An Experimental Study on the Productivity of Taiwanese Tone Sandhi*

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Taiwanese in this paper refers to the South Min dialect of Chinese spoken on the island of Taiwan. Taiwanese, as a variety of the South Min Dialect, has been observed to display tonal changes when words are put together. This phenomenon is commonly known as 'tone sandhi' in the literature. In the following section, we will briefly sketch the phenomenon. For more detailed discussions of the phenomenon, please refer to R. Cheng (1968, 1973).

1. The phenomenon of tone sandhi

Taiwanese is traditionally considered as having seven tones, two of which being entering and the other five non-entering. The entering tones are those in syllables ending in stops /p, t, k, ?/, while the non-entering tones are those in other syllable types, including syllables ending in vowels, glides and nasals.

Using a five-point tonal scale with 5 representing the highest pitch and 1 the lowest pitch, the Taiwanese tones and their sandhi changes are summarized in (1).

(1)   Taiwanese tones
    a. non-entering

	isolation	sandhi	gloss
hue	55	33	'flower'
bin	33	21	'face'
ts'ai	21	51	'vegetable'
hai	51	35(55)[1]	'sea'
t'ao	24	21(33)[1]	'head'

    b. entering

tsap	4	3(2)[1]	'ten'
kɔk	3	4	'country'

When a word is said in isolation or is used in the final position of a tonal group, the isolation tone is used.[2]   When it occurs in non-final positions of a tonal group, the sandhi tone is used. Such changes constitute sandhi relationships as diagramed below.[3]

(2) Tone sandhi chain
   a. non-entering tones
      55 --> 33 --> 21 --> 51 --> 35
                      ↑
                      |
                     24
   b. entering tones
     4 <--> 3

2. The psychological reality of tone sandhi rules

In the generative paradigm, as proclaimed by Chomsky and Halle (1968), the mission of a linguist is to construct, from the regularities observed in a language, a grammar which is a description of the speaker's competence. From this proclamation stem the many psycholinguistic experiments in the post-SPE era, testing the validity of linguistic rules as respresentations of the speaker's competence. One of the more noted experiments was done by H.I. Hsieh (1970) on the psychological reality of Taiwanese tone sandhi rules.

Because the standard assumption of a generative account is to have one basic phonological form posited for each lexical item, and the other alternate forms are all arrived at by the application of relevant rules, Hsieh wanted to test whether this assumption was valid for Taiwanese tone sandhi. More specifically, he wanted to find out whether Taiwanese speakers are psychologically aware of the tone sandhi rules and produce sandhi forms accordingly. Thus, following Berko (1958), he made up some nonsense syllables using the accidental tonotactic gaps in Taiwanese and presented them to the native speakers in proper environments to see if they could produce the predicted sandhi forms. Of the five non-entering tones tested, he found that the subjects produced only 10 to 30 percent correct sandhi forms in their answers. The great majority of the errors made resulted from not changing the tones at all. Hsieh thus concluded that the generative assumption does not provide satisfactory explanation for the phenomenon, and should therefore be abandoned. He proposed instead to list both the the isolation tone and the sandhi tone in the lexicon and choose the appropriate form in proper environments.

However, Liao (1972) considered Hsieh's proposal counterintuitive. He conducted another experiment in an attempt to verify the validity of Hsieh's claim. In his experiment he used written stimuli: the test items were

presented in Chinese characters. He asked the subjects
to read two-morpheme compounds in one column and the
reversed-order morphemes in anther column. The
compounds in the first column are familiar to the
subjects, while those in the second column, composed of
the two morphemes in the first column but in reverse
order, are unfamiliar. His assumption was that, if the
tone sandhi rule is productive, then the unfamiliar
compounds should demonstrate tone sandhi behaviors. The
results showed that the predicted tone sandhi behavior
was observed close to 100 percent of the time. In the
second part of the experiment he used three-morpheme
compounds were administered, among which some of the
second two morphemes were identical to the second
column of part one. The results also showed close to
100 percent correct response according to the tone
sandhi rules. He therefore concluded that the tone
sandhi rules as formulated by linguists are productive
and hence have psychological reality.

Faced with this kind of contradictory evidence, one
is certainly curious to know which conclusion is closer
to the truth. Liao's experimental results do not really
falsify Hsieh's theory, because Hsieh proposes for both
isolation form and sandhi form to be listed in the
lexicon. If such is the case, the subjects in Liao's
experiment were still able to pick out the appropriate
form facing the unfamiliar combination of morphemes, so
long as he/she could identify the proper environments.
But Liao's feeling that the phenomenon should be
productive is not unfounded. We have at hand two pieces
of evidence to that effect. One is the newly coined
compound [kai51 sien55] 'someone who is good at witty
talk' which appeared about twenty years ago and has
become a normal expression. The corresponding verb for
'to engage in witty talk' is [kai21], such as in [i33
tsin33 gao33 kai21] 'He is good at witty talk'. The
tonal alternation '21'-'51' is precisely one of the
tone sandhi relationships described above. The second
piece of evidence comes from loan words. In Taiwanese
there are a number of loan words which were borrowed
from Japanese. These words all bear Taiwanese tones for
individual syllables. For example, [t'ɔ33 ma55 toʔ3]
'tomato' but [t'ɔ33 ma55 toʔ4 tsiap3] 'tomato juice';
[ɔ33 to55 bai51] 'motorcycle' but [ɔ33 to55 bai55
tiam21] 'motorcycle shop'. The alternations '3'-'4'
and '51'-'55' all demonstrate sandhi behaviors.

Therefore, the controvercy is not settled by these
two papers. Hsieh (1975) therefore conducted another
experiment using both child and adult subjects to test

whether they could manipulate the tonal changes with
unfamiliar morphemes or compounds with unfamiliar
morpheme combinations. He concluded that whatever
productivity demonstrated in the experiment was the
result of familiarity of the morpheme or morpheme
combination, and such familiarity provides the basis
for lexical diffusion (W. Wang 1969) and analogical
association of the relationships. In this way, Hsieh
maintains his 'surface- forms-too' hypothesis for
lexical representation as opposed to the generative
assumption which he terms 'base-form-only'. This
familiarity account can certainly accomodate the two
pieces of evidence we presented in the previous
paragraph, but it still falls short of explaining why,
for example, the sandhi form for [kai21] is necessarily
[kai51 (sien55)], because if both forms are listed in
the lexicon, the isolation form can be associated with
any other tone for its sandhi variant. There is
obviously some more general principle that guides its
association.

The purpose of this study is to explore whether
familarity factor really plays a role in the tone
sandhi phenomenon, and if so, how the phenomenon can
best be characterized. In order to test the familiarity
factor, a long-term experiment spanning over four
months was conducted, using made-up words similar to
Hsieh (1970) but differring in important ways.

3. The experiment

1) Subjects

Twenty-two native speakers of Taiwanese took part
in this experiment, all of whom used the subdialect of
Hsin-chu. Among these subjects three were male and the
other 19 were female. Their ages at 1990 ranged from 46
to 72 (Mean=61.73, s.d.=7.38). They were paid for their
participation.

2) Procedure

Two nonce words were made up for each of the
seven tones, which constitutes a total of 14 words.
These words are shown below:

(3) Nonce words and their made-up meanings

Tones	Nonce word	Meanining	Nonce word	Meaning
55	p'uai	'scissors'	ts'ã	'pen'
33	biu	'flute'	pué	'clothes'
21	sɔm	'necklace'	ts'ũãĩ	'rabbit'

51	biang	'shoes'	p'ẽ	'hat'
24	pia	'flower'	tuai	'jade'
4	p'at	'bird'	biɔk	'wine'
3	tip	'wax apple'	kiak	'chair'

These nonsense words were designed in such a way that except for [sɔm] and [pẽ], none of the segmental combinations appear as real words in Taiwanese. These are accidental phonotactic gaps.

The experimenters met with the subjects six times in total. There was a one-week lapse between the first, second and third meetings, and a one-month lapse between the third, fourth, fifth and sixth meetings. In the first meeting the nonsense words and their pretended meanings were taught to the subjects in random order. The actual testing began in the second meeting. In these subsequent meetings the words were reviewed, and test frames such as

(4)
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li55 be55 k'i55 _____    tiam21 be35 ____
you  want go              shop    buy
'You are going to _____ shop to buy ____'
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were presented to the subjects. The subjects were expected to say the sentences and fill the slots with the nonsense word. For this sentence, the first slot, since it occurs before [tiam21] 'shop' and should therefore form a compound, is a proper place to expect a sandhi tone, while the second slot is at the sentence final position and should carry an isolation tone. These test sessions were all recorded and transcriptions were done afterwards.

4. Results and Discussion

Of the 22 subjects, two failed to attend the meeting in the last week. Due to mishandling of the tape recorder, the test materials of one of the subjects was not properly recorded during the third week. These were all regarded as 'missing values' in the following analyses.

Table 1 shows the percentages of the correct answers according to the sandhi rules above. It should be noted that the percentages for '51' tone represent the combined answers of '35' and '55'. This is because the '35' answers for '51' were very few: only 3 were observed over the five weeks. '55' answers are accepted because the speakers might have been influenced by

speakers of the majority of other subdialects who use
'55' as the sandhi form for '51'. But as can be seen,
the percentages for this tonal category are still very
low.

Table 1. Percentages of correct answers over the weeks.

	WK2	Wk3	Wk4	Wk5	Wk6
p'uai55	54.5	61.9	61.9	59.1	55.0
ts'ã55	54.5	38.1	50.0	45.5	55.0
biu33	40.9	42.9	59.1	59.1	55.0
puẽ33	59.1	52.4	54.5	72.7	85.0
sɔm21	81.8	66.7	81.8	90.9	75.0
ts'ũãĩ21	54.5	33.3	36.4	45.5	50.0
biang51	18.2	14.3	27.3	13.6	15.0
p'ẽ51	4.5	9.5	13.6	9.1	10.0
pia24	50.0	28.6	50.0	68.2	75.0
tuai24	59.1	47.6	50.0	81.8	75.0
p'at4	22.7	14.3	22.7	18.1	35.0
biɔk4	77.3	66.7	59.1	81.8	75.0
tip3	45.5	42.9	45.5	50.0	35.0
kiak3	27.3	38.1	45.5	27.3	35.0
Mean	46.4	39.8	47.0	51.6	52.1

We can see from this table that there is a slight
trend of increase of correct rates over the weeks
except Week 3. In order to test whether the increase is
significant, correct scores were calculated for each
subject per week. One-way ANOVA was performed but the F
ratio was not significant, indicating that the
difference observed among these weeks is not
significant. Polynomial tests did not show a
significant linear trend either. Natural log
transformations were done on the scores, but the ANOVA
test still did not give a significant F ratio, and the
linear trend is a little less than significant
(p=.068). A comparison between the log-transformed
scores between Week 2 and Week 6 gives a
close-to-significant t (paired $t(19)=1.94$, p=.068).
However, Cochran's Q tests on individual words over the
weeks did show that for three of the words the trends
of increase are significant. Of the 14 comparisons
performed, the two comparisons on the '24' tone were
both significant at .01 level, while the one done on

[puẽ33] was significant at .05 level. This shows that familiarity has limited effect on the productivity of the phenomenon.[5]

We started out looking for familarity effects in the sandhi behaviors, but did not find significant trends of increase over the weeks except in 3 (out of 14) words. However, the familarity effect should not be dismissed so easily. As mentioned previously, Hsieh (1975) argued that familiarity played a role in his experiment. As there is a general trend of increase, we can only assume that given time and proper environments, the trend will become significant.[6]

It is also easily observed from Table 1 that the performances of individule words differ: the sandhi forms of some of the words, such as [sɔm21], are realized quite readily, while others, such as [p'ẽ51], are much less productive. Thus Cochran's Q tests were similarly performed among the items within each week. The results showed that the five comparisons were all significant at .001 level. Comparisons among the words were done, and the results indicate that the behaviors of the tones are consistent: no two words in each tonal category are significantly different except tone '4'. Thus it is reasonable to collapse the values of the pair of words in each tonal category and compare the means. ANOVA test showed that such comparison is significant ($F(6,147)=6.98$, $p<.001$), and the individual comparisons (Scheffe method, alpha=.05) are shown in Table 2.

Table 2. Comparisons of Tone Scores over the Weeks

Tone	Mean	Rank	1	2	3	4	5	6
21	62.27	1						
24	58.75	2	-					
33	57.95	3	-	-				
55	52.95	4	-	-	-			
4	44.20	5	-	-	-	-		
3	39.20	6	-	-	-	-	-	
51	13.30	7	*	*	*	*	-	-

Tone '51', being a non-entering tone, is significantly different from the other non-entering tones, and its comparisons with the other four non-entering tones are the only significant differences observed in Table 2. From the generative point of view, if there is to be a general 'rule' that is responsible for the sandhi behavior, as W. Wang (1967) has attempted, tone '51',

with its sandhi form '35' or '55', should not be a proper member of it. That is, the tonal chain described in (2a) should stop at '51', at least for the case we are studying.

It is interesting to observe that tone '21' words produced the most correct answers. The correct sandhi tone for '21' is '51', which is just the isolation tone with the fewest correct answers. This phenomenon is obviously not coincidental, but is difficult to reason from a 'rule' point of view. However, if we categorize the response types, as in Table 3, there seems a clearer clue to what might be at play.

Table 3. Response Types Made Over the Weeks to Each Word

	55	33	21	51	24	35	4	3	missing
p'uai55	42	62	2						4
ts'ã55	49	52	4	2					3
biu33	9	41	55			2			3
puẽ33	4	34	69						3
sɔm21		7	15	85					3
ts'ũãĩ21	2	14	42	47	1	1			3
biang51	16	5	6	77		3			3
p'ẽ51	10	1	2	94					3
pia24	3	24	58	1	8	13			3
tuai24		24	67	1	7	8			3
p'at4							83	24	3
biɔk4							30	77	3
tip3							49	58	3
kiak3							37	70	3
Total	135	264	320	307	16	27	199	229	43

In this table, the response types '21' and '51' rank the highest. For '21' to rank the highest is expected, because it is the sandhi form of TWO source tones '33' and '24'. But if we examine the response type '51', we will find that the contributions are mostly from '21' and '51'. From the 'rule' point of view, it is natural for '21' to make the contribution; but for '51' to make this great contribution is quite unexpected. This response type is the 'no change' response for '51' tone. The average no change responses

for the non-entering tones is 40.9, hence the two no-change responses for this tone are too high. It is also the high no-change responses that result in the low correct answer rates. Combining the highest correct answer rate and the highest no change rate, both falling within the response type '51', we would propose, following Bybee and Moder (1983), that '51' forms a 'product-oriented schema' and the subjects responded not according to the 'rule' but according to the goodness of the shape of the outcome.[7] The correct answers for '21' may partly due to the 'rule' and partly due to the 'product-oriented' attraction. The low correct answer rates for '51' may be due to its being already a good sandhi form and the subjects did not bother to change it. This is similar to the formation of the English past tense in which subjects tend to omit the affix [t/d] when the verb stem ends with '-t' or '-d' (Bybee and Slobin, 1982, p.269). But the schema in this case does not operate alone. It is confounded with the sandhi rule, because as seen from Table 3, most of the '51' answers come from '21' and '51' words as source. If the schema is an independent factor, it should receive more contributions from other source tones.[8]

The low response rates for '24' are expected, because no tone uses '24' as its sandhi form. However, the fact that its no-change rate (i.e., with '24' as responses) is so low should somehow be accounted for. The no-change answers have haunted the production-type experiments on the psychological reality of phonological rules such as the English vowel shift rule (see H.S. Wang, 1985 for a summary of the experiments) and the Taiwanese tone sandhi rule. It seems that unless the change is meaningful (such as the addition of a plural morpheme) or unless there is a surface phonotactic constraint (such as the voicing pronunciation of the English plural form), the subjects would prefer a no-change answer for the task. Hence the great number of no-change answers in Hsieh's 1970 experiment. Since the isolation tones are all possible sandhi tones themselves except '24', it is reasonable to expect some no-change type of answers from the 'product-oriented' point of view. In this study we have successfully elicited about 47% correct forms, and the no-change response have been reduced to an average of about 41%, but we still expect the no-change answer to be a viable answer. The low no-change response rates for '24' obviously cannot be understood from the 'rule' (source-oriented) point of view. Our specific claim here is that the tones '55', '33', '21', and '51' all

have product-oriented effects, with '51' displaying the strongest effect and defying the 'rule' effect. On the other hand, tone '24' has no such effect (is not a good sandhi form), hence the low no-change rates. But as mentioned before, these product-oriented effects are pretty much source-bound, which is the nature of the 'no-change' type of answers.

6. Concluding Remarks

In this study, we have found that some of the linguistic generalizations such as the sandhi alternations between '55'-'33', '33'-21', '21'-51', '24'-'21' may be maintained, but the relationship between '51'-'35'('55') is not supported. Therefore, contrary to Hsieh (1970, 1975), we believe that 'some' sandhi rules are real to a certain degree, although perhaps not to the degree of 'automatically generative' as assumed in SPE. We therefore assume that the sandhi rules are organizational rather than derivational. That is, the sandhi rules represent the ways the speakers relate the isolation tones and sandhi tones. Like Hsieh, we propose that both tones are listed in the lexicon; but unlike Hsieh, we propose that there are these sandhi rules that govern these relationships. The rules are not derivational in that the results are not obtainable by directly applying the rule on the input to derive the output. Rather, the desired output is obtained when the speaker gradually realizes the relationships and the related forms fall into the 'phonological space.'

Aside from the rules, the product-oriented schemas provide another organizational principle for the phonological relationship. Admittedly they are a competing force with the rules, just as rules can compete with each other (Wang, 1969; Hsieh, 1976). There is no denying that speakers have feelings about the goodness of the product forms, but this kind of feeling has not been explored in great depth, save the work done by Bybee and her associates. We believe that a lot more work needs to be done in this regard before we can reasonably hope to sort out the relationships between rules and schemas, and to draw a clear, truthful picture of the phenomenon.

Notes

1. The sandhi forms for these tones are for the sub-dialect used in Hsin-chu area where the investigation reported in this paper was done. The values in parentheses are for most other subdialects.

2. The environments where tone sandhi occurs is itself a complicated phonosyntactic problem. The interested reader can refer to Liao (1973) and Chen (1987).

3. The relationship in (2a) is usually described as a tonal circle. This description is not true for this particular subdialect because the sandhi form for 51 is 35, rather than the usually observed 55. If the latter is the case, the sandhi form will be identical to the isolation tone of 55, and a circle is completed. Because in this subdialect the sandhi form 35 does not occur as an isolation tone, the circle can not be completed.

4. We used phonotactic gaps rather than tonotactic gaps as Hsieh did because we felt that tonal changes are what we want to test. If tonotactic gaps are used and tonal changes are observed in the test, we would not be certain whether a rule is applied or whether the subject simply resorted to analogy and responded with an existing word. The existing segmental combinations used, [sɔm] and [p'ẽ], were unintentional. The only word with [sɔm] has '55' as its isolation tone, which means 'ginseng'. Fortunately, the tonal value assigned to this segmental combiation was '21', with expected sandhi tone '51', none of which coincides with '55' or its sandhi tone '33'. In fact, this item was one of the most successful in the test, as will be shown in Table 1. The real word [p'ẽ] carries '24', for which '21' is the expected sandhi tone. The nonsense word used here has '51' tone, for which we expect '35' or '55' as the sandhi tone. As shown in Table 1, this item was the least successful, with most of the answers carrying the '51' (unchanged) tone. So

we can be quite sure that analogy did not have effect here.

5. We have to note that the three words with significant trend of correct answers all share '21' as their sandhi form. This means that only the response type '21' has significant increasing trends. This increasing trend is part of the reason why '21' is the highest response type. See Table 3 below.

6. C.C. Cheng (1973) found that of the tones used in Chinese dialects, tone '51' is the most often observed. This observation may not have bearings with the schema indicated here, but coincidence or not, their relationship is something that deserves further research. On the other hand, the schema may be different in other subdialects. Chiou's (1991) study indicates that '33' is the schema. Hsieh's (1975) study seems to point to the similar direction.

7. Chiou (1991), in a similar experiment testing whether subjects produce increased number of sandhi tones over five consecutive tests, also observed a progressive increase of correct answers. No statistic was performed to test whether the increasing trend was significant, but it is interesting to see that his results echoed the results in this study, as both show trends of increase.

8. The response types '21', '51' and '33' form a homogenious group. The reasons for the high rates of types '21' and '51' are as discussed, but that of '33' is more complicated. As a tentative answer, we propose that, '33', besides being the correct answer for '55' and the no change answer for '33', receives sizeable contributions from '24', which is the correct answer for '24' in most of other subdialects (see (1a) and note 1). For the possible influence from other subdialects, see Hsieh (1976).

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