

Phonological Learning Bias in Tone Retention Patterns

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1. Introduction

Cross-linguistic investigation of tone has led to generalizations about common tonal patterns and to hypotheses about which types of tonal patterns are more common. This study seeks evidence of a learning bias toward tonal patterns that are more commonly observed across languages. An artificial grammar learning experiment was carried out to test for differences in learning common vs. uncommon tonal patterns in an attempt to shed light on the relationship between typological asymmetries and language acquisition.

The phonological pattern examined in the present study deals with both segmental and autosegmental features. The theory of autosegmental phonology proposed by Goldsmith (1976) separates these two features into independent representational tiers, and the association between the two levels is not necessarily a one-to-one relationship. For instance, one tone can be associated with multiple vowels, and multiple tones can also be associated with one vowel. When tones are associated with vowels, the vowel and the tone sometimes behave as independent units, as evidenced by cases in which a vowel is deleted but its tone surfaces on a different vowel. Below are two ways in which the tone of a deleted vowel may be realized: either by forming a contour tone with the original tone of some other vowel, or by displacing the tone of some other vowel.

The first strategy is illustrated in example (1) from Margi, a Chadic language spoken in Northern Nigeria. Margi has two lexical tones, a high tone (H), and a low tone (L).

- (1) Margi tonal pattern (Hoffman 1963)¹
- | | | | | |
|----------|---|-------|---|--------------|
| cédè | + | ári | → | cédě̀ri |
| ‘monkey’ | | ‘the’ | | ‘the monkey’ |

As shown in example (1), vowel hiatus across words is prohibited at word boundaries and is resolved by vowel deletion. In this case, the initial vowel of the definite article *ári* is deleted. The surviving vowel is realized with a contour tone which combines the quality of the deleted and the surviving vowel tones. In autosegmental terms, the tone that was associated with the deleted vowel re-associates with the retained vowel, and the two tones combine to form a rising contour tone, as illustrated in (2).

- (2) Contour tone formation in Margi
- | | | | | | | | |
|------|---|-----|---|---------|---|---|---|
| H | L | H | L | H | L | H | L |
| | | | | | ∨ | | |
| cédè | + | ári | → | cédě̀ri | | | |

However, formation of a contour tone is not the only response to deletion of a vowel. For instance, In Ogoja Yala, a West Benue-Congo language of Nigeria with a three-level tone system: High, Low, and Mid tone (M), when one of the two adjacent vowels at a word boundary undergoes deletion, one of the two tones also undergoes deletion.

* For questions, contact Sophia Kao at sophia.kao@stonybrook.edu. This study was supported by the Graduate Fellowships & Faculty Research Program of Stony Brook University. Many thanks to Ellen Broselow, Michael Becker, Jose Elias-Ulloa, and the audience at WCCFL for their comments and suggestions.

¹ High tones are indicated with an acute mark above the vowel (´), low tones with a grave mark (`), and mid tones with a bar over the vowel (¯).

(3) Ogoja Yala tonal dominance hierarchy (Bunkowske 1972)

	<u>Verb</u>	<u>Noun</u>	<u>VP</u>	<u>Gloss</u>	<u>Tonal process</u>
a.	má	òchí	móchí	‘see tree’	H#L → H
b.	dè	áchí	dáchí	‘give grass’	L#H → H
c.	wā	áchí	wáchí	‘tie grass’	M#H → H
d.	bī	òchí	bōchí	‘carry stick’	M#L → M

The tone that surfaces is not necessarily that of the surviving vowel. As examples in (3a)-(3c) show, High tone is always retained, regardless of whether it was originally associated with the surviving or with the deleted vowel. In Maddieson’s (1972) terminologies, High tone is said to have dominance over Mid and Low tones in this language. (3d) further shows that Mid tone is dominant over Low tone. Thus, the dominance tonal hierarchy in Ogoja Yala is H » M » L.

In contrast, Ogori, a Benue–Congo language spoken in Nigeria that also has a three-level tonal system (H, M, L), displays a different dominance hierarchy.

(4) Ogori tonal dominance hierarchy (Chumbow 1982)

	<u>Noun</u>	<u>Adjective</u>	<u>NP</u>	<u>Gloss</u>	<u>Tonal process</u>
a.	òtéélé	òkèka	òtéélókèka	‘big pot’	H#L → H
b.	ìgilà	óbòrò	ìgilóbòrò	‘good yam’	L#H → H
c.	ṣdṣ	óbòrò	ṣdóbòrò	‘good rat’	M#H → H
d.	ṣdṣ	ònébé	ṣdònébé	‘that rat’	M#L → L

Similar to Ogoja Yala, High tone is always retained in Ogori as shown in examples (4a)-(4c). Therefore, High tone has dominance over Mid and Low tones in this language. However, (4d) shows that Low tone is dominant over Mid tones, yielding the dominance tonal hierarchy as H » L » M.

The exact same pattern can also be observed in Yoruba, a Volta–Niger language spoken in Nigeria with three level tones (H, M, L), and the dominance hierarchy of H » L » M as shown in (5).

(5) Yoruba tonal dominance hierarchy (Maddieson 1972)

	<u>Verb</u>	<u>Noun</u>	<u>VP</u>	<u>Gloss</u>	<u>Tonal process</u>
a.	fě	èbà	fěbà	‘like cassava’	H#L → H
b.	fě	ēyīn	fěyīn	‘like eggs’	H#M → H
c.	jē	ògèdè	jògèdè	‘eat plantain’	M#L → L

In all the cases, High tone is always the surviving tone. The dominance hierarchies only vary in Mid vs. Low tones across languages. This suggests that High tone is the preferred tone universally in the case of tone retention patterns. Maddieson (1972) argues that the tone at the bottom of the tonal dominance hierarchy is the unmarked tone in the language. This means in Ogoja Yala, Low tone is the least marked tone, whereas in Ogori and Yoruba, Mid tone is the least marked. Cross-linguistically, High tone is more marked than Low tone (Yip 2002), and according to de Lacy (2002, p.196), “marked elements are subject to greater preservation than less marked ones”, which may explain the preference to retain the High tone in Ogoja Yala, Ogori, and Yoruba.

With this tonal markedness in mind, it is then interesting to test whether there is a learning bias on the preference for tone retention using artificial language learning experiments, where participants are presented with two patterns: a ‘natural’ pattern that is commonly attested cross-linguistically, and an ‘unnatural’ pattern that is rare or unattested in real languages. Evidence from recent research on the learning of phonological processes has suggested that natural phonological patterns are more easily learned than unnatural patterns (Wilson 2003, 2006, Pater & Tessier 2005). The present study examines the learnability of tone retention pattern with the objective to see whether speakers have a preference for more typologically natural patterns, even when their language contains neither the natural nor the unnatural pattern. The methodology and results of the experiment are provided in Sections 2-3, with discussion and conclusion in Sections 4-5.

2. Methods

An artificial grammar was designed to examine the learnability of two tonal patterns: a natural pattern that follows the Ogoja Yala, Ogori, and Yoruba tone rules, and an unnatural pattern that seems to be untested across languages.

(6) Natural and unnatural patterns

- a. Natural pattern: H#L → H and L#H → H
- b. Unnatural pattern: H#L → L and L#H → L

Mid tone was not considered in this experiment because its tone value is hard to distinguish in isolation. The design of the experiment follows Wilson's (2006) artificial grammar learning paradigm that it tests the learnability of tone patterns and also learners' ability to generalize the learned knowledge to novel forms. Participants of the experiment are expected to learn either the natural or the unnatural pattern. The prediction is that participants who are exposed to stimuli with a natural pattern will have better performance in learning the tone pattern and generalizing the learned pattern to novel words.

2.1. Participants

92 speakers of English and 52 speakers of Mandarin Chinese were recruited through Stony Brook University. Mandarin Chinese speakers were chosen because Mandarin Chinese is a tone language. However, the phonological pattern of tone deletion is not present in the language, so it is interesting to test the performance of Mandarin Chinese speakers and see whether there is a bias in learning and generalizing the tonal patterns onto novel forms. In addition to Mandarin Chinese speakers, English speakers also participated in the experiment for comparison in case there are possible linguistic factors in the native language that is affecting the learning of tonal patterns.

2.2. Stimuli

Nonce words were created with the syllable structure of CV and VCV. All segments were made up using five vowels /i, e, a, o, u/ and four consonants /m, n, l, w/. Only sonorant consonants were selected because the voicing of obstruent consonants may have effects on the pitch of the following vowel. Each syllable was assigned either a High or a Low tone. Stimuli with CV structure were used for an ABX discrimination task that tested participants' ability to distinguish sounds with the same segments but different tones (e.g. [ma] with H vs. [ma] with L). Stimuli with VCV structure were designed to create vowel hiatus at word boundary: VCV + VCV → VCVCV. In order to prevent vowel height from affecting its pitch, only mid vowels /e/ and /o/ were used at word boundary.

Each nonce word was associated with a picture of either an animal or a fruit, e.g. [ale] 'penguin' with [L.H] tones or [oni] 'mango' with [L.L] tones. They were combined to form a possessive noun phrase such as [aleni] 'penguin's mango'. The experiment consisted of two conditions: a natural condition in which H is the preferred tone to be retained, and an unnatural condition where L is the preferred tone to be retained. Examples are shown in (7):

(7) Natural vs. unnatural conditions

Condition	Tone Pattern	Animal	Fruit	Possessive NP
Natural	T.H#L.T → T.H.T	[L.H]	[L.L]	[L.H.L]
		[a.le]	[o.ni]	[a.lo.ni]
		'penguin'	'mango'	'penguin's mango'
Unnatural	T.H#L.T → T.L.T	[L.H]	[L.H]	[L.L.H]
		[a.le]	[o.mu]	[a.lo.mu]
		'penguin'	'mandarin'	'penguin's mandarin'

Possessive NPs had two different types: Target NPs and Filler NPs. Target NPs had different tone values at the word boundary to create competition between High and Low tones as seen in (7). Filler NPs were either formed by words with identical tone values at the word boundary, or formed by words that would not trigger vowel deletion as shown in (8). The purpose of Filler NPs was to balance the number of surface tone values on the second syllable of the NPs.

(8) Target and Filler NPs in the Natural Condition

Condition	NP Type	Tonal Patterns
Natural	Target	T.H#L.T → T.H.T
	Filler	T.H#H.T → T.H.T
		T.L#L.T → T.L.T
		T.L#L → T.L.T

Regarding the choice of which vowels to be deleted as the result of vowel hiatus, if the vowel that undergoes deletion is always the first vowel like what occurs in the real languages mentioned above, then it is difficult to tell whether the choice of which tone to retain is determined by the position of the tone or by the value of the tone. For example, if High tone is always associated with the surviving second vowel, then instead of learning the generalization that High tone is preferred to be retained over Low tone, the participants may assume that the tone of the second vowel is retained. To avoid such positional effect, half of the target items had their first vowel deleted and the other half had the second vowel deleted.

All stimuli were produced by a native female speaker of Mandarin Chinese using a Zoom H6 digital recorder in a sound-proof room. All stimuli were produced three times, and the best one was chosen with the average amplitude modified to 65 dB using Praat (Boersma and Weenink 2008).

2.3. Procedure

The experiment was an online task created through Experigen (Becker and Levine 2010). Participants were asked to sit in front of a computer, put on headphones, and adjust the volume to a comfortable level. The experiment consisted of three sessions: a familiarizing session, a training session, and a testing session.

During the familiarizing session, participants were tested on their ability to distinguish High tone from Low tone. They went through 5 trials of ABX paradigm that presented three sound files with either the second or the third sound being identical to the first one. The order of stimuli was randomized by Experigen, and feedback was provided after each trial.

After the familiarizing session, the participants entered the training session. They were told that they were going to learn a new language and would be tested later. The instruction page showed pictures and sounds of an animal and a fruit. Participants were told that by putting the animal and the fruit together, a possessive NP was formed (e.g. the animal's fruit). They were asked to pay attention to the pitch of the middle vowel of the possessive NP, which was the surviving vowel with the surviving tone. Then, they were given 3 practice questions that presented different combinations of animals and fruits, followed by two choices of possessive NPs: one with the same tonal pattern they just learned, and one with a different tonal pattern that is novel to them. They were asked to choose the one that should be pronounced in this new language they were learning, and feedback was given after every choice.

After the practice questions, the training session that consisted of 20 trials began. The order of stimuli was randomized by Experigen, and feedback was provided after each choice to help improving their performance, as shown below in Figure 1.

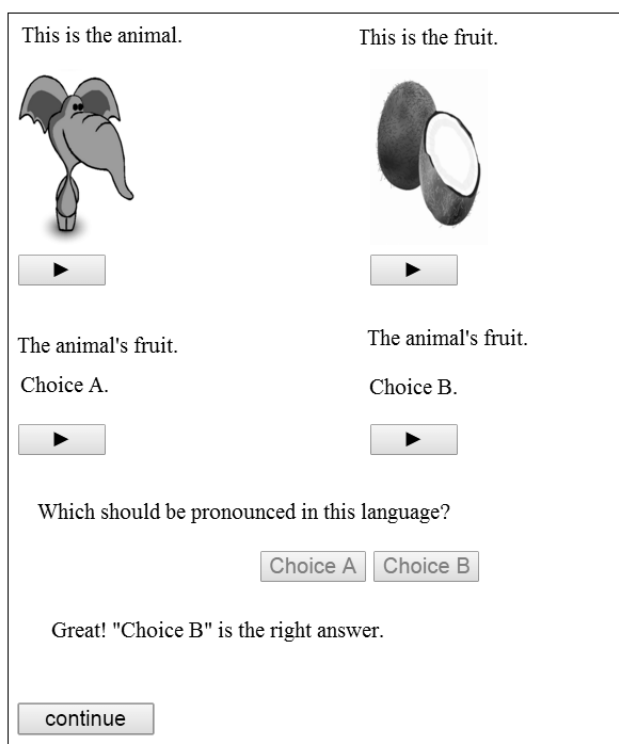


Figure 1. Training session presents the stimuli of the animal and the fruit, followed by two possible possessive NPs that only differ in the tone value of the second syllable.

Following the training session, participants entered the testing session where two types of possessive NPs were formed: Similar NPs and New NPs. Similar NPs consisted of familiar animal and fruits names that were shown in the training session, but with different combinations. Thus, the possessive NPs were new to the participants at the segmental level. The tonal patterns of Similar NPs, however, were the same as those in the training session. The purpose of Similar NPs was to test whether the participants had truly learned the tonal pattern rather than just memorizing the items given in the training session. New NPs consisted of new animal and fruit names that created completely new NPs on both segmental and autosegmental levels. As illustrated in (9), participants in both conditions encountered animal words that ended with High tone and fruit words that began with Low tone in the training session. In the testing session, they were given animal words that end with Low tone and fruit words that began with High tone. The purpose of New NPs was to see whether the participants would make a generalization on the tonal pattern they were exposed to during the training session, and apply the knowledge to novel forms.

(9) Tonal patterns in training and testing sessions

	Natural		Unnatural	
Training	T.H#L.T	→ T.H.T	T.H#L.T	→ T.L.T
Testing	T.L#H.T	→ T.?.T	T.L#H.T	→ T.?.T

Similar to the training session, all possessive NPs in the testing session were also presented as a two-alternative-forced-choice task. If the participants truly learned the tonal pattern regarding the preferred tone value after tone deletion, then their choice of the surface tone value on the surviving vowel was expected to be High tone for participants in the natural condition, and Low tone for participants in the unnatural group. All participants listened to 12 Similar and 12 New NPs in the testing session. The order of stimuli was randomized by Experigen, but no feedback was given.

3. Results

The responses of two-alternative-forced-choice tasks were converted to binary data value (0 = incorrect response; 1 = correct response). Figure 2 below compares the average accuracy rates between natural and unnatural conditions. ANOVAs on the accuracy were performed separately with Condition (Natural vs. Unnatural) as an independent variable for both English and Mandarin Chinese groups using the statistical software R and package *lme4* (Bates, Maechler & Bolker 2012).

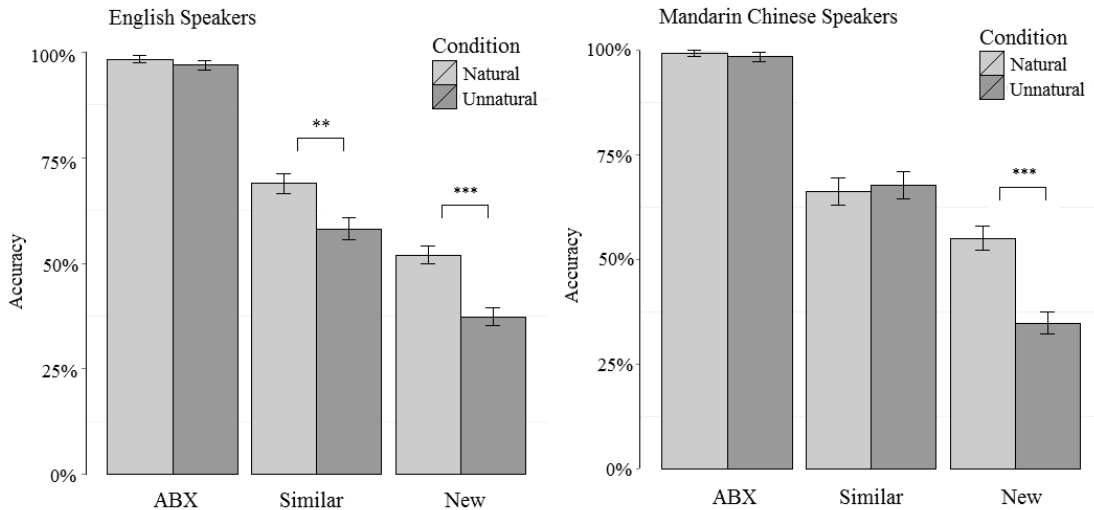


Figure 2. The average accuracy scored by English and Mandarin Chinese speakers

For both English and Mandarin Chinese groups, the average accuracy rates on ABX items are around 100%, indicating that the participants are generally good at distinguishing different tonal values. For English speakers, the average accuracy on Similar NPs is higher in the Natural condition (Natural = 69%, Unnatural = 58%) significantly ($[F(1942, 1) = 12.18, p < 0.001]$). However, no significant difference was found on Similar NPs for Mandarin Chinese speakers (Natural = 66%, Unnatural = 68%). For New NPs, English speakers had a better accuracy in the Natural condition (Natural = 52%, Unnatural = 37%) with a significant difference ($[F(1594, 1) = 27.91, p < 0.001]$). Mandarin Chinese speakers also scored higher in the natural condition on New NPs (Natural = 55%, Unnatural = 35%) significantly ($[F(958, 1) = 34.97, p < 0.001]$).

4. Discussion

The results of English speakers show a learning bias toward the natural tonal pattern, conforming to the prediction. Despite the fact that the tone discrimination task was not a problem for participants in both natural and unnatural conditions, the difference of the accuracy rates on Similar NPs indicates that English-speaking participants had more difficulty learning the unnatural pattern where the retained tone is Low. The accuracy on New NPs further shows that participants in the natural condition were more likely to generalize the learned pattern to novel forms.

A possible source of such learning bias could be the effect of first language influence. In English, lexical stress is distinguished by acoustic cues including duration, intensity, and pitch. Since stressed syllables have higher pitch than unstressed syllables, English-speaking participants might be influenced in their perception of pitch, and thus had a preference for High tones when learning tone patterns.

As for the Mandarin Chinese speakers, the results do not show a significant difference between the two conditions in the accuracy rate on Similar NPs. This indicates that the natural and unnatural tonal patterns were equally learnable for Mandarin Chinese speakers. However, the difference in their accuracy rate on New NPs show that participants who learned the natural pattern were more likely to

generalize the knowledge to novel forms they were not exposed to during the training session. On the contrary, participants who learned the unnatural pattern performed poorly.

Since Mandarin Chinese has both High tone and Low tone in the language², the effect of first language influence on the preference for High tone is much less than English. This explains the good performance in learning tonal patterns regardless of naturalness. However, it does not explain the fact that participants in the natural condition had a better performance in generalizing the learned pattern to novel forms. This may suggest a learning bias toward High tone in tone retention patterns that is less likely due to the acoustic prominence of High tone.

5. Conclusion

Cross-linguistically, some phonological patterns are more commonly observed while others are uncommon or even unattested. The source of these typological asymmetries is controversial. Two possible factors have been argued to give rise to these differences in phonological typology: channel bias and analytic bias (Moreton 2008). Theories that are based on channel bias suggest that the asymmetry between attested and unattested phonological patterns is due to systematic errors in phonetic transmission that result from asymmetries in articulatory difficulties or perceptual salience, factors that serve as precursors for phonologization (Ohala 1993, Blevins 2004). On the other hand, in theories based on analytic bias, the typological difference is driven by cognitive predispositions that facilitate the learning of some phonological patterns over others (Wilson 2003). If this is correct, then there should be a direct connection between the naturalness of a pattern and its learnability.

This study investigates both the learnability of phonological patterns concerning tone, and the ability of extending phonological patterns to novel forms. The results of the Mandarin Chinese speakers support the view of analytic bias that cognitive predispositions may facilitate the learning of tone retention patterns with preference for High over Low tone because the learners were more likely to extend natural tone patterns to novel forms.

For future research, it is interesting to examine the relationship between learnability and learning methodology in terms of explicit vs. implicit learning. It is also important to incorporate Mid tone into the artificial language learning experiments. Furthermore, there are other tonal patterns left for investigation such as the formation of contour tones from level tones. More studies on learning tone patterns will help us understand various asymmetries in the typology of tone patterns, and acquisition of tone as a second language.

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² The first tone in Mandarin Chinese is a high level tone with a pitch value of 55. Although the third tone is a falling-rising contour tone with a pitch value of 214, the rising part is not pronounced when the tone is not pronounced in isolation or at sentence-final position (Chao 1968), and it is often referred as Low tone in literature.

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Proceedings of the 34th West Coast Conference on Formal Linguistics

edited by Aaron Kaplan, Abby Kaplan,
Miranda K. McCarvel, and Edward J. Rubin

Cascadilla Proceedings Project Somerville, MA 2017

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Kao, Sophia. 2017. Phonological Learning Bias in Tone Retention Patterns. In *Proceedings of the 34th West Coast Conference on Formal Linguistics*, ed. Aaron Kaplan et al., 311-318. Somerville, MA: Cascadilla Proceedings Project. www.lingref.com, document #3325.