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Two aspects of productivity in Taiwanese Double Reduplication*

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Abstract

Monosyllabic adjectives can undergo double reduplication in Taiwanese to mark intensification. We argue in this paper that the phonological analysis for the tonal patterns of Taiwanese double reduplication relies on three elements: a floating High tone that prefers to dock onto the left edge of the output, tonal correspondence between the two reduplicants, and the lexical listing of the sandhi tones as part of the non-XP-final allomorphs of existing syllables. We support the analysis with an acoustic experiment and a psycholinguistic "wug"-test experiment in Taiwanese, which showed that (a) the floating High tone appears as early as possible in real doubly reduplicated forms; (b) the tonal allomorphy is not productive in non-existing words; and (c) the floating High docking is productive in non-existing words. The analysis echoes the "allomorph selection" hypothesis of Taiwanese tone sandhi by Tsay and Myers (1996) and the "two-stage" hypothesis of Taiwanese double reduplication by Myers and Tsay (2001).

Keywords: tone sandhi, Taiwanese, reduplication, double reduplication, "wug" test

1. Introduction

As a widely attested phonological phenomenon in Chinese languages, tone sandhi refers to tonal alternations conditioned by adjacent tones or the prosodic or morpho-syntactic position in which the tone occurs (Chen 2000, among others). Taiwanese tone sandhi is typical of Southern Min dialects of Chinese in that it is positionally conditioned and the sandhi patterns are characterized by circular opacity: tones in non-XP-final positions undergo sandhi, and four out of the five tones in the tonal inventory are involved in a circular chain shift, as in (1).[1] The XP-final syllable preserves its tone. This "tone circle" pattern has been shown by earlier works to be generally unproductive when speakers were "wug"-tested (Berko 1958) with novel words (Hsieh 1970, 1975, 1976, Wang 1993, Zhang et al. 2006). This result is in line with other experimental

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[1] In this paper, we are only concerned with unchecked syllables, which are syllables that are either open or closed with a sonorant coda. The five tones given in (1) reflect the tonal inventory of this type of syllables in Taiwanese. Checked syllables — syllables closed with a /ʔ/ or /p, t, k/ — have a reduced tonal inventory (53 and 21) and different tone sandhi behaviors in regular polyllabic words and reduplications. Detailed descriptions of their behaviors can be found in Chung (1996) and Cheng (1997). We do not attempt an analysis of these patterns, but would like to acknowledge that the patterns do not contradict the claims that we make in this paper.

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works (e.g., Sanders 2001, Sumner 2003) that demonstrated the lack of productivity of opaque phonological patterns.

(1) Taiwanese tone sandhi in non-XP-final positions:

51 → 55 → 33 ← 24
↖ ↙
21

Reduplication is a productive morphological process in Taiwanese, and the meaning of reduplication, depending on the part of speech that is being reduplicated, ranges from intensification and tentativeness to repetition and continuity (Wu 1996: p. 27-29). Monosyllabic adjectives can be reduplicated in two different ways in Taiwanese: single reduplication diminishes the meaning of the adjective, while double reduplication intensifies the meaning. The two types of reduplications are exemplified in (2) (from Chung 1996: p.129). Since the tone sandhi occurs in nonfinal positions, we assume that in both types of reduplication, the final syllable is the base and the nonfinal syllables are the reduplicants.

(2) Taiwanese monosyllabic adjective reduplications:

Monosyllabic adjective	Single reduplication 'somewhat adj.'	Double reduplication 'very adj.'	Gloss
pʰoŋ21	pʰoŋ51-pʰoŋ21	pʰoŋ51-pʰoŋ51-pʰoŋ21	'blown-up'
nŋ̩51	nŋ̩55-nŋ̩51	nŋ̩55-nŋ̩55-nŋ̩51	'soft'
sin55	sin33-sin55	sin35-sin33-sin55	'new'
kaw33	kaw21-kaw33	kaw35-kaw21-kaw33	'thick'
tam24	tam33-tam24	tam35-tam33-tam24	'wet'

The tonal pattern of single reduplication follows the general tone sandhi pattern — the initial reduplicated syllable undergoes tone sandhi according to (1). Double reduplication, however, has two different patterns: when the base tone is 21 or 51, the two reduplicants both have the sandhi tone from the pattern in (1); but when the base tone is 55, 33, or 24, the first syllable has a rising tone 35, while the second syllable observes the pattern in (1). These reduplicative tonal patterns are summarized in (3).

(3) Tonal patterns in Taiwanese reduplication:

Monosyllabic adjective	Single reduplication	Double reduplication
21	**51**-21	**51**-**51**-21
51	**55**-51	**55**-**55**-51
55	**33**-55	**35**-**33**-55
33	**21**-33	**35**-**21**-33
24	**33**-24	**35**-**33**-24

The goals of this paper are to first provide a phonological analysis for the tonal patterns of double reduplication in Taiwanese, and then report two experiments that test the predictions of the analysis — an acoustic study of real reduplicative adjectives and a psycholinguistic "wug" test, in which the subjects were asked to reduplicate novel adjectives. To anticipate our analysis and experimental findings, we argue that the derivation of the tonal patterns in double reduplication involves the selection of the appropriate tonal allomorph in non-XP-final positions

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and the docking of a floating High tone, both of which can be captured Optimality-Theoretically — the former by an APPROPRIATE-ALLOMORPH constraint that enforces the appropriate selection of a listed allomorph in a particular context, the latter by the interaction among constraints that govern the occurrence of floating tones and the correspondence between reduplicants. We then support the analysis by experimental results that showed that (a) the floating High tone appears as early as possible in real doubly reduplicated forms; (b) the tonal allomorphy is not productive in non-existing words; and (c) the floating High docking is productive in non-existing words. Theoretically, although our analysis is framed in Optimality Theory, it is nonetheless consistent with the "allomorph selection" hypothesis of Taiwanese tone sandhi by Tsay and Myers (1996) and the "two-stage" hypothesis of Taiwanese double reduplication by Myers and Tsay (2001); the analysis also tentatively supports the existence of correspondence relations between reduplicants proposed by Urbanczyk (2001) and Lin (2004).

2. Phonological Analysis

2.1. Constraints and Constraint Interactions

Assuming that the final syllable represents the base of reduplicated forms, the tonal patterns of Taiwanese double reduplication can be summarized as follows: the tone on the second syllable in a doubly reduplicated form is derivable from the base tone according to the sandhi pattern in (1); the tone on the first syllable can be derived from the same sandhi tone via the insertion of a High tone — the High tone is inserted (vacuously) to the left edge of 51 (base 21) and 55 (base 51), but to the right edge of 33 (base 55 and 24) and 21 (base 33). These observations have been made in various forms in Cheng (1973), Yip (1980), Wu (1996), Myers and Tsay (2001), and Lin (2004). Notice that we have treated the "2" in "21" and the "3" in "33" as identical "Mid" tones here, as acoustic studies have shown that the mid level and low falling tones in Taiwanese start from the same pitch (Lin 1988, Peng 1997). Hence, the insertion of a High tone at the right edge of these tones renders identical 35's.

We propose to account for this tone pattern Optimality-Theoretically as follows.

First, intensification for monosyllabic adjectives is marked by both double reduplication and a floating High tone (Yip 1980, Wu 1996, Myers and Tsay 2001, Lin 2004). The following two constraints govern the general docking of floating tones. The constraint in (4) requires the floating tone to be realized in the output; the ALIGNMENT constraint in (5) requires the floating tone to dock onto the left edge of the word.

(4) REALIZE(Float): A floating tone must be realized in the output.

(5) ALIGN(Float, Left, Word, Left) (abbr. ALIGN-L): The left edge of a floating tone must be aligned with the left edge of a word.

For the floating High in double reduplication, REALIZE(Float) is undominated, as it is never violated by a winning output: the High is realized on the left edge of 51 and 55 and on the right edge of 35. ALIGN-L, however, is violated when the first syllable carries 35. Capitalizing on the observations that the 35 tone is only obtained when the sandhi tone starts with a Mid tone (33, 21) and that the sandhi tone is realized on the second syllable of the doubly reduplicated form, we propose that the ALIGN-L violation is forced by a higher ranked tonal correspondence constraint governing the similarity between the two reduplicants, as defined in (6).

(6) IDENT-RR(Tone, Left) (abbr. ID-RR(T, L)): The left edges of the tones of two reduplicants derived from the same base must be identical.

This constraint demands the identity between the initial tones of the two reduplicants, and when it outranks ALIGN-L, the floating High must dock onto the right edge of first syllable, as illustrated by the mini-tableau in (7).

(7) ID-RR(T, L) » ALIGN-L

RED-RED-55	ID-RR(T, L)	ALIGN-L
☞ 35-33-55		*
53-33-55	*!	

The necessity of RR correspondence here echoes earlier proposals by Urbanczyk (2001) and particularly Lin (2004), who proposed an extended model of correspondence that includes RR correspondence to account for double reduplication in Taiwanese. A general RR correspondence constraint on tone can be stated as in (8).

(8) IDENT-RR(Tone) (abbr. ID-RR(T)): The tones of two reduplicants derived from the same base must be identical.

Finally, our analysis needs to capture how the sandhi tone on the second syllable, which also serves as the base for floating High insertion on the first syllable, is derived. Given that previous research has shown that the "tone circle" is unproductive when tested with novel words (Hsieh 1970, 1975, 1976, Wang 1993, Zhang et al. 2006), we adopt Tsay and Myers (1996)'s position that the sandhi tones on nonfinal syllables are derived through an "allomorph selection" process, and the tonal allomorphs are directly listed in the lexicon, not generated by phonological rules or constraint interactions.[2] To capture allomorph selection, we proposal an APPROPRIATE-ALLOMORPH constraint, as defined in (9), which enforces the appropriate selection of a listed allomorph in a particular context.

(9) APPROPRIATE-ALLOMORPH (abbr. ALLMPH): For an existing syllable, select its surface tonal allomorph as follows:

UR	Surface allomorph	
	XP-final	Non-XP-final
21	21	51
51	51	55
55	55	33
33	33	21
24	24	33

[2] The experimental result in Zhang et al. (2006) in fact shows that the transparent sandhi 24 → 33 has a significantly higher productivity in novel words than the opaque sandhis in the "tone circle." Therefore, the sandhi tone 33 may not have to be listed as an allomorph of 24 in the lexicon. Instead, a highly ranked phonotactic constraint *RISE-NONFINAL may help predict the sandhi tone of 24. We gloss over this complication in the analysis that follows, but it does not affect the validity of our claims.

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This constraint interacts with other constraints in the grammar, in particular, those that govern the docking of the floating High tone, to produce the tonal pattern of double reduplication. The mini-tableau in (10) presents the ranking argument for REALIZE(Float) » ALLMPH, and the mini-tableau in (11) motivates the ranking ALLMPH » ALIGN-L.

(10) REALIZE(Float) » ALLMPH

RED-RED-55	REALIZE(Float)	ALLMPH
☞ 35-33-55		*
33-33-55	*!	

(11) ALLMPH » ALIGN-L

RED-RED-55	ALLMPH	ALIGN-L
☞ 35-33-55	*	*
53-53-55	**!	

We are now in a position to present the full analysis for the tonal patterns of Taiwanese double reduplication. The tableaux in (12) illustrate how the two different tonal behaviors of the initial syllable in double reduplication can be derived. When the base has a sandhi tone that has an initial High, e.g., 21 → 51, as in (12a), the first syllable simply copies this sandhi tone, as it satisfies all the relevant constraints — a High tone is realized in the output, the left edges of the reduplicant tones match, both nonfinal syllables have selected the correct tonal allomorph, the High tone is aligned to the left, and the two reduplicant tones are identical. To have any tone other than 51 either on the first syllable, as in the second and third candidates, or on the second syllable, as in the last two candidates, will violate a subset of these constraints and do in the candidates. When the base has a sandhi tone that does not have an initial High, e.g., 55 → 33, as in (12b), the floating High must dock onto the right edge of the first syllable, as this is the only way to ensure that the High is realized and that the left edges of the reduplicant tones are identical without incurring more APPROPRIATE-ALLOMORPH violations. Docking the High to the left, as in the second candidate, violates IDENT-RR(Tone, Left), and not docking the High at all, as in the third candidate, violates REALIZE(Float). And finally, changing the sandhi tone on the second syllable, as in the last two candidates, will incur one more violation of APPROPRIATE-ALLOMORPH and thus eliminate the candidates from the competition.

(12) a. RED-RED-21 → 51-51-21

	REALIZE(Float)	ID-RR(T, L)	ALLMPH	ALIGN-L	ID-RR(T)
☞ 51-51-21					
55-51-21			*!		*
35-51-21		*!	*	*	*
35-35-21			*!*	*	
21-21-21	*!		**	*	

b. RED-RED-55 → 35-33-55

	REALIZE(Float)	ID-RR(T, L)	ALLMPH	ALIGN-L	ID-RR(T)
☞ 35-33-55			*	*	*
53-33-55		*!	*		*
33-33-55	*!			*	
53-53-55			**!		
35-35-55			**!	*	

2.2. Empirical Predictions of the Phonological Analysis

The phonological analysis laid out above makes a number of empirical predictions regarding the tonal realizations of double reduplication in both real words and novel words of Taiwanese.

For real double reduplications, if we assume that the entire duration of the first syllable is available for the docking of the floating High; in other words, ALIGN-L can be evaluated gradiently according to the duration separating the left edges of the tone and the word, then for a sandhi tone that starts with a non-High tone, the analysis in fact does not necessarily predict right-edge docking of the floating High — as long as the initial pitch is saliently preserved, the floating High should dock as far left as possible. This is illustrated in the tableau in (13): the candidate with left-edge docking of the floating High violates the highly ranked ID-RR(T, L) and loses; the candidate with right-edge docking and the candidate that docks the High in the middle of the syllable both satisfy ID-RR(T, L), but the latter incurs fewer violations of ALIGN-L due to the shorter distance between the left edges of the floating tone and the word and hence wins the competition. Therefore, our prediction is that the tone on the first syllable for base 55, 33, and 24 (sandhi 33, 21, and 33, respectively) should be a complex contour tone with an approximate value of 353.

(13) Gradient evaluation of ALIGN-L predicts earlier docking of floating High:

<table>
<tr><th>RED-RED-55</th><th>ID-RR(T, L)</th><th>ALIGN-L</th></tr>
<tr><td>33333-33-55
|
5</td><td>*!</td><td></td></tr>
<tr><td>33333-33-55
|
5</td><td></td><td>**!</td></tr>
<tr><td>☞ 33333-33-55
|
5</td><td></td><td>*</td></tr>
</table>

For novel words, our analysis predicts that the derivation of sandhi tones, especially those in the "tone circle," should be unproductive in both single and double reduplications. This is due to the fact that novel words do not have listed tonal allomorphs. This forces the speaker to choose a tone from the tonal inventory to use in the reduplicants, and the APPROPRIATE-ALLOMORPH constraint is subsequently evaluated according to this choice: it is satisfied if the choice is used by a candidate and violated if the choice is not used. For factors that influence this choice, such as phonetic duration and the frequency of occurrence of the tones, see Zhang et al. (2006, 2007).

The docking of the floating High on novel words, however, is predicted to be productive by our analysis, as the behavior of High tone docking is governed by the interaction of constraints in an OT grammar, which is operable in both real words and novel words. The productivity is particularly manifested in the speakers' ability to dock the High tone according to the selected sandhi tone, *even when the sandhi tone is selected incorrectly*. For instance, for the base tone 21, its correct sandhi tone should be 51, and the correct tonal pattern for double reduplication should be 51-51-21. But if the speaker (incorrectly) chose 21 as the nonfinal allomorph and hence pronounced 21 on the second syllable of double reduplication, our analysis predicts that the floating High would dock onto the right edge of the first syllable, as the tableau in (14) illustrates: although the winning candidate violates APPROPRIATE-ALLOMORPH (the first syllable does not have the selected allomorph 21), ALIGN(Float, L, Word, L) (the floating High is not at the left edge of the word), and IDENT-RR(Tone) (the two reduplicants are not tonally identical), docking the floating High at the left edge or not docking it at all to avoid the violations of these constraints would cause the violations of higher ranked REALIZE(Float) and IDENT-RR(Tone, Left).[3] The last two candidates in (14) illustrate that the grammar predicts that the second syllable *will* be 21 if the speaker chooses 21 as the nonfinal allomorph of the base, as otherwise, the candidates will have extraneous violations of the APPROPRIATE-ALLOMORPH constraint.

(14) RED-RED-21 → 35-21-21 (nonfinal allomorph of 21 = 21)

	REALIZE(Float)	ID-RR(T, L)	ALLMPH	ALIGN-L	ID-RR(T)
☞ 35-21-21			*	*	*
51-21-21		*!	*		*
21-21-21	*!			*	
51-51-21			**!		
35-33-21			**!	*	

With these predictions in place, the next section discusses an acoustic experiment on real reduplications and a psycholinguistic wug-test experiment on novel reduplications that tested these predictions.

3. Experimental Tests of the Predictions

3.1. Acoustic Experiment

The goals of our acoustic experiments were to test the prediction on the docking site of the floating High as well as to confirm the general patterns of double reduplication reported in the literature. In the experiment, real monosyllabic adjectives were presented on a computer screen in Chinese characters using SuperLab (Cedrus), and eight native speakers of Taiwanese recruited in Chiayi, Taiwan (four male, four female) were asked to produce first the monosyllabic form, and then the single and double reduplicated forms. Their production was recorded by a Marantz solid state recorder PMD 671 at 16 bits and a 44.1KHz sampling rate.

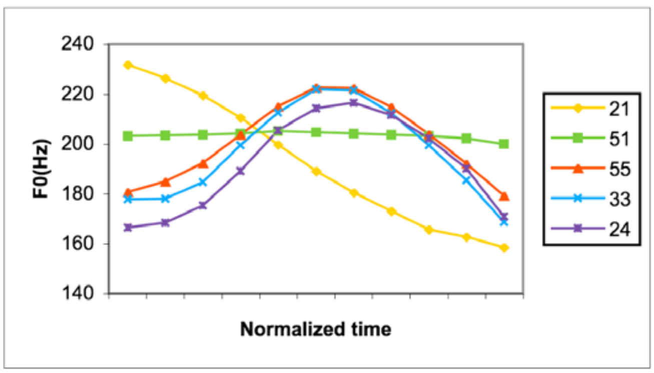
[3] We have streamlined this discussion by only considering the left and right edges as the available docking sites for the floating High. Taking into account the discussion for real words above, our analysis predicts earlier docking of the floating High for novel words as well. Therefore, the true winner for the tableau in (14) is again a complex contour tone similar to 353.

For each of the five tones, two words were recorded, each with three repetitions, and all three repetitions were included in the data analysis. The full list of stimuli is given in Appendix A.

The F0 contours of the rhyme in the first syllable of the subjects' double reduplication responses were extracted using Praat, and an F0 measurement was taken every 10% of the duration of the rhyme, giving eleven F0 points for each rhyme. The F0 data for each tone were then derived by averaging the measurements across speakers, words, and repetitions at each point for the tone.

The result for the F0 contour of the first syllable is given in (15). As expected, for base tones 21 and 51, the first syllable in double reduplication has 51 and 55, respectively. This is because the nonfinal allomorphs of 21 and 51 are 51 and 55, respectively, both of which already have a High tone. And as predicted by our analysis, for base tones 55, 33, and 24, the first syllable in double reduplication assumes a complex contour tone 353, not a high rising tone 35 as reported in the literature. Again, this is due to desire of the floating High to dock as early as possible in the first syllable provided that the initial tone of the nonfinal allomorph — in this case, Mid — is not disturbed.

(15) F0 contour of the first syllable in double reduplication (legend = base tone):



Therefore, the acoustic experiment on the tonal patterns of real double reduplication in Taiwanese supports the predictions of our analysis as well as the general patterns reported in the literature. There are two tonal patterns of double reduplication: on the first syllable of double reduplication, base tones 21 and 51 render tones identical to their sandhi tones — 51 and 55; base tones 55, 33, and 24, however, render complex contour tones with an approximate value of 353, presumably as the result of the phonological grammar requiring the floating High to dock as far left as possible in the word without disrupting the identity between the left edges of the reduplicant tones.

3.2. Psycholinguistic Wug-Test

Our second experiment tests the predictions about the productivity of the tonal processes in double reduplication. In the experiment, eight native Taiwanese subjects recruited in Chiayi, Taiwan (three male, five female; different from subjects used in the acoustic experiment) heard monosyllables through a headphone, and were asked to produce the monosyllable, the single reduplication, and the double reduplication in turn. The experiment was presented in SuperLab (Cedrus), and the subjects' production was recorded by a Marantz solid state recorder PMD 671 at 16 bits and a 44.1KHz sampling rate. We used three different types of words. The first type is real words with actual occurring reduplications (AO). The majority of these words are adjectives that also have double reduplications, but a few of them are verbs and nouns that do not have double reduplications. The second type is real words with *no* actual occurring reduplications, either single or double (*AO). And the third type is novel words, or "wug" words, that conform to Taiwanese phonotactics, which we refer to as accidental gaps, or AG. For a syllable to count as an accidental gap, the segmentals and the tone must both be valid for Taiwanese, but their combination happens to be missing from the Taiwanese syllabary. For each word type and tone combination, we used eight different words, which made 120 test words. The full word list is given in Appendix B.

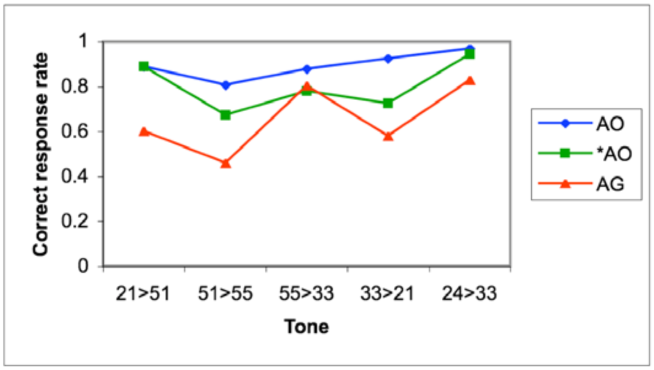
Due to the structure-preserving nature of Taiwanese tone sandhi (Tsay et al. 1999, Myers and Tsay 2001), the tonal responses to all the experimental stimuli were transcribed in Chao letters by two authors of the paper — one native Taiwanese speaker (Lai) and one native Mandarin speaker (Zhang). For the first syllable, visual inspection of the pitch tracks in Praat indicated that correct responses to base tones 55, 33, and 24 all had a complex contour tone with an approximate value of 353. We simplified our transcription of the complex contour to 35, with the understanding that a rising tone in first syllable position necessarily entails a convex tone. Our agreement based on first-time auditory impression was about 95%. With help from pitch tracks in Praat, we agreed on virtually all the tokens. For the handful of tokens on which we did not reach an agreement, we took the native Taiwanese speaker Lai's judgment.

In subsequent statistical analyses, we excluded the token if it fell under one of the following categories: (a) the subject mispronounced the tone of the monosyllable; (b) the subject did not provide a complete set of monosyllable/single reduplication/double reduplication. Also, due to our error in setting up the SuperLab experiment, we connected the wrong audio file to one word each for the tones 21, 24, and 33 for the *AO group. The subjects' responses to these stimuli were also not analyzed.

The hypotheses for the experiment are as follows. First, for AG words, the subjects' correct response rates for sandhi tones, which occur initially in single reduplication and medially in double reduplication, should be low, due to the fact that AG words have no listed nonfinal allomorphs with the appropriate tones. Second, assuming that the second syllable in the subjects' trisyllabic responses had what they considered to be the correct sandhi tone, their first syllable response *based on this second syllable* should be generally correct, even in wug words. For example, for a base tone 21, if the subjects produced the correct sandhi tone 51 in the second syllable, then we would expect them to produce also 51 in the first syllable, which is the correct tone; but if they produced the wrong sandhi tone 21 in the second syllable, we would still expect them to be able to calculate the first tone, only that it would be based on the wrong sandhi tone 21, so the first tone would be 35, as the floating High would now dock to the right to preserve the initial Mid. We would not expect the subjects to provide the correct tone 51 for the first syllable if they had produced the wrong sandhi tone 21 in the second syllable.

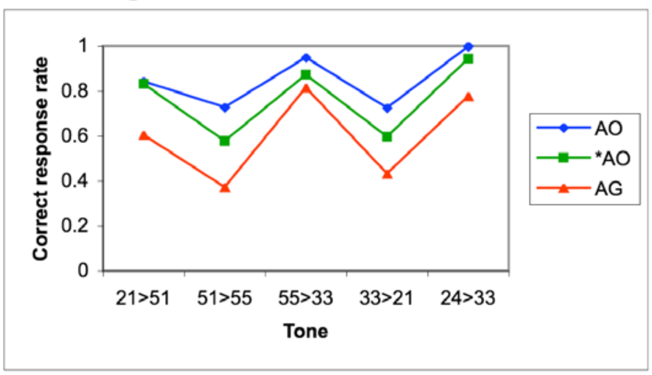
The correct response rates for the sandhi tones in single reduplication, which are on the first syllable, are summarized in (16). A Two-Way Repeated-Measures ANOVA showed that the effect of word type is significant ($F(1.411, 9.878) = 22.875$, $p<0.001$), but the effect of tone is not ($F(4.000, 28.000 = 2.179$, $p>0.05$). The graph also indicates that the subjects performed the sandhis relatively accurately for real words (AO), less accurately for real syllables without existing reduplication (*AO), and the least accurate for novel words (AG), and the difference between any two word types is significant at the $p<0.005$ level. Pairwise comparisons between different tones returned a significant difference between the 51 → 55 and the 24 → 33 sandhis ($p<0.05$), but not other pairs.

(16) Correct response rates for sandhi tones in single reduplication (σ_1):



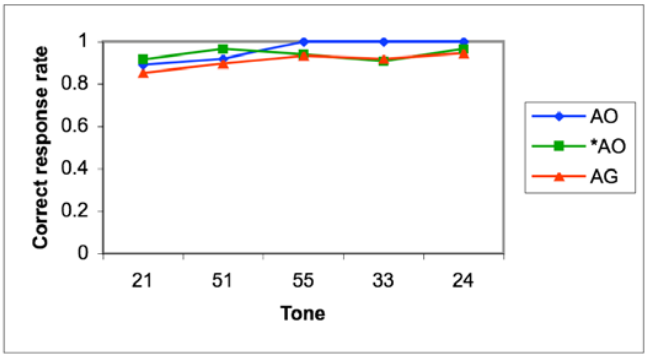
The correct response rates for the sandhi tones in double reduplication, which appear on the second syllable, are given in(17). This result is similar to that for single reduplication. But besides the significant effect of word type ($F(1.234, 8.640) = 40.199$, $p<0.001$), the effect of tone is also significant ($F(3.591, 25.137) = 4.389$, $p<0.01$). Subjects performed better in AO than *AO and AG (both at $p<0.001$), and better in *AO than AG ($p<0.002$); and they performed better in the 55 → 33 and 24 → 33 sandhis than the 51 → 55 and 33 → 21 sandhis (all at $p<0.05$).

(17) Correct response rates for sandhi tones in double reduplication (σ_2):



The crucial graph, which shows the correct response rates for the tone on the first syllable, given the tone on the second syllable as the sandhi tone in double reduplication, is given in (18). This result informs us about the subjects' knowledge of floating High docking and RR-correspondence. As the graph clearly indicates, the correct response rates are close to 100% for all the word types and all the base tones, indicating that this part of the grammar is extremely productive. Neither word type ($F(2.000, 14.000) = 1.723$, $p>0.05$) nor tone ($F(4.000, 28.000) = 1.706$, $p>0.05$) has a significant effect.

(18) Correct response rates for σ_1 tone, given σ_2 tone as sandhi tone:



For each word type in double reduplication, we also compared the subjects' performances between the first two syllables. The comparison showed that for all word types, the subjects performed the tone on the second syllable significantly more poorly than the tone on the first syllable, provided that the tone on the second syllable was used as the base for floating High docking. AO: $F(1.000, 7.000) = 8.450$, $p<0.05$; *AO: $F(1.000, 7.000) = 10.498$, $p<0.05$; AG: $F(1.000, 7.000) = 37.811$, $p<0.001$.

In sum, the results of this experiment generally corroborated the two types of productivity in Taiwanese double reduplication predicted by the phonological analysis. In terms of the productivity of the sandhi circle, although the subjects had some degrees of success in applying the sandhis to novel words, the sandhi application rates were significantly lower in AG than AO and *AO. This is consistent with the results from previous research on wug-testing Taiwanese tone sandhi by Hsieh (1970, 1975, 1976), Wang (1993), and Zhang et al. (2006). It is also consistent with the results from Sanders (2001) and Sumner (2003), which tested the productivity of opaque phonological patterns in other languages. In terms of the productivity of floating High docking, however, we found that generally, subjects had no problems with the presence of the floating High or its docking site in double reduplication, even for non-existing words.

These two different aspects of productivity support a theory that incorporates the selection of an appropriate allomorph as an Optimality-Theoretic constraint. This proposal echoes the theory of Tsay and Myers (1996), which considers Taiwanese tone sandhi to involve an allomorph selection, but no allomorph generation process. The two aspects of the observed productivity are then due to two different aspects of the grammar: the general unproductivity in sandhi tone generation is due to the active lack of this process — the sandhi tone is directly selected by an APPROPRIATE-ALLOMORPH constraint from the lexicon, not generated by constraint interactions; the general productivity of floating High docking, on the other hand, is due to the fact that the behavior of floating High docking is exactly predicted by constraint interactions, which apply to real words and novel words alike. Consequently, our proposal is also consistent with the "two-stage" derivation of Taiwanese double reduplication proposed by Myers and Tsay (2001): the first stage involves the selection of the appropriate tonal allomorphs in final and nonfinal positions; the second stage involves the docking of the floating High to the nonfinal tonal allomorph selected for the first syllable of the doubly reduplicated form.

On the other hand, we have also found that there is a difference in the application of the sandhi patterns between *AO words and AO words. This is not a prediction of our theoretical analysis, as although *AO syllables cannot be reduplicated in Taiwanese, they nonetheless exist in the syllable inventory and can most likely appear in non-XP-final positions; hence, they should have listed non-XP-final allomorphs with the correct sandhi tones, and the subjects should be able to use these allomorphs in novel reduplications. For our theory to predict a productivity difference between AO and *AO words, we need to complement it with a mechanism to encode the lexical listedness of di- and polysyllabic reduplications and discourage the use of unlisted di- and polysyllabic sequences. Then for *AO words, even if the appropriate tonal allomorph for nonfinal positions is known to the speaker, a highly ranked *UNLISTED-REDUP constraint can still deter it from surfacing in the reduplicant; a candidate that simply repeats the base tone in nonfinal position, however, may not be construed as a reduplicated form and hence satisfy the *UNLISTED-REDUP constraint and have a fair chance to win the competition. We leave the details of this mechanism to future research.

4. Remaining Issues

Besides the behavior of *AO words, a number of other questions regarding the results of the wug-test and the phonological analysis also remain for further research.

First, we have not accounted for how the subjects performed as well as they did on tone sandhi in novel reduplications: for *AO and AG words, our results showed that the correct response rates for sandhi tones in the tone circle range from 40 to 80%, which are considerably higher than the results on the sandhis of regular disyllables reported in Zhang et al. (2006), which ranged from 5 to 40%. We surmise that this may have been caused by the difference in the nature of the task. Reduplications are associated with clear semantic meanings, which may have given the novel reduplications a higher degree of word-likeness and therefore encouraged the subjects to search for tonal melodies similar to real words. The segmentals of the reduplication are also simpler than two independent syllables, which may have also helped to make the task easier.

Second, we have not provided an account for the productivity differences among different tones in the sandhi behavior. These differences may have been caused by a combination of two factors: phonetic duration and frequency of occurrence for tones. Given that nonfinal syllables are shorter than the final syllable due to the lack of final lengthening, and the tone sandhi in question occurs on nonfinal syllables, the sandhi that changes a shorter tone to a longer tone may be less productive. Based on phonetic data from Lin (1988) and Peng (1997), the 51 → 55 sandhi is one such process. This point has also been explicitly made in Zhang et al. (2006). We also surmise that the sandhi may be less productive when both the base tone and the sandhi tone have low type frequencies. Frequency counts for a Taiwanese spoken corpus (Tsay and Myers 2005) indicate that 33 and 21 have the lowest type frequencies among the five tones. We may thus expect the 33 → 21 sandhi to be less productive. We will necessarily need an explicit model of phonological representation and computation that incorporates the effects of phonetics and frequency to make precise predictions on the productivity of phonological processes, and we will leave the nature of such a model open.

Third, in our analysis, the preservation of the initial Mid tone in the first syllable is captured by the RR correspondence constraint IDENT-RR(Tone, Left), which mandates that the two reduplicants must have identical tones on the left edge. Although this captures the data pattern, it comes at the cost of complicating the theory of correspondence in Optimality Theory.

An alternative intuition is that the base of floating High docking on the first syllable is directly provided by the APPROPRIATE-ALLOMORPH constraint; in other words, the reason that the initial Mid is preserved in the first syllable is not due to its correspondence with the second syllable, but because of its correspondence to an intermediate stage of derivation, e.g., 33-33-55 for base 55. This is a more direct reflection of the "two-stage" derivation of the tonal patterns in Taiwanese double reduplication.

Formally, this intuition can be captured via the Sympathy Theory of McCarthy (1999). The sympathy candidate selector here is APPROPRIATE-ALLOMORPH, which, when ranked on top, will designate 33-33-55 as the sympathy candidate for the input RED-RED-55. In lieu of the RR correspondence constraint IDENT-RR(Tone, Left), we shall use a correspondence constraint between the output and the sympathy candidate IDENT-❀O(Tone, Left), which, when ranked in the top stratum, will ensure that the initial Mid tone of the sympathy candidate will be preserved in the output.

From the data at hand, it is not clear which approach is favorable, as although the Sympathy approach more intuitively captures the "two-stage" derivation, it also comes at a cost — it also complicates the theory of correspondence in Optimality Theory, possibly in an even more dramatic fashion than RR-correspondence, as it is able to affect more than just reduplication. I leave this choice, along with whether Sympathy is necessary to capture phonological opacity — its original intention, open to further research and debate.

5. Conclusion

In conclusion, we have argued in this paper that the phonological analysis of Taiwanese double reduplication relies on three elements: a floating High tone that prefers to dock onto the left edge of the output, tonal correspondence between the reduplicants, and the lexical listing of the sandhi tones as part of the non-XP-final allomorphs of existing syllables. The empirical predictions of this analysis are corroborated in an acoustic experiment and a psycholinguistic "wug"-test experiment, which showed that (a) the floating High tone appears as early as possible in real doubly reduplicated forms; (b) the tonal allomorphy is not productive in non-existing words; and (c) the floating High docking is productive in non-existing words.

Crucially, the two aspects of productivity in the tonal patterns of Taiwanese double reduplication are due to two different aspects of the grammar: the general unproductivity in sandhi tone generation is due to the active lack of this process — the sandhi tone is directly selected by an APPROPRIATE-ALLOMORPH constraint from the lexicon, not generated by constraint interactions; the general productivity of floating High docking, on the other hand, is due to the fact that the behavior of floating High docking is exactly predicted by constraint interactions, which apply to real words and novel words alike.

Our position, then, echoes the "allomorph selection" hypothesis of Taiwanese tone sandhi proposed by Tsay and Myers (1996) and the "two-stage" hypothesis of Taiwanese double reduplication put forth by Myers and Tsay (2001): the sandhi tones in Taiwanese are listed as part of the non-XP-final allomorphs of existing syllables in the lexicon, and the production of doubly reduplicated forms involves first the selection of the appropriate tonal allomorphs in final and nonfinal positions, and then the docking of the floating High to the tonal allomorph selected for the first syllable of double reduplication.

References

Berko, Jean (1958). The child's learning of English morphology. *Word* 14: 150-177.

Chen, Matthew Y. (2000). *Tone sandhi: patterns across Chinese dialects*. Cambridge University Press, Cambridge, UK.

Cheng, Robert L. (1973). Some notes on tone sandhi in Taiwanese. *Linguistics* 100: 5-25.

Cheng, Robert L. (1997). *Taiwanese and Mandarin structures and their developmental trends in Taiwan: Taiwanese phonology and morphology*. Yuan-Liou Publishing Co., Taipei, Taiwan.

Chung, Raung-fu (1996). *The segmental phonology of Southern Min in Taiwan*. The Crane Publishing Co., Taipei, Taiwan.

Hsieh, Hsin-I (1970). The psychological reality of tone sandhi rules in Taiwanese. *Papers from the 6th Meeting of the Chicago Linguistic Society*. 489-503.

Hsieh, Hsin-I (1975). How generative is phonology. In E. F. Koerner (ed.), *The transformational-generative paradigm and modern linguistic theory*. John Benjamins, Amsterdam, The Netherlands. 109-144.

Hsieh, Hsin-I (1976). On the unreality of some phonological rules. *Lingua* 38: 1-19.

Lin, Chienjer (2004). *Beyond output correspondence: tone sandhi in Southern Min reduplication*. Talk presented at the 78th LSA annual meeting, Boston.

Lin, Hwei-Bing (1988). *Contextual stability of Taiwanese tones*. Ph.D. dissertation, University of Connecticut.

McCarthy, John (1999). Sympathy and phonological opacity. *Phonology* 16: 331-399.

Myers, James and Jane Tsay (2001). Testing a production model of Taiwanese tone sandhi. *Proceedings of the Symposium on Selected NSC Projects in General Linguistics from 1998-2000*. 257-279.

Peng, Shui-Hui (1997). Production and perception of Taiwanese tones in different tonal and prosodic contexts. *Journal of Phonetics* 25: 371-400.

Sanders, Nathan (2001). Preserving synchronic parallelism: diachrony and opacity in Polish. *Papers from the 37th Meeting of the Chicago Linguistic Society*. 501-515.

Sumner, Megan (2003). *Testing the abstractness of phonological representations in Modern Hebrew weak verbs*. Ph.D. dissertation, State University of New York at Stony Brook.

Tsay, Jane, Jan Charles-Luce, and Yung-Song Guo (1999). The syntax-phonology interface in Taiwanese: acoustic evidence. *Proceedings of the 14th International Congress of Phonetic Sciences, vol. 3*. 2407-2410.

Tsay, Jane and James Myers (1996). Taiwanese tone sandhi as allomorph selection. *Proceedings of the 22nd Annual Meeting of the Berkeley Linguistics Society*. 394-405.

Tsay, Jane and James Myers (2005). *Taiwanese spoken corpus*. National Chung Cheng University, Taiwan.

Wu, Tzuling (1996). *A morphological analysis of reduplication in Taiwan Southern Min*. MA thesis, National Tsinghua University, Taiwan.

Urbanczyk, Suzanne (2001). *Patterns of reduplication in Lushootseed*. New York: Garland.

Wang, H. Samuel (1993). Taiyu biandiao de xinli texing (On the psychological status of Taiwanese tone sandhi). *Tsinhua Xuebao* (Tsinghua Journal of Chinese Studies) 23: 175-192.
Wu, Tzuling (1996). *A morphological analysis of reduplication in Taiwan Southern Min*. MA thesis, National Tsinghua University, Taiwan.
Yip, Moira (1990). *The tonal phonology of Chinese*. New York: Garland.

Zhang, Jie, Yuwen Lai, and Craig Turnbull-Sailor (2006). Wug-testing the "tone circle" in Taiwanese. *Proceedings of the 25th West Coast Conference on Formal Linguistics*. Somerville, MA: Cascadilla Proceedings Project. 453-461.

Zhang, Jie, Yuwen Lai, and Craig Turnbull-Sailor (to appear). Effects of phonetics and frequency on the productivity of Taiwanese tone sandhi. *Proceedings of the 43rd annual meeting of the Chicago Linguistic Society*. Chicago, IL.

Appendix A: Stimuli for the Acoustic Experiment

Tone	Word 1			Word 2		
21	膨	pʰoŋ	'inflated'	臭	t͡sʰau	'smelly'
51	水	sui	'beautiful'	短	te	'short'
55	新	sin	'new'	空	kʰaŋ	'empty'
33	重	taŋ	'heavy'	近	kin	'close'
24	澹	tam	'wet'	红	aŋ	'red'

Appendix B: Stimuli for the "Wug"-Test

Tone	AO			*AO			AG
21	膨	pʰoŋ	'inflated'	進	t͡sin	'to enter'	t͡soo
	臭	t͡sʰau	'smelly'	過	kue	'to cross'	t͡sʰue
	碎	t͡sʰui	'shattered'	帝	te	'a chunk'	t͡suan
	破	pʰua	'broken'	吐	tʰoo	'to vomit'	kʰe
	拜	pai	'to pray to'	氣	kʰui	'air'	pan
	怪	kuai	'strange'	退	tʰe	'to back up'	pʰãĩ
	笑	t͡sʰio	'to laugh'	教	ka	'to teach'	tʰua
	夠	gau	'enough'	透	tʰau	'to mix'	t͡sua
51	飽	pa	'full'	炒	t͡sʰa	'to stir fry'	t͡saŋ
	短	te	'short'	轉	tŋ	'to turn'	t͡sʰui
	快	kin	'fast'	體	tʰe	'body'	t͡sue
	圃	po	'dried goods'	表	piau	'cousin'	kʰŋ
	奔	t͡sio	'few'	跑	t͡sau	'to run'	pai
	普	pʰo	'ordinary'	手	t͡sʰiu	'hand'	pʰau
	鬼	kui	'ghost'	請	t͡sʰiã	'to treat'	tʰŋ
	歹	pʰãĩ	'bad'	統	tʰoŋ	'to unite'	t͡sam
55	翹	kʰiao	'perked up'	尊	t͡sun	'to respect'	t͡san
	光	kŋ	'bright'	區	kʰu	'area'	t͡sʰui
	深	t͡sʰim	'deep'	郊	kau	'suburb'	t͡sue
	輕	kʰin	'light'	公	kaŋ	'public'	kʰŋ
	膏	ko	'sticky'	珍	tin	'precious'	pẽ
	甜	tĩ	'sweet'	添	tʰiam	'to add'	pʰoo
	香	pʰaŋ	'fragrant'	車	t͡sʰia	'car'	tʰoo
	清	t͡sʰiŋ	'pure, clear'	偷	tʰau	'to steal'	t͡sam
33	頓	tun	'blunt'	電	tian	'electricity'	t͡sau
	近	kin	'near'	病	pẽ	'sickness'	t͡sʰui
	重	taŋ	'heavy'	樹	t͡sʰiu	'tree'	t͡sui
	大	tua	'big'	市	t͡sʰi	'city'	kʰŋ
	靜	t͡sʰŋ	'quiet'	豆	tau	'bean'	pa
	癢	t͡sĩũ	'itchy'	娶	t͡sʰua	'to marry'	pʰai
	厚	kau	'thick'	渡	too	'to ferry'	tʰoo
	硬	tŋ	'hard'	陣	tin	'battle array'	t͡saŋ
24	濕	tam	'wet'	材	t͡sai	'material'	t͡sa
	長	tŋ	'long'	賠	pue	'to compensate'	t͡sʰue
	鹹	kiam	'salty'	頭	tʰau	'head'	t͡sue
	齊	t͡se	'orderly'	球	kiu	'ball'	kʰŋ
	柴	t͡sʰa	'slow witted'	環	kʰuan	'bracelet'	pŋ
	肥	pui	'fat'	陳	tan	'old'	pʰãĩ
	槌	tʰui	'foolish'	奔	t͡soŋ	'to run quickly'	tʰua
	牢	tiau	'sturdy'	茶	te	'tea'	t͡sam