih  
*University of California, Merced* 
shih@ucmerced.edu  

Sharon Inkelas  
*University of California, Berkeley* 
inkelas@berkeley.edu

1 **INTRODUCTION**

- This talk presents a case of lexically-conditioned tonotactics variation from Mende (Mande, Sierra Leone).

(1) Top trisyllabic surface tone patterns in the Mende lexicon

- Part of speech-sensitive patterns =
  - different lexical classes can exhibit different phonological patterns.
  - noted cross-linguistically: e.g., English noun versus verb stress patterns
  - applications in e.g., comprehension, parsing

- Two hypotheses about how lexical class-conditioned sensitivity could work:

  A. Lexical class differences are limited by the grammar/UG.
     - differences only in faithfulness, not markedness (e.g., Ito & Mester 1995; Alderete 2001; Smith 2011)
     - preferential classes, e.g., nouns // verbs will show a subset of noun patterns (e.g., Smith 2011)
  
  B. Lexical classes can each have their own completely independent phonological profiles (e.g., Ito & Mester 1995; Inkelas & Zoll 2007; Anttila 2002; Pater 2009).
     - We argue for this latter hypothesis here.
This talk:
- quantitatively models space of lexically-conditioned variation and frequency of variation across the corpus,

This approach directly addresses the overarching problem in morphophonology of how to quantify the heterogeneity that morphological conditioning can engender in a phonological system.

2 MENDE TONOTACTICS

2.1 History, early generative accounts

- Early generative accounts of Mende noticed common tone patterns recurrent in the language, particularly in nouns (Leben 1978) → ‘tone melodies’ (see also Hyman 1987 for similar tone melodies in Kukuya),
- In Autosegmental Phonology, these surface tone patterns were modeled using
  - geometric association conventions of Autosegmental Phonology
  - 5 underlying tone melodies (H, L, HL, LH, LHL) as source of all surface patterns.

(2) ndávílú ‘slings’  
\[ \begin{align*}
L & \rightarrow R, \ L \leftrightarrow L & \text{association, then spread.}
\end{align*}\]

- But, subsequent work pointed out many surface patterns that deviate from the supposed five melodies or their “universal” autosegmental association principles (Dwyer 1978; Conteh et al. 1983; Zoll 2003; Zhang 2007).

(3) a. lèleůmá ‘praying mantis’  
\[ \begin{align*}
L & \ L & H
\end{align*}\]  
violates association principles

b. gbágběmá ‘sensitive plant’  
\[ \begin{align*}
H & \ L & H & L
\end{align*}\]  
cannot arise from one of the 5 tone melodies;  
violates association principles

2.2 Data

- Mende dictionary: \( n=5,412 \) (Innes 1969)
- 1 to 3-syllable words: \( n=4,989 \)
  - Morpheme breaks are not indicated in Innes, but a primary source of morphological complexity (in nouns, at least) appears to be total reduplication in 4-syllable words, which we’re not looking at here.
- Parts of speech
  - Nouns 2,494
  - Neutrals 1,442 (verbs, adjectives)
  - Ideophones 762
  - Other 291 (pronouns, conjunctions, interjections, adverbs, etc.)

2.3 A fresh look at tone: the theoretical underpinnings

- Agreement by Correspondence Theory (ABC; Hansson 2001; Rose & Walker 2004; Bennett 2013; a.o.)
  - grounded in basic principles of similarity and proximity attraction, modeling instability in syntagmatic phonological relationships (Wayment 2009; Inkelas & Shih 2013).
  - Elements that are sufficiently similar/proximal interact in e.g., assimilation/dissimilation.
  - For simplicity in this talk, constraints are reformulated into more familiar phonotactic markedness format (but it’s still ABC under the hood; cf. Hansson 2014).
- Q Theory (e.g., Shih & Inkelas 2014)
  - decomposes segments into strings of (2 or 3) smaller, temporally-sequenced, featurally-uniform subsegments, which bear tone features.
(4) a. \( Q \rightarrow (q^1 \ q^2) \)
b. \( \á \rightarrow (\á \á) \)
c. \( \L \H \rightarrow (L \ H) \)

- provides a more fine-grained point of reference for the grammar: crucial for e.g., contour tones.
- divorces issue of what are the minimal units that carry tone features versus what are the units that participate in tonal alternations/phenomena.

- Basic relevant differences between Autosegmentalism (e.g., Leben 1973) and ABC+Q for this talk:
  - Constraints grounded in principles of similarity- and proximity-based interaction.
  - No reliance on geometric, autosegmental ‘line’ representations
  - No reliance on operations that reference autosegmental ‘lines’: i.e., tone association rules.\(^1\)

2.4 **Observed patterns for Mende surface tones**

- Primary observations taken from Inkelas & Shih 2015.

2.4.1 **Contour toned syllables (and tone transitions in general—except at syllable boundaries) are avoided.**

(5) \( \chi^2=6705.270, \ p<0.0001. \)

(6) \(*[\alpha T]::[\beta T]\) (*CHANGE) Penalise every sequence of adjacent \( q \)'s that are tonally non-identical.

(7)

<table>
<thead>
<tr>
<th>( \sigma, \sigma )</th>
<th>freq</th>
<th>( *\text{CHANGE} )</th>
<th>(*[\alpha T]::[\beta T])</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma ) a. HH.HH</td>
<td>995</td>
<td>( \sigma ) freq</td>
<td>( \sigma ) freq</td>
</tr>
<tr>
<td>b. LL.HH</td>
<td>701</td>
<td>W1</td>
<td></td>
</tr>
<tr>
<td>c. LL.HL</td>
<td>389</td>
<td>W2</td>
<td></td>
</tr>
</tbody>
</table>

2.4.2 **If necessary, contour tones are tolerated at the right edge.**

(8) \( \chi^2=353.407, \ p<0.0001. \)

\(^1\) This possibility was hinted at by Zoll (2003), but not fully explored.
(9) \( *([\alpha T]:[\beta T])_{\text{nw}} \) (WeakContour) Penalise every adjacent sequence of non-identical tones within a weak (i.e., non-final) syllable. (cf. Coincide-Contour; Zoll 2003)

(10) | \( \sigma, \sigma \) | freq | *WeakContour | *Change |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. LL.HL</td>
<td>389</td>
<td>( *[\alpha T]:[\beta T] )</td>
<td>2</td>
</tr>
<tr>
<td>b. LH.LL</td>
<td>77</td>
<td>W1</td>
<td>2</td>
</tr>
</tbody>
</table>

2.4.3 Tone changes align with syllable boundaries

(11) Syllable boundaries coincide significantly with tone changes (in polysyllabic words that have non-level surface patterns): \( \chi^2=1428.074, p<0.0001 \)

- Resulting prediction: tone melody complexity should correlate with the number of syllables in a word. More syllables \( \rightarrow \) more non-level tone patterns (Inkelas & Shih 2015).

(12) As \# of syllables in a word increases, so does the percentage of more complex melodies. Conversely, less complex, all-level melodies decrease.

(13) \( *[\alpha T]:[\alpha T] \) (Change@$) Penalise every adjacent, tonally-identical sequence that is separated by a syllable boundary ($). (cf. xx-Edge constraints; Bennett 2013)

(14) | \( \sigma, \sigma, \sigma \) | freq | Change@$ | *WeakContour | *Change |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. LL.HH.LL</td>
<td>233</td>
<td>( *[\alpha T]:[\alpha T] )</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>b. LL.HH.HH</td>
<td>218</td>
<td>W1</td>
<td>L1</td>
<td></td>
</tr>
<tr>
<td>c. LL.LL.LL</td>
<td>112</td>
<td>W2</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>d. LL.LL.HH</td>
<td>78</td>
<td>W1</td>
<td>L1</td>
<td></td>
</tr>
<tr>
<td>e. LH.LL.HH</td>
<td>64</td>
<td>W1</td>
<td>W3</td>
<td></td>
</tr>
<tr>
<td>f. LH.HH.LL</td>
<td>7</td>
<td>W1</td>
<td>W1</td>
<td>2</td>
</tr>
</tbody>
</table>
2.4.4 *HLH troughs are avoided*

(15)

- Troughs are underrepresented, but their presence increases as the number of syllables in words increases.

![Bar chart showing the percentage of HLH troughs and peaks in 1σ, 2σ, and 3σ words.](chart)

(16) **TROUGH**

Penalise any two H tones separated by any number of consecutive L tones.

(Cahill 2007; a.o.)

2.4.5 *Words preferably have at least one H tone*

(17)

- Level H tone patterns (e.g., HH,HH,HH) are more common than Level L tone patterns (e.g., LL,LL,LL).

![Bar chart showing the percentage of Level L and Level H tones in 1σ, 2σ, and 3σ words.](chart)

(18) **HAVEH**

Penalise any word with no H tone.

2.5 **Constraint summary**

(19)

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Nickname</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>αT</em>:[$βT$]</td>
<td><em>CHANGE</em></td>
<td>Penalise every sequence of adjacent q’s that are tonally non-identical.</td>
</tr>
<tr>
<td>*([αT]:[$βT$])&lt;w&gt;</td>
<td><em>WeakCONTOUR</em></td>
<td>Penalise every adjacent q sequence of non-identical tones within a weak (i.e., non-final) syllable.</td>
</tr>
<tr>
<td><em>[αT]:S:[αT]</em></td>
<td><em>CHANGE@$</em>$</td>
<td>Penalise every adjacent, identical q sequence that is separated by a syllable boundary.</td>
</tr>
<tr>
<td><strong>TROUGH</strong></td>
<td><strong>TROUGH</strong></td>
<td>Penalise any two H tones separated by any number of consecutive L tones.</td>
</tr>
<tr>
<td><strong>HAVEH</strong></td>
<td><strong>HAVEH</strong></td>
<td>Penalise any word with no H tone.</td>
</tr>
</tbody>
</table>

- Caveat: as of now, we don’t have anything to say about the alignment of LH and HL melodies over trisyllabic words (e.g., L.H.H versus L.L.H; H.L.L versus H.H.L), so our model will be underdetermined for this portion of the data (for more discussion, see e.g., Inkelas & Shih 2015).

- Note that no matter the OT analysis, the goal in this paper is to examine and model the variance of part-of-speech-specific tonotactics. (Almost) any constraint set would be fine for this, and the fact that there’s lexically-conditioned differences (see (1)) doesn’t change.
3 ANALYSIS

3.1 Maximum Entropy Harmonic Grammar

  - ranks probabilities (i.e., comparative grammaticality) of outcome candidates in variable data.
  - Output = probability distribution over all possible surface tone pattern combinations of LL, HH, LH, HL syllables (LHL, HLH are found on monosyllables only)

3.2 Cophonologies/Indexed Constraints as Varying Slopes

- Morphologically-conditioned phonology can be modeled via indexed constraints (e.g., Ito & Mester 1999; Alderete 2001; Smith 2001) or as cophonologies (e.g., Anttila 2002; Inkelas & Zoll 2005).
  - Varying slopes = additive weight adjustment for constraints in the Base Grammar, per each lexical class.
    - Such an approach has been hinted at before: e.g., Albright 2008; Coetzee & Pater 2011; Moore-Cantwell & Pater, submitted.

\begin{align}
&w_1C_1 + w_2(C_1 \times \text{NOUN}) + w_3(C_1 \times \text{NEUT}) + w_4(C_1 \times \text{Id}) + \cdots + w_kC_{iN} \\
&\text{Base grammar} = w_1C_1 \\
&\text{Adjusted noun grammar} = w_1C_1 + w_2(C_1 \times \text{NOUN}) \\
&\text{Adjusted neutral grammar} = w_1C_1 + w_3(C_1 \times \text{NEUT}) \\
&\text{Adjusted ideophone grammar} = w_1C_1 + w_4(C_1 \times \text{Id})
\end{align}

- Base Grammar predicts overall tonotactics for the language, and lexical class-specific tonotactics are predicted by the additive combination of weights of Base Grammar constraints and class-specific weights.
- Cophonologies \equiv bundles of Indexed Constraints.
  - Because there is a finite set of lexical classes, varying slopes are formally executed here as interaction terms.\(^3\)
    - for other previous uses of interaction terms in MaxEnt HG, usually as weighted constraint conjunction: see e.g., Hayes et al. 2012; Pater & Moreton 2012; Green & Davis 2014; Shih, to appear.

3.3 What is the base grammar?

- Trained a base grammar on bootstrapped samples (n=2500 / sample) of possible tone melodies in Mende, drawn from the existing distribution.
  - mirrors a Mende speaker knowing word tone patterns but not (yet) part of speech.
  - did not want to \textit{a priori} assume one lexical class as “default.”
  - across base grammar samples, the results are stable; a representative result is reported here.

- A grammar trained without any data for base grammar provides very similar results (not reported here).
- Another baseline: grammar on a totally random tone patterns (n=5000), generated from random combinations of HH, LL, LH, and HL syllables for 1–3 syllable words is also provided here for comparison.

\(^2\) Harmony(x,i) = \sum_{k=1}^{N} w_kC_t(x) = w_k \cdot C_i, where x = candidate for input i, w_k = weight of constraint C_i, C_t(x) = number of violations of C_t that x incurs, and N = vector of constraints (C_{i1} \ldots C_{iN}).

\(^3\) For justification on the equivalency of interaction terms and random slopes in this situation, see e.g., Gelman & Hill 2007.
4 Results

(21) Adjusted MaxEnt weights, in graphical form

\( w_{\text{adj}} = w_{\text{base}} + w_{\text{index}} \)

(22) Adjusted MaxEnt weights, in numbers

<table>
<thead>
<tr>
<th>Base</th>
<th>Adjuncted Grammars</th>
<th>Ideophones</th>
<th>Other</th>
<th>Random</th>
</tr>
</thead>
<tbody>
<tr>
<td>*CHANGE</td>
<td>1.356</td>
<td>1.356</td>
<td>1.356</td>
<td>1.374</td>
</tr>
<tr>
<td>*WeakCONTOUR</td>
<td>1.220</td>
<td>1.220</td>
<td>1.391</td>
<td>1.220</td>
</tr>
<tr>
<td>*TROUGH</td>
<td>0.426</td>
<td>1.612</td>
<td>0.426</td>
<td>0.749</td>
</tr>
<tr>
<td>HAVE H</td>
<td>0.017</td>
<td>0.411</td>
<td>1.361</td>
<td>0.017</td>
</tr>
<tr>
<td>CHANGE@$</td>
<td>0</td>
<td>0.175</td>
<td>0.543</td>
<td>0.099</td>
</tr>
</tbody>
</table>

(23) Constraint weights by lexical class (top→bottom: highest weight→lowest weight)

<table>
<thead>
<tr>
<th>Base</th>
<th>Cophonology Indexed Grammars</th>
</tr>
</thead>
<tbody>
<tr>
<td>*CHANGE</td>
<td>*TROUGH, *WeakCONTOUR, *CHANGE, *CHANGE</td>
</tr>
<tr>
<td>*WeakCONTOUR</td>
<td>*CHANGE, HAVE H, *TROUGH, *WeakCONTOUR</td>
</tr>
<tr>
<td>*TROUGH</td>
<td>*WeakCONTOUR, *CHANGE, *WeakCONTOUR, *TROUGH</td>
</tr>
<tr>
<td>HAVE H</td>
<td>HAVE H, CHANGE@$</td>
</tr>
<tr>
<td>CHANGE@$</td>
<td>CHANGE@$</td>
</tr>
</tbody>
</table>

4.1 Results and observations

4.1.1 Sanity check

- A MaxEnt grammar on completely random data yields constraint weights pretty close to 0.

4.1.2 Base grammar

- Reveals importance of general contour tone avoidance and R-edge contour tone alignment.
  - *CHANGE = 1.356
  - *WeakCONTOUR = 1.220
  - cf. “Random” model results, where weights are much lower, nearly at 0.
- These two constraints remain highly weighted across all lexical classes.
  - weight of *WeakCONTOUR stays stable across the lexicon, suggesting that it’s a very general principle.
- Reflects universal dispreferences for (nonfinal) contour tones (e.g., Gordon 2001; Zhang 2004).
4.1.3 Syllable edge – Tone change alignment

- Only nouns and neutrals show an effect of syllable edge-tone transition alignment. → see adjusted weights for \( \text{CHANGE}@\$ \):
  - \( \text{CHANGE}@\$ \times \text{NOUN} = 0.175 \), \( \text{CHANGE}@\$ \times \text{NEUT} = 0.543 \)
  - \( \text{versus} \) \( \text{CHANGE}@\$ \times \text{ID} = 0 \)

- Shows that ideophones often involve much simpler surface tone patterns than the other lexical classes.
  - e.g., \( \text{vòvòlò} \) ‘creaking’
  - In addition, ideophones significantly increase the weight of \( *\text{CHANGE} \)

\[
\begin{array}{|c|c|c|c|c|}
\hline
\sigma \cdot \sigma \cdot \sigma, \text{ID} & \text{freq} & \text{*CHANGE}@\$ \times \text{ID} & \text{CHANGE}@\$ \times \text{ID} & \mathcal{H} \\
\hline
\text{a. LL.HH.LL} & 2 & W2 & 2.537 & 5.073 \\
\hline
\text{b. LL.LL.LL} & 76 & 1 & 0 & 0 \\
\hline
\end{array}
\]

4.1.4 HAVE H: a verb thing

- Neutrals in particular (but also nouns to a certain extent) show a much greater affinity for a requisite H tone than ideophones.
  - = level L surface patterns much more tolerated for Ideophones > Nouns > Neutrals.

\[
\begin{array}{|c|c|c|c|c|}
\hline
\sigma \cdot \sigma \cdot \sigma, \text{NEUT} & \text{freq} & \text{HAVEH}\times\text{NEUT} & \mathcal{H} \\
\hline
\text{a. LL.LL.LL} & 5 & 1 & 1.36 \\
\hline
\text{b. LL.LL.LL} & 25 & 1 & 0.41 \\
\hline
\text{c. LL.LL.LL} & 76 & 1 & 0.02 \\
\hline
\end{array}
\]

4.1.5 *TROUGH: not a verb thing

- Neutrals also differ from Nouns and Ideophones by showing greater preference for tone transitions that align with syllable boundaries, even if these result in a HLH trough.
  - e.g., \( \text{hùvùndí} \) ‘be mouldy, mildewed’
  - Much lower adjusted weight for \( *\text{TROUGH} \) in Neutrals than other lexical classes:
    - \( *\text{TROUGH} \times \text{NEUT} = 0.426 \), \( *\text{TROUGH} \times \text{NOUN} = 1.612 \), \( *\text{TROUGH} \times \text{ID} = 1.409 \)

\[
\begin{array}{|c|c|c|c|c|}
\hline
\sigma \cdot \sigma \cdot \sigma, \text{NEUT} & \text{freq} & \text{*TROUGH}\times\text{NEUT} & \text{CHANGE}@\$ & \mathcal{H} \\
\hline
\text{a. i. HH.LL.HH} & 78 & 1 & 0.426 & 0.43 \\
\text{ii. HH.HH.HH} & 48 & 2 & 0.543 & 1.09 \\
\hline
\text{b. i. HH.LL.HH} & 21 & 1 & 1.612 & 1.61 \\
\text{ii. HH.HH.HH} & 101 & 2 & 0.175 & 0.35 \\
\hline
\text{c. i. HH.LL.HH} & 2 & 1 & 1.409 & 1.41 \\
\text{ii. HH.HH.HH} & 79 & 2 & 0.00 & 0.00 \\
\hline
\end{array}
\]
4.1.6 Correlation of surface tone pattern and lexical class

- How much utility do surface tone patterns have for predicting the lexical class of a word?
- Given a particular trisyllabic tone pattern, which lexical class is it most likely a member of?
  - Predicted results are largely congruent with observations, for level and more complex melodies:

<table>
<thead>
<tr>
<th>Surface tone</th>
<th>Observed class</th>
<th>Predicted class</th>
<th>Correct prediction?</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH.HH.HH</td>
<td>Id</td>
<td>Id</td>
<td>✓</td>
</tr>
<tr>
<td>LL.LL.LL</td>
<td>Id</td>
<td>Id</td>
<td>✓</td>
</tr>
<tr>
<td>HH.LL.HH</td>
<td>Neut</td>
<td>Neut</td>
<td>✓</td>
</tr>
<tr>
<td>LL.HH.LL</td>
<td>Noun</td>
<td>Neut</td>
<td>*</td>
</tr>
</tbody>
</table>

- Misprediction of LL.HH.LL due to the fact that our system cannot yet privilege H’s from L’s (and hence no special privilege of multiple H’s or L’s).

4.2 Importance of lexical conditioning

- Are the cophonology/indexed grammars contributing significantly to improving our base grammar?
- Tested here using Akaike Information Criterion (AICc) model comparison.\(^4\)
  - How much information is lost when cophonology/indexed constraints are removed?

(28) \(\Delta\text{AIC}_c\) from full model for each cophonology removed
  - how much information is lost for each cophonology in turn removed.\(^5\)

- AIC\(_c\) comparison results show that lexical class-specific cophonologies/indexed constraints produce a better fit for the data.
  - Exception that is expected: the “Other” part of speech class, which is heterogeneous as is.
- Certain lexical classes provide more information on top of the baseline, suggesting ‘distance’ from the full model.
  - Neutral-specific cophonology contributes a lot of additional information to the grammar.
  - Interestingly, ideophones are not the most extreme lexical class.
- For future work: comparing individual indexed constraints versus entire cophonologies of indexed constraints.

\(^4\) Second-order AIC\(_c\) is used here, because it adjusts more strictly for differences in the number of constraints between comparison grammars. See e.g., Burnham & Anderson 2002 for justification of AIC\(_c\)-based model comparison. For use in comparing phonological grammars, see e.g., Shih, to appear (cf. Wilson & Obdeyn 2009).

\(^5\) \(\Delta\text{AIC}_c \geq 10\) is considered large (equivalent to 150:1 that the second best model has essentially no support of being as good as the best model).
5 IMPLICATIONS & CONCLUSION

Lexically-conditioned phonology

- Part-of-speech phonological differences go beyond noun-adjective-verb distinctions (as observed by e.g., Smith 2011).
  - more closely resemble the complexity of morphophonological alternations and variation.
  - Lexically-conditioned phonology is not just a matter of differential faithfulness (e.g., FAITHnoun » FAITHverb; Smith 2001, 2011).
    - Though there is undoubtedly a role for faithfulness, we haven’t yet incorporated it into the current system.
  - Overall, indexation of markedness constraints per lexical class gains better fit for the data.
  - There are hints of markedness reversals of the kind that ‘Grammar Dependence’ (Alderete 2001) predicts impossible (cf. Pater 2009):
    - E.g., Across nearly all of the grammars (base and lexical class-specific) in Mende, *TROUGH is ranked fairly highly w/r/t the other constraints.
    - In Neutrals, however, *TROUGH is weighted at the bottom.
  - Therefore, a structure (e.g., HLH) that might otherwise be highly marked in the rest of the language is quite good and (comparatively) unmarked for Neutrals.

Quantifying morphological conditioning

- Our approach can quantify how much lexical class-specific phonotactics can differ from the rest of the lexicon.
  - E.g., how different can ideophone phonology be? → long standing issue for e.g., African languages (see Rose 2015 for recent summary).
  - Results show that ideophones operate within fairly conservative parameters of the overall Mende tonotactics grammar—cf., neutrals.
- Because we a priori restrict standard HG/OT grammars to positive weights (i.e., to only penalise rather than reward structures), we’re not really examining the full potential space of variation between cophonologies yet.
- In the future, this ‘varying slopes’ approach could extend to other types of morphology (e.g., affixation; dominant tone melodies): e.g., what are the tone patterns that are grammaticalised in a language as productive morphemes?

For the future

- What is the utility of these phonological differences between groups?
  - There’s evidence from other languages that speakers are capable of learning these lexical statistics (e.g., Coetzee 2014),
  - and that such phonological differences help in e.g., acquisition, processing, information load (e.g., Monaghan et al. 2010).

Acknowledgements

To save trees, references are available online.
http://cogsci.ucmerced.edu/shih/ShihInkelas_LSA2016handout.pdf
6 References


MOORE-CANTWELL, CLAIRE.; and JOE PATER. submitted. Gradient Exceptionality in Maximum Entropy Grammar with Lexically Specific Constraints.
PATER, JOE.; and ELLIOT MORETON. 2012. Structurally biased phonology: Complexity in learning and typology. The English and Foreign Languages Journal 3.1–44.
WILSON, COLIN.; and MARIEKE ODBEYN. 2009. Simplifying subsidiary theory: statistical evidence from Arabic, Muna, Shona, and Wargamay.