The learnability of segmental and suprasegmental harmony    Regine Lai

Jardine (2016) argues that tonal phonology is computationally more complex than segmental phonology based on the typological asymmetry observed in the unbounded circumambient patterns in the tonal and the segmental domains (common in tonal domain, but rare in segmental domain). Previous work have suggested that segmental processes are at most weakly deterministic (Chandlee et al., 2012; suppressed, 2013; Chandlee, 2014; Payne, 2014), and formally speaking, the unbounded circumambient pattern is computationally more complex than the weakly deterministic class because it has to keep track of the information on both sides of word with an unbounded length. But as pointed out by Jardine (2016), such patterns are common in the tonal domain, and this suggests that tonal processes are more complex than segmental ones. The asymmetry can be explained if tonal processes are learned through a mechanism that is less restrictive than that of a segmental pattern learner. From a psycholinguistic point of view, the differences of the computational complexities can be reflected in their learnability in experimental settings. Similar studies which focused on the differences among different segmental patterns with different levels of computational complexities have been carried out (Lai, 2015). This study aims to investigate whether humans process tonal patterns differently than segmental patterns. If so, we should be able to detect the difference in the learnability of the same phonological process, namely, unbounded circumambient process, when instantiated at tonal and when instantiated at segmental level.

**Methodology:** The artificial language learning paradigm was used to test and compare the learnability of the following processes in the tonal domain and the vowel domain.

<table>
<thead>
<tr>
<th>Types</th>
<th>Processes</th>
<th>Formal characteristics</th>
<th>Typology</th>
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<tbody>
<tr>
<td>Unbounded circumambient pattern</td>
<td>Plateauing (Plateau)</td>
<td>Beyond the weakly deterministic class</td>
<td>Only attested in tonal but not segmental processes</td>
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<tr>
<td>Progressive harmony</td>
<td>Left-to-Right (LR)</td>
<td>Within the weakly deterministic class</td>
<td>Attested in both tonal and segmental processes</td>
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</table>

The participants were trained before they were tested. During the training phase, the participants listened to a list of words that conform to LR, Plateau, or they received no training (Control). After the training, a two-alternative-force-choice task was given, during which, participants had to judge which word within a test pair was more likely to belong to the language they heard during the training. The total duration was roughly 20 minutes. There were two domains for each condition (tonal and vowel). 132 participants, aged 18-35, participated in total and they are all native speakers of Cantonese speakers. Tonal language speakers are better suited for this study than any non-tonal language speakers as their language requires them to be sensitive to both tones and vowels. The trigger is H tone for the tonal processes and high vowel /u/ for the vowel processes. (1) and (2) are both examples that conform to Tonal Plateau process.

(1) /fu\text{33}l\text{55} k\text{o33}lu\text{55}/ \rightarrow [fu\text{33}l\text{55}k\text{o33}lu\text{55}]  
(2) /k\text{o55}fu\text{33} ku\text{33}l\text{55}/ \rightarrow [k\text{o55}fu\text{33} ku\text{33}l\text{55}]

As shown in (1) and (2), the tone-bearing units between the first and final high level tone are harmonized to H tone in the surface forms, and the segments remain unchanged. (3) and (4) are examples that conform to the Vowel Plateau process.

(3) /fu\text{33}l\text{55} k\text{o33}lu\text{55}/ \rightarrow [fu\text{33}l\text{55}ku\text{33}lu\text{55}]  
(4) /k\text{o55}fu\text{33} ku\text{33}l\text{55}/ \rightarrow [k\text{o55}fu\text{33} ku\text{33}l\text{55}]

(1) and (2) are both examples that conform to Tonal Plateau process.
Only the vowels between the trigger /u/ are harmonized, and the tones remain unchanged. We predicted that if the tonal learning mechanism is more complex than the segmental one, the learnability of the Tonal Plateau process should be higher than that of the Vowel Plateau.

The LR process only triggers harmony from the leftmost high tone/vowel and spreads to the right. Since it is computationally less complex than Plateau and it is attested in both tonal and segmental domain, we predicted that LR should be 1. more learnable than Plateau, and 2. Learnable in both V and T domains. The control condition did not contain any training. The participants were only given the test items to judge which word within the pair they liked better in order to ensure they had no inherent preferences and to establish baseline.

**Results:** The accuracy rates and the reaction time was collected by the E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). The percentage of choosing any particular choice within the pair will be compared to the control data. The data was analyzed using the *linear mixed effect model*. The model was fitted in R (v.3.4.1) (R Development Core Team 2017), using `glmer()` and `lmer()` from the `lme4` package (Bates, Maechler, and Bolker 2011) for mixed-effects models. The results show that the accuracy rates of both LR and Plateau are significantly higher than the Control condition ($p=1.56e-10$ and $p=0.0004285$). We further analyzed the accuracies of the LR and Plateau conditions and found that the difference in accuracies between the vowel and tonal domain in the LR condition is significant ($p=0.02511$), with tonal domain (73.6%) being higher than the vowel domain (58.7%). However, the differences between the vowel and the tonal domains are not significant in the Plateau condition ($p=.442$).

The reaction time results align with the accuracy rates results. The tonal domain’s RT is significantly faster than the vowel domain’s in the LR condition ($p=0.0441$), but not in the Plateau condition.

**Conclusion:** The participants were able to internalize both harmony patterns (LR and Plateau), but the performance of the vowel group is better than the tonal group’s. This is only evident in the LR but not in the Plateau condition. The results are consistent with the hypothesis that the learnability of tonal processes and vowel processes are different. However, this difference is only observable in the computationally less complex pattern, LR, not in Plateau.

**References:**