

## **TONE SANDHI**

Jie Zhang  
Department of Linguistics  
The University of Kansas

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## **INTRODUCTION**

Tone sandhi, a phonological process by which lexical tones exhibit contextually determined alternation, is commonly observed in tone languages around the world from Bantu to Zapotec. The term, however, is typically associated with Chinese languages, not only because the phenomenon is especially wide-spread and well-documented in these languages, but also because the contour-rich tonal inventories of Chinese languages present a particularly fertile ground for intricate, yet typologically well-structured sandhi patterns. The entries in this article reflect this bias. Typologically, the trigger of tone sandhi can be adjacent tones, as exemplified by the famous Mandarin Third-Tone sandhi, whereby a Third Tone (dipping) becomes a Second Tone (rising) in the context of a following Third Tone, but it can also be the prosodic or

morphosyntactic position in which the tone appears, as exemplified by Taiwanese, in which a tone undergoes sandhi provided that it is not in the final position of a maximal projection. The typology of the sandhi change includes local tone substitution (e.g., Mandarin, Taiwanese), long distance spreading (e.g., Shanghai), and a combination of the two, whereby the tone is first substituted and then spread (e.g., Wuxi). Tone sandhi has played a unique role in the development of phonological theory, particularly the autosegmental nature of phonological features and the feature-geometric representations of tones. But complete theoretical analyses of any tone sandhi systems have proven to be difficult, likely due to a combination of the following factors. First, the sheer complexity of certain tone sandhi systems (e.g., those in Wu and Min dialects) is deterrent enough for a formal analysis; second, as the result of diachronic changes, many of the sandhi patterns in the present-day systems are phonetically arbitrary. Third, due to complex contact situations as well as internal factors, many sandhi patterns are riddled with variations and exceptions. Advances in phonological theory have allowed some of these problems to be addressed (e.g., variations and exceptions), but recent experimental studies have also shown that traditional tone sandhi descriptions need to be supplemented with more detailed acoustic and psycholinguistic evidence to serve as the empirical basis for theoretical analysis. Another aspect of tone sandhi that is theoretically both informative and challenging is how tone sandhi applies to longer sequences with complex morphosyntactic structures. It is informative to our understanding of phonology-syntax interface, but the derivation of the sandhi patterns is difficult in both rule and constraint-based frameworks.

## GENERAL OVERVIEWS

The works in this section provide general overviews of tone sandhi from empirical patterns to theoretical analysis. They include Ph.D. dissertations (or their published versions) that have both made significant theoretical advances and achieved good typological coverage (Yip 1980/1990, Bao 1990/1999, Duanmu 1990), survey articles (Yip 1995, Zhang 2010), an early classic on tone languages (Pike 1948), a textbook on tone (Yip 2002), and a seminal volume by Matthew Chen (Chen 2000) that provides a comprehensive survey of the patterns of tone sandhi in Chinese languages as well as theoretical issues related to tone sandhi.

Bao, Zhiming. 1999. *The structure of tone*. Oxford: Oxford University Press.  
Revision of his 1990 MIT dissertation "On the nature of tone," incorporating scholarships since then. Includes a discussion of a wide array of tone sandhi patterns in Chinese dialects and how the patterns shed light on the autosegmental nature of tone and its feature-geometric representation.

Chen, Matthew Y. 2000. *Tone sandhi: Patterns across Chinese dialects*. Cambridge, UK: Cambridge University Press.  
Definitive volume on the tone sandhi typology in Chinese dialects and the challenges it poses to phonological theory. Issues discussed include tonal representation, directionality, structure sensitivity, tone sandhi domain, and the relation between tone and accent as well as intonation. Includes a bibliography on tone sandhi classified by dialect groups.

Duanmu, San. 1990. *A formal study of syllable, tone, stress and domain in Chinese languages*. Ph.D. diss., Massachusetts Institute of Technology, Cambridge, MA.  
Argues from a wide range of segmental and tone sandhi processes in Chinese dialects that all syllables in Chinese are bimoraic, the mora is the Tone-Bearing Unit, and there is no contour tone

unit. Also discusses the relation between stress and tone and the issue of tone domain with tone sandhi data from Mandarin and Shanghai.

Pike, Kenneth. 1948. *Tone languages*. Ann Arbor: University of Michigan Press.  
Provides a classification of tone languages into level-tone register and gliding-pitch contour systems, but recognizes that hybrid systems exist. Identifies characteristics of tone (e.g., presence of tone sandhi) that contribute to the difficulties of tonemic analysis and offers methodological guidance. Includes detailed discussions of tone sandhi in Mixteco and Mazateco.

Yip, Moira. 1990. *The tonal phonology of Chinese*. New York: Garland.  
Revision of her 1980 MIT dissertation with the same title. Presents rule-based analyses for the tonology of five Chinese dialects: Mandarin, Shanghai, Amoy, Fuzhou, and Cantonese.

Yip, Moira. 1995. Tone in East Asian languages. In *Handbook of theoretical phonology*. Edited by John A. Goldsmith, 476-494. Oxford: Blackwell Publishers.  
Reviews the typological arguments for various theories of tonal representation focusing on the questions of the Tone-Bearing Unit, the primitive features of tone, and the feature-geometric organization of the primitive features.

Yip, Moira. 2002. *Tone*. Cambridge, UK: Cambridge University Press.  
The only textbook on tone. Covers theoretical mechanisms for tonal analysis couched in Optimality Theory as well as typological properties of tone in different regions of the world. Includes tone sandhi discussions on both Chinese dialects and languages in other parts of Asia and the Americas.

Zhang, Jie. 2010. Issues in the analysis of Chinese tone. *Language and Linguistics Compass* 4.12: 1137-1153.  
Reviews the roles that Chinese tone has played in generative phonology, points out the reasons why theoretical analysis of tone sandhi is challenging, especially for markedness based Optimality Theory, and outlines potential directions in which the studies of Chinese tone can fruitfully proceed.

## **TYPOLOGICAL DESCRIPTIONS**

The works included in this section generally fall under two categories. The first is discussions of universals related to tones in general (Maddieson 1978, Hyman 2007). The second is the typological classification of tone sandhi systems in Chinese dialects (Yue-Hashimoto 1987, Ballard 1988, Chen 1991, Duanmu 1993, Bao 2004, Zhang 2007) and how the theory should be restricted to predict the observed classes (Duanmu 1993, Bao 2004, Zhang 2007). A third type of typological works — those that discuss the classification of the types of tone sandhi rules observed in Chinese dialects and how it bears on the issue of the feature-geometric representation of tone — is listed under Theoretical Analysis: Tonal Representation.

Ballard, William L. 1988. *The history and development of tonal systems and tone alternations in South China*. Study of Languages and Cultures of Asia and Africa Monograph Series No. 22. Tokyo: Institute for the Study of Languages and Cultures of Asia and Africa.  
A comparative typological study of tone sandhi patterns in Southern China, with a particular focus on Wu and Min dialects.

Bao, Zhiming. 2004. Accentualism in Chinese. *Language and Linguistics* 5.4: 863-889.  
Proposes a typology of tone sandhi systems based on whether the sandhi undergoer is confined to its lexical host and whether there is an active sandhi trigger and argues that the typology cannot be derived from the assignment of metrical prominence.

Chen, Matthew Y. 1991. "An overview of tone sandhi phenomena across Chinese dialects." In *Languages and dialects of China, Journal of Chinese Linguistics* monograph series no. 3. Edited by William S.-Y. Wang, 113-158.

Envisions the typology of Chinese tone sandhi systems as occupying various points on an evolutionary continuum from strong-tone languages that have very little sandhi to weak-tone languages in which only one tone melody per word survives. Also discusses the relation between tone sandhi and syntax in Xiamen and Mandarin.

Duanmu, San. 1993. Rime length, stress, and association domains. *Journal of East Asian Linguistics* 2: 1-44.

Classifies Chinese languages into M-languages (Mandarin-type), whose syllables are bimoraic, and S-languages (Shanghai-type), whose syllables are monomoraic, and uses this distinction to capture the different types of tone sandhi observed in the two types of languages.

Hyman, Larry. 2007. "Universals of tone rules: 30 years later." In *Tones and tunes, vol. 1: Typological studies in word and sentence prosody*. Edited by Tomas Riad and Carlos Gussenhoven, 1-34. Berlin: Mouton de Gruyter.

An update of the classic Hyman and Schuh 1974 paper "Universals of tone rules: Evidence from West Africa" (*Linguistic Inquiry* 5: 81-115). Upholds the ubiquity of tonal assimilation and rarity of tonal dissimilation and the preference for rightward spreading. Argues that regressive tonal assimilation is due to special circumstances involving tone attraction to prosodic positions or pressure from intonation at the right edge. Shows that the typology of contour reduction needs to consider both the syllable bearing the contour and its tonal contexts.

Maddieson, Ian. 1978. "Universals of tone." In *Universals of human language, vol. 2: Phonology*. Edited by Joseph H. Greenberg, 335-366. Stanford: Stanford University Press.

Proposes a number of implicational statements in a language regarding tonal inventory, tone rules, and the interaction between tone and non-tone features using data from African, Asian, and American languages.

Yue-Hashimoto, Anne O. 1987. Tone sandhi across Chinese dialects. In *Wang Li memorial volumes, English volume*. Edited by Chinese Language Society of Hong Kong, 445-474. Hong Kong: Joint Publishing Co.

Classifies the tone sandhi systems in Chinese into first-syllable dominant (Northern Wu) and last-syllable dominant (Mandarin, Southern Wu, Min) systems; observes that initial-dominant systems tend to involve rightward spreading of the initial tone, while final-dominant systems tend to undergo local default insertion or contour reduction in nonfinal positions.

Zhang, Jie. 2007. A directional asymmetry in Chinese tone sandhi systems. *Journal of East Asian Linguistics* 16: 259-302.

Refines Yue-Hashimoto's observations into the implicational statements "in a language with bidirectional tone sandhi, if the left-dominant sandhi involves default insertion, so does the right-

dominant sandhi; if the right-dominant sandhi involves tone extension, so does the left-dominant sandhi.” Proposes an Optimality-Theoretic analysis whose factorial typology predicts the implicational statements.

## DESCRIPTIONS OF INDIVIDUAL LANGUAGES

There is a long tradition of descriptive work on tone sandhi in Chinese dialects. Two journals in China — *Fangyan (Dialects)* and *Zhongguo Yuwen (Studies of the Chinese Language)* — routinely publish tone sandhi descriptions by Chinese linguists, especially before 2000. This section includes representative descriptive and phonetic studies on individual dialects from Chinese sources as well as more accessible articles and dissertations written in English, with a particular focus on dialects whose tone sandhi patterns have played important roles in theoretical debates such as tonal representations and tone sandhi domains. Works that include theoretical analyses, but also make important descriptive contributions are listed here as well; but works with a purely theoretical focus using secondary data are listed in separate theoretical sections. Experimental works that are psycholinguistic in nature are also listed separately.

### Mandarin Dialects

This section includes representative references on the tone sandhi patterns of two of the best documented Mandarin (Northern) dialects of Chinese — Mandarin and Tianjin.

#### *Mandarin*

The literature on Mandarin tone sandhi is vast. The works collected here include early classics on Mandarin tone (Dow 1972) as well as on phonology and grammar in general (R. Cheng 1966, Chao 1968, C. Cheng 1973), newer dissertations on Mandarin tone and tone sandhi (Shih 1986, Lin 1996), recent books on Mandarin phonology (Duanmu 2007, Lin 2009), and phonetic descriptions of the tone patterns (Peng 2000). Due to the widely availability of works written in English, I did not include Chinese sources here, without the intention of implying that they are insignificant. But interested readers can find these sources easily from the reference section of the works here and Chen 2000 cited under “General Overviews.”

Chao, Yuen-Ren. 1968. *A grammar of spoken Chinese*. Berkeley: University of California Press. An early classic on the grammar of Mandarin Chinese, with a clear description of the various tone sandhi processes, including the Tone 3 sandhi, Half-Third sandhi, Tone 2 sandhi, and neutral tone sandhi.

Cheng, Chin-Chuan. 1973. *A synchronic phonology of Mandarin Chinese*. The Hague: Mouton. Revision of his 1968 dissertation “Mandarin phonology” (University of Illinois, Urbana-Champaign). Provides a comprehensive SPE-style treatment of Mandarin Chinese phonology including tone sandhi and the realization of the neutral tone.

Cheng, Robert L. 1966. Mandarin phonological structure. *Journal of Linguistics* 2: 135-158. Provides a generative treatment of Mandarin phonemics and morphophonemics, including the representations of tones and Tone 3 sandhi, Half-Third sandhi, and Tone 2 sandhi.

Dow, Francis. 1972. A discussion on tone sandhi problems in Chinese. *Journal of the International Phonetic Association* 2: 13-19.

A description of the Third-Tone sandhi, Half-Third sandhi, and neutral tone sandhi in disyllabic and longer sequences in Mandarin.

Duanmu, San. 2007. *The phonology of Standard Chinese*, 2<sup>nd</sup> edition. Oxford: Oxford University Press.

A comprehensive study of Mandarin phonology, with a particular focus on word formation and its implications for foot formation and stress in Mandarin. Includes a detailed discussion of tones and the Third-Tone sandhi in Mandarin and how the application of the Third-Tone sandhi in long sequences is predictable from syllabic trochaic feet.

Lin, Hua. 1996. *Mandarin tonology*. Taipei: Pyramid Press.

Revised version of her 1992 University of Victoria dissertation entitled "On the nature of Mandarin tone and tone sandhi." Discusses the representations of Mandarin tones and syllables and how the various tone sandhi processes in Mandarin can be accounted for by these representations.

Lin, Yen-Hwei. 2007. *The sounds of Chinese*. Cambridge, UK: Cambridge University Press.

A textbook on the phonetics and phonology of Mandarin Chinese. Includes a detailed discussion of tones, tone sandhi, and the application of the Third-Tone sandhi to long sequences based on Chilin Shih's work.

Peng, Shu-hui. 2000. "Lexical versus 'phonological' representations of Mandarin sandhi tones." In *Language acquisition and the lexicon: Papers in laboratory phonology V*. Edited by Michael Broe and Janet Pierrehumbert, 152-167. Cambridge, UK: Cambridge University Press.

Shows that the Third-Tone sandhi in Taiwan Mandarin involves incomplete neutralization acoustically, but the acoustic difference cannot be reliably perceived by Taiwan Mandarin speakers.

### *Tianjin*

Tianjin is spoken around 70 miles to the southeast of Beijing and is closely related to Beijing Mandarin. Tianjin has a considerably more complex tone sandhi pattern than Mandarin both in disyllables and longer sequences. The works in this section include descriptions of the sandhi pattern (Li and Liu 1985, Shi 1986), a sociophonetic study on the variation and diachronic changes of the sandhi pattern (Shi and Wang 2004), an acoustic study on Tianjin tone sandhi and tonal coarticulation (Zhang and Liu 2011), and a collection on the phonetics and phonology of Tianjin (Lu 2004). Additional works on the analysis of Tianjin tone sandhi can be found under Directionality.

Li, Xingjian and Sixun Liu. 1985. Tianjin fangyan de liandu biandiao (Tone sandhi in the Tianjin dialect). *Zhongguo Yuwen* (Studies of the Chinese Language) 1: 76-80.

Provides a description of Tianjin tone sandhi in di-, tri-, and tetra-syllabic words.

Lu, Jilun, ed., 2004. *Phonetic and phonological studies on Tianjin dialect: Festschrift for Professor Wang Jialing's 70<sup>th</sup> birthday*. Beijing: Beijing Institute of Technology Press.

A collection of articles on the phonetics and phonology of Tianjin, focusing on sociophonetic variation. Notable articles include one by Jing Gao on the disappearance of the T4+T4 sandhi

and one by Jilun Lu on the change of the sandhi tones of the T1+T1 combination from T3+T1 to T2+T1.

Shi, Feng. 1986 Tianjin fangyan shuangzizu shengdiao fenxi (Analysis of disyllabic tones in Tianjin dialect). *Yuyan Yanjiu (Studies in Language and Linguistics)* 1986: 77-90.  
A description of disyllabic tone sandhi in Tianjin using acoustic data from two speakers.

Shi, Feng and Ping Wang. 2004. Tianjinhua shengdiao de xin bianhua (New changes in Tianjin tones). In *The joy of research: Festschrift in honor of Professor William S.-Y. Wang on his 70<sup>th</sup> birthday*. Edited by Feng Shi and Zhongwei Shen, 176-188. Tianjin: Nankai University Press.  
A sociophonetic study on 204 Tianjin speakers showing that a number of the tone sandhi processes are undergoing changes, likely due to the influence of Beijing Mandarin.

Zhang, Jie and Jiang Liu. 2011. *Tone sandhi and tonal coarticulation in Tianjin Chinese. Phonetica* 68: 161-191.

An acoustic study of tone sandhi and tonal coarticulation patterns in Tianjin. Shows that most of the tone sandhi patterns are non-neutralizing, contra traditional descriptions. Discusses recent changes to the sandhi system and variable patterns. Also shows that Tianjin's tonal coarticulation pattern agrees with crosslinguistic tendencies.

## Jin Dialects

The classification of Jin dialects as separate from other geographically adjacent Northern dialects is controversial. Phonologically, Jin dialects have preserved the checked syllables (syllables closed by a stop coda) that other Northern dialects have lost, and they typically have considerably more complex tone sandhi patterns than most Northern dialects. The works in this section include descriptions of the tone sandhi patterns in two representative Jin dialects. The best documented Jin dialect, Pingyao (Hou 1980, 1982a, b), has a structurally sensitive trisyllabic tone sandhi pattern, and Changzhi (Hou 1993) has played a role in the debate regarding the existence of Contour Tone Units due to a tone sandhi pattern that looks like contour assimilation (see Duanmu 1994 vs. Bao 1999 under Theoretical Analysis — Tonal Representation).

Hou, Jingyi. 1980. Pingyao fangyan de liandu biandiao (Tone sandhi in the Pingyao dialect). *Fangyan (Dialects)* 1980: 1-14.  
Describes the disyllabic tone sandhi pattern in Pingyao.

Hou, Jingyi. 1982a. Pingyao fangyan sanzizu de liandu biandiao (Tone sandhi in trisyllabic words in the Pingyao Dialect). *Fangyan (Dialects)* 1982: 7-14.  
Describes the tone sandhi pattern in reduplicative, adjectival, and adverbial trisyllabic words in Pingyao.

Hou, Jingyi. 1982b. Pingyao fangyan guangyongshi sanzizu de liandu biandiao (Tone sandhi in trisyllabic words with a general grammatical structure in the Pingyao Dialect). *Fangyan (Dialects)* 1982: 85-99.  
Describes the tone sandhi pattern in trisyllabic words with other grammatical structures (e.g., verb+object, modifier+noun) in Pingyao.

Hou, Jingyi. 1993. Changzhi fangyan jilüe (A grammatical sketch of the Changzhi dialect). *Fangyan (Dialects)* 1983: 260-275.

A grammatical sketch of the Changzhi dialect including a description of its disyllabic tone sandhi pattern.

## Wu Dialects

Wu dialects arguably provide the most colorful tone sandhi patterns in Chinese. According to Yue-Hashimoto's (1987) taxonomy, Northern Wu dialects such as Shanghai (Sherard 1972, Shen 1981, 1982, Xu et al. 1981, 1982, 1983, Zhu 2006), Suzhou (Ye 1979), and Danyang (Lü 1980) typically exhibit initial dominance and spread the tone of the initial syllable rightward, while Southern Wu dialects such as Wenzhou (Zheng-Zhang 1964) and Wenling (Li 1979) tend to have final dominance and reduce tonal contrasts in nonfinal syllables. But a careful examination of the descriptions indicates that in Northern Wu dialects, initial-dominant and final-dominant sandhis often co-occur and apply to different grammatical structures, e.g., Shanghai and Tangxi (Kennedy 1953), and that tone spreading sometimes requires tone substitution first, e.g., Wuxi (Chan and Ren 1989). Many Wu dialects have played important roles in the debate regarding tonal representation due to the phonetic nature of the sandhi changes attested in them, e.g., Chongming (Zhang 1979, 1980), Wenzhou, Wenling, Danyang, and Suzhou. Ballard (1980) and Rose and Toda (1994) provide overviews of the tone sandhi patterns in Wu.

### *Typological Studies in Wu Tone Sandhi*

The two articles included here discuss typological properties of tone sandhi in Wu dialects.

Ballard, William L. 1980. On some aspects of Wu tone sandhi. *Journal of Asian and African Studies* 19: 83-163.

Provides detailed discussions of tone sandhi in a number of Wu dialects and a comparative/historic analysis of the sandhi patterns. Argues that the phonetic origin of the tone sandhi systems has been lost in diachronic changes and the synchronic patterns are not phonetically based.

Rose, Phil and Takako Toda. 1994. A typology of tone sandhi rules in Northern Wu. In *Current Issues in Sino-Tibetan Linguistics*. Edited by H. Kitamura, 267-273. Osaka: Organising Committee, the 26<sup>th</sup> International Conference on Sino-Tibetan Languages and Linguistics. Provides a typology of tone sandhi rules in Northern Wu including contour spreading, default realization, contour leveling, citation target, and categorical shift.

### *Shanghai*

This section includes references on the tone sandhi of Shanghai — the best documented Wu dialect.

Shen, Tong. 1981, 1982. Laopai Shanghai fangyan de liandu biandiao I, II (Tone sandhi in Old Shanghai I, II). *Fangyan (Dialects)* 1981: 131-144; 1982: 100-114.

A two-part description of tone sandhi in disyllabic and trisyllabic words of different grammatical contexts in the dialect of Shanghai spoken by older generations in the early 1980's.

Sherard, Michael. 1972. *Shanghai phonology*. Ph.D. diss., Cornell University.  
A comprehensive grammar of Shanghai that includes a careful description of tones in monosyllables as well as polysyllabic sequences.

Xu, Baohua, Zhenzhu Tang, and Nairong Qian. 1981, 1982, 1983. Xinpai Shanghai fangyan de liandu biandiao I, II, III (Tone sandhi in new Shanghai I, II, III). *Fangyan (Dialects)* 1981: 145-155; 1982: 115-128; 1983: 197-201.

A three-part description of tone sandhi in different grammatical contexts from disyllables to tetrasyllables in the dialect of Shanghai spoken by younger generations in the early 1980's.

Zee, Eric and Ian Maddieson. 1980. Tones and tone sandhi in Shanghai: Phonetic evidence and phonological analysis. *Glossa* 14: 45-88.

An acoustic description and a rule-based phonological analysis of Shanghai tone sandhi.

Zhu, Xiaonong. 1999. *Shanghai tonetics*. München: Lincom Europa.

A revision of his 1995 Australian National University dissertation with the same title. Provides detailed acoustic analyses for tones in isolation and disyllabic tone sandhi.

Zhu, Xiaonong. 2006. *A grammar of Shanghai Wu*. München: Lincom Europa.

The latest comprehensive grammar of Shanghai that includes a detailed description of its tone sandhi.

#### *Other Wu Dialects*

Descriptions of tone sandhi in other Wu dialects that have played important theoretical roles are included here.

Chan, Marjorie K. M. and Hongmo Ren. 1989. Wuxi tone sandhi: From last to first syllable dominance. *Acta Linguistica Hafniensia* 21: 35-64.

Presents the tone sandhi pattern in Wuxi with a particular focus on pattern substitution. Argues that pattern substitution resulted from the diachronic shift from last to first syllable dominance in Wuxi.

Kennedy, George A. 1953. Two tone patterns in Tangsic. *Language* 29: 367-373.

Describes two tone sandhi patterns in Tangsic (Tangxi): left-dominant sandhi for modifier-noun compounds and right-dominant sandhi for verb-noun phrases.

Li, Rong. 1979. Wenling fangyan de liandu biandiao (Tone sandhi in the Wenling dialect).

*Fangyan (Dialects)* 1979: 1-29.

Provides a detailed description of tone sandhi in disyllabic and trisyllabic words in Wenling.

Lü, Shuxiang. 1980. Danyang fangyan de shengdiao xitong (The tonal system of the Danyang dialect). *Fangyan (Dialects)* 1980: 85-122.

A detailed description of the tonal system of Danyang, with discussion of tone sandhi in different grammatical contexts from disyllables to tetrasyllables.

Rose, Phil. 1990. Acoustics and phonology of complex tone sandhi: An analysis of disyllabic lexical tone sandhi in the Zhenhai variety of Wu Chinese. *Phonetica* 47: 1-35.

An acoustic and auditory description of disyllabic tone sandhi in Zhenhai. The sandhi depends on whether stress falls on the first or second syllable. Second-syllable stress involves paradigmatic tone changes on both syllables; first-syllable stress involves tonal neutralization on the second syllable, but the analysis is not initial spreading.

Ye, Xiangling. 1979. Suzhou fangyan de liandu biandiao (Tone sandhi in the Suzhou dialect). *Fangyan (Dialects)* 1979: 30-46.

A description of tone sandhi in two- to four-syllable words in Suzhou. The first of a series of articles by various scholars on Suzhou tone sandhi published in *Fangyan*.

Zhang, Huiying. 1979, 1980. Chongming fangyan de liandu biandiao; Chongming fangyan sanzizu de liandu biandiao (Tone sandhi in the Chongming dialect; Tone sandhi in trisyllabic words in the Chongming dialect). *Fangyan (Dialects)* 1979: 284-302; 1980: 15-34.

Describes the disyllabic and trisyllabic tone sandhi patterns in different grammatical contexts in Chongming.

Zheng-Zhang, Shangfang. 1964. Wenzhou fangyan de liandu biandiao (Tone sandhi in the Wenzhou dialect). *Zhongguo Yuwen (Studies of the Chinese Language)* 1964: 106-152.

A detailed description of tone sandhi in different grammatical contexts from two- to five-syllable words in Wenzhou.

#### *Tone-Voice Interaction in Wu Dialects*

Finally, Wu dialects are known to have a three-way laryngeal contrasts in obstruents among the voiceless aspirated, voiceless unaspirated, and “voiced.” The “voiced” series, however, is not realized with typical closure voicing, but is known to be “voiceless with voiced aspiration,” especially in initial position. The voicing difference is also concomitant with tonal differences in that voiceless consonants co-occur with the higher *yin* tones on the following vowel, while voiced ones co-occur with the lower *yang* tones. When interacting with tone sandhi, this creates interesting scenarios in which phonological contrasts are cued differently in different contexts. This phenomenon is particularly well studied in Shanghai (Ren 1992, Chen 2010, Wang 2011), but Cao and Maddieson’s (1992) study also includes speakers from other Wu dialects.

Cao, Jianfen. 1992. An exploration of phonation types in Wu dialects of Chinese. *Journal of Phonetics* 20: 77-92.

An acoustic and aerodynamic study of phonation properties of “voiced” and voiceless consonants in four Wu dialects. Shows that the two series may differ in H2-H1, F1-H1, and airflow on the following vowel. In sandhi contexts, the phonation differences are curtailed, but the “voiced” series shows true voicing.

Chen, Yiya. 2010. How does phonology guide phonetics in segment-f0 interaction? *Journal of Phonetics* 39: 612-625.

An acoustic study of f0 perturbation and phonation effects by laryngeal contrasts in non-initial position in Shanghai. Shows that f0 perturbation depends on the tone of the initial syllable, and the H1-H2 difference based on laryngeal contrasts differs according to vowel contexts. Argues that the phonological interaction between tone and voicing and the phonetic consonant production combine to produce the observed effects.

Ren, Nianqi. 1992. *Phonation types and stop consonant distinctions: Shanghai Chinese*. Ph.D. diss., University of California, Los Angeles.

An acoustic, perceptual, and aerodynamic study of phonation and tone in Shanghai. Shows that the “voiced” series has a steeper spectral slope on the following vowel, and the spectral difference is a sufficient perceptual cue for the voicing distinction in medial position. But f<sub>0</sub> contributes to perception as well.

Wang, Yizhi. 2011. *Acoustic measurements and perceptual studies on initial stops in Wu dialects — Take Shanghainese for example*. Ph.D. diss., Zhejiang University, Zhejiang, China.

An acoustic and perceptual study of laryngeal contrasts in Shanghai. Shows that in initial position, vowel f<sub>0</sub> differentiates stop voicing both acoustically and perceptually; medially, voiced and voiceless stops differ in both closure duration and f<sub>0</sub> of the following vowel, but closure duration plays a more important role in perception.

## Min Dialects

The Min dialects of Chinese are spoken to the south of the Wu dialects and typically share with Southern Wu dialects in having complex right-dominant tone sandhi. Two of the best documented Min dialects are the Eastern Min dialect Fuzhou and the Southern Min dialect Xiamen/Taiwanese. In addition to the right-dominant tone sandhi, Fuzhou and some of its neighboring dialects (e.g., Fuqing, Ningde) are also characterized by an interesting set of co-occurrence restrictions between tones and vowels, and Southern Min dialects often exhibit circular chain shifts (“tone circle”) in their tone sandhi.

### *Fuzhou*

This section includes references on the tone sandhi of Fuzhou, an Eastern Min dialect spoken on the northeastern coast of the Fujian province (M. Chan 1985, L. Chan 1998, Jiang-King 1999, Li 2002).

Chan, Lee Lee L. (1998). *Fuzhou tone sandhi*. Ph.D. diss., University of California, San Diego. Provides a detailed description of the tone sandhi patterns in two to four-syllable words as well as longer phrases in Fuzhou. Theoretical proposals include that a stress tier plays an important role in tone sandhi behavior, and the tone sandhi domain is defined within Selkirk’s Prosodic Theory.

Chan, Marjorie K. M. 1985. *Fuzhou phonology: A non-linear analysis of tone and stress*. Ph.D. diss., University of Washington.

An autosegmental treatment of Fuzhou phonology focusing on the relation between tone and stress, tone sandhi domain, and the interaction between tones and vowels.

Jiang-King, Ping. 1999. *An optimality account of tone-vowel interaction in Northern Min*. Ph.D. diss., University of British Columbia.

A formal discussion of the tone-vowel co-occurrence restrictions in Fuzhou and Fuqing. Proposes that both the tone and vowel distributions are due to the moraic make-up of the syllables they belong to.

Li, Zhuqing. 2002. *Fuzhou phonology and grammar*. Springfield, VA: Dunwoody Press.

A grammatical description of Fuzhou with extensive examples of tone sandhi in di- and trisyllabic words.

#### *Xiamen/Taiwanese and Other Southern Min Dialects*

This section includes references on the tone patterns in Xiamen/Taiwanese (Cheng 1968, 1973, Du 1988, Lin 1988) as well as other Southern Min dialects (Wong 1979, S. Zhang 1979, 1980, Z. Zheng 1983).

Cheng, Robert L. 1968. Tone sandhi in Taiwanese. *Linguistics* 41: 19-42.

Describes the Taiwanese tone circle, the occurrence of the neutral tone, tone sandhi domain, and tonal coarticulation.

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

Additional description and analysis of Taiwanese tone sandhi.

Du, Tsai-Chwun. 1988. *Tone and stress in Taiwanese*. Ph.D. diss., University of Illinois, Urbana-Champaign.

Investigates issues in Taiwanese tone sandhi based on both production and perception data. Shows that the domain of tone sandhi is rate-sensitive, and that there is no clear acoustic correlates of stress. Also proposes a feature-based analysis of the tone sandhi pattern.

Lin, Hwei-Bing. 1988. *Contextual stability of Taiwanese tones*. Ph.D. diss., University of Connecticut, Storrs.

An acoustic and perceptual study of tones in both isolation and sandhi contexts in Taiwanese. Shows that acoustically, the f<sub>0</sub> contours of the sandhi tones differ from the corresponding tones in the non-sandhi context, and there is a small perseverative tonal coarticulation effect, but no anticipatory effect; perceptually, f<sub>0</sub> patterns are the primary cue for tonal contrasts, but listeners do not reliably recover the base tone from the sandhi tone in novel word contexts.

Wong, Wee-Lee. 1979. A synchronic phonology of Hainan dialect I, II. *Journal of Chinese Linguistics* 7: 65-100; 268-302.

Describes the synchronic phonology of Hainan, with particular attention to its tonal systems and the literary vs. colloquial pronunciation differences.

Zhang, Shengyu. 1979, 1980. Chaoyang fangyan de liandu biandiao I, II (Tone sandhi in the Chaoyang dialect I, II). *Fangyan (Dialects)* 1979: 93-121; 1980: 123-136.

A two-part description of tone sandhi in disyllables and trisyllables in Chaoyang. Divides the discussion into initial sandhi and final sandhi. Also discusses how the tonal sandhi domain is determined in phrases.

Zhang, Zhenxing. 1983. Zhangping (Yongfu) fangyan de liandu biandiao (Tone sandhi in the Zhangping (Yongfu) dialect). *Fangyan (Dialects)* 1983: 175-196.

Describes the tone sandhi pattern in disyllabic and trisyllabic words in Zhangping.

#### **Yue Dialects**

Yue dialects, spoken primarily in the Guangdong and Guangxi provinces and Hong Kong, are not known to have complex tone sandhi behavior. But a process called “changed tones,” which can derive new morphemes from morphologically related ones by a tone change, is commonly attested. This process is well studied and this section includes works that investigate this process descriptively or phonetically (Whitaker 1955, 1956, Kam 1977, 1980, Wong 1982, Yu 2007) as well as more general works on the phonology of Yue dialects that include a discussion of it (Yue-Hashimoto 1972, Cheng 1973, Bauer and Benedict 1997).

Bauer, Robert S. and Paul K. Benedict. 1997. *Modern Cantonese phonology*. Berlin: Mouton de Gruyter.

A comprehensive description of Cantonese phonology with a discussion of a High Falling to High Level tone sandhi before High Falling or High Level and a very detailed discussion of changed tone morphemes (around 90 pages).

Cheng, Teresa M. 1973. The phonology of Taishan. *Journal of Chinese Linguistics* 1: 256-322. Discusses Taishan phonology, including its changed tones, based on acoustic results.

Kam, Tak Him. 1977. Derivation by tone change in Cantonese. *Journal of Chinese Linguistics* 5: 186-210.

Classifies the morphological tones in Cantonese into four groups based on the tonal category of the derived morpheme and proposes historical origins for a subset of them.

Kam, Tak Him. 1980. Semantic-tonal processes in Cantonese, Taishanese, Bobai, and Siamese. *Journal of Chinese Linguistics* 8: 205-240.

Describes the “changed tone” process in three Yue dialects (Cantonese, Taishan, Bobai) and Siamese (Thai).

Whitaker, Katherine Po Kan. 1955, 1956. A study on the modified tones in spoken Cantonese I, II. *Asia Major, New Series* 5: 9-36, 184-207.

A comprehensive study on changed tones with a long list of examples (Part I) and speculations on their origins and functions (Part II).

Wong, Maurice Kuen-Shing. 1982. *Tone change in Cantonese*. Ph.D. diss., University of Illinois, Urbana-Champaign.

A comprehensive study of changed tone in Cantonese, including its synchronic phonetic realization and phonological analysis, its diachronic origin, a comparative study in related dialects, and the nature of its variation. Argues for a lexical diffusion account for how it originated. Has a list of changed tone morphemes in the appendix.

Yu, Alan C. L. 2007. Understanding near mergers: the case of morphological tone in Cantonese. *Phonology* 24: 187-214.

Shows in an acoustic study that the mid-rising changed tone is incompletely merged with the lexical mid-rising tone in Cantonese and proposes an exemplar-based model for the diachronic change that caused the near merger.

Yue-Hashimoto, Anne O. 1972. *Studies in Yue dialects I: Phonology of Cantonese*. Cambridge, UK: Cambridge University Press.

A description of Cantonese phonology, with a focus on how the synchronic system matches up

with historical initial and rime groups. Has a short description of regular and irregular tone change. Has a bibliography of Cantonese in the appendix.

### **Hakka (Kejia) Dialects**

Hakka (Kejia) dialects are primarily spoken in the Guangdong, Jiangxi, Guangxi, and Fujian provinces of southern China and Taiwan. Its tone sandhi patterns are mostly right-dominant and can be complex. This section includes works that achieve good descriptive coverage of the tone sandhi patterns in these dialects, with a particular focus on Changting (Li 1965, Luo 1982, 2002, Rao 1987), which has the most detailed descriptions and has played an important role in demonstrating the problem that directionality poses for the theoretical analysis of tone sandhi in long sequences (see Chen 2000 under “General Overviews” and Chen 2004 under “Directionality”). Two descriptions of Hakka spoken in Taiwan are also included here (Chung 1989, Hsiao and Chiu 2006).

Chung, Raung-fu. 1989. *Aspects of Kejia phonology*. Ph.D. diss., University of Illinois, Urbana-Champaign.

Provides a detailed description and theoretical analysis of the phonology of a dialect of Kejia spoken in Taiwan. The discussion of tone includes its autosegmental representation, tone sandhi rules, and the interaction between tone sandhi domain and syntax.

Hsiao, Yuchau E. and Yunyi Chiu. 2006. Dongshi Keyu biandiao: san zhi sizizu fenxi (Trisyllabic and tetrasyllabic tone sandhi in Dongshi Hakka). *Language and Linguistics* 7: 455-482. Describes and analyses trisyllabic and tetrasyllabic tone sandhi in a Hakka dialect spoken in Taiwan. Shows that different tones may differ in how tonal domains are determined and the mode of sandhi application; argues for the “indirect reference hypothesis” whereby syntax informs prosodic phrasing, which in turns informs the tone sandhi domain.

Li, Rulong. 1965. Changting hua liangyinjie sanyinjie de liandu biandiao (Disyllabic and trisyllabic tone sandhi in the Changting dialect). *Xiamen Daxue Xuebao (Journal of the Xiamen University)* 1: 57-67.

The first detailed description of disyllabic and trisyllabic tone sandhi in Changting Hakka.

Luo, Meizhen. 1982. Fujian Changting Kejia hua de liandu biandiao (Tone sandhi in the Kejia dialect of Changting, Fujian). *Yuyan Yanjiu (Studies in Language and Linguistics)* 1982: 188-197. Another description of disyllabic and trisyllabic tone sandhi in Changting Hakka. Compared to Li (1965), has additional disyllabic patterns and more discussions of how trisyllabic sandhis are derived from disyllabic sandhis.

Luo, Meizhen. 2002. Fujian Changting hua biandiao guilü buyi (Additional tone sandhi patterns in Fujian Changting). *Yuyan Yanjiu (Studies in Language and Linguistics)* 2002: 91-97.

An addendum to Luo (1982), with discussions of tone sandhi patterns in specific syntactic structures and four-syllable words.

Rao, Changrong. 1987. Fujian Changting (Kejia) fangyan de liandu biandiao (Tone sandhi in the Kejia dialect of Changting). *Zhongguo Yuwen (Studies of the Chinese Language)* 1987: 191-200. Yet another description of tone sandhi in disyllabic and trisyllabic words in Changting Hakka, with generally good agreements with Luo (1982, 2002).

## DIRECTIONALITY

Tone sandhi often applies to sequences longer than two syllables. In Chinese dialects with non-spreading tone sandhi that is also conditioned by adjacent tones, a thorny issue is the directionality of disyllabic sandhi application (left-to-right or right-to-left) in longer sequences, how it interacts with the morphosyntactic structure of the sequence, and its theoretical analysis. Chen (2000) (under General Overviews) devoted two chapters to the directionality issue. This section includes works that focus on the analysis of directionality in Tianjin (Chen 1987, Lin 2008, Milliken et al. 1997, Wee 2010) and Changting Hakka (Chen 2004) — two of the best documented Chinese dialects with the directionality problem, as well as a Tibeto-Burman language Hakha Lai (Hyman 2004). Additional works on the interface between phonology and syntax are listed under “Tone Sandhi and Syntax.”

Chen, Matthew Y., ed. 1987. *Special feature: A symposium on Tianjin tone sandhi*. *Journal of Chinese Linguistics* 15: 203-307.

A collection of articles on the theoretical analysis of tone sandhi in Tianjin, with a particular focus on the directionality of sandhi application, the relevance of morphosyntactic structure, and prosodic domains in longer sequences.

Chen, Matthew Y. 2004. Changting Hakka tone sandhi: Analytical challenges. *Language and Linguistics* 5: 799-820.

Presents the analytical challenges that Changting Hakka trisyllabic tone sandhi poses for both rule-based and constraint-based theories of phonology.

Hyman, Larry. 2004. Directional rule application and output problems in Hakha Lai tone. *Language and Linguistics* 5: 821-861.

Shows that although the disyllabic tone sandhi in Hakha Lai — a Tibeto-Burman language — can be easily accounted for by markedness conspiracies in Optimality Theory, the analysis runs into problems in accounting for tone sandhi in longer words. Argues for a “direct-mapping” analysis, which directly encodes ranked I → O statements.

Lin, Hui-shan. 2008. Variable directional applications in Tianjin tone sandhi. *Journal of East Asian Linguistics* 17: 181-226.

Proposes an analysis of both disyllabic and trisyllabic tone sandhi in Tianjin. The directionality of sandhi application in trisyllabic sequences is accounted for by a combination of markedness considerations and output-output correspondence.

Milliken, Stuart, Guang-Ping Zhang, Xue-Yi Zhang, Zhi-Qiu Li, and Ying Lü. 1997. “Resolving the paradox of Tianjin tone sandhi.” In *Studies in Chinese phonology*. Edited by Jialing Wang and Norval Smith, 53-79. Berlin: Mouton de Gruyter.

Discusses how disyllabic tone sandhi and its cyclic application in trisyllables can both be derived through operations and OCP statements defined on a particular tonal representation.

Wee, Lian-Hee. 2010. A percolative account of Tianjin tone sandhi. *Language and Linguistics* 11: 21-64.

Argues for an Inter-tier Correspondence analysis of trisyllabic tone sandhi in Tianjin, in which a hierarchical prosodic structure is determined by the tones, and corresponding tones on different layers of the prosodic structure are regulated by Inter-tier Faithfulness.

## TONE SANDHI AND SYNTAX

Another important issue in tone sandhi in longer sequences is the light it sheds on the relation between phonology and syntax. The mode of sandhi application is often informative to whether the mapping between prosodic structures and syntactic structures is direct or indirect, and in the case of mismatch between the two, the architecture of the grammar that can predict the mismatch. In addition, tone sandhi behavior may also inform underlying syntactic structure (Simpson and Wu 2002). This section includes works on Mandarin (Shih 1997, Zhang 1997), Shanghai (Selkirk and Shen 1990, Soh 2001), and Taiwanese (Chen 1987, Lin 1994, Soh 2001, Simpson and Wu 2002) as well as typological studies (Hsiao 1991, Zhang 1992) that focus on these questions.

Chen, Matthew Y. 1987. The syntax of Xiamen tone sandhi. *Phonology Yearbook* 4: 109-150. Seminal article on the syntax-phonology interface in Xiamen tone sandhi. Proposes that tone sandhi occurs in nonfinal positions of an XP provided that XP is not an adjunct c-commanding its head.

Hsiao, Yuchau E. 1991. *Syntax, rhythm, and tone: A triangular relationship*. Taipei: Crane. The published version of Hsiao's dissertation from UC San Diego. Based on tone sandhi phenomena in a Mandarin, Taiwanese, and Pingyao, argues for the "indirect reference hypothesis," which states that the phonology-syntax interface is mediated by prosodic structures.

Lin, Jo-wan. 1994. Lexical government and tone group formation in Xiamen Chinese. *Phonology* 11: 237-275.

Proposes an alternative to Chen's (1987) analysis of tonal domain in Xiamen based on lexical government. In this analysis, tone sandhi occurs on nonfinal positions of maximal projections  $X^{\max}$  provided that  $X^{\max}$  is not lexically governed. Extends a similar analysis to tone spreading in Shanghai as well.

Selkirk, Elizabeth and Tong Shen. 1990. "Prosodic domains in Shanghai Chinese." In *The phonology-syntax connection*. Edited by Sharon Inkelas and Draga Zec, 313-337. Chicago: CSLI. Argues that the tone spreading domain in Shanghai is defined by both lower-level Prosodic Words and higher-level Major Phrases, both of which are left-headed.

Shih, Chi-lin. 1997. "Mandarin Third Tone sandhi and prosodic structure." In *Studies in Chinese phonology*. Edited by Jialing Wang and Norval Smith, 81-123. Berlin: Mouton de Gruyter. Describes the application of the Third Tone Sandhi in morphosyntactically complex sequences in Mandarin and proposes a foot formation algorithm to account for the sandhi pattern.

Simpson, Andrew and Zoe Wu. 2002. IP-raising, tone sandhi and the creation of s-final particles: Evidence for Cyclic Spell-Out. *Journal of East Asian Linguistics* 11: 1-45. Proposes that the tone sandhi behavior in Taiwanese provides insights into a movement analysis for the sentence-final particle *kong*.

Soh, Hooi Ling. 2001. The syntax and semantics of phonological phrasing in Shanghai and Hokkien. *Journal of East Asian Linguistics* 10: 37-80.

Argues that the tone sandhi domains in both Shanghai and Hokkien are sensitive to the feature [ $\pm$ definite]; Shanghai marks the left edge, while Hokkien marks the right edge, of all XPs, except [-definite] XPs.

Zhang, Hongming. 1992. *Topics in Chinese phrasal tonology*. Ph.D. diss., University of California, San Diego.

Uses typological data on tone sandhi in syntactically complex strings to argue for the accessibility of syntax to phonology.

Zhang, Ning. 1997. The avoidance of the Third Tone sandhi in Mandarin Chinese. *Journal of East Asian Linguistics* 6: 293-338.

Argues that Mandarin tone sandhi domains are defined based on both syntactic structures and category-specific constituent strength. The unspecified constituent strength in a prepositional phrases allows the Third-Tone sandhi to be avoided on prepositions, but not on other syntactic categories. The tone sandhi behavior is predictable by constraint interaction in Optimality Theory.

## THE RELATION BETWEEN TONE SANDHI AND STRESS

Related to the morphosyntactic dependency in tone sandhi is the relation between the edge dominance of tone sandhi and stress. In dialects with structure-sensitive tone sandhi such as Shanghai and Tangxi (see references under “Wu dialects” above), the edge dominance of the sandhi is often correlated with “nonhead stress”; e.g., disyllabic modifier-noun compounds have stress on the initial syllable and left-dominant sandhi, while disyllabic verb-object phrases have stress on the final syllable and right-dominant sandhi. But the relation is not universal: verb-object phrases in Shanghai have variable left-dominant and right-dominant sandhi depending on lexicality and frequency, and Duanmu (1995) shows that modifier-noun compounds are left-headed in Shanghai and right-headed in Taiwanese. The issue is further compounded by the facts that grammatical stress in Chinese typically has no clear acoustic correlates in duration or pitch due to the tonal nature of the language, and when such correlates can be found, there is often disagreement between the phonetic stress and the edge prominence of tone sandhi. This section includes both typological discussions of the relation between the tonal domain and the metrical domain (Wright 1983, Li 2003) and discussions of individual languages (Chan 1995, Cao 2003, Duanmu 1995).

Cao, Shane Xuexin. 2003. Resolving tension between tone and stress: A two-way model. *Cahiers Linguistiques d’Ottawa* 31: 95-120.

Shows that in the Southern Wu dialect Wenzhou, there is a prosodic mismatch between right-dominance in tone sandhi and initial stress; proposes a derivational metrical analysis for the mismatch.

Chan, Marjorie K.-M. 1995. An autosegmental analysis of Danyang tone sandhi: some historical and theoretical issues. *Wuyu yanjiu (Studies in Wu dialects)*, ed. by Eric Zee, 145-184. Hong Kong: New Asia Academic Publishing.

Proposes a diachronic explanation for the mismatch between the right-dominance in tone sandhi and initial stress in the Northern Wu dialect Danyang: the right-dominant sandhi pattern is a vestige of a historical stage of the language with final stress.

Duanmu, San. 1995. Metrical and tonal phonology of compounds in two Chinese dialects. *Language* 71: 225-259.

Argues from generalizations about the length and ordering of different grammatical components in compounds that modifier-noun compounds have initial stress in Shanghai, but final stress in Taiwanese. The metrical prominence in these two dialects agrees with the dominant edge in tone sandhi.

Li, Zhiqiang. 2003. *The phonetics and phonology of tone mapping in a constraint-based approach*. Ph.D. diss., Massachusetts Institute of Technology, Cambridge, MA.

Argues that the analysis of Chinese tone sandhi patterns needs to recognize two types of prominence: peripheral prominence and metrical prominence. The dual-prominence theory can account for languages in which stress agrees with the position of tonal preservation like Yantai and Xiamen as well as languages in which they diverge, like Zhenhai and Wenzhou.

Wright, Martha. 1983. *A metrical approach to tone sandhi in Chinese dialects*. Ph.D. diss., University of Massachusetts, Amherst.

A typological study on the relation between tonal domains and metrical domains. Argues that weakly stressed syllables have shortened duration, which causes the loss of tonal contrasts.

## **THEORETICAL ANALYSIS**

Tone sandhi has presented considerable challenges to theoretical phonology. Pre-OT theoretical analysis of tone sandhi has focused on the issue of tonal representation and how an appropriate formulation of it allows the correct predictions on the typology of tone sandhi patterns to be made. In the OT era, the representation issue somewhat receded to the background and replaced by how the interaction of markedness and faithfulness could lead to correct base-tone and sandhi-tone mappings. But the phonetic arbitrary nature of many tone sandhi patterns thwarted the theoretical progress in both areas. This section includes works that have contributed to the discussion of tonal representation based on tone sandhi and attempts at Optimality-Theoretic analysis of tone sandhi patterns. Additional theoretical works can also be found under "Directionality," "Tone Sandhi and Syntax," and "The Relationship between Tone Sandhi and Stress."

### **Tonal Representation**

The issue of tonal representation is highly contentious. It typically revolves around the following questions. (a) What is the Tone-Bearing Unit? (b) What are the primitive features of tone? (c) Are contour tones represented by unitary features or sequences of level features? (d) If there are different layers of tonal features such as Register (representing the overall pitch height) and Contour (representing TBU-internal pitch change), what is the geometric relation among the features — independence, dominance, or sisterhood? The works in this section provide different answers to these questions. Wang 1967 and Woo 1969 are before autosegmental phonology and both treat tone features as segmental features. But they differ in whether contour features are primitives. Tsay 1994 considers tone to be represented with a single multivalued feature whose value can range from 1 to n. The rest of the works assumes a feature-geometric structure for tonal representation and recognizes separate Register and Contour tiers. Yip 1989, 1990, Chen 1996, and Bao 1990 all consider the syllable to be the Tone-Bearing Unit and treat contour tones

as units, but differ in what they think is the relation between Register and Contour. Duanmu 1994 considers the mora to be the Tone-Bearing Unit and treats contour tones as level concatenations. The discussion of the formal representation of tone seems stymied, likely for two reasons. First, the impressionistic tonal transcriptions that theorists use are easily open to reinterpretation according to any theoretical position. Second, due to tone's diachronic malleability, the synchronic tone sandhi patterns are often phonetically arbitrary. This makes the practice of using particular phonetic realizations of sandhi patterns as arguments for tonal representation suspect. More fruitful approaches to tonal representation are likely found in phonetic and psycholinguistic studies. See citations under "Phonetic and Psycholinguistic Studies" for details.

Bao, Zhiming. 1999. *The structure of tone*. Oxford: Oxford University Press.

Argues that the typology of tone sandhi patterns in Chinese dialects can be best accounted for by a representation of tone that treats both Register and Contour as daughter nodes of the Tone-Bearing Unit — the syllable.

Chen, Matthew Y. 1996. "Tonal geometry — a Chinese perspective." In *New Horizons in Chinese Linguistics*. Edited by C.-T. James Huang and Y.-H. Audrey Li, 49-95. Dordrecht: Kluwer Academic Publishers.

Argues that in Chinese, Register dominates Contour in the tonal representation as this representation better captures the typological properties of Chinese tone sandhi. This is the same position as Yip 1989.

Duanmu, San. 1994. Against contour tones. *Linguistic Inquiry* 25: 555-608.

Argues against contour tone units by refuting or reanalyzing tone sandhi cases that have been suggested to necessitate such units, e.g., contour tone dissimilation in Tianjin and contour tone spreading in Changzhi and Danyang (cf. Yip 1989). The Tone-Bearing Unit is therefore the mora, not the syllable.

Tsay, Suhchuan Jane. 1994. *Phonological pitch*. Ph.D. dissertation, University of Arizona.

Uses tone sandhi in Chinese dialects as well as tone rules elsewhere to argue for a representation of tone in which tone is represented with a single multivalued feature (Pitch) whose value can range from 1 to n, where n is a language-specific number with no universal upper limit.

Wang, William S.-Y. 1967. Phonological features of tone. *International Journal of American Linguistics* 33: 93-105.

Analyzes tone sandhi in Taiwanese; argues for contour features such as [rise], [fall] as primitive tone features.

Woo, Nancy. 1969. *Prosody and phonology*. Ph.D. diss., Massachusetts Institute of Technology, Cambridge, MA.

Establishes a framework of distinctive features for tone. Proposes that contour tones are concatenations of tone levels and [high], [low], and [modify] are primitive tone features. Applies the framework to the tone sandhi phenomena of a number of Chinese dialects.

Yip, Moira. 1990. *The tonal phonology of Chinese*. New York: Garland.

Argues for a representation of tone that includes an independent Register tier in addition to a Contour tier that specifies Hs and Ls with data from a variety of Chinese dialects.

Yip, Moira. 1989. Contour tones. *Phonology* 6: 149-174.

Argues that Register and Contour are in a dominance relation and contour tone units exist, with support from tone sandhi behavior in both Chinese dialects and other languages. This is a revised position from Yip 1990, which is based on her 1980 dissertation. Yip 1990 considers Register and Contour to have an independent relation.

## Optimality Theory

Optimality Theory brought to the forefront the issues of markedness and constraint interaction, and many attempts have been made to analyze the tone sandhi patterns in Chinese dialects and elsewhere using OT. But these attempts have only been met with limited enthusiasm in the field. Many scholars remain unconvinced that OT is an appropriate model for complex sandhi processes and synchronic analysis remains lacking for many sandhi systems. A major reason for the limited success in constraint-based analyses of tone sandhi patterns is the phonetic arbitrariness that permeates present-day sandhi systems. Consequently, if we look for generalizable markedness constraints that OT relies on for the synchronic analysis of tone sandhi, we tend not to get very far. But typological generalizations do exist, and the works cited here have capitalized on these generalizations in their constraint-based analyses. Yip (2004), J. Wang (2002), Barrie (2006), and X. Wang (2009) represent OT analyses of tone sandhi in individual languages, and Yip (1999) and Li (2003) offer typological perspectives. Barrie (2006), in particular, proposes an OT solution for the circular chain shifts in Xiamen based on contrast preservation, and both Yip (1999) and Yip (2004) point to the importance of tonal allomorph listing for tone sandhi in prosodically weak positions. Proposals on how markedness should be treated in constraint-based analysis of tone sandhi systems and how Optimality Theory can potentially provide a better model for variable sandhi behavior are discussed in works cited under "Phonetic and Psycholinguistic Studies." Additional OT analyses of tone sandhi directionality and tone sandhi-syntax interface are given in the relevant sections above.

Barrie, Michael. 2006. Tone circles and contrast preservation. *Linguistic Inquiry* 37.1: 131-139. Proposes an analysis for the Xiamen tone circles based on contrast preservation: the neutralization of tone features such as register and contour is penalized by a contrast preservation constraint, which interacts with other markedness constraints such as \*RISE, \*CONTOUR, and \*HIGH to predict the circular chain shifts.

Li, Zhiqiang. 2003. *The phonetics and phonology of tone mapping in a constraint-based approach*. Ph.D. diss., Massachusetts Institute of Technology, Cambridge, MA. Proposes a dual-prominence theory of tone sandhi couched in OT that predicts a range of relations between metrically prominent positions and positions that preserve the base tones.

Wang Jialing. 2002. Youxuanlun he Tianjinhua de liandu biandiao ji qingsheng (Optimality Theory and tone sandhi and neutral tone in the Tianjin dialect). *Zhongguo Yuwen (Studies of the Chinese Language)* 2002.4: 363-371.

An OT analysis of tone sandhi in disyllables, including disyllables with a neutral tone on the second syllable, in Tianjin.

Wang, Xiaomei. 2009. *Guangxi Rongshui Eihua shengdiao xingcheng de youxuanlun fenxi* (An Optimality-Theoretic analysis of tone patterns in the Eǎ language of Rongshǎ, Guangxi). Ph.D. diss., Nankai University, Tianjin, China.

Based on original fieldwork, proposes an OT analysis for the tone sandhi patterns in five dialects of the Eǎ language spoken in Guangxi — a Kam-Tai (Zhuang-Dong) language that has absorbed many Chinese properties due to contact.

Yip, Moira. 1999. Feet, tonal reduction and speech rate at the word and phrase level in Chinese. In *Phrasal Phonology*. Edited by Rene Kager and Wim Zonneveld, 171-194. Nijmegen: Nijmegen University Press.

Offers a positional-faithfulness-based OT analysis of the cross-dialectal pattern of tone sandhi in non-head syllables and non-head feet as well as the variation in foot size.

Yip, Moira. 2004. Phonological markedness and allomorph selection in Zahao. *Language and Linguistics* 5.969-1001.

Provides an Optimality-Theoretic analysis of disyllabic tone sandhi in Zahao, a Chin language spoken in Burma, and argues that the sandhi allomorphs must be listed in the lexicon, but the choice of the allomorph in a given environment is predicted by markedness.

## PHONETIC AND PSYCHOLINGUISTIC STUDIES

The phonetic arbitrariness of synchronic tone sandhi patterns not only makes it difficult to use such patterns to argue for a particular tonal representation, but also makes markedness-based analyses of them difficult. But considerable progress has been made in our understanding of the phonetics and processing of Chinese tone, which sheds light on the tonal representation issue, and psycholinguistic studies on the processing of tone sandhi and the productivity of tone sandhi patterns in novel words further inform us about the nature of the base and sandhi tone mapping in phonological grammar. This section focuses on these studies and discusses briefly how and why they are fruitful approaches to our understanding of tone sandhi patterns.

### Experimental Studies that Shed Light on Tonal Representation

In a large body of work on the nature of timing and coarticulation of Mandarin tones in different syllable types and speaking rates, Xu and colleagues show that (a) contextual tonal variations are better accounted for by asymptotic approximations of tonal targets that include both static and dynamic targets rather than static targets alone, (b) when the duration of a syllable carrying a contour tone increases due to a slower speech rate, the dynamic portion of the contour shifts to the later part of the syllable, thus keeping the contour target relatively constant, and (c) the critical points within a tone, such as the f<sub>0</sub> peak for a rise and the f<sub>0</sub> valley for a fall, are closely aligned with edges of the syllable. Xu and colleagues hence argue in their Target Approximation model that the underlying units for contour tones consist of dynamic targets such as [rise] and [fall] with a linear movement specification, and the entire syllable, regardless of its segmental composition, is the TBU. Representatives of Xu's work on both the empirical findings (Xu 1998, 2001) and discussions of the model (Xu 2005, Prom-on et al. 2009) are included here. Xu's view on the unit nature of contour tones is supported by Wan and Jaeger's (1998) speech error study on Taiwan Mandarin tones. Although these works do not directly address tone sandhi, they provide more direct evidence for tonal representation than tone sandhi can and are therefore included here.

Prom-on, Santitham, Yi Xu, and Bundit Thipakorn. 2009. Modeling tone and intonation in Mandarin and English as a process of target approximation. *Journal of the Acoustical Society of America* 125. 405-424.

A quantitative implementation of the PENTA model in Xu (2005). Shows that the model using parameters obtained through supervised learning makes good f0 predictions when it is used to simulate the prosody of Mandarin and English.

Wan, I-Ping and Jeri Jaeger. 1998. Speech errors and the representation of tone in Mandarin Chinese. *Phonology* 15: 417-461.

Reports speech errors in Taiwan Mandarin tone. Finds that tonal errors are characterized by a predominance of whole-tone substitution, a lack of tone splitting or hybrid tones in word-blend and telescoping errors, and a lack of errors that must be accounted for by register or tone feature spreading.

Xu, Yi. 1998. Consistency of tone-syllable alignment across different syllable structures and speaking rates. *Phonetica* 55. 179-203.

Shows that the alignment of f0 contours to syllables in Mandarin is consistent regardless of syllable type or speaking rate and argues that syllable is the proper domain for tone implementation and that tone contours are implemented as dynamic targets rather than combinations of static targets.

Xu, Yi. 2001. Fundamental frequency peak delay in Mandarin. *Phonetica* 58: 26-52.

Investigates the f0 peak delay in the Rising and High tones in Mandarin in different speaking rates and shows that the peak delay pattern can be accounted for by a model in which the pitch targets can be either static or dynamic, and the targets are implemented asymptotically from one to the next.

Xu, Yi. 2005. Speech melody as articulatorily implemented communicative functions. *Speech Communication* 46. 220-251.

A qualitative discussion of the parallel encoding and target approximation (PENTA) model of speech melody, whose crucial elements include four primitives of speech melody — local pitch targets (static or dynamic), pitch range, articulatory strength, and duration — and a syllable-synchronized target approximation articulatory process.

## **Experimental Studies on Tone Sandhi Productivity and Processing**

Another aspect of tone sandhi worth investigating experimentally is the productivity of the sandhi patterns under nonce-probe tests (“wug” tests). This type of investigation serves at least two purposes. First, it tests whether the complex sandhi processes observed in the language’s lexicon are truly productive. Recent phonological research has shown that phonological learning can be characterized by both “the poverty of the stimulus” and “the surfeit of the stimulus,” and native speakers’ phonological knowledge is not necessarily identical to the lexical patterns. A series of works of Taiwanese, for example, has shown that the opaque tone circle is not fully productive (Hsieh 1970, 1975, 1976, Wang 1993, Zhang et al. 2011), indicating that the analysis for the sandhi pattern likely should not be in the form of UR to SR derivation, but lexical or allomorph listing. Second, although markedness universals are hard to come by in tone sandhi, while phonetically unexpected patterns are ubiquitous, it is possible that markedness principles are encoded as analytical biases in the learning process that favor patterns with strong phonetic

bases. To test the analytical bias hypothesis in tone sandhi, we can investigate whether the productivity of a sandhi pattern in novel words is positively correlated with the phonetic naturalness of the sandhi. Zhang and Lai (2010) use this line of reasoning and test the productivity difference between the Third-Tone sandhi and the Half-Third sandhi in Mandarin and argue for both the relevance of phonetics in synchronic grammar and the lexicality of existing T3 Sandhi words. Zhou and Marslen-Wilson's (1997) auditory priming study involving T3 sandhi words in Mandarin partially supports the view that these words are represented in their surface tones.

Hsieh, Hsin-I. 1970. "The psychological reality of tone sandhi rules in Taiwanese." In *Papers from the 6<sup>th</sup> Meeting of the Chicago Linguistic Society*. Edited by M. A. Campbell, 489-503. Chicago: Chicago Linguistic Society.

Tests the productivity of tone sandhi in disyllabic and trisyllabic words in Taiwanese using wug tests. Shows that in disyllables, provided that the first syllable is an accidental gap in the Taiwanese syllabary, the majority of the responses involved non-sandhi-application. In trisyllables, subjects also applied the sandhi inconsistently even though the first two syllables are existing syllables of Taiwanese.

Hsieh, Hsin-I. 1975. "How generative is phonology." In *The transformational-generative paradigm and modern linguistic theory*. Edited by E. F. Koerner, 109-144. Amsterdam: John Benjamins.

Shows that (a) native speakers could not reliably apply or undo tone sandhi in tetrasyllabic novel words, and (b) in a wug test using trisyllabic words with three children aged 5, 7, and 9, and an adult, the rate of correct sandhi application increased with age. Argues that juncture forms and sandhi forms gradually become listed in the lexicon during acquisition.

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

Shows that when a speaker of a coastal dialect of Taiwanese learned the Inland dialect, which has the same lexical tones, but different sandhi behavior, the sandhi tones she produced varied on a morpheme-by-morpheme basis between the coastal and Inland forms. Supports a "surface-forms-too" model of the lexicon.

Wang, H. Samuel. 1993. Taiyu biandiao de xinli texing (On the psychological status of Taiwanese tone sandhi). *Tsinghua Xuebao (Tsinghua Journal of Chinese Studies)* 23: 175-192.

In a six-month longitudinal study in which 32 Taiwanese speakers were asked to produce novel noun-noun compounds in a sentential context, shows that speakers applied the sandhis around 50% of the time and had a slight improvement over the course of the study, and that the accuracy of the sandhi application is strongly correlated with the base tone. Supports a lexical, not rule-based, analysis of Taiwanese tone sandhi.

Zhang, Jie and Yuwen Lai. 2010. Testing the role of phonetic knowledge in Mandarin tone sandhi. *Phonology* 27: 153-201.

Investigates the productivity difference between the Third-Tone sandhi and the Half-Third sandhi in Mandarin and shows that the former applies less productively in novel words than the latter in wug-tests. Argues that the results support the analytical bias approach to phonetically based markedness as the Half-Third sandhi has a stronger phonetic basis than the Third-Tone sandhi.

Zhang, Jie, Yuwen Lai, and Craig Sailor. 2011. Modeling Taiwanese speakers' knowledge of tone sandhi in reduplication. *Lingua* 121: 181-206.

Tests Taiwanese speakers' application of tone sandhi in novel reduplications and shows that the sandhi accuracy is influenced by whether the sandhi is phonotactically opaque or transparent, the phonetic nature of the sandhi, and the lexical frequency of the base tone. Also proposes a Maximum Entropy learning model for the tone sandhi pattern.

Zhou, Xiaolin and William Marslen-Wilson. 1997. "The abstractness of phonological representation in the Chinese mental lexicon." In *Cognitive Processing of Chinese and Related Asian Languages*. Edited by Hsuan-Chih Chen, 3-27. Hong Kong: The Chinese University Press.

Compares three views on the lexical representations of T3 Sandhi words in Mandarin: canonical representation, (cai[3] qu[3]), surface representation (cai[2] qu[3]), and abstract representation (cai qu[3]). In two auditory priming experiments using disyllabic words with T3 Sandhi as either the target or the prime, shows that the results are partially consistent with the surface representation view and partially consistent with the canonical representation view.

## THE ACQUISITION OF TONE SANDHI

Children's acquisition of tone sandhi systems is understudied, and what we know is limited to a few major dialects of Chinese. This section includes a number of published sources as well as MA theses and Ph.D. dissertations that provide information about tone sandhi acquisition in Mandarin (Li and Thompson 1977, Zhu and Dodd 2000, Wang 2011), Taiwanese (King 1980, Hsu 1989), and Cantonese (J. Tse 1978, S. Tse 1982). It is hoped that future research will fill the gap of this understudied area and shed light on the acquisition of other types of complex tone sandhi systems.

Hsu, Hui-Chuan. 1989. *Phonological acquisition of Taiwanese: A longitudinal case study*. MA thesis, National Tsing Hua University, Taiwan.

A 1.5-year longitudinal study of a child's phonological acquisition of Taiwanese, starting from the age of 1;4. Shows that the child made tone sandhi mistakes in sandhi contexts and proposes an order of acquisition for the different tone sandhi processes in Taiwanese.

King, Brian. 1980. *The acquisition of tone in Taiwanese*. MA thesis, Fu Jen University, Taiwan. In a longitudinal study of five Taiwanese speaking children aged one to three, shows that children at the two-word stage still made mistakes in tone sandhi by confusing base and sandhi tones in the non-sandhi context and using the wrong sandhi tones in the sandhi context.

Li, Charles N. and Sandra A. Thompson. 1977. The acquisition of tone in Mandarin speaking children. *Journal of Child Language* 4.2: 185-199.

Reports the tonal acquisition of 17 Mandarin speaking children from 1;6 to 3;0 in Taiwan. Finds that both the Third-Tone sandhi rule and the Half-Third sandhi rule were acquired with few errors as soon as the children's multiword utterances began, but the Half-Third sandhi rule was acquired earlier than the Third-Tone sandhi rule.

Tse, John Kwok-Ping. 1978. Tone acquisition in Cantonese: A longitudinal case study. *Journal of Child Language* 5.2: 191-204.

Reports a longitudinal study of the tonal acquisition of a Cantonese-speaking child up to the age of 2;8. Finds that the 53 → 55/ \_\_ {53, 5} sandhi rule reported in the Cantonese literature did not exist for the child.

Tse, Sou-Mee. 1982. *The acquisition of Cantonese phonology*. Ph.D. diss., The University of British Columbia, Vancouver.

Reports the acquisition of phonology by three Cantonese speaking children, with a short discussion of tone, tone sandhi, and “change tones.” Supports J. Tse’s observation on the lack of the 53 → 55 sandhi rule.

Wang, Chiung-Yao. 2011. *Children’s acquisition of Tone 3 sandhi in Mandarin*. Ph.D. diss., Michigan State University, East Lansing, MI.

In a series of production and repetition experiments with children with the age of 3-6, shows that it takes time for children to acquire how to set up the tone sandhi domain and reach adult-like mastery of the interaction between cyclic and non-cyclic application of Tone 3 sandhi, especially in sequences with complex morphosyntactic structures.

Zhu, Hua and Barbara Dodd. 2000. The phonological acquisition of Putonghua (Modern Standard Chinese). *Journal of Child Language* 27: 3-42.

Reports a cross-sectional study on the phonological acquisition of 129 Mandarin-speaking children aged 1;6 to 4;6. Shows that tones were acquired early with few errors, and tone sandhi errors were only observed in the two younger age groups, but recognizes that this could be due to learning the sequences as single words.