

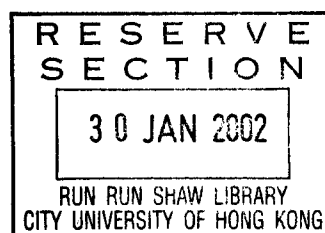
CITY UNIVERSITY OF HONG KONG
香港城市大學

Tonal Behavior in Some Tone Languages
一些聲調語言中的聲調變化

Submitted to
Department of Electronic Engineering
電子工程系
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
哲學博士學位

by

Liu Juan
劉娟



October, 2001
二零零壹年十月



Abstract

This thesis explores some cross-linguistic constraints on tonal behavior. Phonologically, tones behave like segmental sounds in some tone languages. Therefore, linguistic principles such as the Margin Principle and the Size Principle, which are based on segmental phonology, are investigated here for their applicability on tonal behavior. Specifically, we focus on the production and perception of tones from a phonetic angle.

With regard to tonal production, a quantitative comparison of the amount of contextual tonal variation among three languages, i.e. Mandarin, Jinanese, and Hong Kong Cantonese is carried out. These languages differ either in tonal inventory size or in tonal contrast. The results show that tones in Mandarin and in Jinanese vary more greatly on average than do tones in Cantonese in contexts, though all vary in a confined space. This demonstrates the presence of both the Margin Principle and Size Principle in tonal production. Tones in a system with a smaller inventory size would undergo a greater amount of contextual perturbation, while tones in a system with a larger inventory size could tolerate a smaller amount of contextual perturbation. That the tones vary in a confined space indicates that tonal variation due to coarticulation is not sufficient to damage the identifiability of particular tones. The statistical results further strengthen this point. Moreover, the cross-language investigation of this study shows that tonal coarticulation is mostly assimilatory in nature, as is the case with vowel-to-vowel coarticulation. A dissimilatory coarticulation only occurs when a tone is followed by a low tone, primarily because of physiological constraints. A register effect is also found to exist in tonal coarticulation: tones at the high register usually vary more greatly than tones at the low register. In addition, a direction change in F_0 movement is observed to occur consistently with falling contour tones across languages, suggesting a possible link between phonetic variation and historical change.

Concerning the Margin Principle in tonal perception, several experiments of categorical perception are carried out with pairs of tones from each of the three languages. However, the results show some inconsistency. While the perceptual boundary between Mandarin tone 1 and tone 4 is rather clear-cut, indicating a categorical perceptual mode, the perception of the boundary between Mandarin tone 2 and tone 3 shows a continuous mode. The perception of the boundary between the two Jinanese falling tones is somewhat different from that between the two Cantonese rising tones. The transition stage lasts longer between the two falling tones than between the two rising tones, indicating that listeners are more sensitive to the F_0 difference on the tonal offsets than on the onsets. However, in either perceptual mode, categorical or continuous, the perceptual margin between tone categories shifts along a variety of other factors. These factors could be intrinsic, such as vowel quality, tonal duration, and extrinsic, such as language background, physiological constraints and psychological experience. Further refined studies are needed to reveal the mechanisms for the perception of lexical tones.

Table of Contents

ABSTRACT.....	ii
ACKNOWLEDGEMENT.....	iii
TABLE OF CONTENTS.....	v
LIST OF FIGURES.....	viii
LIST OF TABLES.....	x
CHAPTER 1: INTRODUCTION.....	1
CHPATER 2: GENERAL HYPOTHESIS.....	7
2.1 Some Cross-linguistic Constraints on Segmental Sounds.....	7
Intrinsic and Extrinsic Constraints.....	7
Margin Principle.....	8
Space Principle.....	8
Maximal Contrast Principle.....	9
Size Principle.....	10
2.2 Phonological Features of Tone.....	11
2.3 Tone Space.....	14
2.4 Hypothesis on Tonal Behavior.....	15
CHAPTER 3: PRODUCTION BEHAVIOR.....	19
3.1 Background.....	19
3.2 Methodology.....	24
Material.....	24
Recording.....	27
F ₀ Extraction and Processing Procedure.....	28
F ₀ Normalization.....	30
Calculating Magnitude of Tonal Variation	30
3.3 Results.....	31

3.3.1	Contrasts of Citation Tones in Acoustic Tone Space.....	31
	Acoustic Results.....	31
	Discussion.....	35
	Duration Contrast.....	38
3.3.2	Carryover Effects in Bitonal Combinations.....	39
	Acoustic Results.....	39
	Calculating Carryover Effects.....	45
	Summary of Carryover Effects.....	46
3.3.3	Anticipatory Effects in Bitonal Combinations.....	47
	Acoustic Results.....	47
	Calculating Anticipatory Effects.....	52
	Summary of Anticipatory Effects.....	53
3.3.4	Statistical Analysis.....	54
3.3.5	Tonal Variation in Sequential Situation.....	58
3.4	On Magnitude of Tonal Variation	63
3.5	Register Effect.....	68
3.6	A Direction Change in F ₀ Movement with Falling Tonal Contour.....	76
3.7	The Nature and Directionality of Tonal Variation.....	82
3.8	Summary of Chapter 3.....	89

CHAPTER 4: PERCEPTION BEHAVIOR.....91

4.1	Background.....	91
4.2	Experiment 1: Perceptual Boundary between Mandarin Tone 2 and Tone 3.....	94
	Background.....	94
	Stimuli.....	95
	Subjects and Procedure.....	97
	Results.....	97
	Discussion.....	102
4.3	Experiment 2: Perceptual Boundary between Mandarin Tone 1 and Tone 4.....	106
	Background.....	106
	Stimuli.....	107
	Subjects and Procedure.....	109
	Results.....	110
	Discussion.....	115
4.4	Experiment 3: Perceptual Boundary between the Two Cantonese Rising Tones	116
	Background.....	116
	Stimuli.....	117
	Subjects and Procedure.....	119
	Results.....	120
4.5	Experiment 4: Perceptual Boundary between the Two Jinanese	

Falling Tones.....	121
Stimuli.....	121
Subjects and Procedure.....	123
Results.....	124
Discussion for Experiments 3 and 4.....	126
4.6 Summary of Chapter 4.....	128
CHAPTER 5: CONCLUSIONS AND REMANINING QUESTIONS.....	130
5.1 Conclusions.....	130
Margin Principle in Tonal Production Behavior.....	130
Margin Principle in Tonal Perception Behavior.....	133
5.2 Remaining Questions.....	135
5.3 Perspective of Linguistic Principles on Tonal Behavior.....	138
BIBLIOGRAPHY.....	140
APPENDICES.....	150
Appendix 1: Individual Variation on Pitch Range with Six Citation Tones across Four Cantonese Speakers.....	150
Appendix 2: Individual Difference in the Production of Mandarin Tone 2 under Anticipatory Effects across Four Speakers.....	151
Appendix 3: Individual Difference in the Production of Jinanese Tone 2 under Anticipatory Effects across Four Speakers.....	151
Appendix 4: A Sample of Answer Sheet Used in Tonal Perceptual Experiment..	152

List of Figures

Figure 2.1. Distribution of vowels in acoustic vowel space.....	13
Figure 2.2. Distribution of tones in acoustic tone space	14
Figure 2.3. Illustration of the phonetic range of noncontour features.....	17
Figure 3.1. Sample display of a recording containing Cantonese tone sequence of tone 1+ 5 carried by syllables /sisi/.	29
Figure 3.2. Contrasts of six Cantonese tones in the acoustic tonal space associated with syllable /si/ when recorded in isolation.....	32
Figure 3.3. Contrasts of four Jinanese tones in the acoustic tonal space associated with syllable /shi/ when recorded in isolation.....	33
Figure 3.4. Contrasts of four Mandarin tones in the acoustic tonal space associated with syllable /shi/ when recorded in isolation.....	34
Figure 3.5. Carryover effects in Cantonese.....	40
Figure 3.6. Carryover effects in Jinanese.....	42
Figure 3.7. Carryover effects in Mandarin.....	44
Figure 3.8. Anticipatory effects in Cantonese.....	48
Figure 3.9. Anticipatory effects in Jinanese.....	50
Figure 3.10. Anticipatory effects in Mandarin.....	51
Figure 3.11. Comparisons between the canonical citation form of a particular tone and its contextual variants in Cantonese.....	59
Figure 3.12. Comparisons between the canonical citation form of a particular tone and its contextual variants in Jinanese.....	60
Figure 3.13. Comparisons between the canonical citation form of a particular tone and its contextual variants in Mandarin.....	61
Figure 3.14. Tripartition of tone space in different manner of register overlapping	70
Figure 3.15. The production of Cantonese mid-level tone under both anticipatory	

and carryover effects by four speakers.....	72
Figure 3.16. Examples showing a register effect in both carryover and anticipatory coarticulation.....	74
Figure 3.17. Tonal variations of four falling tones in sequential situation in the three languages.....	77
Figure 3.18. Anticipatory effects on the Jinanese high-falling tone and the Cantonese low-falling tone.....	80
Figure 3.19. Anticipatory effects on the Jinanese high-falling tone by individual speakers.....	81
Figure 3.20. A dissimilatory association in anticipatory coarticulation with Mandarin tone 3 and Jinanese tone 4.....	85
Figure 4.1. Schematic diagram of synthesized F_0 patterns	96
Figure 4.2. Tone 3 response for syllables [pa] and [pi], perceiving respectively as a function of onset value and duration ratio of pre-rise portion by subjects.....	98
Figure 4.3. Comparisons of tone 3 response on syllables [pa] and [pi] among three groups of subjects.....	99
Figure 4.4. Schematic diagram of synthesized F_0 patterns.....	108
Figure 4.5. Perceptual results from identification test.....	110
Figure 4.6. Perceptual results from discrimination test.....	112
Figure 4.7. Perceptual curves for discrimination test under different conditions.....	113
Figure 4.8. Categorical perception of synthesized tones.....	115
Figure 4.9. The schematic diagram of synthesized F_0 pattern.....	118
Figure 4.10. Labeling data from identification test both with set A stimuli and set B stimuli.....	120
Figure 4.11. The schematic diagram of synthesized F_0 pattern.....	122
Figure 4.12. Labeling data from the identification test both with set A stimuli and set B stimuli.....	124
Figure 4.13. Labeling data from the identification test on Cantonese tone 2 and tone 5 during the second trial.....	125

List of Tables

Table 3.1. Summary of the paradigms of citation tones in Mandarin, Jinanese and Cantonese.....	25
Table 3.2. Slope values of the five average portions of the falling tones in Cantonese, Mandarin and Jinanese.....	37
Table 3.3. Duration patterns of all citation tones in the three tonal paradigms	38
Table 3.4. Magnitude of carryover effects on each tone represented by the variation space area in the three languages.....	45
Table 3.5. Magnitude of anticipatory effects on each tone represented by the variation space area in the three languages.....	53
Table 3.6. F values of main effect and two-way interaction of the three independent variables in carryover effects from a GLM-Multivariate model.....	54
Table 3.7. F values of main effect and two-way interaction of the three Independent variables in anticipatory effects from a GLM-Multivariate model.	55
Table 3.8. F values of carryover effects of pre-tones on Mandarin, Jinanese four tones and Cantonese six tones.....	56
Table 3.9. F values of anticipatory effects of post-tones on Mandarin, Jinanese four tones and Cantonese six tones.....	56
Table 4.1. Information of the two original tones from real speech, from which the stimuli for perception were synthesized.....	95
Table 4.2. Matrix of tone 3 response in percentage score on syllable [pi] by Beijing Mandarin speakers.....	100
Table 4.3. Statistical results from the first set ANOVA. The onset value was taken as independent variable.....	101
Table 4.4. Statistical results from the second set ANOVA. The duration ratio was	

taken as independent variable	102
Table 4.5. Pearson correlation from regression analysis.....	115
Table 4.6. Average values of F_0 and duration of the two falling tones from real speech and of the original tone for synthesizing.....	118
Table 4.7. Average values of F_0 and duration of the two rising tones from real speech and of the original tone for synthesizing.....	122