

PITCH CONTOUR FORMATION IN MANDARIN CHINESE:

A STUDY OF TONE AND INTONATION

DISSERTATION

Presented in Partial Fulfillment of the Requirement for  
the Degree Doctor of Philosophy in the Graduate  
School of the Ohio State University

BY

Rongrong Liao, B.A., M.A.

\* \* \* \* \*

The Ohio State University

1994

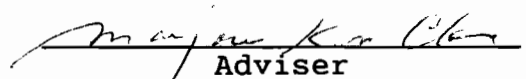
Dissertation Committee:

Marjorie K.M. Chan

James H.Y. Tai

Keith Johnson

Approved by

  
Adviser

Department of East Asian  
Languages and Literatures

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To My Family

## ACKNOWLEDGMENTS

I am indebted to Marjorie K.M. Chan for her persistent guidance in this dissertation. She faithfully advised me on my graduate study at the Ohio State University which lead to my successful completion of this study. Also, she was fundamental in providing important information on research in this area of study. Moreover, she introduce me to the necessary equipment to conduct the major experiment of this study.

I am also grateful for the encouragement of the other members of my dissertation committee. Professor James Tai assisted me to view my work from the perspective of closely related fields. Professor Keith Johnson carefully read this work and provided valuable comments.

Although not on my committee, Professor Mary E. Beckman generously helped in the design of an experiment within this paper and in providing Laboratory facilities used in part of the experiment. Professor Robert A. Fox provided me generous support important to the completion of the present work.

I thank Professor Feng Shi and his colleagues of the Phonetic Lab of NanKai University in Tianjing, China. In 1991, with the use of Visi-pitch, they performed experiments of selected tape recordings which contained each type of designed and spontaneous speech. From the experimental data, I was able to derive a general analysis of tonal phenomena in Mandarin Chinese before conducting further experiments with CECIL.

I thank my editor, Laura Dowd who helped make my ideas more fluent and coherent.

I am grateful to my friends and family for their moral support.

## VITA

- 1976                      B.A. Chinese Literature, Teacher's University of Inner Mongolia, Huhehote, China
- 1982                      M.A. Chinese Linguistics, People's University of China, Beijing, China
- 1982-86                  Asistant professor, People's University of China, Beijing, China
- 1988                      M.A. Linguistics, University of California, Los Angeles, California
- 1991                      M.A. Chinese Linguistics, the Ohio State University, Columbus, Ohio
- 1992-94                  Visiting Instructor, University of Iowa Iowa City, Iowa

## PUBLICATIONS

*Yuyin Conggao* (Papers in Phonetics) (in cooperation with Shi Feng). Beijing Language Institution, 1994.

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#### FIELDS OF STUDY

Major Field: East Asian Languages and Literatures

Studies in Chinese Phonetics, Phonology,  
and Dialectology.

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## LIST OF SYMBOLS

According to the Scheme for the Chinese Phonetic Alphabet in Chinese-English Dictionary (1980), phonetic elements in Pinyin romanization is transcribed in International Phonetic Alphabet.

	Pinyin Romanization	International Phonetic Alphabet
Consonants:	b	p
	p	p <sup>h</sup>
	m	m
	f	f
	d	t
	t	t <sup>h</sup>
	n	n
	l	l
	g	k
	k	k <sup>h</sup>
	h	x
	j	tɕ
	q	tɕ <sup>h</sup>
	x	ɕ
	z	ts
	c	ts <sup>h</sup>
	s	s
	zh	tʃ
	ch	tʃ <sup>h</sup>
	sh	ʃ
	r	ʐ
	w	w
	y	j
	ng	ŋ
Vowels:	a	a, ɑ, æ, e
	o	ɔ, o
	e	e, ə, ɤ
	i	i, ɪ, ɿ
	u	u
	ü	y

## LIST OF ABBREVIATIONS

Abbreviation	Full Terms
ASP	aspect marker
CL	classifier
M	measure word
PART	particle
PERF	perfect marker
V	verb

## CHAPTER I

### INTRODUCTION

The aim of this dissertation is two-fold: to describe the prosodic hierarchy of Mandarin Chinese and to discover the rules that govern the formation of surface tonal contours of the prosodic hierarchy. A qualitative analysis is conducted based on the phonetic experiments of both tonal controlled and uncontrolled speech in different styles. This analysis relates phonetic aspect of tonal phenomena in Mandarin Chinese with the corresponding aspect of phonology.

The description of tones on isolated syllables or short phrases of Mandarin have attracted the interests of scholars for many years (Chao 1930, 1968). Most experimental analyses support this phonological description (Wang 1967, Howie 1976, J. Shen 1985, Wu 1986, Kratochvil 1986). However, tonal phenomena found in connected spontaneous Mandarin speech are discovered highly unpredictable by experimental studies (Tseng 1981, Kratochvil 1986); thus the predictive capability of relative phonological description is questioned.

The phonological description of tonal events in Mandarin speech is closely related to the study of prosodic structures (Chen 1979, 1980, 1984, 1990; Shih 1986; Zhang 1988). These studies which have been conducted based on theories of Autosegmental Phonology (Goldsmith 1976, 1990), Metrical Phonology (Liberman & Prince 1977, Hayes 1981, 1984) and Prosodic Phonology (Kaisse 1985, Selkirk 1984, 1986, 1990). Also, the Domains in which tones interact have been defined according to metrical and syntactic relations. Surface tones have been mechanically created in the testing sentences. The unexpected tonal phenomena, which are used to be unknown, indicates that phonological rules for both prosodic phrasing and tonal variation in connected Mandarin speech need reconsideration.

Most previous phonological and phonetic studies of Chinese tonal or intonational phenomena are based on data from carefully designed and formal speech. Style difference is usually neglected in the design, and few studies account for the pragmatic, non-linguistic and other known or unknown effects. In fact, data from spontaneous speech has never been used to discover rules rather than to detect problems in the available description.

Phonological researches of non-tone languages, such as English and Japanese, define prosodic constituents according to phonetic aspects, i.e. F0 contours of intonational

patterns (Pierrehumbert 1980, Beckman & Pierrehumbert 1986). This approach shed light on tonal and intonational analysis of Mandarin. The present thesis proposes to relate prosodic constituents in Mandarin with surface information of speech including not only F0 forms, but also stress pattern and other phonetic information of the utterance. The prosodic hierarchy of Mandarin is proposed as follows.

(1)	Prosodic levels	Tonal constituents
	-----	-----
	(Higher Levels)	(Group of Intonations)
	Intonational Phrase	Intonation
	Intermediate Phrase	Tune
	Prosodic Word	Tone

Since Mandarin is a tone language, most of its syllables have underlying tones with specific heights and shapes. Surface pitch contour formation in Mandarin speech is more complex than in non-tone languages. However, there has not yet been a comprehensive interpretation of how surface forms of tonal or intonational contours are realized in the whole course of a Mandarin utterance. This thesis provides a descriptive analysis of pitch contour formation in connected Mandarin speech. The fundamental conviction of this study is that there exist general principles which govern pitch movement in utterance of any style and length.

The first hypothesis concerns the existence of an tacit but important factor which strongly conditions surface pitch contour realization: the tendency of pitch undulation. The fact that pitch tends to undulate within a given range is crucial to the interpretation of many unpredictable tonal phenomena. As emphasized by Pierrehumbert and Beckman (1988) that in the spirit of the first expositions of generative theory of phonology (Jakobson, Fant, and Halle 1952, Halle 1964), phonological structure is viewed as being rooted in human physical and psychophysical capabilities. The explanation to the tendency of pitch undulation refers to the physical constraints of tonal production in speech.

The second hypothesis concerns a principle of pitch contour formation in intermediate phrases. This principle accounts for the factors which condition surface tonal realization at intermediate level. An intermediate phrase is the domain of tonal interaction, or in a broad sense, the domain of tone sandhi.

Previous phonological and phonetic studies of Mandarin tonal phenomena refer to the effect of degrees of stress (Chao 1968, Yip 1982, Zhang 1988, S. Shen 1990). Some of these studies treat stress as the only factor which influences surface realization of tones. However, this is only partially true. This thesis provides evidence that the

surface realization of tones is only partially conditioned by stress pattern, or the strength of prosodic constituents at each level. However, other factors also play important roles in tonal realization. These factors include the occurrence and order of tones, the undulatory tendency of pitch movement, and underlying height of pitch range for each prosodic constituent at different levels.

The nature of one of the four lexical tones in Mandarin, i.e. the Third Tone (T3), has been discussed frequently. Many studies prefer to select the low variant as the basic T3 (Hartman 1944; Hockett 1947; Woo 1969; Kratochvil 1968, 1986; J. Shen 1985; Shih 1986). This thesis provides experimental data of sequences of T3's which exhibit fixed patterns of pitch contours in intermediate phrases. The previous phonological rules did not predict this fixed patterns. Also the experimental data reflects unusual T3 reaction to stresses. Tone sandhi normally occurs in relatively weakly stressed or unstressed syllables, but T3 sandhis often occur in strongly emphasized syllables. This thesis assumes that the T3 is basically a low falling tone, and there is physical constraints of tonal production that cause T3 to behave in unusual manner in certain situation. because of the same physical constraints, a T3 requires both preceding and proceeding high targets to create and release muscle tenseness for its production.

Based on experimental evidence, this thesis also proposes that the principle of pitch contour formation in intermediate phrases is often overridden by factors at different prosodic levels. At the level of intermediate phrase, the above mentioned physical constraints of T3 production overrides this principle. In addition, strong emphasis at the intonational level overrides the function of this principle in intermediate phrases that proceeding the emphasis. The effect of fast speech rate and/or large pitch range from the different levels also may override the principle. All of these interactions between the different factors and the principle influence pitch contour realization in Mandarin speech.

Also the effect of catathesis is examined in this thesis. Catathesis has been found as an phenomenon in many languages (Schachter and Fromkin 1968, Meyers 1976, Clement and Ford 1979, Liberman and Pierrehumbert 1984, Beckman & Pierrehumbert 1986, Shih 1986). Although the effect of catathesis in Mandarin does not change the overall pattern of pitch contours, it does, though, affect the quantitative aspects of the shape of pitch forms.

There is a long-standing issue about the relationship between Mandarin tones and intonations. However, the dual use of the F0 contour tends to complicate the relationship. The most frequently adopted definition treats a Mandarin



intonation as a curved band of pitch range (Chao 1933, 1968; Chang 1958; De Francis 1963; Kratochvil 1968; Gåding 1983, 1984, 1987; J. Shen 1985, 1987, 1992; S. Shen 1990). This thesis redefines the intonation as simply pitch contours, or a pitch undulation, of an intonational phrase. The underlying form of the intonation is a sequence of underlying tones and underlying features of strength and heights at each level.

The remainder of this thesis is organized as follows. Chapter Two reviews relative linguistic theories and previous studies in Mandarin tonal literature. Chapter Three introduces the methodology of this study and the design of experimental materials. Chapter Four examines the experimental data and use these data to test the phonological rules formulated in previous studies. The subsequent three chapters provide an in-depth analysis of the points introduced previously in this chapter. Thus, Chapter Five focuses on the principles of pitch contour formation in the intermediate phrases; chapter Six on tonal behavior of T3's; and Chapter Seven discusses the different effects on pitch contour formations in speech. Finally, in Chapter eight, Mandarin intonation is discussed.

## Chapter II

### LITERATURE REVIEW

The complicated tonal phenomena and the relationship between tone and intonation in Mandarin Chinese has attracted increasing attention in the last few decades. Recent studies have attempted to make adequate progress toward an explicit description of tonal events in different prosodic levels in Mandarin speech. In this chapter, I will review the major studies in this area.

#### 2.1. Phonological studies on Mandarin tonal event

Basic concerns of phonological studies on Mandarin tonal phenomena include how to represent tones, what type of tone sandhi rules are available, how to apply the rules, what is the domain of tone sandhis, what is the prosodic structure of Mandarin speech, and how to define an intonation in Mandarin. Studies on these questions are introduced in the following subsections.

### 2.1.1. Representation of tones

The term "representation of tones" concerns the units where tonal features are represented. Most of the theories proposed fall into one of two contrasting positions: the single-tier phonological position (Fromkin 1972, Woo 1969, Maddieson 1971) or the multi-tier morphological position (Goldsmith 1976, Leben 1978, Yip 1980). The former proposed that the syllable or segment is the domain of tonal features, and no independent tiers are posited. The latter, those working in the autosegmental framework, in contrast, represent tone of the morpheme or some other tone bearing unit on a tier separate from the segmental tier. The tones and tone bearing units are linked later by association rules and conventions.

Most recent phonological descriptions of Mandarin tones adopt an autosegmental theory that represents Mandarin tones on the phonological unit of the syllable. I will adopt this position in this thesis, although my tonal transcriptions will be simply put under the corresponding syllables as expressed in a single-tier position for ease of presentation.

The term "representation of tones" not only concerns tone bearing unit, but also the transcription of tones. Tonal systems of different dialects have been described in modern Chinese phonological literature (Chan 1985, 1991, T.

Shen 1985, Qian 1988). In order to represent pitch heights and the shapes of tones, various transcriptions have been adopted. The device most often used is called the tone number, devised by Chao (1930). The tone range is divided into five levels, which are marked by digits from the lowest, which is "1" to the highest, which is "5". Tonal heights and contours are specified by the digits. For example, the four Mandarin tones are transcribed as [55], [35], [214], and [51]. A more visual and schematic representation of the tones is Chao's corresponding system of tone letters, where a vertical line represents the tone range, and a non-vertical line to the left of the vertical line represents the tone. The four tones in Mandarin are represented as: ˥, ˨, ˨˥, and ˥˨. Another transcriptional notation of tones, used in generative phonology, expresses the tonal features: H (high) and L (low) (Yip 1980). The four Mandarin tones are expressed as HH, LH, LLH, and HL (Zhang 1988).

In this thesis, both tone numbers and the transcription of H's and L's will be used. For the segmental transcriptions of Mandarin examples, Pinyin romanization will be used.

### 2.1.2. Mandarin tones

Generative linguistics develops the view of how surface tones are related to underlying tones. The citation forms of the four Mandarin tones are described by Chao (1968) and other scholars as high-level, high-rising, low falling-rising, and high-falling. These same forms also serve as the basic, or underlying, forms. Each stressed syllable in Mandarin has one of these four tones. As mentioned above, the four Mandarin tones are expressed as in Table 2.1.

Table 2.1 Expression of Mandarin tones

Tones	Tone Values		Examples	
T1	55	HH	ba1	"eight"
T2	35	LH	ba2	"pull up"
T3	214	LLH	ba3	"hold"
T4	51	HL	ba4	"handle"

As reviewed by Chan (1989), there is controversy over the basic, or underlying form of T3. A low T3, /21/, is adopted by Hartman (1944), Hockett (1947), Kratochvil (1968), Woo (1969) and other scholars. This is because of the widest distribution of the low variant. In this thesis, the low variant is also selected as the underlying form of T3. Besides of the widest distribution, the choice is also

based on an hypothesis about the production of T3 which will be discussed in later chapters.

Unstressed syllables are treated as atonic and their pitch contours belong to the category called "neutral tone". There is no special underlying tonal form set for a neutral tone syllable. The surface values of neutral tones are generally treated as being derived from prosodic context; that is, the pitch value of a neutral tone is dependent on the tone of the preceding syllable. Using "0" to indicate atonic status, Chao's (1968) description can be expressed as follows (with citation forms of the stressed syllables given):

$$(1) \quad 0 \quad \text{--->} \quad \left\{ \begin{array}{l} 2 \quad / \quad 55 \text{ ---} \\ 3 \quad / \quad 35 \text{ ---} \\ 4 \quad / \quad 214 \text{ ---} \\ 1 \quad / \quad 51 \text{ ---} \end{array} \right.$$

Chao (1968:36) makes a distinction between two categories of neutral tone syllables. In the first category, the syllables are "a very small number of morphemes, such as suffixes and particles," which are inherently toneless. In the second category, the syllables are originally "morphemes in one of the four regular tones," which lose their tones "under certain conditions."

Other studies describe neutral tones in similar

surface values. Some studies also pay attention to the shapes of neutral tones. For example, Dreher and Lee's (1966) and Cheng (1973) suggests that the shape of a neutral tone is a rising tone after the third tone, and a falling one after other tones.

### 2.1.3. Tone sandhi rules

After being described in isolated syllables, tonal phenomena have been observed in a sequence of syllables in many studies. There are several well known tone sandhi rules in Mandarin. The following rules are based on Chao's (1968) description, where the citation form of T3 [214] serves as the underlying form.

(2) Half-T3 Rule:  

$$214 \text{ ---} \rightarrow 21 / \text{ \_\_\_\_\_\_ } \begin{cases} 55 \\ 35 \\ 51 \end{cases}$$

(3) T3 Rule:  

$$214 \text{ ---} \rightarrow 35 / \text{ \_\_\_\_\_\_ } 214$$

(4) T2 Rule (formulated by Hyman, 1975):  

$$35 \text{ ---} \rightarrow 55 / \begin{cases} 55 \\ 35 \end{cases} \text{ \_\_\_\_\_\_ } T \quad (T = 55 / 35 / 214 / 51)$$

(5) Half-T4 Rule:  

$$51 \text{ ---} \rightarrow 53 / \text{ \_\_\_\_\_\_ } 51$$

Chao (1968:28) states that Rule (4) applies only to "speech at conversational speed". The following is one of his examples, which show that the Rule (3), can be fed into Rule (4).

(6)		214	214	214	
	---	35	214	214	(Rule 3)
	---	35	35	214	(Rule 3)
	---	35	55	214	(Rule 4)
		hao	ji	zhong	

"quite a few kinds"

Lin's (1985) T4 sandhi rule, the application of which is also optional, as well as speaker- and context-dependent is formulated as:

(7) T4 Rule:  
 51 ---> 35 / \_\_\_\_ 51

All of the above rules are formulated according to auditory impression. Phonetic evidences which are provided by previous studies and the present study indicate that these rules cannot reflect a high percent of tonal phenomena in normal speech. In this thesis, the general principle about tonal realization at certain prosodic level as well as in the whole course of an utterance will be hypothesized.



#### 2.1.4. Effect of stress on tones

Tonal phenomena in Mandarin are found to be conditioned by stress patterns. As just reviewed, any one of the four citation tones occurs only in stressed syllables. A neutral tone, whether inherent or not, occurs only in unstressed syllables. In other words, normal or contrastive stresses keep their full tones, while weak stresses lose them.

Chao (1968) distinguishes between three degrees of stress: weak stress, normal stress, and contrasting stress. He further analyzes how degrees of normal stresses are arranged in polysyllabic forms:

Actually, sequences of normally stressed syllables without intermediate pause, when in a phrase or in a compound word, are not all of the same degree of phonetic stress, the last being the strongest, the first next, and the intermediate being least stressed.

(Chao 1968:35)

Chao does not relate tone sandhi with difference among degrees of normal stress.

Yip (1982) attempts to relate stress pattern with tone sandhi, where the T2 Rule is rewritten as follows:

$$(8) \quad L \quad \text{--->} \quad H \quad / \quad H \quad \begin{array}{c} W \\ / \quad \backslash \\ \text{---} \quad H \end{array}$$

Yip's formulation indicates that the T2 change is not a process of tonal assimilation, but also a combination of weakening and assimilation. Capturing the insight that stresses conditioned tonal changes, Zhang (1988) reformulates the Half-T3 Rule and the Half-T4 Rule as follows:

$$(9) \quad \text{Half-T3 Rule:} \quad \begin{array}{c} / \quad \backslash \\ w \quad s \end{array} \\ 214 \text{ ---} > 21 / \text{ ---}$$

$$(10) \quad \text{Half-T4 Rule:} \quad \begin{array}{c} / \quad \backslash \\ w \quad s \end{array} \\ 51 \text{ ---} > 53 / \text{ ---}$$

Zhang treats the rules as weakening of the tones. The loss of a part of the complete tonal contour is only attributed to the effect of the stress pattern. He further hypothesizes that "the weakening process is a general one applying to all tones at the weak position" (Zhang 1988:66) and states a general weakening rule:

$$(11) \quad \begin{array}{c} / \quad \backslash \\ w \quad s \end{array} \\ T \text{ ---} > Tw / \text{ ---} \quad (Tw = \text{weakened tone})$$

By "weak position," Zhang indicates a position which has a weaker normal stress. According to Zhang, the effect of tonal environment is not involved in determining changes in the weakened tone. However, he does not provide a general description about how tones are weakened by the weakening process. Do they simply lose the second portion and save the first portion of their tones as reflected by the reformulated Half-T3 Rule and Half-T4 Rule? What should be their surface forms in different tonal environments, and how would they obtain the surface forms? A further question is: is there any other general principle which governs the realization of surface tones in weaker positions?

There are five tone sandhi rules in Mandarin as reviewed in Section 2.1.3. Now three of them are restated as conditioned, at least in part, by stress pattern. A few questions may be raised at this point. Are the other two rules, the T3 Rule and the T4 rule, also influenced by stress pattern? If the answer is yes, then how does stress affect them? If the answer is no, what motivates the rules? How should the tone sandhi phenomena be restated in general? And what is the relationship between the effect of stress and that of tonal environment? In this thesis, I hypothesize that tone sandhi relates to both the local stress pattern and to the tonal environment, as well as the tendency of pitch undulation in an utterance. Furthermore, I will pro-

vide evidence to support this hypothesis.

#### 2.1.5. Tone sandhi domain and general linguistic approaches

Issues on tone sandhi domain in Mandarin has been studied by adopting different linguistic approaches which is relevant to domain condition of rule application.

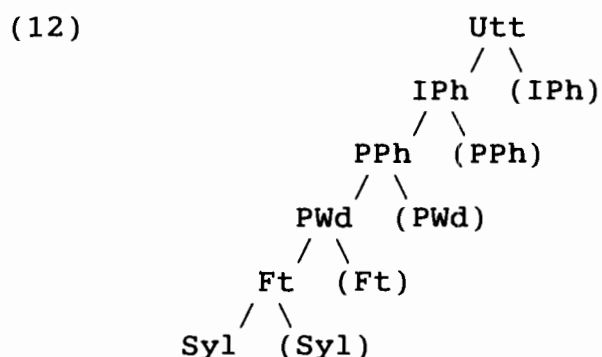
The metrical approach (Liberman and Prince 1977, Hayes 1981, Halle and Vergnaud 1987) attracts much attention. It was originally developed as a theory of stress. The rules of stress assignment in languages are formulated in order to place boundaries of constituents at certain places such as an edge of a syllable or a boundary of a word.

Similar to Chao's (1968) description of stresses in sequence of syllables, Yip (1980) developed a metrical treatment of stress patterns which differentiates constituents between two levels: foot and phrase. Trees are left-branching at the foot level and right-branching at the phrase level. In order to accommodate iambic forms (the stress pattern of [w s] forms in a phrase) and to arrange the degree of stresses in a more realistic manner, Zhang (1988) suggests introducing an additional level between Yip's two levels. However, he does not describe in detail this three-level model.

Theories on the relation between syntax and phonology also receive much attention in dealing with tone sandhi

domains in Chinese. There are two influential positions on how syntax influences phonology. The first position, Direct Syntax Approach (Kaisse 1985, Odden 1990), claims that phonological rules apply in a domain directly defined by syntactic structure, such as c-command domain, and there is no prosodical structure between syntax and phonology. The second position, Indirect Syntax Approach (Selkirk 1978, 1984, 1986; Nespor and Vogel 1982, 1986; Hayes 1984, 1989), argues for the existence of intermediate prosodic structure which is created according to syntactic entities. This position is also referred to as Prosodic Phonology or theory of Prosodic Hierarchy. The domain of rule application is either referred to as the ends or the edges of certain syntactic constituents in Selkirk's (1984, 1986) end-based model, or referred to as the syntactic relation between a head and its complement in Nespor and Vogel's (1986) relation-based model.

The most important hypothesis of Prosodic Phonology is that there is a hierarchy of prosodic constituents. Selkirk (1978) proposes the following hierarchical structure:



The prosodic constituents proposed in this structure include: utterance (Utt), intonational phrase (IPh), phonological phrase (PPh), phonological word (PWd), foot (Ft), and syllable (Syl).

There are different opinions regarding the domain of tone sandhi, especially the T3 sandhi in Mandarin. As found in Zhang's survey (1988), Cheng (1973) assumes a linear syntactic domain. The boundaries of the domain correspond to syntactic constituents, and the tone sandhi rules apply simultaneously. Liu (1980) proposes a cyclic prosodic domain which is restated as a cyclic syntactic domain by Kaisse (1985). Their application of the T3 Rule is cyclic and subject to the Branch Condition. By using a modified version of Chen's (1979, 1980, 1984) Foot Formation Rule (originally devised for analyzing Chinese poetry), Shih (1986) states that the cyclic prosodic domain does not correspond to any

syntactic constituent. However, Chen (1990) claims that these domains are relation-based. He holds that his Foot Formation Rule "treats S-structure as unlabeled trees: it focuses on Bracketing/branching alone, and is indifferent to node labels." (Chen 1990, p31) Chen uses Hung's (1987) example to demonstrate that end-based prosodic approach fails to account for facts in Mandarin.

Concurring with Shih (1986) and Liu (1980), Zhang (1988) develops the cyclic prosodic position. He relates the construction of the domain to a pragmatic, discourse structure. He also revised the Foot Formation Rule by separating the lexical and post-lexical components and incorporating the revised Branch Condition. His system thus allows reanalysis of the prosodic structure. Up to now, Zhang's description of Mandarin tonology is still the most comprehensive one. In order to discuss the predictive capability of the available phonological system, the idea of Zhang's prosodic description will be introduced in Section 2.1.6.

In recent years, the connection between phonology and semantics has also been studied in dealing with issues related to phonological domains. It is claimed to incorporate semantics in determining the intonational structure of a sentence. Selkirk (1984) requires that intonational phrases correspond to "sense units". Nespor and Vogel (1986)

concern information about semantic prominence of phonological phrases. Vogel and Kenesei (1987) define intonational phrase by referring to semantic notions, such as scope.

Hung (1987) and Cheng (1990) adopt Selkirk's (1984) "Sense Unit Condition" and substitute it for Chen's Foot Formation Rule, which will be introduced in Section 2.1.5. This is because that tree-based analysis of Mandarin prosodic structure leaves much unsolved problems, such as phrases that allows alternative readings. According to the "Sense Unit Condition", if two constituents are relate to each other in a relation of head-argument or head-adjunct, they form a sense unit. Comparing with the original Foot Formation Rule, the relation-based Foot Formation Rule is able to deal with alternative readings better. However, Chen (1990) points out that there are still problems in the description. In fact, this description of the prosodic system of Mandarin remains similar as Zhang's (1988) analysis. Therefore, I will still introduce Zhang's system in Section 2.1.6.

Studies on prosodic constituents have also related phonetics with phonology. Pierrehumbert (1980), Liberman and Pierrehumbert (1984), Beckman and Pierrehumbert (1986), Pierrehumbert and Beckman (1988) developed a system of phonological study of intonational event in English and Japanese based on phonetic data. These studies propose



underlying tonal and intonational entities for different types of prosodic constituents as well as rules of surface tonal realization. An phonetic rule explains how F0 values of tone bearing units are intoperlated between specified tonal values. According to surface F0 contours, prosodic constituents of an utterance in the two languages can be identified.

This analysis shed lights on the study of Mandarin tonal phenomena. Could Mandarin prosodic constituents be identified through surface tonal contours or through more surface information of speech? How are Mandarin intonations formed in underlying forms and are realized in surface forms? This thesis tries to provide answers to these questions.

#### 2.1.6. Zhang's description of tone sandhis in Mandarin

The principle of Zhang's system is introduced in this section. First of all, Zhang incorporates the role of pragmatics to deal with the variability of output. His examples include the following sentence:

(13)	wo	xiang	mai	xiao	hua	mao	
	I	wish	buy	little	tabby		
	3	3	3	3	1	1	UT
a	3	2	3	3	1	1	
a'	3	2	2	3	1	1	
b	2	3	2	3	1	1	
c	2	2	3	3	1	1	
c'	2	2	2	3	1	1	

"I wish to buy a little tabby."

The numbers 1-4 indicate the four tones in Mandarin. Each group of the tonal variants should be included as part of the answer to the corresponding question in the following, each of which emphasizes a different word:

- (14)
- a. Have you bought the little tabby?
  - b. Do you wish to sell the little tabby?
  - c. Does he wish to buy the little tabby?

Chen's (1983) Foot Formation Rule was adjusted by Shih (1986) and was also revised by Zhang. Shih's rule reads:

(15) Foot Formation Rule (FFR):

- I. Foot (f) construction
  - a. IC (Immediate Constituency): Link immediate constituents into disyllabic feet.
  - b. DM (Duple Meter): Scanning from left-to-right, string together unpaired syllables into binary feet, unless they branch to the opposite direction.





Another example of Zhang's shows derivation with reanalysis in fast speech:

(22)	shao	mai	jiu	
	little	buy	wine	
	3	3	3	underlying tones
		[	]f	by IC
	3	2	3	
	[		]f	by DM
	[		]f'	by super-f
	2	3	3	cycle 1
	2	2	3	cycle 2

In this example, if reanalysis is not allowed, there should be only one output of tone sandhi: T3T2T3. However, if reanalysis is possible, i.e. DM overrides IC, then there are two more variants, T2T3T3 and T2T2T3.

For reanalysis of normal speech, Zhang does not discuss in great length nor show examples of the long sequence. However, when mentioning the reanalysis of poetry, he said that the Branch Condition does not apply and IC does not take precedence over DM.

From the above review, it seems that the largest domain of tone sandhi is a super-foot, which is constructed by stringing together one or two unpaired syllables into a binary foot. Although Zhang does not give a clear definition for the term "domain" in his discussion of the Branch Condition, Zhang (1988: 112) does mention, however, that the

.rm58

"application of the rule within a domain is obligatory but it is optional across domains." In the optional case, why should a tone sandhi occur between tone sandhi domains? One of the major interests in this thesis is to see how syllables group into prosodic constituents in an utterance. I will provide evidence to confirm the existence of intermediate phrases which are tone sandhi domains and are often larger than super-feet.

Although Zhang's (1988) phonological system mentioned above is are developed by using strings of T3's as in most of the examples, it is supposed to be significant for any arbitrarily formed tonal sequences. This system is one of the most current phonological description of Mandarin tonal phenomena and theoretically, it should allow for the prediction of any tonal changes in Mandarin sentences. In order to study how well the tonal changes in spontaneous speech and planned speech can be predicted by the phonological rules that we now have, I will use Zhang's above system to make prediction of surface tones and compare predicted tonal forms with actual tonal forms in Chapter 4.

#### 2.1.7. Intonation

Many studies have focused on characteristics of English or other non-tonal languages (Beckman & Pierrehumbert 1986, Bolinger 1958, Inkelas, Leben & Cobler 1986). In

these languages, an intonation is the pitch movement over a sentence. In pitch tracks, it is shown as pitch curves, disconnected in voiceless consonants and pauses. However, in a tone language, since pitch movements represent both tones and intonations, intonational phenomena becomes more complicated. As for Mandarin, because of the dual usage of pitch movement, scholars are facing the difficulty of defining Mandarin intonation. "Intonation" in Mandarin is a term without a clear or commonly accepted definition in literature. Most authors avoid describing it, although they discuss the relationship between tones and intonations.

There are two major types of definitions of Mandarin intonation. The first of these regards Mandarin intonation as the combined information of different aspects of speech sounds which include variations of pitch, strength, length, and rate. J. Shen (1987) reviews the major opinions of several studies regarding these elements (Luo and Wang 1957, Xu 1980, Yin 1984, Hu 1987). These studies emphasize other aspects of intonation besides the pitch movement of speech sounds. Although certain interesting phenomena about emphasis, loudness, tempo, stops or ending shapes of pitch contours are discussed, pitch movement over a whole sentence is not analyzed. Chao (1968) classifies Mandarin intonations into 13 types and describes them in this manner. Compared with other studies, his observations focus on pitch

range and height.

The second definition concerning Mandarin intonation is the assumption that an abstract contour of pitch or pitch range superimposes on tones in a sentence. Most experimental studies are based on this assumption. Chao (1933) does not directly state what Mandarin intonation is. Yet his description of the relationship between tones and intonation suggests that his ideas are similar to those embodied in the second definition. He repeats this opinion in his book (1968).

The question has often been raised as to how Chinese can have sentence intonation if words have definite tones. The best answer is to compare syllabic tone and sentence intonation with small ripples riding on large waves (though occasionally the ripples may be "larger" than the waves). The actual result is an algebraic sum of the two kinds of waves. Where two pluses concur, the result will be more plus; when a plus meets a minus, the algebraic addition will be an arithmetical subtraction.

One of his example is Ni xing Wang, wo xing Lu. 'Your name is Wang, my name is Lu'. Chao explained the tonal phenomena in this example as:

the rising intonation in the further referring clause will make the rising 2nd Tone Wang rise higher than usual and the falling intonation on the falling 4th Tone Lu [lu] fall lower than usual (or, in this particular instance, since a 4th Tone falls to near the limit of the voice, the falling intonation will make it start lower and squeeze it narrower).

(Chao 1968: 39-40)



This section prefaces a detailed description of the 13 types of intonations which, unexpectedly, are all classified under the first type of definition.

I infer from the above quotation that Chao views Chinese intonation as an abstract pitch contour. Therefore, he thinks that intonation and tones in the same sentence can be summed up algebraically. Omitted from his discussion, though, is the change of pitch range. The words such as "fall lower" or "rise higher" are only descriptions of shape and height of pitch contours.

When describing the 13 types of intonations, Chao suggests a type of successive addition of intonations and tones: to add a rising or a falling ending as a form of intonation to a tone of the last syllable in a sentence. However, he decides to abandon this method and regard the rising and falling endings as two particles (Chao 1968). Therefore, there are 11 types of intonations left.

Later scholars accept Chao's basic assumption in the above quotation and develop his idea. Their attention focuses on aspects of speech sound relating to pitch movement. Most scholars regard Mandarin intonation as an abstract contour of pitch range which is shaped as a curved band. They suggest that the relationship between Mandarin intonation and tones is that the former superimposes upon

the latter resulting in a variety of adjusted tonal shapes.

Kratochvil's (1968) general description of how tones are realized in a sentence clearly reflects this second opinion regarding intonation. By drawing figures, he illustrates that after entering a sentence, contours and heights of tones are first adjusted by stress and tonal environment in five stages. In the sixth stage, an intonation superimposes itself on the tones and decides their final contours and heights. Kratochvil draws a pair of parallel dashed lines in a level-falling shape, to indicate the abstract contour of the intonation in a declarative sentence. The figure clearly shows that the assumed intonation is not a single line, but a band with a fixed range. Both pitch contours and average pitch level of the tones are adjusted by this imagined band, or intonation. Although Kratochvil draws a clear picture of assumed intonation, his description of tonal realization is rather general, and does not provide evidence to show how to analyze actual tonal phenomena in natural speech. As discussed previously, when dealing with data of spontaneous speech (Kratochvil 1986), Kratochvil does not find any explanation for unpredicted tonal contours.

Chang's study (1958) of intonation based on natural spontaneous speech is often referred to in tonal literature. As most early studies of intonation do, Chang (1958) focuses

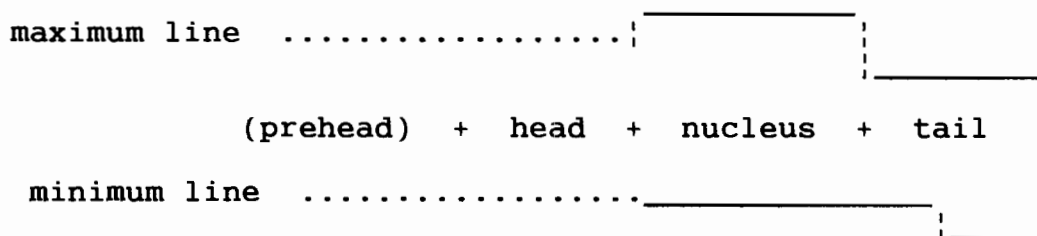
on explaining how tonal contours are adjusted by intonation in the final position of sentences. The assumption of intonation is the same as Kratochvil's. She describes in detail how contour features of tones in sentence final positions are neutralized or emphasized by intonations with different directions. Later studies (De Francis 1963, Ho 1977, S. Shen 1990) continue the description of pitch movement in a similar manner.

Gårding (1983, 1984, 1987) suggests a grid model for surface tone generation in Chinese. An intonation is again assumed as a contour of pitch range which is represented by two grid lines. Tonal targets are then placed on the grid lines, and tones are illustrated by linking the targets. The pitch range which is indicated by the distance between the grid lines, is adjustable. In this model, although the influence of intonation on tones is assumed to occur much earlier than in Kratochvil's model, the assumption of intonation is similar to Kratochvil's. However, Gading's model, which Shih (1989) comments upon, fails to capture the variations exhibited in natural speech data.

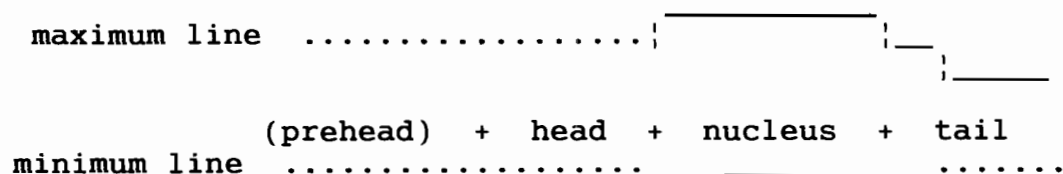
J. Shen's study of intonation in Mandarin (1987, 1992) is based on pitch tracks of both designed and spontaneous sentences. Utilizing a similar assumption of intonation as that of Kratochvil and Gading, Shen also draws two lines to show an imagined intonation. Following Ladd (1980), J. Shen

suggests that a Mandarin intonation is composed of four portions: prehead, head, nucleus, and tail. A nucleus is the most important portion of an intonation, and it occurs in words that are semantically focused. J. Shen pays more attention to pitch range, and uses the difference between patterns of pitch range variation over sentences to distinguish declarative and interrogative intonations. The basic difference between declarative and interrogative intonations are: (1) after the nucleus, the maximum line of a declarative intonation falls suddenly and significantly, however, that of an interrogative intonation falls less and in a gradual manner; (2) in the ending portion, the minimum line of a declarative intonation is very low, but that of an interrogative intonation is considerably higher. The two imagined intonations are outlined by J. Shen as follows:

(23) Declarative intonation:



## (24) Interrogative intonation:



As mentioned before, J. Shen does not try to analyze how tones are affected by intonations.

S. Shen's (1990) study of intonation focuses more on its average height. Some scholars (De Francis 1963, Ho 1977, J. Shen 1985) claim that the whole, or average, pitch level in questions are higher than those in statements. Confirming these conclusions with her own data, S. Shen assumes three basic intonation contours for three types of sentences: two interrogative intonations which, even though they both start high, one ends high and one ends low; and one assertive intonation which starts low and also ends low. She calls each assumed abstract contour of intonation a "tune". Although S. Shen (1990:26) illustrates each tune with a single line, she did not explain whether her basic assumption of an intonation is different from most of the above reviewed assumptions, i.e. an imagined pitch range. Based on her data, S. Shen (1990) also describes how intonations influence the realization of pitch contours in sentence initial and final positions.

In short, more recent studies of Chinese intonation share the definition that a Chinese intonation is an abstract contour of pitch or pitch range. The studies separate tones from intonations and assume an interaction between the two. However, no one, hitherto, has provided a clear picture of how pitch contours of tones, especially those unexpected pitch contours, are realized in all positions of continuous speech. This situation should raise doubts about this assumption of Mandarin intonation. I suggest that a Mandarin intonation is not an abstract curve of pitch range, rather its surface form is simply the pitch movement of the sentence, or a sequence of surface tones. The underlying form of an intonation includes the sequence of underlying tones, the underlying strengths and heights of prosodic constituents at each level. I will exemplify this position in later chapters.

## 2.2. Phonetic study of Mandarin tonal phenomena

Most phonetic studies of Mandarin tonal phenomena focus on acoustic analysis, although perceptual tests are often employed. The most frequently studied aspect is fundamental frequency (F0). The level and contour of F0 are confirmed to be the main acoustic cue in Mandarin tone perception (Howie, 1976). Though other phonetic aspects of tones or related segments (amplitude contour, duration, glottaliza-

tion, voice onset time, or vowel quality,) provide hints about tones, none of their functions are as important as the F0 properties. The influence of stress and intonation on F0 movement have also attracted much attention in phonetic studies of tonal phenomena (Kratochvil 1968, Garding 1984, J. Shen 1985, 1989, Shih 1989, Wu 1990, S. Shen 1990). However, still very little is known and much controversy has arisen.

#### 2.2.1. Domain of Mandarin Tone

The traditional opinion about the domain of Mandarin tone is not based on experimental evidence. Chao's opinion on tone is a popular one and might still be predominant:

In addition to an initial and a final, every syllable has as an essential component a tone, which is primarily the pitch pattern of the voiced part of the syllable, so that, if the initial is voiced, the tone begins with the initial and spreads over the whole syllable, while, if the initial is voiceless, the tone is spread over the final only.

(Chao 1968: 19)

As Kratochvil (1986) pointed out, the logic of this opinion that a tone is an auditory impression of the F0 and is determined by the F0. The F0 reflects the rate of laryngeal vibration and is determined by laryngeal vibration. Therefore, the domain of a tone is the whole voiced portion of

the syllable. Kratochvil (1970) criticizes this logic:

This may have a kind of logic to it, and it is presumably substantiated by subjective kinesthetic observations, but it is quite untrue from the strictly phonetic viewpoint: instrumental analysis of the fundamental frequency patterns of Mandarin syllables commonly shows that voiced initial consonants have erratic F0 characteristics which obviously do not contribute to the general tonal tendency of the given syllables.

(Kratochvil 1970: 515)

Experimental evidence from other sources supports Kratochvil's analysis (Howie 1976, Shen et al 1961). Howie (1976) divides 136 Mandarin syllables into nine groups according to their structures and compares the averaged pitch curves of each group for each tone. He finds that pitch curves of syllables with initial voiced consonants or non-syllabic vowels have humps or shoulders near the beginning. The turning point of the hump or shoulder coincides with the segment boundary between the initial voiced consonant or non-syllabic vowel and the syllabic vowel. The other portion of the curves, which follows the turning point, appears to be similar in shape to the entire curve of the same tone of syllables in all the other types. Howie concludes that the domain of tone in Mandarin is not the entire voiced portion of the syllable:



...it appears that the basic contours of Mandarin tones are co-extensive only with the syllabic vowel and any voiced segment that may follow it, while those portions of the pitch pattern that occur with initial voiced consonant or non-syllabic vowel are merely anticipatory adjustments of the voice.

(Howie 1976: 252-253)

The word "pitch pattern" means F0 pattern in this quotation. In order to make this dissertation more readable to readers who usually do not use acoustic terminology, I will use "pitch contour" or "pitch movement" in most cases to indicate contour or movement of F0.

#### 2.2.2. Predictable pitch contours of Mandarin tones

Pitch contours of tones are regarded as predictable when they are similar in both shape and height to the corresponding predicted phonological tonal contours.

##### 2.2.2.1. Typical pitch contours of Mandarin tones

Predictable pitch contours of the four Mandarin tones have been observed in many instrumental studies (Howie 1976, Tseng 1981, J. Shen 1985, Wu ed. 1986, Kratochvil 1987, Shih 1989). Figures 2.1 and 2.2 show typical pitch tracks of the tones adapted from different studies. Figure 2.1 presents pitch contours of the four Mandarin tones which are similar in shape to those published by Howie (1976), Tseng (1981), and Wu (ed., 1986). Figure 2.2 provides the

pitch contours which are close to those published by J. Shen (1985) and Shih (1989). Comparing the patterns of each tone in the two figures, it is apparent that the patterns for T1, T2, or T4 in both figures are similar. The major difference between the two sources of pitch tracks occurs in T3.

In Figure 2.1, T3 is typically in a falling-rising contour, but in Figure 2.2, it is in a low falling contour. In both phonological and phonetic tonal literature, the falling-rising contour is reported to occur in a final position or before a pause, and the low falling one occurs in a non-pausal position and not before another T3.

The low falling variant of T3 has also attracted attention with respect to attempting to distinguish it from the falling pitch contour of T4. Garding et al. (1986), for example, compare them by auditory tests of acoustically adjusted contours. After listening to manipulated pitch contours over the syllable mai from T4 to T3 in the following sentence, listeners are asked if they had heard mai<sub>3</sub> 'buy' or mai<sub>4</sub> 'sell'.

- (25)        Song<sub>4</sub>   Yan<sub>2</sub>   mai?   niu<sub>2</sub>rou<sub>4</sub>  
              Song   Yan   buy/sell   beef  
              "Song Yan buys/sells beef."

The manipulation of pitch contours that change T4 to T3 follows one of three strategies: shifting the peak,

lowering it, or increasing its steepness. The results show that some features are constant for the pitch contours of T3 as opposed to that of T4. T3 has a low pitch level for the second half of the vowel, whereas T4 has a gradual fall over the main part of the vocalic segment.

The rising tone sandhi, which is a variant of T3, has also been widely studied. Wang and Li (1967) conduct auditory tests in order to compare the variant of T3 with the original T2, placing them on the first syllable of disyllabic forms. They conclude that there is no significant difference between the two. Based on spectrographic evidence, however, Zee (1980) claims that acoustically they are not identical. Kratochvil (1987) reaches a similar conclusion from his data on spontaneous speech. He finds that in most cases the "new T2" tends to be classified together with T3 rather than with T2.

#### 2.2.2.2. Average pitch contours in spontaneous speech

Most observations on pitch contours of tones reviewed above are based either on single word utterances or on artificially created sentences. Kratochvil (1986) criticizes the exclusive recourse to this kind of data in both phonetic and phonological descriptions. His reason is:

...that the relationship between citation forms and other similar artificial forms, and normal speech is unknown, and it is thus impossible to assess if and to what degree observations based on the former apply to the latter.

(Kratochvil 1986:260)

In order to describe the pitch contours of tones in normal speech, Kratochvil calculates the average pitch contour of each Mandarin tone from a monologue of spontaneous speech produced by a female native speaker. The tone-carrying part of each syllable is divided into five portions that is, each portion contains 20% of the duration. The duration of each tone-carrying portion is measured, and then, six measurements are also made of fundamental frequency and of the overall amplitude -- one at the onset and another at the end of each subsequent fifth. The arithmetic means of the six values of fundamental frequency (Hz) for each tone are given in Table 2.2.

Table 2.2 Arithmetic means of measurements for each Mandarin tone from Kratochvil (1968)

Tones	Numbers of samples	Measurements (Hz)					
		0%	20%	40%	60%	80%	100%
T1	246	240	237	234	232	231	226
T2	233	215	211	214	224	235	237
T3	281	216	202	191	187	186	187
T4	458	266	260	250	238	226	217

With respect to the mean values of the F0 contours above, Kratochvil notes that they are considerably different from the means arrived at by acoustical analysis of isolated forms. He states that the contours of fundamental frequency can therefore be considered as real frames of reference. In particular, he points out that T3 does not display the final sharp rise in F0 which characterizes the isolation form.

A question then arises as how well Kratochvil represents the tonal contours in spontaneous speech through his numbers. Both the pitch height and the contour of tones may be affected by many factors in spontaneous speech. Without knowing how many factors affect each tone and how strong the effect of each factor is, how can we know whether the averaged contours represent the basic forms of the tones?

In fact, the question, "What is the typical pitch contour of each tone in different positions of running speech?" deserves attention, as few observations have been made. Shih (1989) reported that southern speakers often keep the low falling pattern even in the final position in casual speech. Thus, in spontaneous speech, do native Mandarin speakers always produce falling-rising contours of the final T3? Also is the low-falling contour the most widely distributed variant of T3?

### 2.2.2.3. Pitch contours of neutral tones

Much attention has been paid to the phonetic realization of neutral tones. Before instrumental analysis was available, the description of pitch values of neutral tones in isolated disyllabic or polysyllabic forms were based on auditory impressions. Chao's (1968) description, as reviewed previously, indicates that the pitch height of the neutral tone is determined by the preceding stressed syllable. In a sequence of neutral tones, Chao's (1933) diagram is a chained dependence: the pitch of each depends on the preceding tone, and from the second tone onwards, all neutral tones are low in pitch. Cheng (1973) also describes how pitch contours of neutral tone syllables are decided by the tones of preceding stressed syllables. According to Cheng, the pitch contour of the neutral tone is low falling when it follows a T1, T2, or T4, and high rising when it follows a T3.

Acoustic data shows many details of pitch curve in neutral tone syllables. Tseng (1981) finds that the pitch curve of neutral tones varies much more than expected. It is very often the case that they are not controlled by the tone of the preceding stressed syllables. In her data on spontaneous speech, only 29.55% of neutral tones are phonologically predictable. Wu (1984) points out that in trisyllabic sequences, a neutral tone in the second

syllable serves as the transition between tones in the other syllables. S. Shen's data (1990) also exhibit similar phenomena: a neutral tone constitutes a transition between tones of stressed syllables.

Aside from tones on the preceding syllables, other factors that influence the phonetic value of the neutral tone had been considered. Kratochvil (1968) claims that intonation influences the pitch contour of the neutral tone more than stress on adjacent syllables does. For example, the tone may rise if the intonation contour is a rising one. Based on her data, S. Shen (1990) also describes how neutral tones are contoured to conform with the intonation pattern in the case of sentence-initial or sentence-final position.

### 2.2.3. Unpredicted pitch contours of Mandarin tones

Pitch contours of tones are regarded as unpredicted when they are different in shape and/or height to the corresponding predicted phonological tonal contours.

#### 2.2.3.1. Tseng's study

Several studies report the phenomena of unpredicted tonal changes in sentences. Tseng (1981) compares the pitch contours of isolation forms to those of spontaneous speech to see whether there is a one-to-one correlation between

the acoustic information obtained from spontaneous speech and phonological predictions. She uses pitch tracks of 24 syllables (6 syllables \* 4 tones) produced by a female native speaker as a standard of isolated forms. The spontaneous speech comes from one speaker's lectures given on modern Chinese literature, and from the casual conversations between her and another female native speaker. 50 simple declarative sentences are selected from the speech. Among the 50 sentences, 25 come from one speaker's lectures and chats, and the other 25 come from the other speaker's chats. A summary of an examination of the 465 pitch contours is provided by Table 2.3.

Table 2.3 A summary of an examination of 465 pitch contours from Tseng (1981)

syllable type	phonological prediction	match between predicted and actual pitch contours	
full-tone syl.	361	145	(40.17%)
neutral-tone syl.	44	13	(29.55%)
reduced-tone syl.	60	10	(16.67%)
total	465	168	(36.13%)

The result shows that only a small number of syllables are produced with their predicted lexical tones. Tseng asserts that the phonological prediction only involves rules at the phrase level. Phrases read in citation forms may serve as



better sources to test the specified prediction. She treats the causes of unpredicted tonal phenomena as that of only partial acoustic information. She believes the absence of specific rules at the sentence level, which incorporate intonation and the interaction between tones and intonation, cause unpredicted tones.

In order to find out how well tones from spontaneous speech can be perceived without context, Tseng selects 50 reduced tones and 50 unreduced tones from each of the two speakers. The term "reduced" tone refers to tones in both inherent neutral tone syllables and other unstressed syllables. The 200 tokens are randomized and recorded on tape. 12 native Chinese are asked to listen to the tape and make a choice from among the following six possibilities: the four lexical tones, the neutral tone, and nothing recognized. The results of the perception test which was scored under the two conditions, unreduced and reduced, are provided in Table 2.4.

Table 2.4 Results of perception test  
neutral tones by Tseng (1981)

Correct identification according to	unreduced tokens	reduced tokens
phonological prediction	55.66%	25.42%
actual pitch contour	58.58%	24.83%

Tseng explains that the rather poor perception of the extracted tones might be due to absence and distortion of acoustic information.

Tseng's study confirms the high frequency of occurrence of unpredicted tonal changes in spontaneous speech, and it raises the question about the relationship between phonological predictions at the word level and those at the sentence level.

#### 2.2.3.2. Wu's study

Unpredicted tone sandhis are found not only in spontaneous speech, but also in read speech of isolated citation forms. Wu (1982a, 1982b, 1984, 1990) studies pitch contours in monosyllabic, disyllabic, trisyllabic, and quadrisyllabic forms and relates them to intonations. He suggests that the pitch contour of each of these forms as a whole serves as a basic tonal constituent in a sentence. The general pattern of these tonal units are formed according to the phonological rules reviewed in Chapter 2 except some cases in trisyllabic forms.

Wu (1984) found that in trisyllabic forms, several factors, such as the tonal environment, syntactic structure and speech rate, may affect the pitch contour of the whole unit. At a normal speech rate, the pattern of pitch contour

for a trisyllabic form may be unpredicted only because of tonal environment. For example, when the pitch contour ends high in the first syllable but starts low in the third syllable, a T2 in the second syllable often becomes a high falling transition instead of a high level tone, as predicted by the T2 Rule given earlier. The pitch contour of the second syllable, hence, changes the entire pattern of the pitch contour of the trisyllabic forms. Two such examples from Wu (1984) are transcribed as follows:

- (26)      / 55    35    214 /    underlying form  
           ( 55    55    214    predicted surface form )  
           55    53    214    unpredicted surface form  
           Xian    yu    kou  
           "Xianyu intersection"
- / 35    35    214 /    underlying form  
           ( 35    55    214    predicted surface form )  
           35    53    214    unpredicted surface form  
           zha    liu    guan  
           "thyratron"

Wu states that in a sentence, mood can change pitch range, but not general patterns of these tonal units. However, an accelerated speech rate might totally change the general patterns.

#### 2.2.3.3. J. Shen's (1987) study.

Unpredicted pitch contours also occur in J. Shen's (1987) data, although the study focuses on intonations

rather than tone sandhis. To illustrate his analysis of intonation, J. Shen provides many examples, which have been selected from among 1200 pitch tracks of both designed and spontaneous sentences. He transcribes the pitch contours of the examples in a visual way to express the general pitch movement as shown in the following diagram.

(27)

		ting		shuo	
a		l	i	l	
o		a	sh	e	
	oo		oo		e

The underlying and the predicted surface tones in the sentence, together with the English gloss, are given as follows.

(28) / 51    55    214    55    55    0 / underlying form  
       51    55    21    55    55    2 predicted surface form  
       ao,   ting lao   shi   shuo le  
       oh   hear teacher   say PART  
       "Oh, the teacher told me that."

In this example, I am interested in the unpredicted rising tonal contour on shi. The expected tone is the high level tone. The syllable belongs to a content word laoshi, "teacher". It does not come with the option of a neutral tone word with a tone change according to the phonological rules that we already have. Though the way

that the tone changes in this syllable is similar to what Wu (1984) describes for the tone sandhi of the second syllable in a trisyllabic sequence, shi does not occur in such a sequence.

There is another interesting example from J. Shen's data:

(29)

```

      j
      i
t a   u
      u
      'i sh
          an xi
              i d
                  e eh

```

In the transcription, "'" indicates that the consonant sh is dropped in the pronunciation. The underlying and the predicted surface tones in this sentence are as follows:

(30)

/	55	51	51	55	55	0	0	/ underlying form
	55	53	51	55	55	2	1	predicted surface
	ta	jiu	shi	Shan xi	de	eh		form
	he	just	is	Shan xi	of	PART		
	"He is just from Shanxi."							

According to J. Shen, there is a strong emphasis on the syllable jiu. We see that the T4 in this syllable starts very high and spans a large pitch range. The pitch forms a

continuous fall in the syllables that come after this tone. Obviously, the low falling contours in Shanxi are unexpected.

#### 2.2.3.4. S. Shen's (1990) study

S. Shen (1990) also makes detailed observations on pitch contours of tones in sentences. Her methodology for implementing her experiment is interesting because it combines certain advantages of observing both spontaneous speech and controlled speech. Although the sentences that she uses were specifically designed for this experiment, she asks speakers to say them rather than read them. During recording, S. Shen first tells the speakers the sentence and its relevant context, then asks the speakers to utter the sentence according to the context without seeing the text. In this way, the speech sounds similar to sentences spoken in spontaneous speech. S. Shen designs 72 sentences, which are divided into 6 groups based on different intonations and syntactic structures. Each group contains a sequence of the same tones, and each tone occurs in 3 sentences.

S. Shen relates unpredicted tonal changes to the influence of stress. She describes the relationship between stress and tone reduction as follows: a syllable loses its underlying tone only when it is unstressed, while a toneless neutral tone recovers its underlying tone when stressed.

This conforms to the conclusions of previous studies concerning the relationship between stresses and tones (Chao 1968, Krotchvil 1968, Wu 1984). S. Shen develops the conclusions by saying that the relationship between stress and tone reduction is proportional. She finds that 357 unstressed syllables lost their inherent tones in the unstressed positions of the uttered sentences. But tone sandhi never takes place on a syllable that is stressed, even though the environment for the tone sandhi is met. She observes how pitch contours are formed in neutral tone syllables in her data. However, she does not provide a general description about how pitch contours realize in syllables which have partially lost their tones.

S. Shen also attributes certain unpredicted tonal changes to the influence of intonation. She pays much attention to tonal contours at the beginning portions of sentences. In her data, with the exception of sentences consisting of a sequence of T4's, pitch contours in sentences of T1, T2, or T3 strings all start with a rising trend in the first syllable. Based on her observations, she claims that there are different underlying intonational contours, all of which start with an initial rise. The influence of intonation is very strong at the initial position of a sentence, hence overriding tone sandhi, resulting in a rising trend.

#### 2.2.4. Variation of pitch range

Variation of pitch range has been discussed in most studies which deal with intonation in Chinese (Chao 1932, 1933 and 1968, Chang 1958, Ho 1976, Wu 1984 and 1990, Shih 1989, J. Shen 1985 and 1987). However, there are only a few experimental studies that focus on this.

##### 2.2.4.1. Catathesis

Catathesis, or down step, reflects modification of pitch range. It is a process of pitch lowering triggered by a sequence of tones alternating L with H. For example, in the sequence HLH, the second H would be obviously lower than the first H because of the intervention of the L. In Mandarin, the tones in the following word contain such an HLH sequence.

- (31)
- |      |     |    |
|------|-----|----|
| shou | bao | ji |
| 55   | 51  | 55 |
| HH   | HL  | HH |
- receive telegraphic machine  
"telegraphic receiver"

If the effect of Catathesis existed in Mandarin, the H immediately following the L would be obviously lower than the H immediately preceding the L.



The effects of Catathesis have been found in other languages (Pierrehumbert and Beckman 1988, Pierrehumbert 1980, Meyers 1976, Schachter and Fromkin 1968). Shih (1989) studies the effect of catathesis on the tones in four Chinese sentences. Each of her sentences contains the tone sequence: T1 Tx T1 Tx T1, where Tx is one of the four tones. Each of the sentences is recorded four times in natural speech and reiterated four times using the syllable da (all syllables were replaced by da pronounced with the original tone). Because T1 and T2 have L targets, all sentences containing these tones exhibit the effect of catathesis. Shih notes that the magnitude of the effect is related to the actual pitch level of the preceding L. In both natural and reiterant speech, it is more pronounced when triggered by T3 than by T2 and T4. Sentences which contain only T1's are found to have pitch declination from the beginning. Speech rate is slightly greater in natural speech than in reiterated speech.

Although Shih's study is interesting, the small quantity of its data and the shortness of its sentences may make the study unrepresentative. In this study, I will use more data to test the effect of catathesis in Mandarin.

#### 2.2.4.2. Pitch range and prosodic constituents

J. Shen (1985) conducts a well designed study on variation in pitch range. He asks five broadcasters to read a list of 24 sentences in Mandarin. In order to observe the change of pitch range, he divides the sentences into six groups. In each group, there are four sentences which have the same number of syllables and the same syntactic and prosodic structure. The design of the tone sequences of the six groups is listed as follows:

- (32)
- |      |                        |
|------|------------------------|
| I.   | N N N N N N N N .      |
| II.  | 1 N 1 N 1 1 N.         |
| III. | N 1 1 N 1 0 N.         |
| IV.  | N 0 N 0 N 0 N 0 N 0 N. |
| V.   | N N N N N N N 0 ?      |
| VI.  | N N N N N N N ?        |

"N" denotes any one of the four tones, T1, T2, T3, or T4;

"1" denotes T1, and "0" the neutral tone. For example, the sentences in group I are as follows:

(33)

Ia: T1    T1    T1    T1 T1    T1    T1 T1 T1  
 Zhang Zhongbing jintian xiu    shouyinji.  
 Zhang Zhongbing today    repair radio  
 "Zhang Zhongbing repairs a radio today."

Ib: T2 T2 T2    T2    T2    T2    T2 T2    T2  
 Wu Guohua mingnian hui    Yangchenghu.  
 Wu Guohua next year go back to Yangcheng Lake  
 "Wu Guohua will go back to Yangcheng Lake next year."

Ic: T3 T3 T3 T3 T3 T3 T3 T3  
 Li Xiaobao jiudian xie jiangyangao  
 LiXiaobao9:00 write draftfor a lecture  
 "At 9:00 LiXiaobao is writing a draft for a lecture."

Id: T4 T4 T4 T4 T4 T4 T4T4  
 Zhao Shuqing banye shang jiaoyubu.  
 Zhao Shuqing midnight go to Ministry of Education  
 "Zhao Shuqing goes to the Ministry of Education in  
 the middle of the night."

In order to observe how pitch range is affected by prominence, some words are emphasized by design. Sentences in group II are given in the following as examples, where tones in emphasized syllables are marked by "\*".

(34)

IIa: T1 \*T1\*T1 T1 T1 T1 T1  
 Ta jintian xiu shouyinji.  
 he today repair radio  
 "He repairs the radio today."

IIb: T1 \*T2 \*T1 T2 T1 T1 T2  
 Ta mingtian na shadingyu.  
 he tomorrow take sardine  
 "He will take sardine tomorrow."

IIc: T1 \*T3\*T1 T3 T1 T1 T3  
 Ta meitian pao fengdengchang.  
 he every day go to wind-lamp factory  
 "He goes to the wind-lamp factory every day."

IIId: T1 \*T4 \*T1 T4 T1T1 T4  
 Ta houtian qu xiguadi.  
 he the day after tomorrow go to watermelon  
 field  
 "He will go to the watermelon field the day after  
 tomorrow."

As shown in Figure 2.2, the pitch track of each tone occurs only in a portion of the whole pitch range. The reason the whole pitch range can be seen in this figure is that the four tones overlap in time. Using the same method, J. Shen overlaps the pitch tracks of every sentence in each group to show the variation of pitch range.

J. Shen measured pitch values of the total 120 sentences and analyzed how pitch range changes in each group read by the five speakers. He found that adjustment of either the lower limit or the upper limit may expand pitch range. The adjustment of the lower limit of a pitch range corresponds to a prosodic structure of a sentence. J. Shen marked prosodic structures in his examples; however, he made no comment on them. The following example shows the correlation between the lower limit of pitch range and the prosodic structure in sentences in group I.

(35)

sentences in group I:

	\$1	\$2	\$3	\$4	\$5	\$6	\$7	\$8	\$9
Prosodic: structure									
Value of lower limit in each syllable:	7.13	7.92	1.96	6.23	4.35	2.89	4.43	4.88	0.91

The values of lower (or upper) limits are normalized averages among speakers and are denoted as a relative unit "D".

J. Shen finds that the upper limit of a pitch range relates to emphasis of meaning. Value of the upper limit is larger in emphasized syllables than in neighboring unemphasized syllables. The adjustment of the upper limit also corresponds to prosodic groups. It is relatively narrow inside a small group. J. Shen also finds that the lower limit of the pitch range is not obviously lowered in emphasized syllables. Therefore the expansion of the pitch range is mainly due to a raising of the upper limit. Following is the example showing how the upper limit varies as a function of emphasized meaning in sentences in group II. Emphasized syllables are marked by "\*", where the high limit of pitch range is obviously raised.

(36)

Sentences in group II:

Prosodic group:	\$1	*\$2	*\$3	\$4	\$5	\$6	\$7
	__	_____			_____		
Value of upper limit in each syllable:	10.56	13.71	12.37	9.63	9.14	8.97	9.36

J. Shen referred to his findings as prosodic units, which up to that time were not considered in experimental

studies of Chinese tone. Although J. Shen (1985) did not discuss the function of prosodic units in tone sandhi or pitch contour formation, his findings are inspiring.

Shih (1989) also conducted experimental study on the variation of pitch range. She embedded time words with the tones TxTl in the sentence "Lao3 Wang2 \_\_\_\_\_ yao4 mai3 yu2." "Lao Wang wants to buy fish \_\_\_\_\_. " Also, she asked a speaker to read the sentences in three different manners of speech: (1) plain, (2) emphasis on "Lao2 Wang3", and (3) emphasis on the time words. She also asked the speaker to read an additional three sentences emphasizing the subject of the sentence, but changing "Lao3 Wang2" to "Lao3 Wang3". Her purpose was to test the influence of prominence on pitch realization. Her conclusion is consistent with that of J. Shen's: from the viewpoint of frequency, prominence is reflected in the expansion of the pitch range, which raises a high target, but may or may not lower a low target.

In the later chapters of this study, I will use a similar design to that found in J. Shen's (1985) and Shih's (1989) studies to analyze the variation of pitch range as well as how it affects pitch contours.

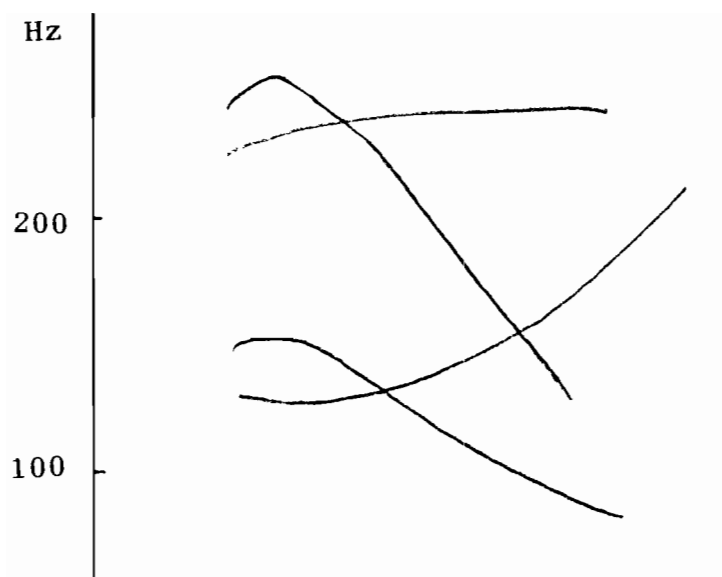


Figure 2.1 Pitch contours of  
the four Mandarin tones. Set 1.

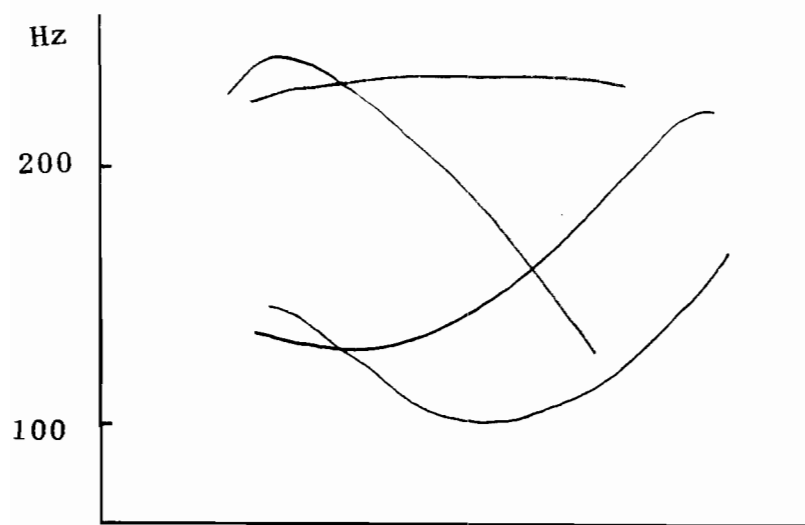


Figure 2.1 Pitch contours of  
the four Mandarin tones. Set 2.

## CHAPTER III

### METHODOLOGY

In this chapter, I will introduce the general purpose and detailed designation of experiments conducted in this study. Also, I will briefly describe the method used to transcribe segmental elements and syllabify pitch tracks.

#### 3.1. Purpose and methodology

The primary purpose of this study is to discover how tonal contours are adjusted in sentences and how the overall curve of an intonation is formed in continuous Mandarin speech. I adhere to the belief that in running speech there must be a general principle which governs both predicted and unpredicted tone sandhi, according to the phonological analysis that is currently available. Although this purpose makes the study phonological in nature, the data that my discussion is based upon is the output of instrumental analysis, i.e. curves of fundamental frequency, usually called "pitch tracks". I will place much more emphasis on qualitative rather than quantitative character-



istics of the data. I will describe basic principles rather than providing phonological representation such as the sequences of H and L tones, metrical structures and lining up rules.

The reasons why I use pitch movement as the basis of this study are the same as presented by Pierrehumbert (1980, p3-5). I will focus on why it is important to use pitch contour as evidence in the phonological study of intonation. As Pierrehumbert pointed out: transcription of intonation by ear is the source of many gross errors in literature, since native speakers' introspective capability about the intonational form is far inferior to that about lexical items. The difficulties of describing forms of tonal contours in Chinese is commonly experienced. Despite native speakers' ability to judge whether different words have similar tones, they are unable to describe the shape of the tones. Even linguists with special training can only roughly tell the shapes, and because they are based upon a vague auditory impression, they are often controversial and unreliable. A specific example which illustrates the importance of observing fundamental frequency is the unexpected difference between the contours obtained from computerized analysis versus auditory impression. This has lead linguists to the realization that many tone sandhis in spontaneous Mandarin speech are unpredicted (Tseng 1981).

The study of Mandarin tone sandhi and intonation in running speech is still in its infancy. Phonological descriptions of tone sandhi being based on auditory impressions, and also on carefully produced, short, artificial sentences or isolated sequences are both contributive reasons for this. The situations under which tonal and intonational phenomena have been studied are too limited. Consequently, there are few studies that pay attention to how pitch contours of tones are manipulated when entering sentences, especially relatively long and spontaneous sentences.

As I have mentioned, Tseng (1981) and Kratochvil (1986) have conducted two studies based on data of spontaneous speech. Both studies confirm the existence of unpredicted tonal variations; however, Tseng and Kratochvil analyze the cause differently. Tseng attributes the high, unpredictable, tone sandhi phenomena to tone sandhi rules of different levels. She assumes that the unpredicted pitch contours are a result of the application of tone sandhi rules at the sentence level, while the phonological rules that we currently have are at the phrase level. Oppositely, Kratochvil appears to be more cautious and does not suggest a cause for the unpredictableness, but instead states that the relationship between "citation forms and other similar artificial forms" and "normal speech" (Kratochvil 1968:260)

is unknown. He calls spontaneous speech "normal speech" and the reading of designated test words as "citation form" or "artificial form". The former is always produced in a casual style, while the latter in a careful, or formal, style. By emphasizing the difference between the forms, he tends to attribute the unpredictable nature of tones more to speaking styles rather than levels.

Surprisingly, most studies of tone or intonation are based upon data of formal style speaking, with disregard for style differences, although this might seriously influence pitch contours of tones. The main reason for reliance upon formal style is, again, due to the low sensitivity of human ears to tonal forms. In comparison to formal speech, casual speech varies much more in speaking rate, general loudness, places of emphasis, and quality of segments. Without hesitation, native speakers are able to point out differences in these aspects between sentences produced in the two typical styles. However, according to auditory impression, tones do not seem to differ between speeches of casual and formal styles. This idea is reinforced by native speakers sensing that tone forms in both styles are almost the same.

Both Tseng (1981) and Kratochvil (1986) compare pitch contours of tones in continuous speech spoken in a casual style to those in isolated phrases spoken in a formal

style. Since both variants, level and style, are involved, it is difficult to differentiate whether effect of one or both are present and influence tone sandhis. In order to find a cause for the highly unpredictable nature of tones in spontaneous speech, it seems necessary to observe various types of data. The data should be derived from formal and casual styles of speaking at different levels. However, it is impossible to obtain a naturally spoken pre-determined isolated phrases. Consequently a speaker has to read, although in a relatively casual manner, rather than say the tonally controlled phrases. Therefore, I will observe pitch tracks of isolated words or phrases in a reading style that is less formal than those in other studies. I will also use two groups of sentences as my data in the study of tone sandhis and intonations. I will compare the pitch tracks of each group's sentences in spontaneous and read speech. I will hypothesize general regulations about how tones change and intonations are formed.

Elements that have been previously studied in tonal literature and found to effect tone sandhis include: tonal environment, speaking rate, and position of emphasis. How each element may function under certain conditions warrants considerably more studies. However, I will use specifically designed sentences, as well as certain spontaneous sentenc-

es, as data to discuss the effects such elements may have upon tone sandhis.

### 3.2. Speakers and the transcription of test material

Throughout this study, seven subjects have been used. They are all native Beijing Mandarin speakers, of whom five are females, H, C, Z, Q and ZH, and two are males, Sh and J. They range in age from twenty-eight to forty-four, and all have a college education. They had lived in the United States for less than two years at the time of the tape recording for this study. Among these subjects, H, C, and Z, are the main speakers. They were recorded for the test materials discussed in the following sections: spontaneous speech in 3.3 and controlled speech in 3.4.1-3.4.4. The other four subjects read test material only in 3.4.5.

The tape recordings were made in the Linguistic Laboratory, at Ohio State University. Test material for speakers to read was transcribed in Chinese characters. In the text of this dissertation, all test materials are transcribed using Pinyin romanization, the system generally used in Mainland China, and in some other countries. Because the attention is focused on pitch movement, segmental transcription is phonemic and hence does not reflect phonetic changes such as consonant-voicing and vowel-neutralization. Consonant-deletion occurs quite often in

spontaneous speech. Figures in this dissertation are all output of instrument analysis. Weak syllables in the figures, due to lack of space or a dropped initial consonant, are marked by a "'" above the vowel in the same syllable, and a dropped vocalic portion is not transcribed. Tone numbers are marked above the segmental transcriptions in some figures.

In order to help readers who are not familiar with the Mandarin sound system to obtain a general impression of the quality of the consonants and vowels, a table of correspondence between Pinyin romanization and International Phonetic Alphabet is provided in the List of Symbols.

### 3.3. Test material of spontaneous speech

For the purpose of analyzing how pitch contours of tones behave when entering sentences in both casual and relatively formal styles, uncontrolled data is produced using the following method.

The three main subjects, H, Z and C, were asked to sit together in the laboratory's sound-treated booth and chat. One by one, they were asked to tell stories about driving, and the narrations were recorded. Then, a portion from each recording was randomly selected and transcribed. The number of syllables in the speakers' selected portions of stories are 410, 392, and 423 for speaker H, Z, and C respectively.

The total number is 1225.

Several weeks later, each speaker was asked to read the transcription of her own story in the laboratory, which was again recorded on tape. The instructions for reading were: to read continuously, do not stop even if a few syllables are misread. The number of syllables in the speakers' reading of their own stories are 409, 387, and 418 for speaker H, Z, and C respectively. The total number is 1214.

H and C were also asked to read the transcription of Z's story and, again, were recorded. The number of syllables in the other speakers' readings of speaker C's story are 421 and 328 for speaker H and Z respectively. The total number is 749.

There are differences between the narration and reading of each story, since various speakers dropped and added syllables. However, the number of these syllables is only 0.1% of the total number of the syllables. These mistakes should not affect the comparison of tonal change between the speaking and reading versions.

### 3.4. Test material of controlled speech

For the purpose of observing tones in isolated phrases and the single influence of certain effects, controlled materials are utilized in the following sections.

#### 3.4.1. Isolated words

Each of the speakers were asked to read the isolated words in Table 3.1 and 3.2. The monosyllabic words in Table 3.1 were read twice because they were small in number. The disyllabic words in Table 3.2 were read only once. The purpose of recording the isolated words was to examine the general characteristics of the four Mandarin tones in a less formal reading style. Therefore, the instructions were only, "To read naturally, and have a clear pause after each word so that its sound is not connected with that of the next word". I did not ask the speakers to practice before making the recordings. Even so, the speakers still read the test words with care, although not too much.

The reasons why I did not want the test words to be read in a rather formal style are as follows. First, as reviewed in section 2.2.2, several studies have introduced pitch contours of the four citation tones in a formal reading style and I did not wish to repeat this. Secondly, I have conducted other pilot experiments on formally produced Mandarin tones. The pitch contours of the carefully produced citation tones are always similar to those reviewed in section 2.2.2.

Each of the test words were produced in a similar environment, without a carrier sentence but surrounded by pauses. Because of this arrangement, I can observe tones in



an truly isolated form, and see how their characteristics might have changed. Since a T3 is always described as a falling-rising contour, in such an environment, I will pay close attention to its pitch contours to see if there is any variation.

Table 3.1 Monosyllabic words with different tones

T1	T2	T3	T4
ba `eight'	ba `pull'	ba `hold'	ba `father'
di `low'	di `enemy'	di `bottom'	di `ground'
gu `lone'	gu `bone'	gu `drum'	gu `hire'

Table 3.2 Disyllabic words with different tonal combinations

Tones	word A	word B
T1T1	dongbian `east side'	huamao `tabby'
T1T2	qinghe `clear river'	jinnian `this year'
T1T3	shanshui `mountains & rivers'	jinliang `weight'
T1T4	dichu `low place'	gonglu `high way'
T2T1	maobian `rough edge'	baimao `white cat'
T2T2	huanghe `Yellow River'	niumao `ox hair'
T2T3	laoku `toil'	baima `white horse'
T2T4	tudi `apprentice'	duli `independence'
T3T1	yeji `pheasant'	yuyi `rain coat'
T3T2	wutai `stage'	naiyou `cream'
T3T3	shoubiao `watch'	xiaoma `little horse'
T3T4	shuiba `dam'	xiaolu `lane'
T4T1	mifeng `bee'	shangyi `jacket'
T4T2	danbai `egg white'	shulin `woods'
T4T3	Hanshui `Han river'	shangyan `perform'
T4T4	zhengdao `the right way'	dalü `continent'

### 3.4.2. Sentences with T<sub>i</sub> strings

The following four sentences, each of which contains a sequence of the same tones, were used as test sentences. The series number `Si' (where S = sentence, i = 1, 2, 3, or 4) indicates the corresponding tone found in each syllable in the sentence. For example, `S1' is used for sentences in which each syllable bears T<sub>1</sub>. The basic sentences were designed by J. Shen (1985). Two syllables, the words after the time word, were added to each sentence in order to make them longer for this study.

(1)

S1a: Zhang Zhongbing jintian yinggai xiu shouyinji.  
Zhang Zhongbing today should repair radio  
"Zhang Zhongbing should repair a radio today."

S2a: Wu Guohua mingnian cai neng hui Yangchenghu.  
Wu Guohua next year only can go back Yangcheng Lake  
"Wu Guohua cannot go back to Yangcheng Lake until next year."

S3a: Li Xiaobao jiudian ye xiang xie jiangyangao  
LiXiaobao9:00 also want write draft for a  
lecture  
"At 9:00, Li Xiaobao also wants to write a draft for a lecture."

S4a: Zhao Shuqing banye you yao shang jiaoyubu.  
Zhao Shuqing midnight again will go to the Ministry  
of Education  
"Zhao Shuqing will go to the Ministry of Education in the middle of the night again."

In order to compare the pitch movement of these sentences using different styles, moods, or with emphasis at different places, each speaker was asked to repeat each of these sentences six times, producing them in each of the following manners, designed by 'a' through 'f'.

(2)

Sia: formal, statement, plain;  
 Sib: casual, statement, plain;  
 Sic: casual, yes-no question.  
 Sid: casual, statement, emphasis on the subject  
       (To answer the question "Who...?").  
 Sie: casual, statement, emphasis on the time word  
       (To answer the question "When...?").  
 Sif: casual, statement, emphasis on the object  
       (To answer the question "What/Where...?").

First, the speakers are asked to simply read each of the four sentences using a formal reading style for the recording. Then, the differences among the other five repetitions were explained to them. When making the tape recording, they were asked to say the sentences, rather than read them, by answering a sequence of questions. For example, they answered each of the following questions to record sentences S1b-S1f.

(3)

Question for S1b:  
 Zhang Zhongbing jintian yinggai zuo shenme?  
 Zhang Zhongbing today should do what  
 "What should Zhang Zhongbing do today?"

Question for S1c:

Zhang Zhongbing jintian yinggai xiu shouyinji ma?  
 Zhang Zhongbing today should repair radio PART  
 "Should Zhang Zhongbing repair the radio today?"

Question for S1d:

Shei jintianyinggai xiu shouyinji?  
 who today should repair radio  
 "Who should repair the radio today?"

Question for S1e:

Zhang Zhongbing shenme shihou yinggai xiu shouyinji?  
 Zhang Zhongbing what time should repair radio  
 "When should Zhang Zhongbing repair the radio?"

Question for S1f:

Zhang Zhongbing jintian yinggai xiu shenme?  
 Zhang Zhongbing today should repair what  
 "What should Zhang Zhongbing repair today?"

### 3.4.3. Additional sentences containing T2 or T3 strings

Observing J. Shen's (1985) sentences, which contain a sequence of the same tones, T2 and T3 exhibit more unexpected variants than T1 and T4. In order to obtain more pitch tracks of T2 strings and T3 strings, two sets of additional sentences were designed. For the purpose of analyzing if tone sandhi is affected by syntactic structure or syllable number, the sentences in each set differ from one another in syntactic structure and/or number of syllables. The full set of sentences which contain T2 strings is S5a-S5d, and which contains T3 strings is S6a-S6h.

(4)

S5a:Guohua lai chan Guoping wanr qiaopai.  
 Guohua come pester Guoping play Bridge  
 "Guohua pestered Guoping to play Bridge."

- S5b: Guohua chang lai chan Guoping wanr qiaopai.  
 Guohua often come pester Guoping play Bridge  
 "Guohua often comes to pester Guoping to play Bridge."
- S5c: Guohua he Guoping chang wanr pai.  
 Guohua and Guoping often play Bridge  
 "Guohua and Guoping often play Bridge."
- S5d: Guohua chang lai wanr pai.  
 Guohua often come play Bridge  
 "Guohua often comes to play Bridge."
- S6a: Li Xiaobao jiudianzheng ye xiang xie jiangyangao  
 LiXiaobao 9:00 sharp also want write draft for  
 a lecture  
 "At exactly 9:00, Li Xiaobao also wants to write a draft for a lecture."
- S6b: Li Bao jiudianzheng xie jianggao  
 LiBao 9:00 sharp write draftfor a lecture  
 "At exactly 9:00, Li Bao will be writing a draft for a lecture."
- S6c: Li Bao jiudian ye xie jianggao  
 LiBao 9:00 also write draftfor a lecture  
 "At 9:00, Li Bao also will be writing a draft for a lecture."
- S6d: Wo jiudianzheng xiang xie jianggao.  
 I 9:00 sharp want write draft for a lecture  
 "At exactly 9:00, I want to be writing a draft for a lecture."
- S6e: Wo jiudian zong xiang xie jianggao.  
 I 9:00 always want write draft for a lecture  
 "At 9:00, I always want to write the draft for a lecture."
- S6f: Wo ye zong xiang xie gao.  
 I also always want write draft  
 "I always want to write the draft, too."
- S6g: Wo zong xiang xie gao.  
 I always want write draft  
 "I always want to write the draft."
- S6h: Wo jiudian xie gao.  
 I 9:00 write draft  
 "At 9:00, I will write the draft for a lecture."

#### 3.4.4. Sentences containing neutral tone syllables.

J. Shen (1985) designed four sentences to test neutral tones. These same four sentences are also used in this study, and are given below as Si ( $i=7, 8, 9, 10$ ). Each speaker read these sentences twice: Sia in a formal reading style, and Sib in a casual speaking style.

(5)

S7: Gege      zhuo shang ge    zhe    xin de   boli   bei.  
 brother desk top    put ASP   new PART glass cup  
 "There is a new glass cup on my brother's desk."

S8: Yeye      lou      shang cang zhe lan    de    gezini.  
 grandpa building top hide ASP blue PART tartan  
 "There is some tartan hidden upstairs in mygrand-  
 father's    place."

S9: Jiejie shou shang you    ge zhi    de    labatong.  
 sister hand top    have CL    paper PART megaphone  
 "There is a paper megaphone in my sister's hands."

S10: Didi      bei      shang fang zhe sui      de    mutoukuai.  
 brother quilt top    put    ASP broken PART wood cube  
 "There are broken pieces of wood on my brother's  
 quilt."

#### 3.4.5. Sentences testing the effect of catathesis

In order to test for the effect of catathesis, a set of sentences were designed. All of these sentences have the following segmental sequence and for each sentence, all of the syllables except two have the high level tone T1:

- (6)                    Zhang Wu-yi yao maomi.  
                          55        ?    55 ?       55 55  
                          Zhang ?    yi ?       cat  
                          "Zhang ? -yi ? a cat."

By changing the tone for the syllable wu, the subject's name is changed and the tone change on yao, results in different verbs. By using different tones in each of the two syllables, different combinations and thus, different sentences would be formed.

If T1 was used in both the syllables wu and yao, the sentence would have a sequence of T1's, i.e. a sequence of high tones. A sequence of HLH would be formed if either a T2, T3, or T4, all of which contain a low target, is used in any of the two syllables. In such a case, the effect of catathesis may exist. I will not examine all of the possible HLH sequences resulted by changing the tones in the syllables wu and yao for two reasons. First, my purpose is only to see if catathesis, single or chained, exists in Mandarin. Secondly, I want to limit the quantity of experiment. Specifically, I will not use T2 to test the effect of catathesis. The reason is that L in a T2 is associated with a rising contour while that in a T3 or T4 with a falling contour. I would like to see if there is any difference in the effect of catathesis triggered by the L's in the two falling contours, rather than in one rising and one falling contour. I wonder if the lower L in a T3 would cause a

stronger effect of catathesis than the higher L in a T4 would, if the effect indeed exists in Mandarin. By alternating T1, T3, and T4 in the syllables wu and yao, there should be nine combinations, or sentences. To test if there is a chained effect of catathesis, I will examine those triggered by the L's in the same tones, i.e. in both T3's or T4's, rather than in different tones, i.e. in one T3 and one T4. From this method, I will also be able to see what type of difference may exist between the chained effects triggered by two T3's and those triggered by two T4's. Now seven combinations, and thus seven different sentences, are left. The seven sentences differ only in the tones of the syllables wu and yao and are identified as W<sub>i</sub>Y<sub>j</sub> (i or j = 1, 3, or 4) as follows.

- (7) W<sub>1</sub>Y<sub>1</sub>: Zhang Wu-yi yao maomi.  
 55 55 55 55 55  
 Zhang Wu-yi invite cat  
 "Zhang Wu-yi invites a cat."
- W<sub>1</sub>Y<sub>3</sub>: Zhang Wu-yi yao maomi.  
 55 55 55 214 55 55  
 Zhang Wu-yi bite cat  
 "Zhang Wu-yi bites a cat."
- W<sub>1</sub>Y<sub>4</sub>: Zhang Wu-yi yao maomi.  
 55 55 55 51 55 55  
 Zhang Wu-yi want cat  
 "Zhang Wu-yi wants a cat."
- W<sub>3</sub>Y<sub>1</sub>: Zhang Wu-yi yao maomi.  
 55 214 55 55 55 55  
 Zhang Wu-yi invite cat  
 "Zhang Wu-yi invites a cat."



W3Y3: Zhang Wu-yi yao maomi.  
 55 214 55 214 55 55  
 Zhang Wu-yi bite cat  
 "Zhang Wu-yi bites a cat."

W4Y1: Zhang Wu-yi yao maomi.  
 55 51 55 55 55 55  
 Zhang Wu-yi invite cat  
 "Zhang Wu-yi invites a cat."

W4Y4: Zhang Wu-yi yao maomi.  
 55 51 55 51 55 55  
 Zhang Wu-yi want cat  
 "Zhang Wu-yi wants a cat."

Each of the four speakers, Q, Zh, Sh and J, read all of the seven sentences ten times in random order. The reason why the speakers should read the sentences ten times rather than once or twice is related to the nature of the test. The effect of catathesis is reported to be rather small in size (Shih 1989), and hence causes only phonetic variations rather than phonological differences of tonal contours. If this would also be true for my data, then only one or two samples from each speaker would be too few to reflect the fact. Ten samples from each of the four speakers result in forty samples altogether. If these samples confirm the existence of the effect, it would be more convincing.

### 3.5. Speech analysis

Part of the tape recordings were analyzed by the speech analysis system which belongs to the Linguistic Laboratory, Department of Linguistics, The Ohio State

University. The majority of the tape recording was analyzed by a speech analysis system called the "Computerized Extraction of Components of Intonation in Language" (CECIL) in the Department of East Asian Languages and Literatures, at Ohio State University. CECIL uses an 8-bit resolution of speech signal, and a sample size of 10K.

Sentence ZJ2, spoken by Z was analyzed by CECIL. The pitch track is show in Figure 3.1, "UT" indicates underlying tones.

(8) ZJ2:  
 Kao wan le ta ye mei jiancha wo  
 214 35 0 55 214 35 214 35 214  
 test finish PERF she also not check me  
 "After taking the test, she did not check  
  
 shenme deng a,...  
 35 0 55 0 UT  
 what light PART  
 things likelights,..."

During experimentation with the CECIL, I tried to syllabify the waveform of the data on the screen and put transcriptions above the syllables. The process involves locating the boundary between syllables by analyzing the pattern of waveform and also by listening to the portion of the sentence being examined. As mentioned in section 3.2, if an initial consonant is dropped from a weakened syllable, it is marked by a "'" above the following vowel.

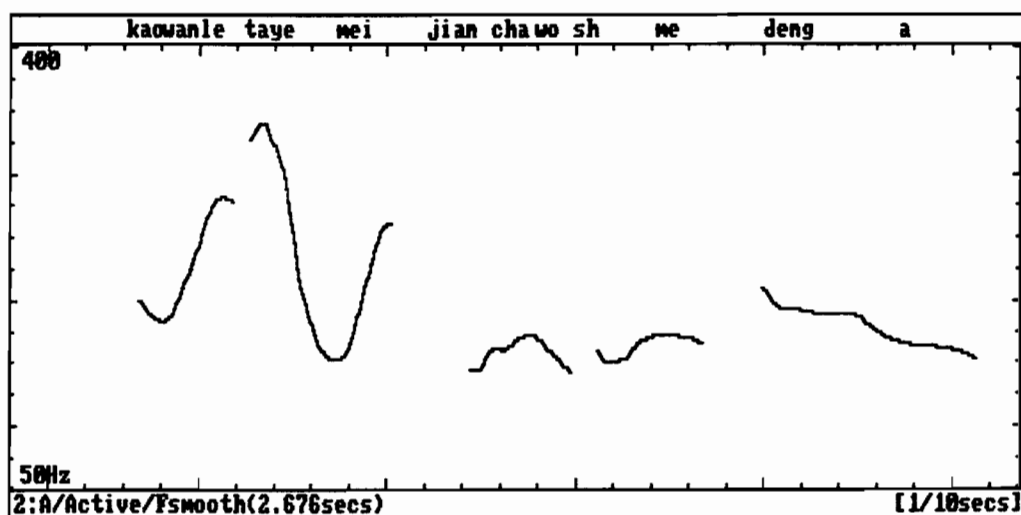
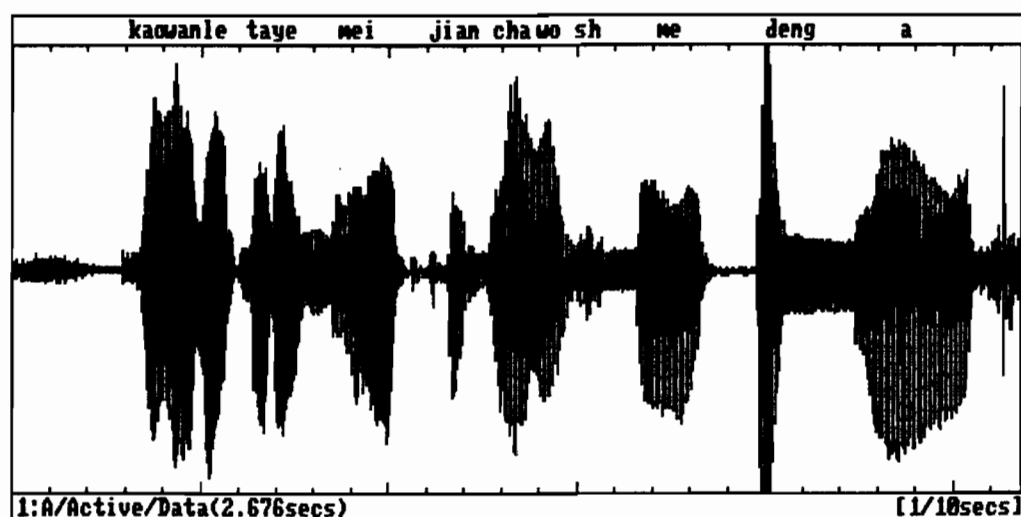
If the vocalic portion of a weakened syllable is dropped, only the consonant is transcribed. In the above example, no syllable exhibits this type of weakening. In the very weak syllable shen, the waveform of both consonant and vocalic portions are visible, although the amplitude is rather low.

It is often rather difficult to locate a clear-cut boundary between two syllables, according to the waveforms or listening to tape-recordings. For example, when the first syllable ends, and the second syllable starts with a vowel or a nasal consonant, there may be no clear boundary since the change is gradual. In such cases, a judgment concerning where the boundary is, has to be made. The judged boundary provides a reference for locating and identifying the pitch contour of the following syllable.

After syllabifying the waveform, the pitch curve of each syllable could be located on the pitch track of the whole sentence, according to the time scale in the figure. A more direct method of identifying the pitch track of a syllable is to draw two vertical lines on the waveform, at the boundaries between this syllable and the surrounding syllables, and to extend the lines from the upper portion of the figure to the lower portion. The section of pitch track which is cut out by the lines is the corresponding pitch track of the syllable. Figure 3.2 provides an example of a syllable pitch track identified by this method. The sentence

and the output from the CECIL are the same as those in the above example. In order to identify the pitch track of the syllable denq, two vertical lines are drawn on the waveform at the boundaries between it and the surrounding syllables me and a. The lines are extended from the upper portion of the figure, the portion of waveform, to the lower portion of the figure, the portion of pitch tracks. The high level curve of the pitch track, which is between the two extended vertical lines, represents the tonal contour in the syllable denq. The pitch track does not start from the very beginning of the syllable because its initial consonant is a voiceless stop.

Later in this study, when I discuss the pitch track of tones in the data, I will not actually draw the vertical lines on the figures. I suggest the reader imagine the lines by referring to the time scale, and use a ruler to check the imagination, if necessary.



Figures 3.1 An output from the CECIL system: waveform and pitch tracks of sentence ZJ2, Kao wan le, ta ye mei jiancha wo shenme deng a ... 'Took the test, then, she did not check things like lights ...'

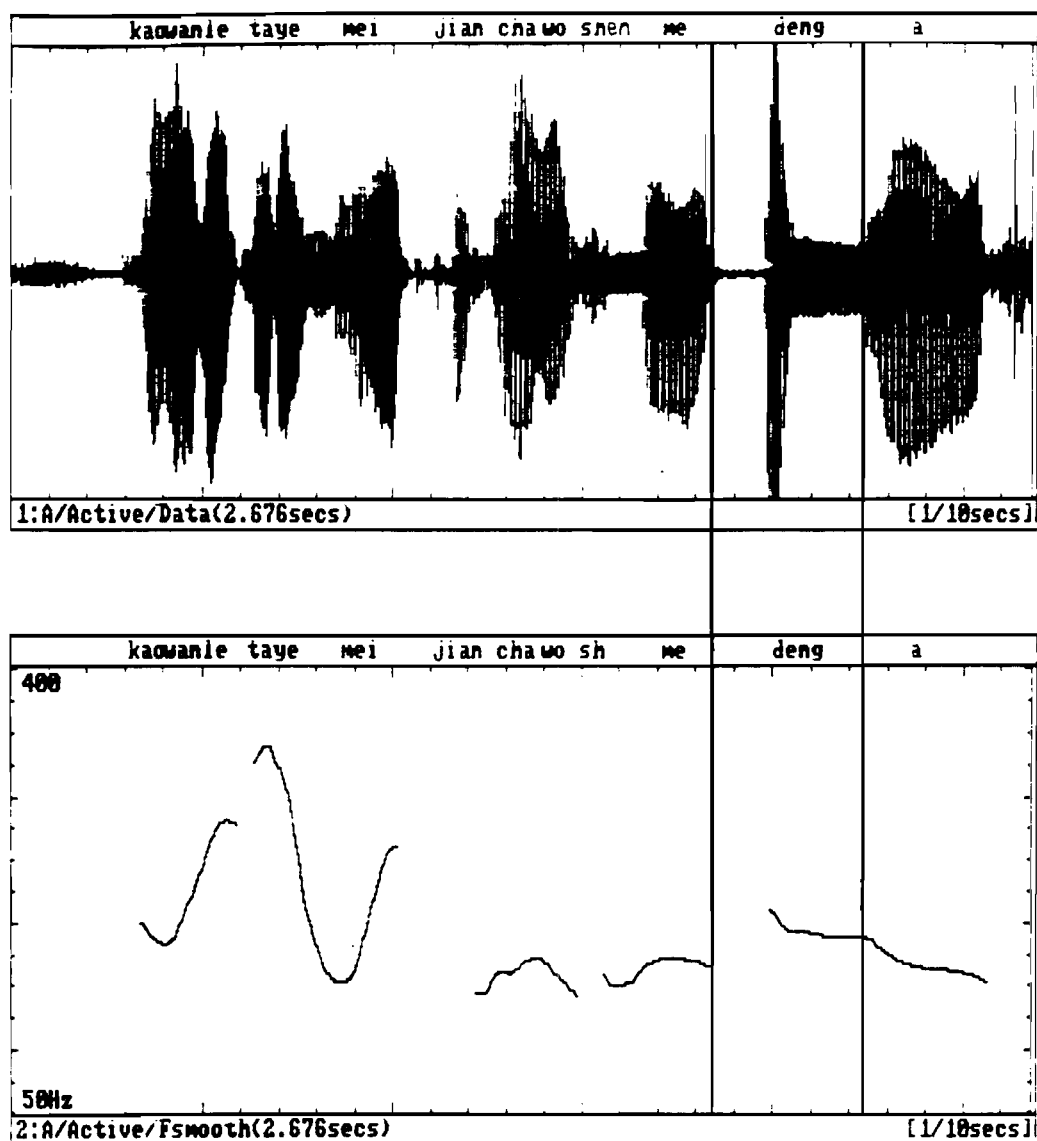


Figure 3.2 Identification of pitch track of syllable deng according to the waveform of the syllable in sentence ZJ2, kao wan le, ta ye mei jiancha wo shenme deng a ... 'Took the test, she did not check things like light ...'.

## CHAPTER IV

### TONE PRODUCTION AND PREDICTION

In this chapter I will observe pitch contours of tones in the experimental data in order to see how well surface tones are pre-dicted in both isolated monosyllabic and disyllabic forms and also in spontaneous story tellings. Issues concerning the transition of tones will also be addressed.

#### 4.1. Tone production in monosyllabic words

For the collection of data regarding individually pronounced syllables, I have chosen to use the syllables ba, di, gu. These syllables are ideal because they contain Mandarin stops in all articulatory positions and Mandarin vowels in extreme heights or backness. Also because all of these syllables can occur with any of the four tones. Pitch tracks and waveforms of the syllable "ba", pronounced in the four basic tones by speaker H, are given in Figures 4.1. and 4.2. The pitch curves are well predicted by the

phonological descriptions that are reviewed in section 2.1.2. Although the T3 does not raise its tail quite as high as what is usually described by the value "214", it does have a falling-rising shape. All the T1's, T2's and T4's, as well as most of T3's produced by the three main speakers, have pitch contours that are similar to those shown in Figures 4.1 and 4.2.

Although the monosyllabic tones in our data are generally predictable by the phonological rules, T3's produced by speaker C exhibit some unusual contours. Instead of falling-rising shapes, the T3's are produced as a purely low falling curve in syllables "di" and "gu". Figures 4.3 and 4.4 show these curves together with those of T4's spoken by the same speaker.

Reviewing Chapter 2, according to most tonal studies, there are two types of T3 variants if the T3 is not followed by another T3: a low falling-rising type and a low falling type. These variants never occur in the same environment. The former always appears in a position preceding a pause or stop, while the latter occurs in a position not followed by a pause or stop. Isolated forms belong to the former. Shih (1986) mentioned that the low falling variant of T3's occurs in sentence final positions in spoken Taiwanese Mandarin. J. Shen (1985) and S. Shen (1990) also found this type of variant in final position in



their Beijing Mandarin data. However, no study has yet reported any low falling T3 which occurs in the isolated form. A rising tail is always expected in an isolated T3 and consequently speaker C's low level and low falling T3's are of interest.

The question might arise: did speaker C produce the test syllables too close together, resulting in tone sandhi (T3 becomes a half T3 before a T4)? Figures 4.3 and 4.4, however, show that the pauses between the T3's and the following T4's are not that short. They range from 450 to 550 milliseconds in length, which are long enough to keep the shape of the falling-rising T3's unaffected. The speaker read the monosyllabic words twice. In fact, the second time that she read the words, the T3 in the syllable "gu" was produced as a falling-rising tone before a pause of about 500 milliseconds. Also, though the pause following the T3 by speaker H in Figure 4.2 is about the same in duration, the T3 maintains its falling-rising shape. Therefore, the production of the unusual isolated T3 curves in the data should not be attributed to tone sandhi.

The unusual variations of isolated T3's sound very natural to native speakers. I have played the tape to several native speakers and asked them if they feel that the T3's sound unnatural or different from other speakers' T3's. The answers were always the same: they sound natural, and

are similar to the other speakers' T3's.

The fact that native speakers are not sensitive to the difference between a low falling shape and a falling-rising shape for an isolated T3 indicates that the basic features of this isolated T3 are the same as those of a non-isolated T3. It has a low pitch level and a non-rising pitch contour. Whether the T3 has a rising tail or not is unimportant.

It might be questioned why different shapes for the isolated T3's arise. I would like to assume that they are physically conditioned, rather than caused by different positions. The physical condition which favors the production of the low falling T3 usually occurs in front of a T1, T2, or T4, I call it position 1. The physical condition which favors the production of the low falling-rising T3 occurs before a pause or stop, I call this position 2. This gives linguists the impression that each of the two T3 variants can only occur in one position. Under certain situations, the physical condition favoring the low falling T3 may instead occur in position 2 instead, and the physical condition which favors the low falling-rising T3 may occur in position 1. The low falling T3 variants in Figures 4.3 and 4.4 help to confirm this assumption. More evidence, which will be seen in my data in the later chapters, proves that low falling T3's may occur in sentence

final positions and that low falling-rising T3's may occur in front of T1's, T2's, or T4's.

#### 4.2. Tone production in disyllabic words

Figures 4.3-4.10 show all of the pitch tracks and waveforms of disyllabic words produced by speaker H. There are two test words for each tonal combination. For example, dongbian 'east side' and huamao 'tabby' for the T1T1 tonal combination. The shapes of the pitch tracks for each pair of test words are similar. The main difference between the members of the pairs is that the second syllable contains a voiceless consonant onset in word A but a voiced one in word B. The corresponding difference seen on the pitch track is the pitch curve which contains a broken line for word A but a continuous line for word B. However, T2T1 maobian 'rough edge', T3T3 shoubiao 'watch', and T4T2 danbai 'egg white' are influenced by the surrounding vowels. The phonological voiceless consonants become voiced intervocalically, so the pitch tracks are continuous. On the other hand, for T1T3 jinliang 'weight', T3T3 xiaoma 'little horse', and T4T3 shangyan 'perform', the continuous pitch tracks are broken for a short duration because there was a change in the speaker's voice quality, which is clearly reflected in the corresponding waveform.

Do the pitch tracks of all tones for disyllabic words show the predicted features in both height and shape? As mentioned in the introduction, it is commonly assumed that the basic contour of a tone is co-extensive only with the syllabic vowel and any voiced segment that may follow it (Howie 1976). Therefore, I will examine the portion of each pitch track that corresponds to the syllable finals, i.e. the vowel and the following segment(s) in the syllables. As seen in Figures 4.3-4.10, most tones keep their isolated heights and shapes when entering disyllabic tonal combinations. As expected, the T3 exhibits a rising contour in front of another T3, and a low falling contour before other tones. Also, the T4 does not quite end low in the first syllable of a disyllabic word. Similar tonal representation also occurs in other speakers' data. Therefore, most tonal combinations in disyllabic words are generally predicted by the phonological descriptions mentioned.

As noted in the discussion of isolated forms, the shape of T3 in the final position, or before a pause, is not always predictable. Although it shows a low falling-rising curve in the tonal combinations T1T3 and T4T3, it does not have the final rise in T2T3, which is the same as what was noticed in speaker C's isolated T3's. Also, the T3 starts as high as a T4 in the combination T2T3. This high starting T3

variant is another phenomenon that has never been reported in previous studies. In each of the other speakers' pronunciation, there were also two cases of final T3's without rising tails.

#### 4.3. Reading style and phonological prediction

In summarization of the above observation, the phonological description cannot predict all of the monosyllabic and disyllabic tones in our data, since T3 has several unpredictable variants, which occur in every speaker's pronunciation.

The question then arises: why are there unpredicted variants of T3 in this data but not in other studies? I would say that this concerns the speaker's style of reading. As mentioned earlier, none of the speakers were instructed to read the words very carefully or formally, nor were they asked to practice their pronunciation before being recorded. They had also chatted and told stories in the sound booth before reading the words, thus setting up an informal atmosphere. Therefore, the words were read in a relatively casual style. Most speakers in other studies read in a formal style, and many were asked to practice the pronunciation carefully before making the tape recording. Consequently the more casual articulation in this data is the main reason for the variations of T3.

There is evidence which confirms the observation that the speakers produced the controlled test words in a relatively casual style. For example, there is speaker C's production of some monosyllabic words. When asked to read the monosyllabic words twice, and she read them much more carefully in one time than the other time. As a result, the unpredicted low falling T3, which occurs in one pronunciation of the syllable gu `drum', does not show up in the other pronunciation. Instead, she pronounced the predicted falling-rising contour for the syllable, which is shown in Figure 4.21.

What, then, are the characteristics of casual articulation? By common sense, casual speech is a "lazy" kind of speech, in which many sounds are not clearly enunciated and some sounds are "swallowed". Also, changes between sounds become smoother and harder to distinguish. A casual type of articulation is one in which sounds are not fully articulated since some gestures are not completed. This phenomenon is often clearly reflected in spectrograms. For example, dynamic movement of some acoustical components, such as the second formant, among a sequence of sounds is different in formal speaking. As for a specific sound, not only unrequired optional features, but also features thought of as required, can be seriously affected. The disyllabic word shoubiao `watch', can serve as such an example. The

optional feature of roundness, which is "unrounded", in the consonant sh is strongly assimilated by that of the following rounded vowel ou, and hence becomes "rounded". As previously mentioned, the required feature "voiceless" in the voiceless stop b is also seriously influenced by the surrounding vowels in the mid position of the disyllabic word, and changes to "voiced" in phonetic representation. The higher the degree of casualness, the more the features may be weakened. The most notable evidence is that most voiceless consonants are voiced in my data of spontaneous speech.

I have attributed the occurrence of unpredicted T3 variants in my data to the casual speaking style, and it is known that casual articulation weakens sounds. The rule that a T3 becomes a half T3 in front of other tones has also been treated as a weakening rule in some studies (Zhang 1988). However, it is not yet known what the general regulation of tonal weakening is at this moment. I will show complicated phenomena of tonal weakening exhibited in my data of spontaneous speech, and hypothesize a general principle which governs the realization of pitch contours in weakened syllables.

Regardless, a modification of the knowledge presented as a phonological description of monosyllabic and disyllabic tones is necessary. Note that the description is about a

particular style, the formal or careful style. If a speaker reads test words in a rather casual style, then not only the T3, but also the other tones might vary their heights or shapes a great deal, and thus become hard to predict. In fact, figure 4.5 and 4.6 shows that there are two examples of this type of change, even though the speaker did not read the words in a highly informal manner. The first example is that the second T1 in the T1T1 dongbian 'east side' is much lower than the first T1. In fact, it is in a mid level or a level even lower than a mid. The second example is the T1T2 qinghe 'clear river', where T1 is rather curved in shape, but T2 is rather flat, compared with the phonological prediction. It can hardly be classified as a rising tone, since the whole shape is a falling- rising.

In short, for isolated tonal combinations, the phonological description of tones that has been discussed cannot adequately predict tones produced in the casual style. Therefore, the traditional phonological description should be limited to tones produced in the formal style.

#### 4.4. Transitions between tonal contours

In order to communicate a comprehensive knowledge of tonal variation in a sequence of sounds, I must address not only the basic contour of the tones, but also the transitions between them.



Based on his observation of pitch tracks of monosyllabic tones, Howie (1976) concluded that the portions of pitch tracks which occur with initial voiced consonants or non-syllabic vowels are "anticipatory adjustments of the voice". Examining the same portions of pitch tracks in the syllables of monosyllabic forms disyllabic forms and connected sentences in the data, I find that Howie's conclusion is also correct if referring to syllables in any initial position. This includes not only monosyllabic words, but also the initial syllables of di- or polysyllabic words. For syllables in non-initial position, the same portions of pitch tracks often serve not only as "anticipatory adjustments" of the voiced portions that they are leading, but also as "progressive adjustments" of those that they are following. In other words, they serve as transitions between the basic tonal contours of connected syllables. Figure 4.2.1.5 provides two examples of this type of tonal transitions between T2 and T1. The transition is rather smooth in the word baimao 'white cat' but rather curved in the word maobian 'rough edge'. The shape of the transition in the latter clearly shows how the pitch first tends to fall down as a progressive adjustment after a low rising T2 and then tends to rise up as an anticipatory adjustment before the high level T1. If the basic tonal contour ends high in one syllable but starts low in the

next, or conversely, if one ends low and the next starts high, the adjustment would cross quite a large frequency range. This is reflected in examples from Figures 4.5-4.10. There is a high-low transition, which crosses a large frequency range, between T1 and T2 in jinnian 'this year' or between T2 and T2 in niuniao 'ox hair'. The starting and ending points can be identified by referring to the waveform of the co-extensive consonant n or m. A low-high transition, which also crosses a large frequency range, is exhibited between T3 and T4 in xiaolu 'lane' or between T4 and T4 in dalü 'continent'. It can also be easily located by referring to the corresponding waveform of l. In the same manner, a high-high transition between T1 and T4 in gonglü 'high way' or a low-low transition between T3 and T2 in naiyou 'cream' is easily recognizable. However, this transition does not cross a large pitch range.

Certain manners of articulation of consonants also affect the shapes of the transitions. As noted, some of the pitch curves mentioned above do not show a smooth transition between connected syllables. These rather curved transitions are exhibited in examples such as T2T1 maobian 'rough edge', T2T4 duli 'independence', and T3T3 shoubiao 'watch'. I have attributed the curve to the combination of its two portions: the progressive adjustment of the preceding tonal contour and the anticipatory adjustment of

the following tonal contour. In fact, the curve is also due to the perturbative explosion of the following consonant which suddenly raises the pitch height somewhat. Sometimes the pitch track breaks because of the explosion, and consequently the frequency after the break jumps up a little. Thus the pitch curve seems to serve only as the progressive adjustment of the preceding tonal contour. Transitions in T1T1 dongbian 'east side', and T2T4 tudi 'apprentice' are examples of this type. The frequency is approximately raised as much as 20 Hz across the explosion in the latter. Even so, the small break is negligible when studying the whole shape of the pitch contour.

#### 4.5. Pitch range in spontaneous speech

Pitch tracks and waveforms of several sentences from speaker Z's story-telling are given in Figure 4.22-4.24 as examples. The sentences are as follows:

- (1) ZJ14:  
 Ta shuo, ta jiu gaosu wo guoqu.  
 She said she then tell me drive through  
 55 55 55 51 51 51 214 51 51 UT  
 "She said, she told me to drive through."
- ZJ15:  
 Chong wo baishou,  
 toward me wave hand  
 51 214 214 214 UT  
 "(She) waved her hand at me,"

ZJ16:

Rang wo wang qian kai.  
 let me toward front drive  
 51 214 214 35 55 UT  
 "(She) let me drive forward."

ZJ17:

Wo jiu zhidao ta shuo shang nar qu.  
 I just know she said go there go  
 214 51 55 51 55 55 51 51 51 UT  
 "I know that she wanted me to go there."

The frequency varies between about 125 Hz and 280 Hz in the pitch track of these sentences. If this range is taken as the reference range to figure out the general value in a five-level system, then the ranges (in Hz) 125-156, 156-187, 187-218, 218-249, and 249-280 would correspond to the levels 1, 2, 3, 4, and 5 respectively.

The range of phonetic realization varies dramatically, however, for the phonological tones in a pitch track of different syllables. A phonologically predicted high tone might actually be very low in frequency, and a low tone could be rather high. For example, in Figure 4.22, the high tones "5" are realized at about 180 Hz in tashuo 'she says' and guo 'go'. They are only equal to "2" in the above five level scale. But the same high tone in gaosu 'tell' shows up as high as 280 Hz. In Figure 4.23, the low tone in the syllable chong 'toward' is realized at about 175 Hz. In Figure 4.24, on the other hand, even the highest tone is realized lower than 160Hz, or "2" in the five level scale.

Obviously, pitch range keeps changing in spontaneous speech. It is impossible to establish a reference range for all tones in different sentences as is done for isolated words read carefully and formally. It often happens that even in one sentence, the reference can vary. When observing tones in a sentence, the best approach is to imagine a dynamic pitch range using pitch tracks as a guide. How the range changes along the time scale can generally be determined as follows: draw a straight line from one high point to the next of the predicted high "5" tones and from one lowest point to the next of the predicted low "1" tones. The variation of the range between the connected maximum line and minimum line, should approximately reflect the dynamic tonal range of the sentence.

By applying this method to Figures 4.22-4.24, I obtained the outlined pitch range for Figure 4.25-4.27. When drawing the lines for the pitch range of the first four syllables in Figure 4.25, a minimum line is merely suggested, because there are no low tones. By observing the change in values of the lowest points of the low tones in the data, I found that, if without prominence, the minimum line is usually quite level. Take the last five or six syllables from Figure 4.25. and 4.26. as an example. The frequency of the lowest point of the low tones varies only within a rather small range. However, in Figure 4.26, since

the lowest point of the low tone in syllable wo `I' is rather high, the difference between the lowest points of the low tones in "wo" and "shuo" is much larger than usual. This might be caused by a prominence in pitch. When suggesting a minimum line in a sequence of high tone syllables which are normally stressed, one may adopt a line similar in height to the minimum lines for the preceding or following syllables. I followed this method in Figure 4.25 to suggest the minimum line for the tones of the first four syllables.

However, if there is no high tone in any portion of a sentence, however, it is much harder to predict the maximum line of the pitch range. The variation of frequency among high points compared to that of the low points, can be much larger in size, and far more complicated in pattern. This variation has been noted in previous studies (J. Shen 1985, Shih 1989) and my data has clearly shown it in the present corpus. It is illustrated in Figure 4.26 in the syllables shou `hand', wo `I', and wang `toward'. The effects of catathesis and prominence always play important roles in adjusting the variation. We will pay special attention to them later in Chapter 7.

Examples of clearly outlined pitch ranges, such as those in Figures 4.25-4.27, demonstrate that the dynamic movement of the pitch range includes variation in both the width and the height of the range. As just mentioned, though

the minimum line of a pitch range does not usually vary much in its height, it does on occasion. Therefore, more than likely, the pitch range of a sentence as a whole occurs as a level band with a rather flat minimum line, and it varies mainly in width and height. Figures 4.25 and 4.27 are of this type. Sometimes, however, the band is in a somewhat contoured shape, either falling or rising, and with variation in width. Figure 4.26 provides an example of both. Interrogative sentences often have rising contours of the band, as seen in some of the controlled sentences in my data.

#### 4.6. Scores for tonal prediction in sample sentences

Let us now come back to individual tones. Of interest here is the following question: are the tones in the data predictable when referring to a dynamically varying pitch range? Height and shape represent two major features of each tone, so I will check how are they predicted according to the phonological rules.

I will start by discussing the tonal realization in Figure 4.25. The utterance depicted includes two short sentences "Ta shuo," and "ta jiu gaosu wo guoqu." It is necessary to (1) derive the surface tones from the underlying tones according to phono-logical prediction, (2) provide a phonetic transcription of the actual pitch tracks

of the tones, and (3) to evaluate how the actual tones are predicted by using the predicted tones as reference. I will adopt Zhang's (1988) cyclic prosodic system for the following derivation. Although I prefer to use "21" as the underlying form of a T3, in this chapter I will adopt "213" as the form of an underlying T3, according to Zhang's system. The assignment of underlying tone to each syllable is consistent with that in Modern Xinhua Dictionary (1979). "UT" and "ST" indicates underlying tones and predicted surface tones respectively. "IC", "DM" and "super-f" are the abbreviations of Zhang's terms "Immediate Constituency", "Duple Meter" and "Super-foot" respectively.

(2) ZJ14:

Ta	shuo,	ta	jiu	gaosu	wo	guoqu.	
She	said	she	then	tell	me	drive through	
55	55	55	51	51 0	214	51 0	UT
				[ ]f	[ ]f		by IC
[ ]f	[ ]f						by DM
					[ ]f'		super-f
55	55	55	51	51 1	21	51 1	ST
"She said, she told me to drive through."							

From Figure 4.25, we see that the pitch contours of the three beginning syllables ta, shuo and ta are generally predicted by suggesting the dynamic pitch range. They are rather high and are in an approximately level shape. Both T4's in the fifth syllable gao and the eighth syllable guo are derived as falling tones of the value 51. The actual



pitch contours start high and fall low, and hence are predicted, too. The actual low pitch curve in syllable su is also predicted, since the derived surface value of this neutral tone is 1. Tones in the other syllables, however, are not predicted. The T4 in the fourth syllable jiu is realized as a short, high level curve, rather than as a high falling tone. The seventh syllable wo and the last syllable qu were produced in a very weak fashion. From the tape, I only hear an strong glottal stop in wo and an aspirated palatal affricate in qu. In the upper portion of Figure 4.25 these sounds are reflected in the waveform with a very low amplitude. Since the vowels of both syllables were dropped, nothing appeared on the pitch track where each of the syllables should have, in the lower portion of Figure 4.25.

To help broadly outline how tones in spontaneous speech are predicted, I will use simple statistics. The scores "0", ".5", "1", "1.5" and "2" will be used to indicate how the tone, as a whole, is predicted. "0" means totally unpredicted, and "2" means well predicted. The height and shape are worth up to one point each. A "/" will be used when there is no pitch track produced in a given syllable. The phonetic transcription of both the actual pitch contours in Figure 4.5.2.1 and the scores for how the pitch contours are predicted are given as follows. "APC" indicates the

phonetic transcription of the actual pitch contours of the tones.

(3) ZJ14:

	Ta	shuo,	ta	jiu	gaosu	wo	guoqu.		
	She	said	she	then	tell	me	drive	through	
	55	55	55	51	51 0	214	51 0		UT
	55	55	55	51	51 1	21	51 1		ST
	53	55	44	5	51 1	/	52 /		APC
scores:									
height	1	1	1	0	1 1	/	1 /		
shape	.5	1	1	0	1 1	/	1 /		
-----									
total	1.5	2	2	0	2 0	/	2 /		

"She said, she told me to drive through."

In the same manner, it is possible to count scores for the prediction of tones in all of the sentences in Figures 4.26 and 4.27 as follows.

(4) ZJ15:

	Chong wo bai shou,				
	toward me wave hand				
	51	214	214	214	UT
	[	]f	[	]f	by DM
	51	21	35	214	ST
	53	31	15	113	APC
scores:					
height	.5	1	.5	1	
shape	1	1	1	1	
-----					
total	1.5	2	1.5	2	

"(She) wave her hand to me,"

(5) ZJ16:

	Rang	wo	wang	qian	kai.	
	let	me	toward	front	drive	
	51	214	214	35	55	UT
	[	]f	[	]f		by DM
	[		]f'	by	super-f	
	51	35	21	35	55	ST
or	51	21	21	35	55	ST
	51	22	21	21	21	APC
scores:						
height	1	.5	1	0	0	
shape	1	.5	1	0	0	
<hr/>						
total	2	1	2	0	0	

"(She) let me drive forward."

(6) ZJ17:

	Wo	jiu	zhidao	ta	shuo	shang	nar	qu.	
	I	just	know	she	said	go	there	go	
	214	51	55 0	55	55	51	51	0	UT
	[	]f	[	]f	[	]f			by IC
								]f'	super-f
	21	51	55 2	55	55	53	51	1	ST
	21	22	53 3	33	32	/	41	/	APC
scores:									
height	1	0	.5 0	.5	0	/	.5	/	
shape	1	0	.5 0	1	.5	/	1	/	
<hr/>									
total	2	0	1 0	1.5	.5	/	1.5	/	

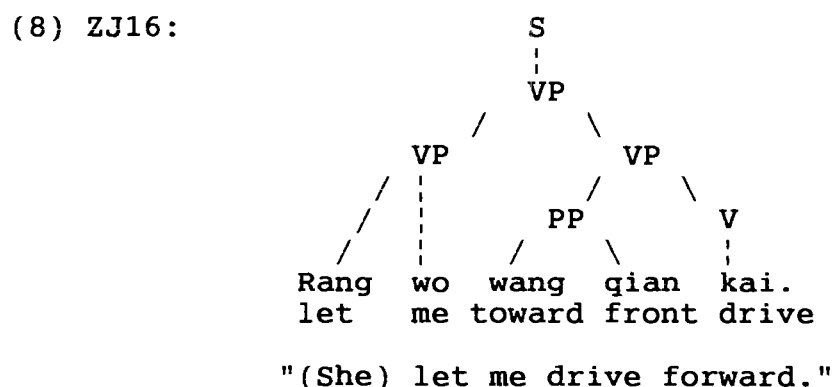
"I know that she wants me to go there."

The reasons for scoring the prediction of T3 in wo "I" in ZJ16 as "1" requires a bit of an explanation. It seems that T3 in wo should only be expected to undergo a tone sandhi between feet to become a T2 in front of the T3 of syllable wang 'toward'. However, as discussed in several studies about T3 Rule (Liu 1980, Kaisse 1985, Zhang 1988), there is an optional constraint on the application of the

rule between "a" and "b" in the following syntactic configurations:



Since the structure of the sentence ZJ16 is as follows, the syllables wo and wang are in the position of "a" and "b" respectively.



Therefore, the T3 in wo could also be expected to have its basic low falling shape for a non-final position. The actual pitch contour in the syllable wo in Figure 4.26 shows that it is in a low level curve, which is close to the low falling variant. Therefore, I score the shape as ".5". The height of its beginning portion is in a predicted mid-low level in the local pitch range, but the height of the other portion of the curve is not low enough for a typical falling

curve. Therefore its score should be ".5".

Table 4.1 is a summary of how well tones are predicted in the sentences discussed above. Only 27 percent of tones are well pre-dicted, and others are unpredicted to varying degrees.

Table 4.1 Scores for tonal prediction in four sentences in Z's story telling

Score	Number of Syllables				Total
	ZJ14	ZJ15	ZJ16	ZJ17	
2	5	2	2	1	10 (37%)
1.5	1	2	0	2	5 (19%)
1	0	0	1	1	2 ( 7%)
.5	0	0	0	1	1 ( 3%)
0	1	0	2	2	5 (19%)
/	2	0	0	2	4 (15%)
Total	9	4	5	9	27 (100%)

#### 4.7. Evaluation of tonal prediction in story telling and reading

By using the same method to quantify how well tones are predicted in each speaker's story telling and in the reading of her own story, I have arrived at the results in Tables 4.2 and 4.3. The transcription of speaker C's story was read not only by herself, but also by speaker H and Z. Table 4.4 shows how well tones were predicted in their readings.

Table 4.2 Scores for tonal prediction in the speakers' story telling.

Score	Number of Syllables							
	Spk H		Spk Z		Spk C		Total	
2	176	43%	173	44%	190	45%	539	44%
1.5	54	13%	48	12%	60	14%	162	13%
1	44	11%	47	12%	41	10%	132	11%
.5	25	6%	25	6%	24	6%	74	6%
0	104	25%	53	14%	73	17%	230	19%
/	7	2%	46	12%	35	8%	88	7%
Total	410	100%	392	100%	423	100%	1225	100%

Table 4.3 Scores for tonal prediction in each speaker's reading of her own story

Score	Number of Syllables							
	Spk H		Spk Z		Spk C		Total	
2	228	55%	218	56%	299	72%	745	62%
1.5	52	13%	77	20%	57	14%	186	15%
1	36	9%	36	9%	19	5%	91	8%
.5	20	5%	18	5%	12	3%	50	4%
0	67	16%	31	8%	27	6%	125	10%
/	6	1%	7	2%	4	1%	17	1%
Total	409	100%	387	100%	418	100%	1214	100%

Table 4.4 Scores for tonal prediction in each speakers' reading of C's story.

Score	Number of Syllables							
	Spk H		Spk Z		Spk C		Total	
2	289	69%	304	71%	299	72%	892	70%
1.5	53	13%	50	11%	57	14%	160	13%
1	24	5%	35	8%	19	5%	78	6%
.5	10	2%	7	2%	12	3%	29	2%
0	41	10%	32	8%	27	6%	100	8%
/	4	1%	0	0%	4	1%	8	1%
Total	421	100%	428	100%	418	100%	1267	100%

Recall that in Tseng's (1981) data of spontaneous speaking, only 37 percent of the tones in 465 syllables spoken by one speaker are well predicted. In Table 4.2, we see similar percentages of predicted tones: 43, 44, and 45 percent. Among the unpredicted tones, most are scored from 0 to 1. The distribution of different scores for each speaker is very close, although the score for a specific syllable may differ among speakers. Obviously, tonal realization in spontaneous speech cannot be predicted if only the phonological rules previously mentioned are used. Tseng (1981) treats the phonological rules as being at phrase level, and believes that there must be specific rules at the sentence level. I would rather think that there must

be an unknown general principle that governs tonal realization in speech strings. I will explain this further in the next chapter.

Percentages in Table 4.4 show how tones are predicted when the speakers are reading. Compared with those in Table 4.2 the percentages of the highest score of 2 for all of the speakers is higher: 55, 56, and 72 percent. This suggests a regularity related to a variation of styles, because the phonological rules predict tone shapes better in careful speech than in casual speech. As noted earlier, the phonological rules are abstracted from formal readings of isolated words. Therefore, it is natural that the phonological rules can predict read speech better than spontaneous speech. Generally speaking, people read more carefully and formally than they speak, though the degree of carefulness and formality in reading can also vary.

The differences in styles among the speakers in Table 4.3 is obvious. The scores of speakers H and Z are rather close, though the content of their reading is different. Compared to their scores, speaker C has a much higher percentage of the high score "2" and lower percentages of the low scores, "1" and ".5". This shows that speaker C's reading style is more careful and formal than those of speakers H and Z. However, as reflected in Table 4.4, the scores for all three speakers become very close when they



read speaker C's story. This must be because the speakers H and Z paid more attention and spoke more carefully when reading someone else's story.

#### 4.8. Tonal prediction in controlled sentences

A high percentage of unpredicted tones is also exhibited in the pitch tracks of controlled sentences. In this study, there are sentences produced in contrasting styles by each speaker, thus allowing a close look not only at how well tones are predicted in controlled sentences but also at how tonal prediction of the same sentence varies for different styles.

As noted in the discussion of uncontrolled sentences, the difference in styles also occurs in the tonal realization of controlled sentences. Tones are more predictable in formal styles than in casual ones. This is supported by pitch tracks of the controlled sentences Sia and Sib (Sia are read in formal styles, and Sib in relatively casual styles;  $i=1, 2, 3$ , and  $4$ , and each syllable in an Sia or Sib bears a  $T_i$ ) read by speaker H and given in Figures 4.28-4.35.

The derivation of the surface tones of each sentence in these figures is based on Zhang's (1988) system of phonological description and prediction. The pitch tracks of these same sentences are observed to see how many of them are well

predicted and how many are not.

One could expect the surface tones in S1a and S1b to be the same as the underlying tones according to the following derivation.

(9)

Zhang	Zhongbing	jintian	yinggai	xiu	shouyinji.							
Zhang	Zhongbing	today	should	repair	radio							
55	55	55	55 55	55 55	55	55	55	55	55	55 55	UT	
	[	]f	[	]f	[	]f		[	]f		IC	
[		]f'		[		]f'	[		]f'	super-f		
55	55	55	55 55	55 55	55	55	55	55	55	55 55	ST	

"Zhang Zhongbing should repair a radio today."

All pitch tracks of the tones, shown in Figure 4.28, are generally predicted except for three: those of the syllables Zhang, tian, and xiu. The pitch track in Zhang occurs in falling and those in tian and xiu in rising shapes. There is no unpredicted pitch contours in Figure 4.29.

Following are the derivation of the tones for sentences S2a and S2b. By optional application of the T2 Rule, T2 sandhi may occur in any of the super-foot to result in one or more sequences of "35 55 35", creating several possible options in the surface tones.

(10)

	Wu	Guo	hua	ming	nian	cai	neng	hui	Yang	cheng	hu.	
	Wu	Guo	hua	next	year	only	can	back	Yang	cheng	Lake	
	35	35	35	35	35	35	35	35	35	35	35	UT
		[		]f	[		]f		[		]f	by IC
								[		]f		by DM
		[		]f'		[		]f'	[		]f	sup-f
	35	35	35	35	35	35	35	35	35	35	35	ST
or	35	55	35	35	35	35	35	35	35	35	35	ST
or	35	55	35	35	35	35	55	35	35	35	35	ST
or	35	55	35	35	35	35	35	35	35	55	35	ST
or	35	55	35	35	35	35	55	35	35	55	35	ST
or	35	35	35	35	35	35	55	35	35	35	35	ST
or	35	35	35	35	35	35	55	35	35	55	35	ST
or	35	35	35	35	35	35	35	35	35	55	35	ST

The pitch tracks in Figure 4.30 show that most T2's are realized as a low rising tone with a dip corresponding to the beginning of the vocalic portion in a syllable. This shape has been treated as normal for T2 in previous studies, and hence as predicted here. There are two T2's, in the syllables nian and hui, which are unpredicted in shape. The first one is realized as a falling tone, and the second one as a level tone which is not predicted by the above options of tone sandhis. As for the height of the tones, all are predicted except those of the syllables wu, guo, and cheng which all start too high. When put together, there are four tones which are partially predicted, and one is totally unpredicted. However, in Figure 4.31, only in two syllables, ming, and yang, is the T2 well predicted. The T2 is

completely unpre-dicted in the syllables guo, hua, and nian, and only partially predicted in the syllables wu, cai, neng, hui, cheng and hu.

Figures 4.32 and 4.33 show how T3's are realized. The surface tones of S3a and S3b are derived as follows:

(11)

Li	Xiao	bao	jiu	dian	ye	xiang	xie	jiang	yan	gao.	
Li	Xiao	bao	9:00			also	want	write	draft	for a lecture	
214	214	214	214	214	214	214	214	214	214	214	UT
	[		]f	[		]f		[		]f	by IC
							[		]f		by DM
	[		]f'		[		]f'	[		]f'	sup-f
	21	35	21	35	21	21	35	21	35	21	ST
or	21	35	21	35	21	21	35	21	35	55	ST

Since the structure of the second super-foot can be subject to reanalysis (Zhang 1988), the derivation of the surface tone for the sentence could also be:

(12)

Li	Xiao	bao	jiu	dian	ye	xiang	xie	jiang	yan	gao.	
Li	Xiao	bao	9:00			also	want	write	draft	for a lecture	
214	214	214	214	214	214	214	214	214	214	214	UT
	[		]f	[		]f		[		]f	by IC
							[		]f		by DM
	[		]f'		[		]f'	[		]f'	sup-f
	21	35	21	35	21	35	35	21	35	35	ST
or	21	35	21	35	21	35	35	21	35	55	ST
or	21	35	21	35	21	35	55	21	35	55	ST
or	21	35	21	35	21	35	55	21	35	35	ST

Looking at Figure 4.32, it is seen that nine out of eleven T3's are fully predicted, and there are only two unpredicted cases. One of these is the T3 in the syllables

xie, and it is realized as a low falling-rising tone which is not expected to occur in the mid-position of a sentence. The other case is that of the T3 in the syllables yan. It is neither low rising nor high level as pre-dicted, but rather it is a high falling-rising tone. In Figure 4.33 there are five such unpredicted tones, occurring in the syllables li, ye, xie, jiang, yan, and gao.

Figure 4.34 and 4.35 illustrate how the T4 varies in S4a and S4b. By applying the Half-T4 Rule once or twice in each foot or super-foot, the derivation of the tones is:

(13)

Zhao	Shu	qing	ban	ye	you	yao	shang	jiao	yu	bu.	
Zhao	Shu	qing	mid	night	again	will	go	Minis.	of	Edu.	
51	51	51	51	51	51	51	51	51	51	51	UT
	[	]f		[	]f			[	]f		IC
						[	]f				MD
[		]f'		[	]f'	[	]f'	[	]f'	sup-f	
51	53	51	53	51	51	53	51	53	53	51	ST

Because the foot in the second super-foot could be restructured, the derivation could also be as follows:

(14)

Zhao	Shu	qing	ban	ye	you	yao	shang	jiao	yu	bu.	
Zhao	Shu	qing	mid	night	again	will	go	Minis.	of	Edu.	
51	51	51	51	51	51	51	51	51	51	51	UT
[	]f		[	]f				[	]f	by	IC
					[	]f				by	MD
[		]f'		[	]f'	[	]f'	[	]f'	sup-f	
53	53	51	53	51	53	53	51	53	53	51	ST

In Figure 4.34, all of the pitch tracks are falling in their shape. However, two of them do not start as high as predicted and one of them neither starts as high nor falls as low. They occur in the syllables ye, yao, and you respectively. In Figure 4.35, T4's in the five syllables zhao, shu, ye, you, and yao start quite low, and that in the penult has an unexpected rising contour.

From the above examples we have seen in detail that there are indeed unpredicted tones in controlled sentences. Also, we see that there exist more unpredicted tones in casual speech than in formal speech. The comparison between styles for the same controlled sentences produced by speakers Z and C also shows this same tendency. This phenomenon is reflected in Table 4.5

To conclude this chapter, the following comment is quoted from Kratochvil on predicting surface tones in speech:

As far as the assumption about the appropriateness to use isolated citation forms alone is concerned, this seems to be based on the belief that these forms represent target values of tones, and that other instances of tones can be described as approximations of these target values. Unfortunately, this is no more than a belief: the nature of the relationship between isolated citation forms and normal speech tones is not known (...), and it has never been shown how the shapes of the latter could be derived from the former. The use of isolated citation form tones as the frame of reference in phonetic description thus cannot be justified."

(Kratochvil 1986: 258)

I agree with this opinion. The general relationship between tones of isolated citation form and those of continuous normal speech, either in a formal or casual style, is not yet known. What is already known are only tone sandhi rules under certain situations. It is not known under what type of situations the sandhi rules can predict tonal changes in different degrees. From the analysis in this chapter, it has been seen that unpredicted tonal changes occur not only in continuous speech and in spontaneous speech, but in isolated speech and also in read speech. Different styles affect the degree of prediction of tone sandhis. Despite this knowledge, important questions remain unanswered, some of which include: what are the relationships among the tone sandhi rules? What is the more general principle that governs both predicted and unpredicted tonal changes? I will provide my answer to the questions in the following chapters.

Table 4.5      Number of unpredicted tones in  
controlled sentences by the three speakers

	sen- style tence	number of syllables	number of speaker H	unpredicted speaker Z	syllables speaker C
formal	S1a	11	3	0	2
	S2a	11	5	4	3
	S3a	11	2	2	4
	S4a	11	3	2	4
	total	44 100%	13 30%	8 18%	13 30%
casual	S1b	11	0	4	3
	S2b	11	9	7	6
	S3b	11	6	5	5
	S4b	11	6	5	5
	total	44 100%	19 57%	21 48%	19 43%



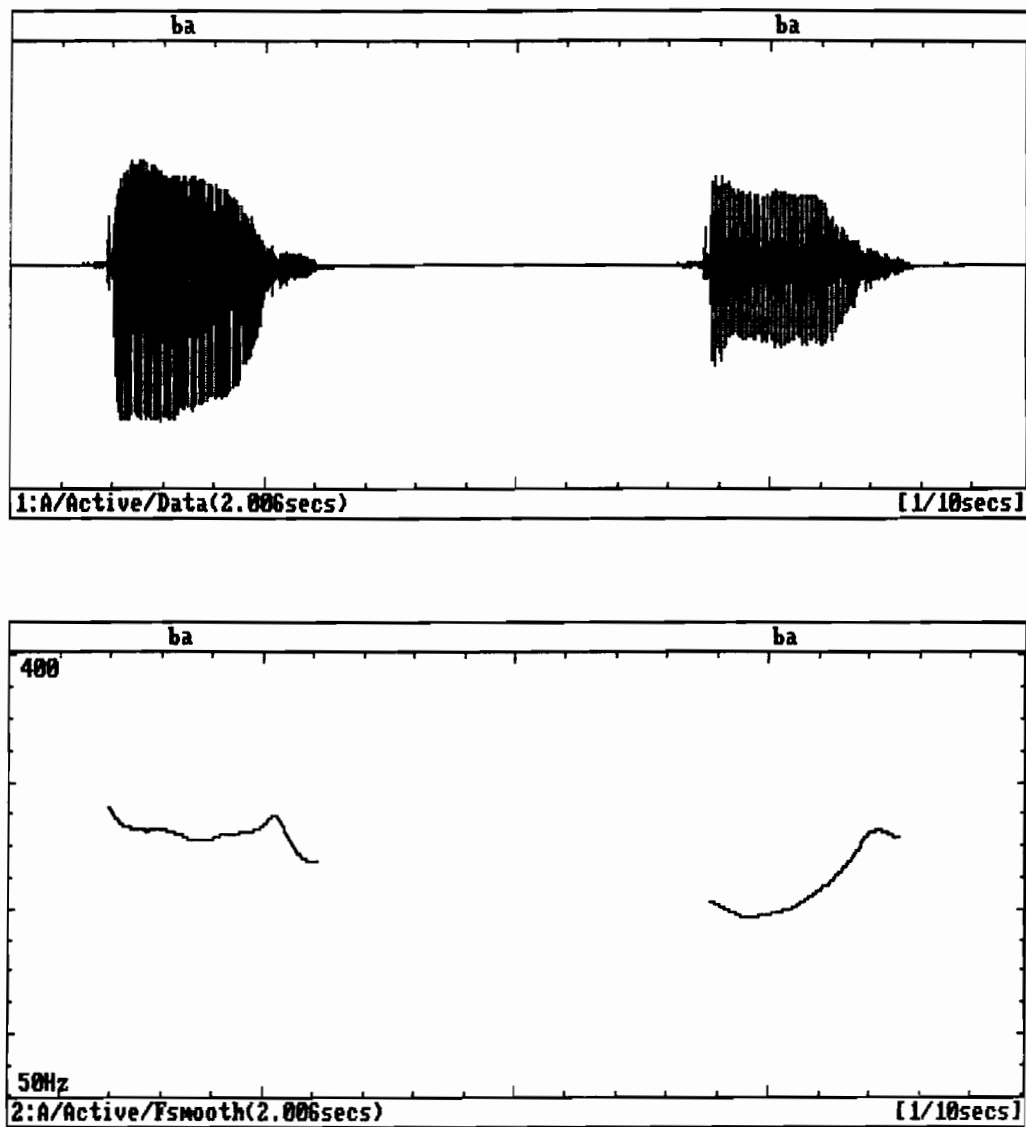


Figure 4.1 Waveform and pitch tracks of T1  
T2 in syllables ba by speaker H.

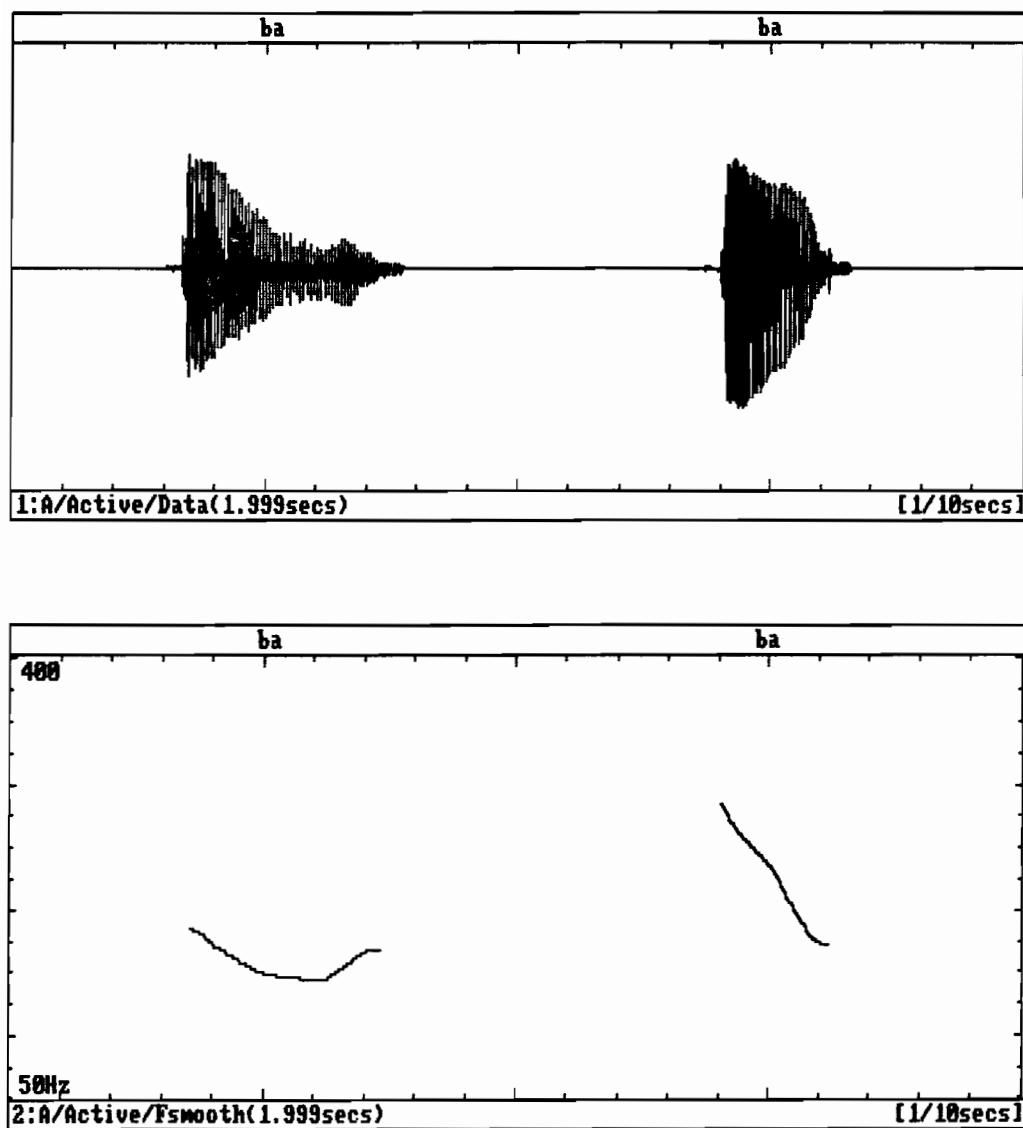


Figure 4.2 Waveform and pitch tracks of T3 and T4 in syllables ba by speaker H.

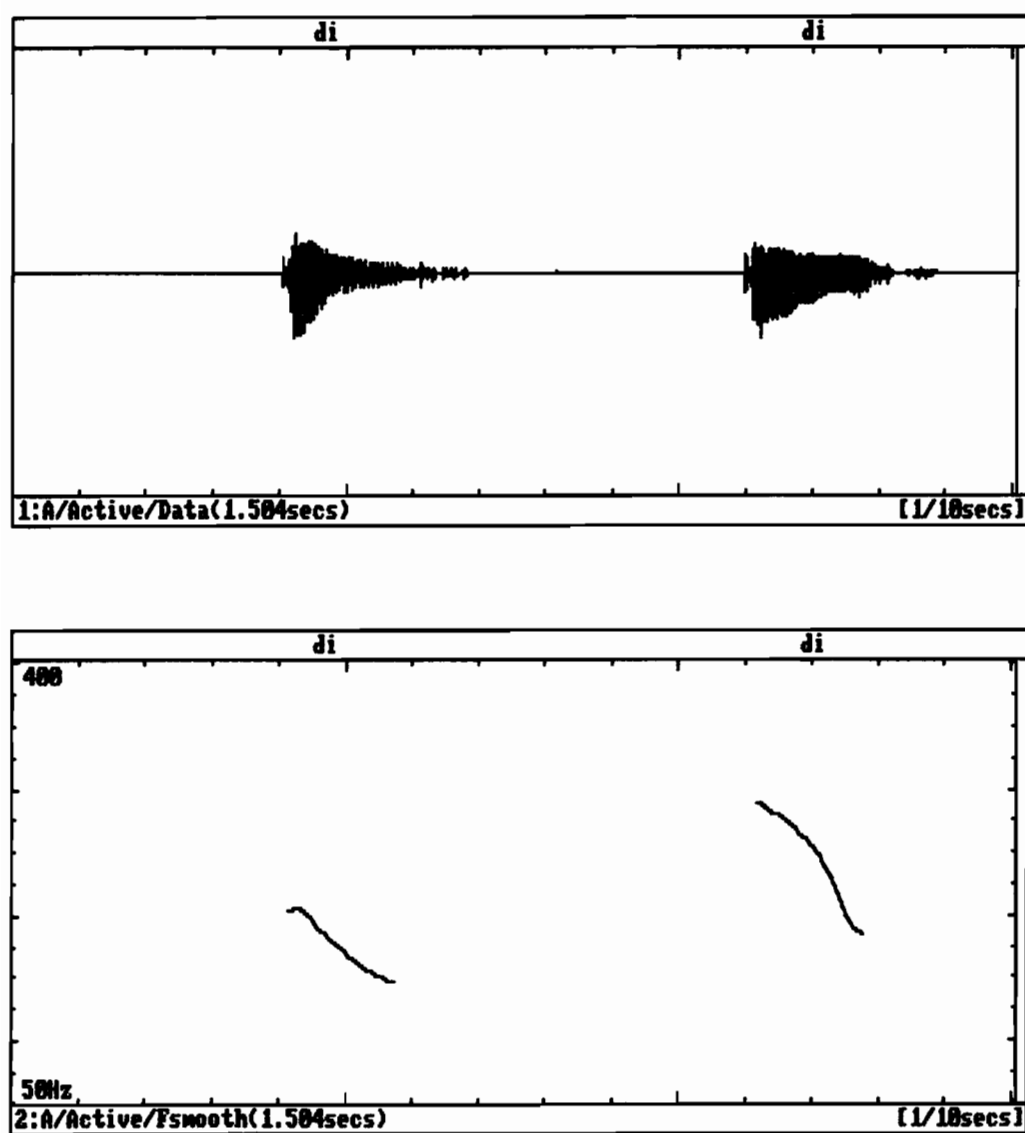


Figure 4.3 Waveform and pitch tracks of T3 and T4 in syllables 'di' by speaker C.

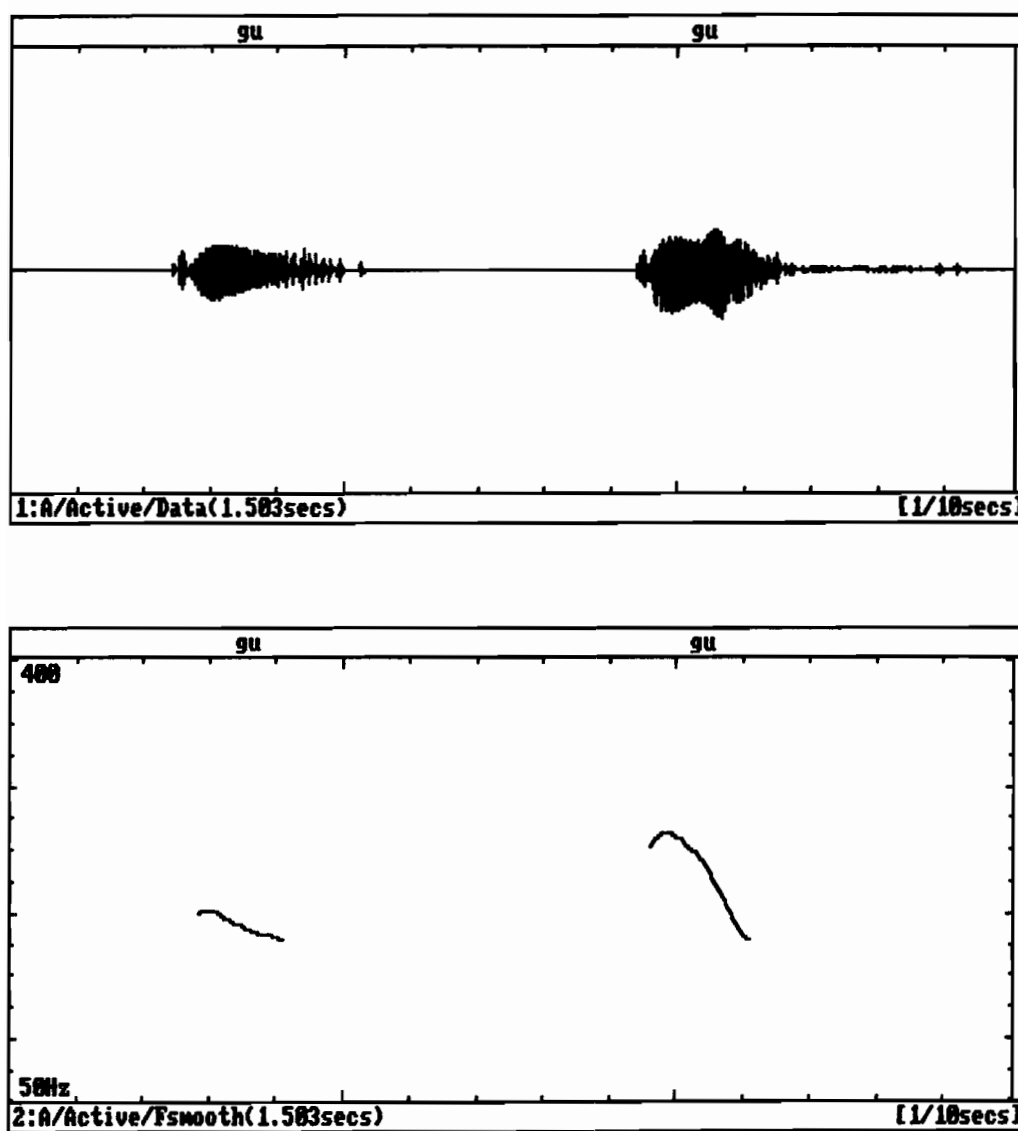


Figure 4.4 Waveform and pitch tracks of T3 and T4 in syllables gu by speaker C.

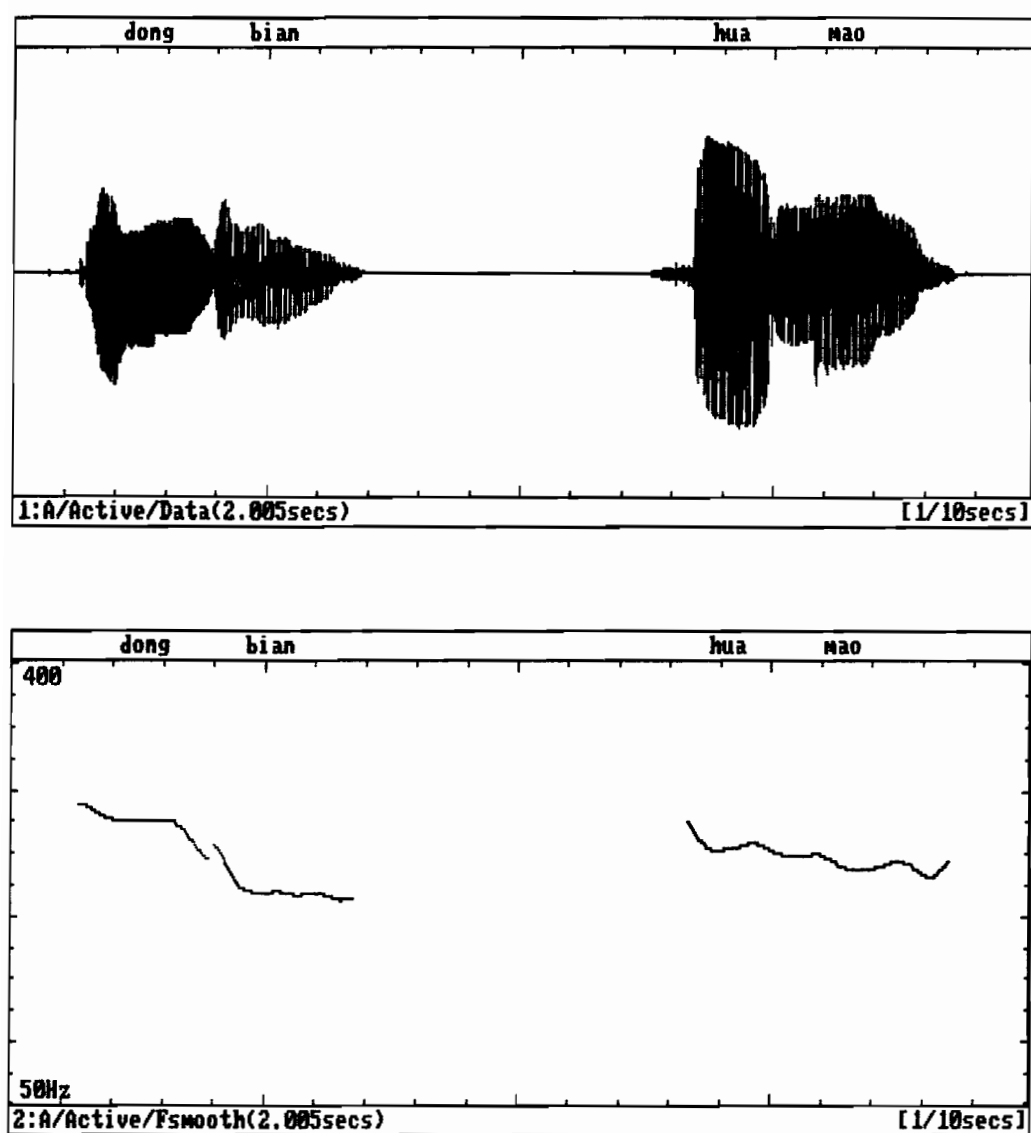


Figure 4.5 Waveform and pitch tracks of T1T1 in disyllabic words by speaker H.

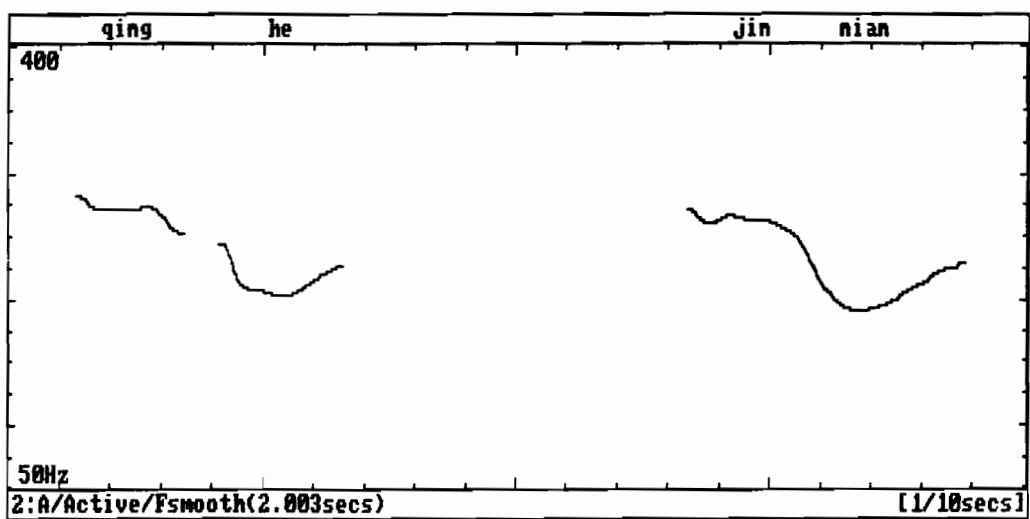
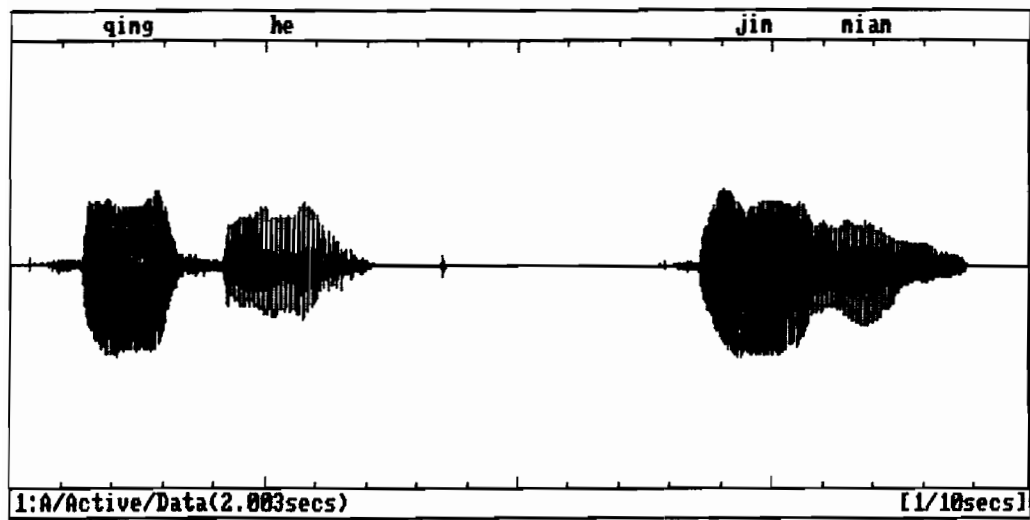


Figure 4.6 Waveform and pitch tracks of T1T2 in disyllabic words by speaker H.

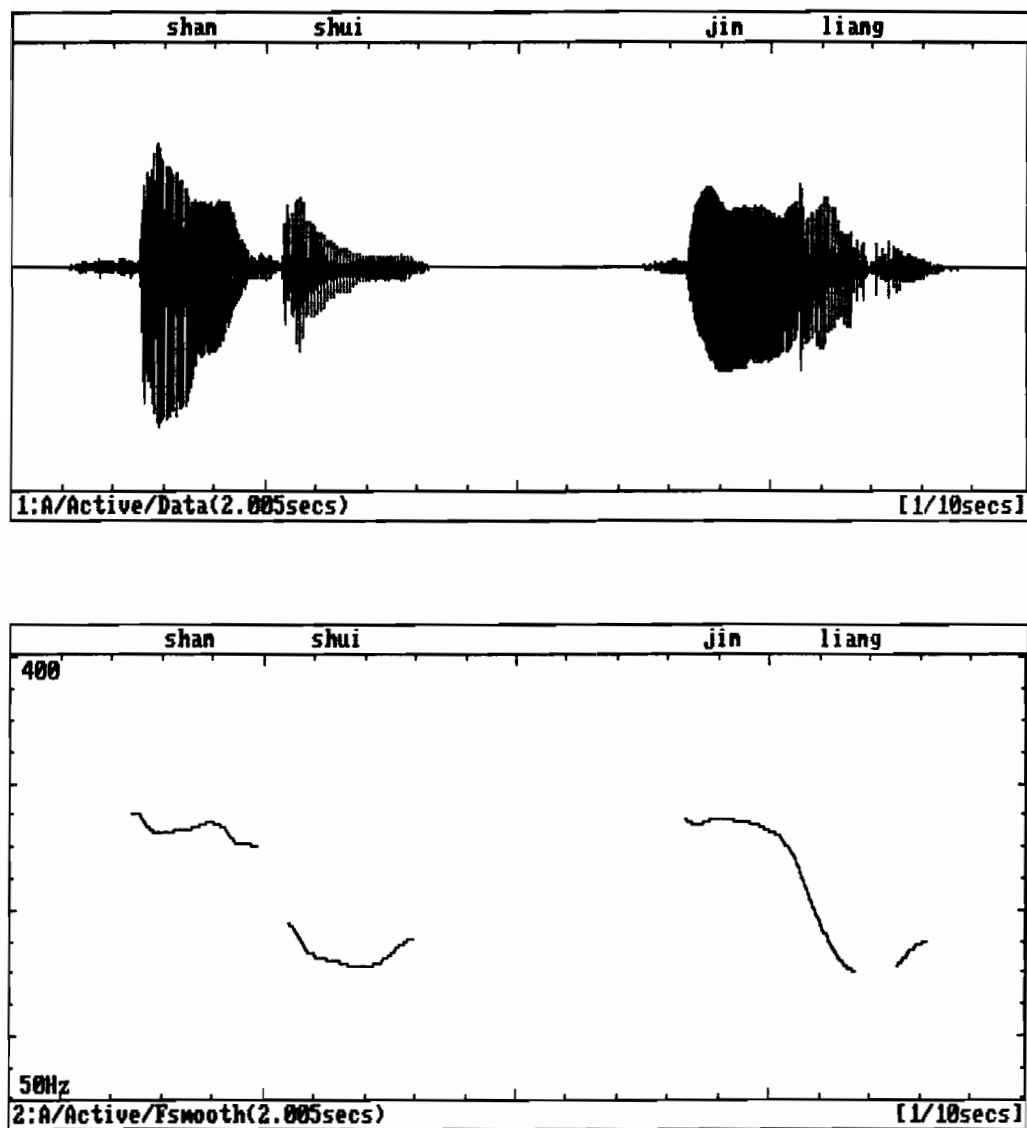


Figure 4.7 Waveform and pitch tracks of T1T3 in disyllabic words by speaker H.

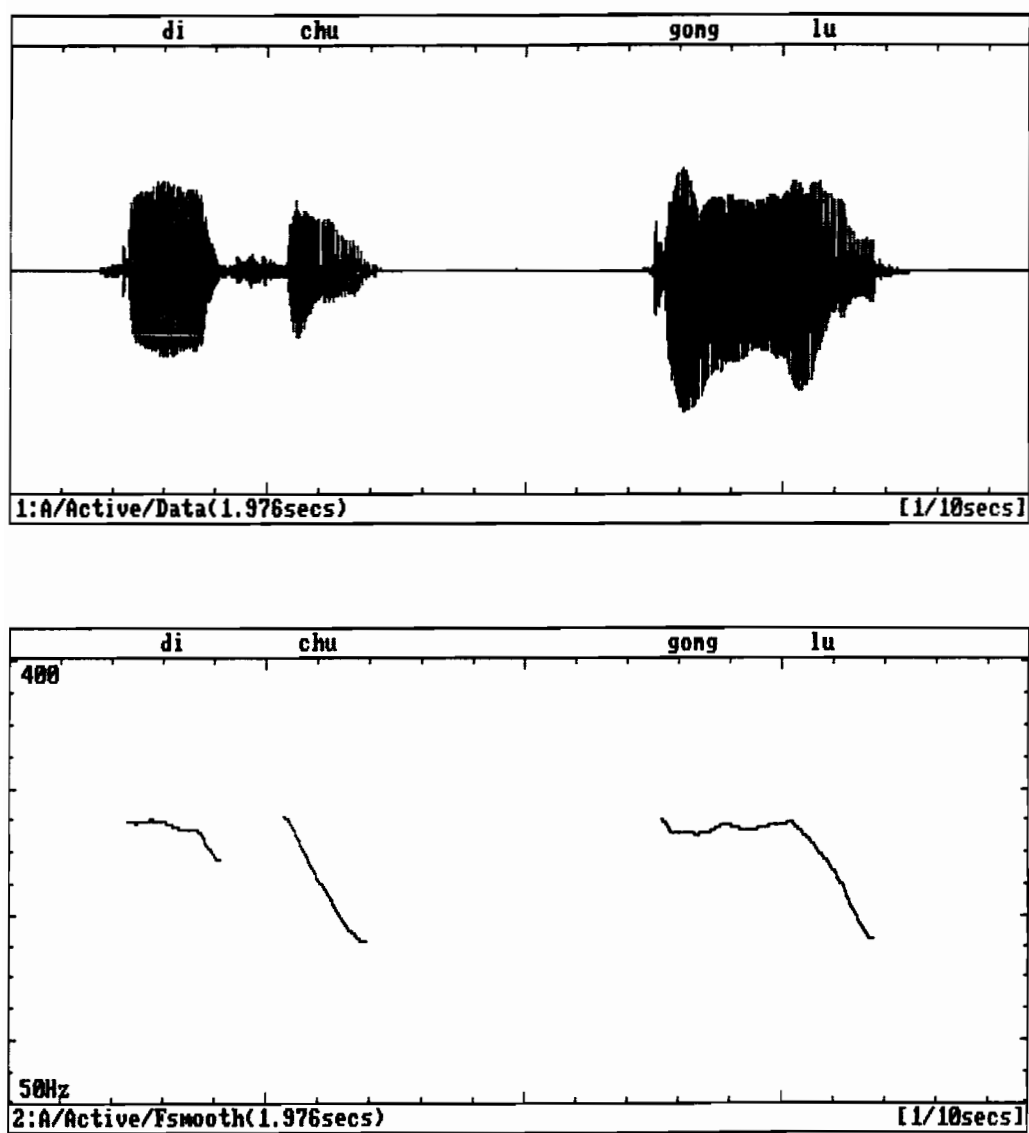


Figure 4.8 Waveform and pitch tracks of T1T4 in disyllabic words by speaker H.



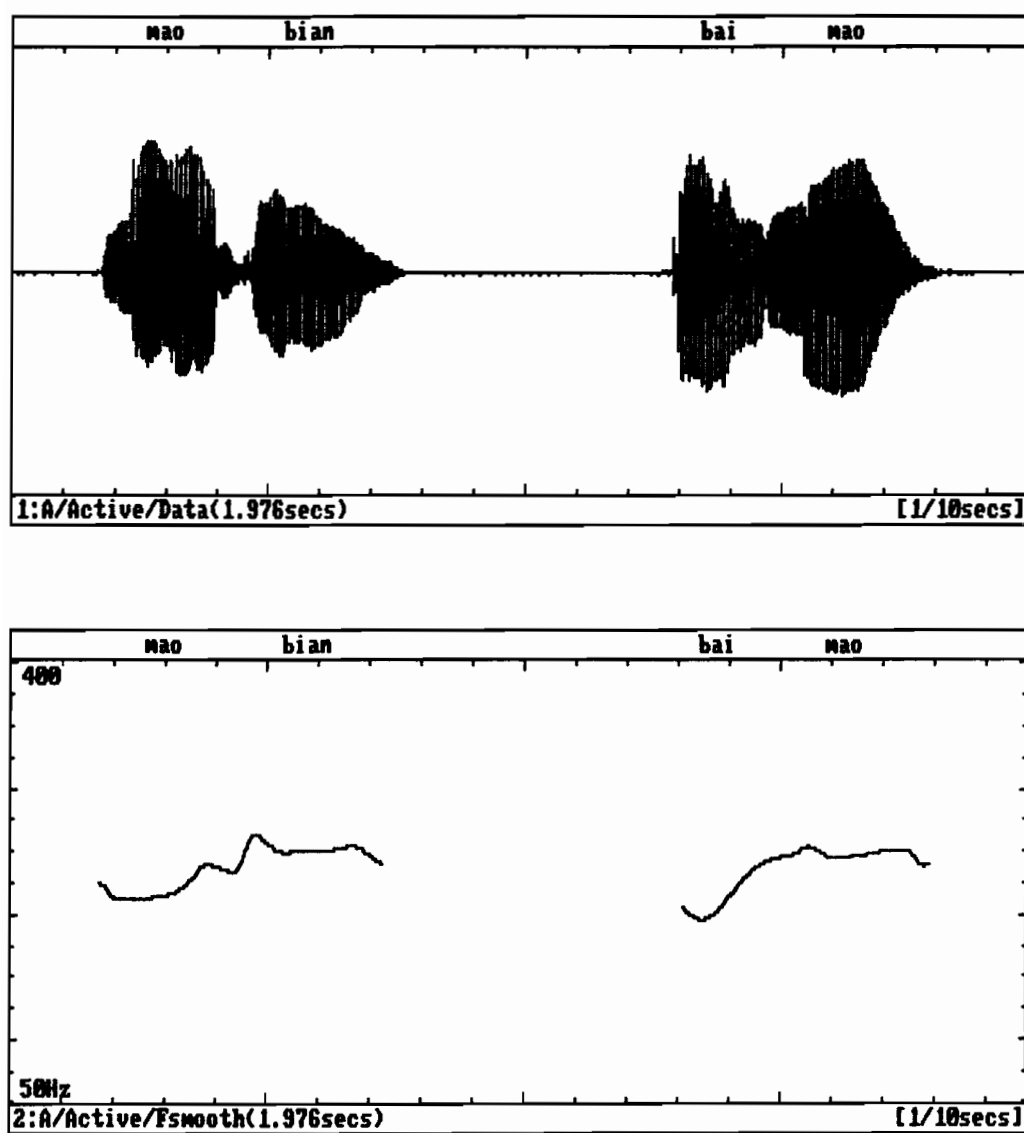


Figure 4.9 Waveform and pitch tracks of T2T1 in disyllabic words by speaker H.

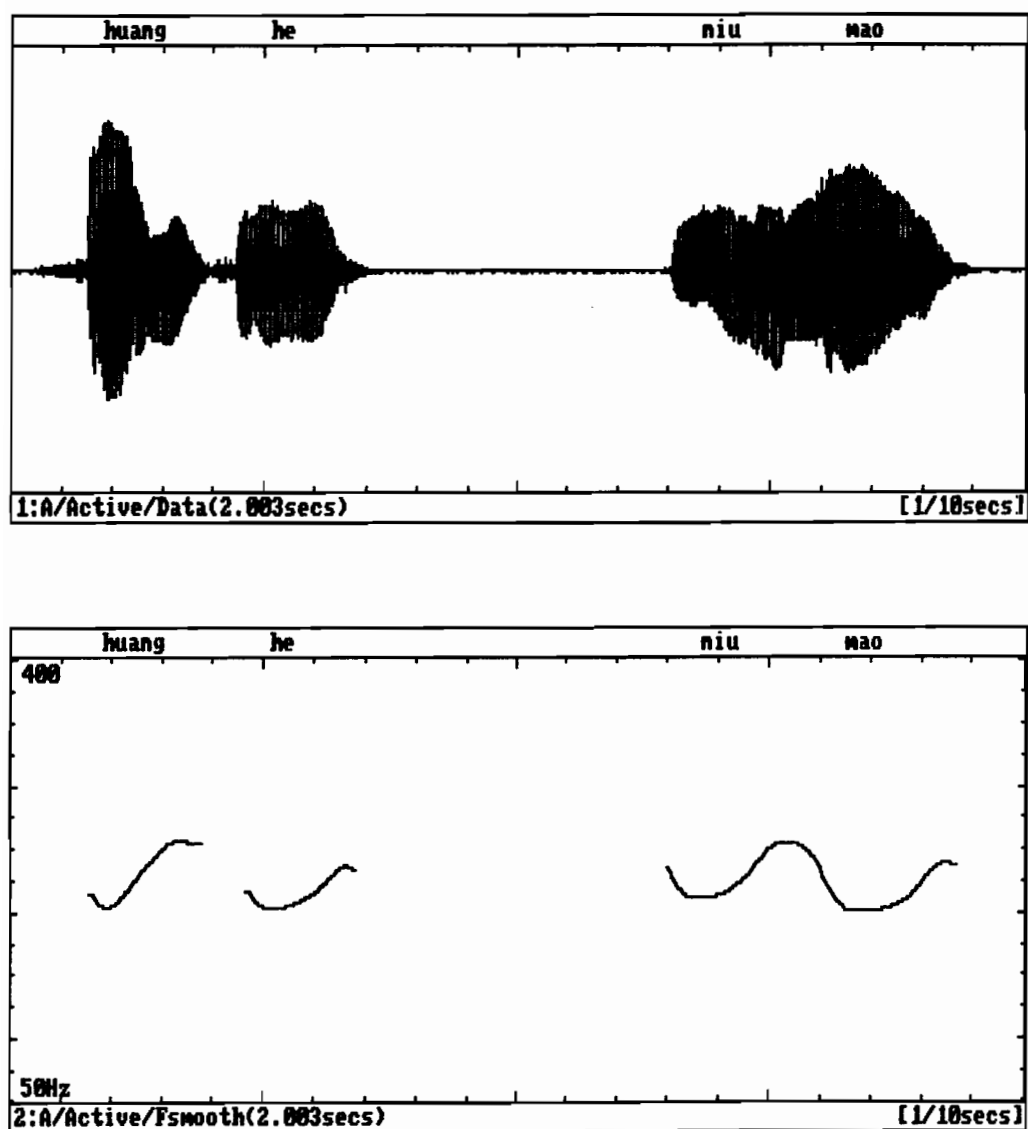


Figure 4.10 Waveform and pitch tracks of T2T2 in disyllabic words by speaker H.

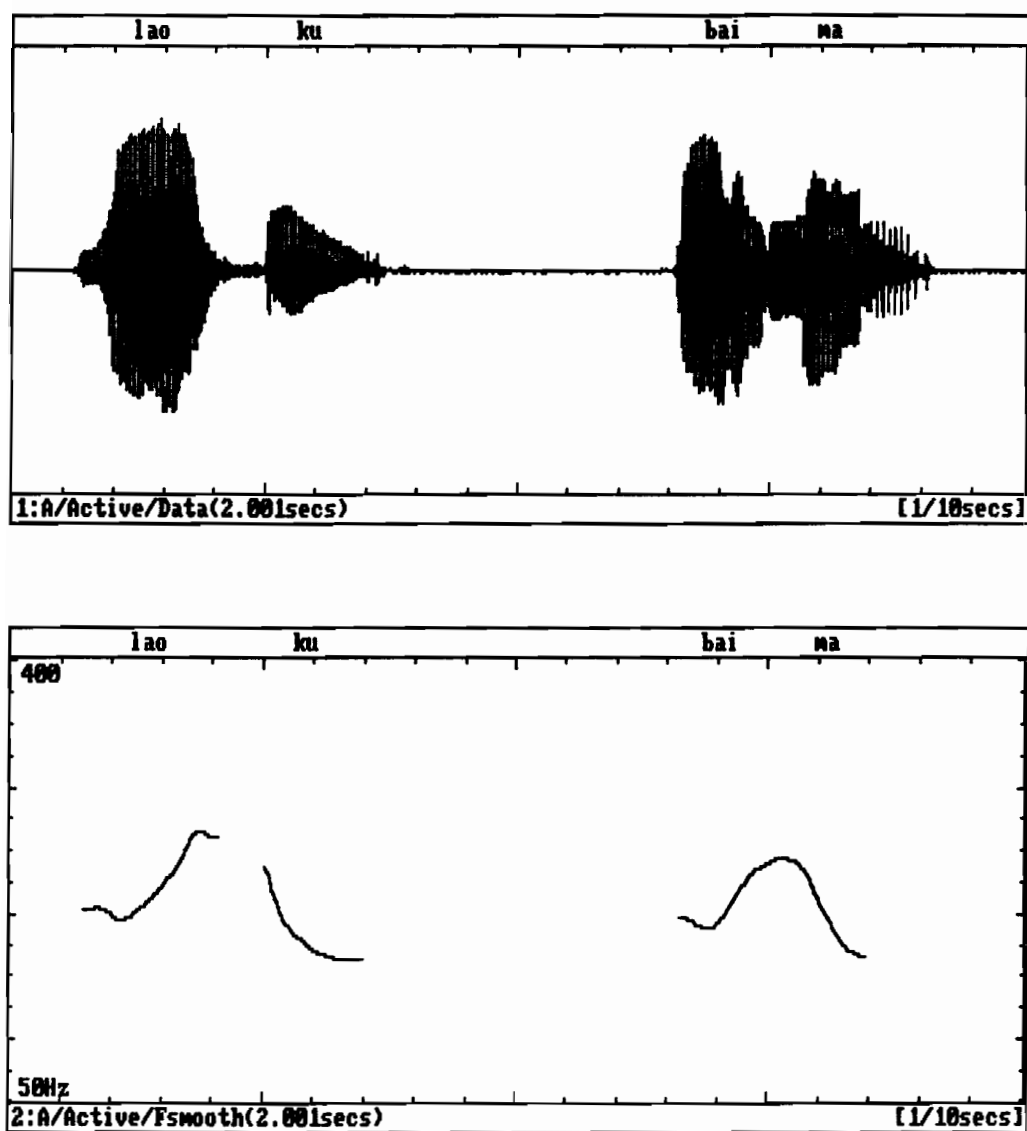


Figure 4.11 Waveform and pitch tracks of T2T3 in disyllabic words by speaker H.

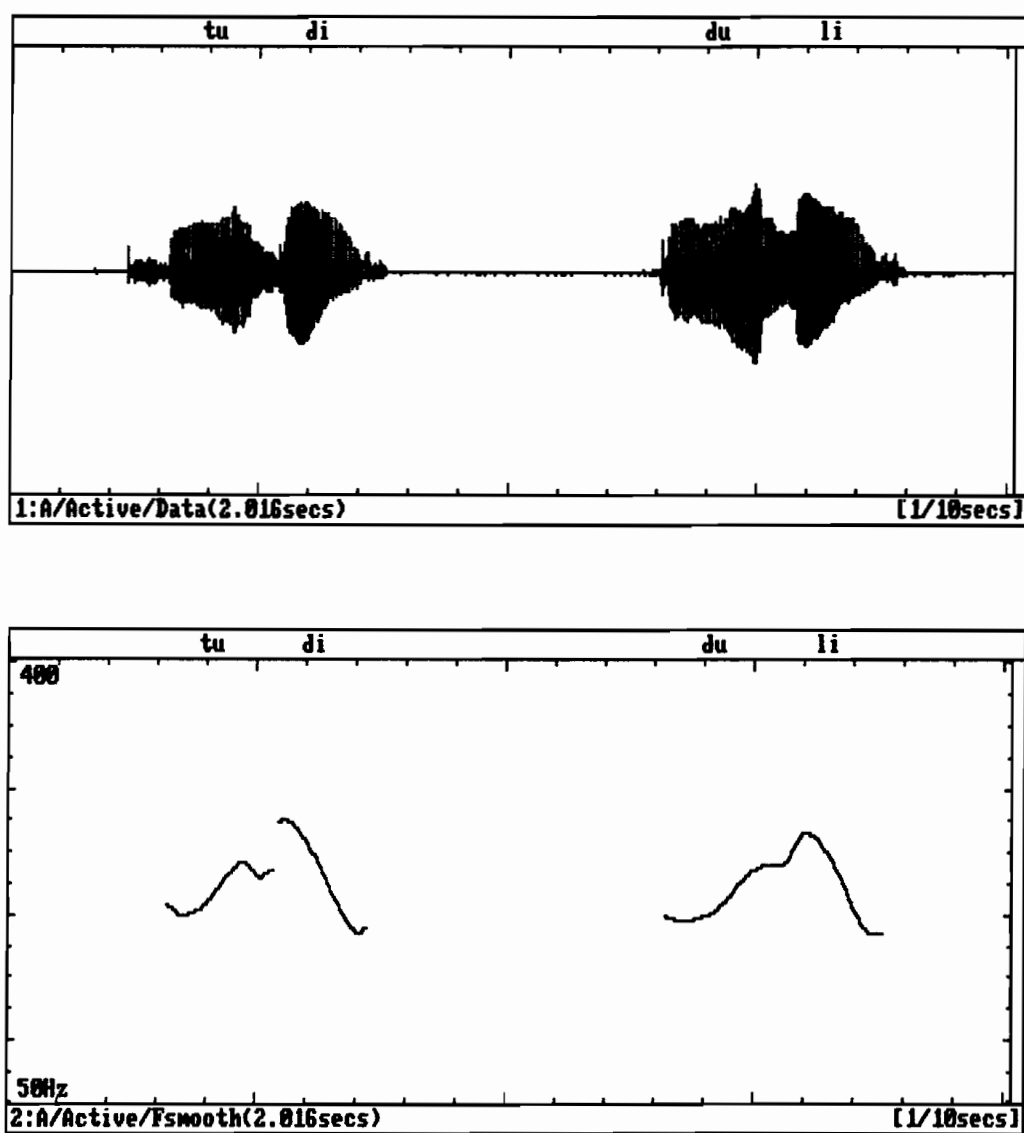


Figure 4.12 Waveform and pitch tracks of T2T4 in disyllabic words by speaker H.

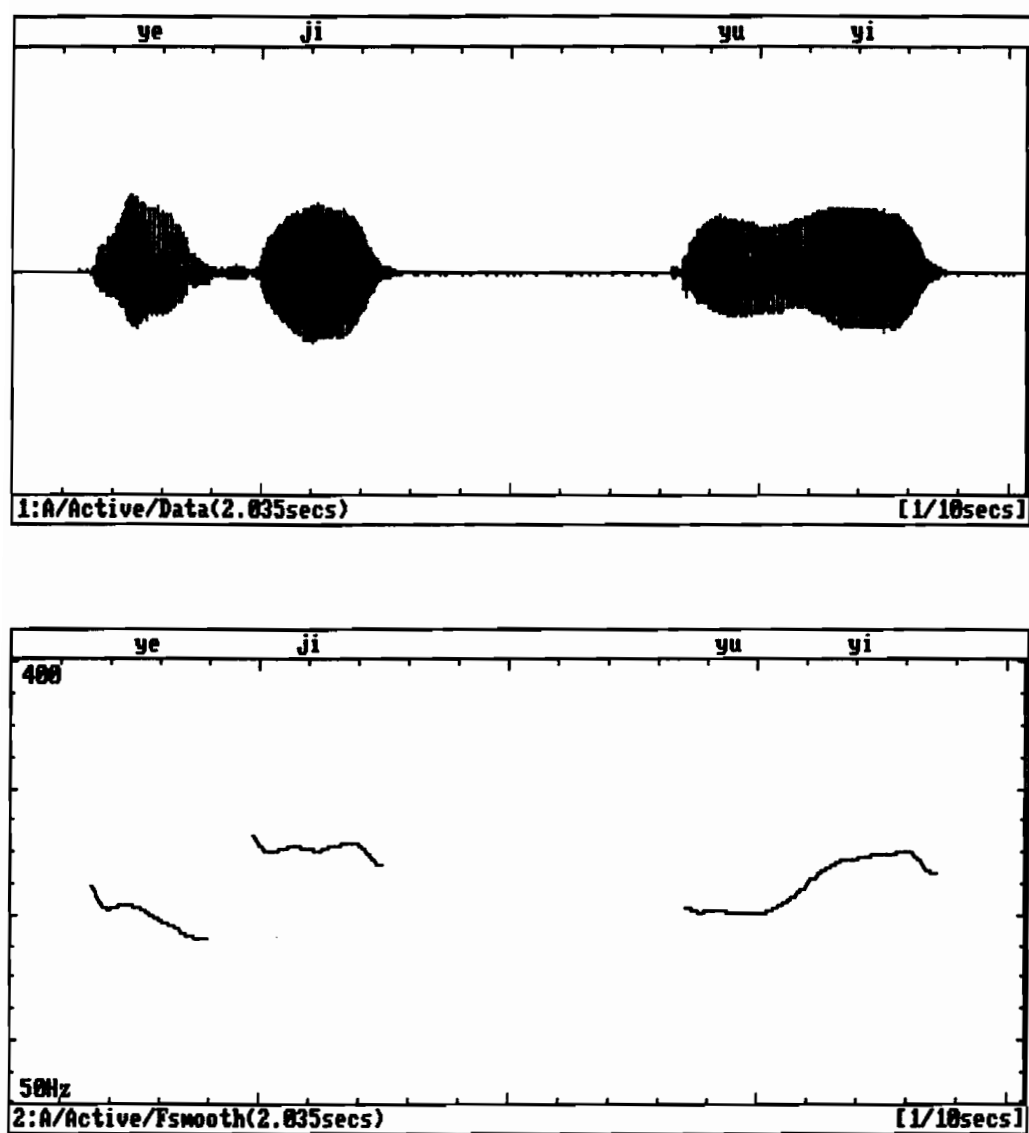


Figure 4.13 Waveform and pitch tracks of T3T1 in disyllabic words by speaker H.

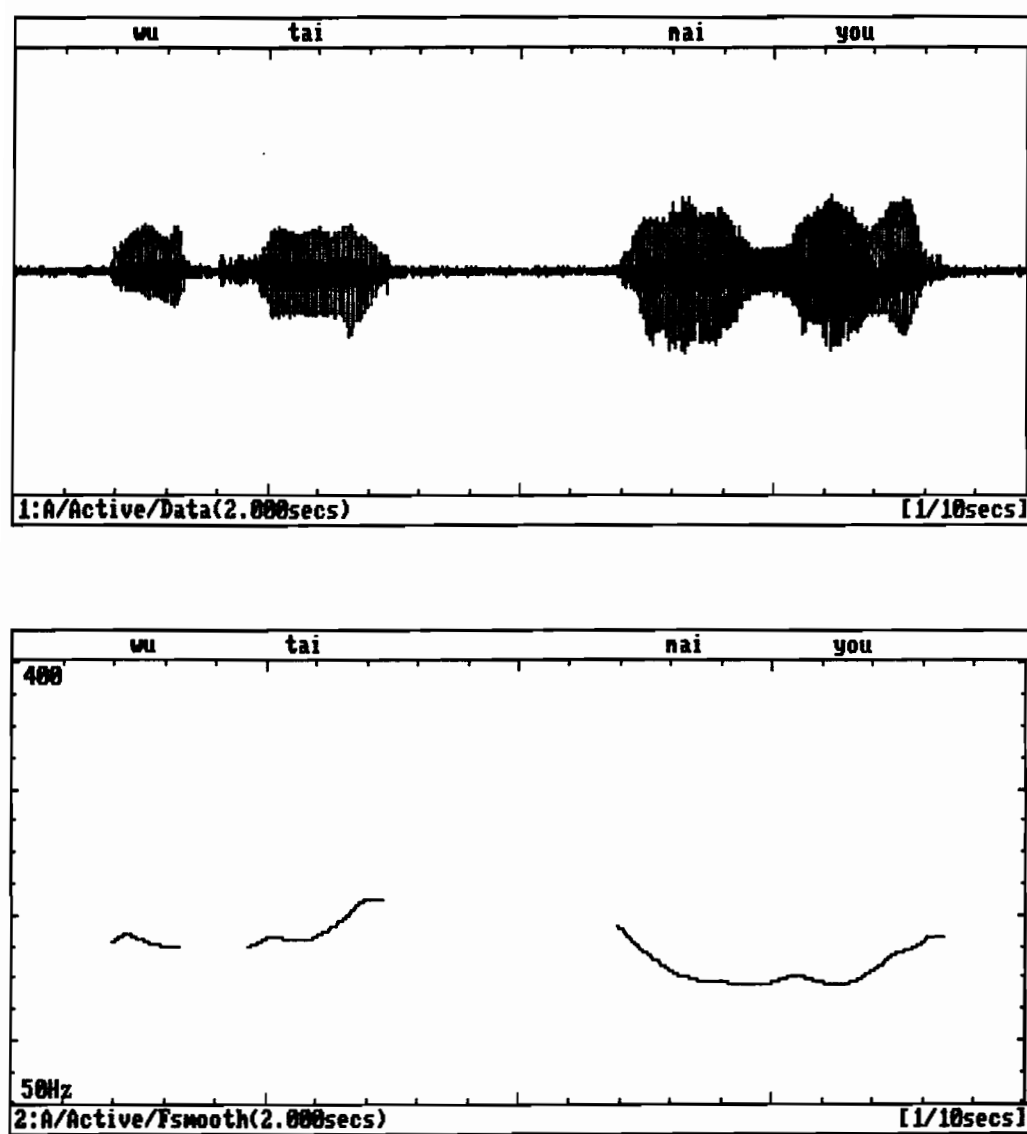


Figure 4.14 Waveform and pitch tracks of T3T2 in disyllabic words by speaker H.

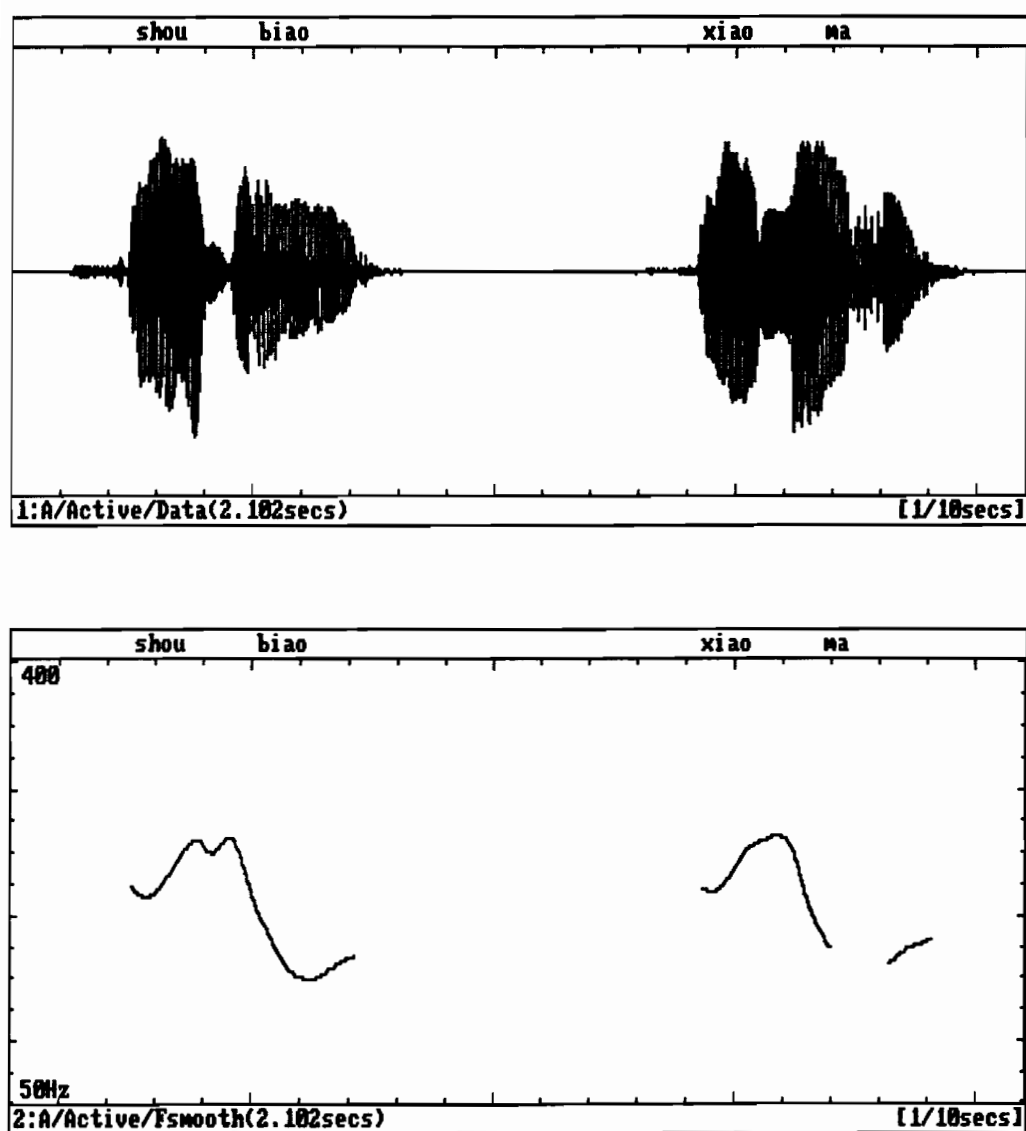


Figure 4.15 Waveform and pitch tracks of T3T3 in disyllabic words by speaker H.

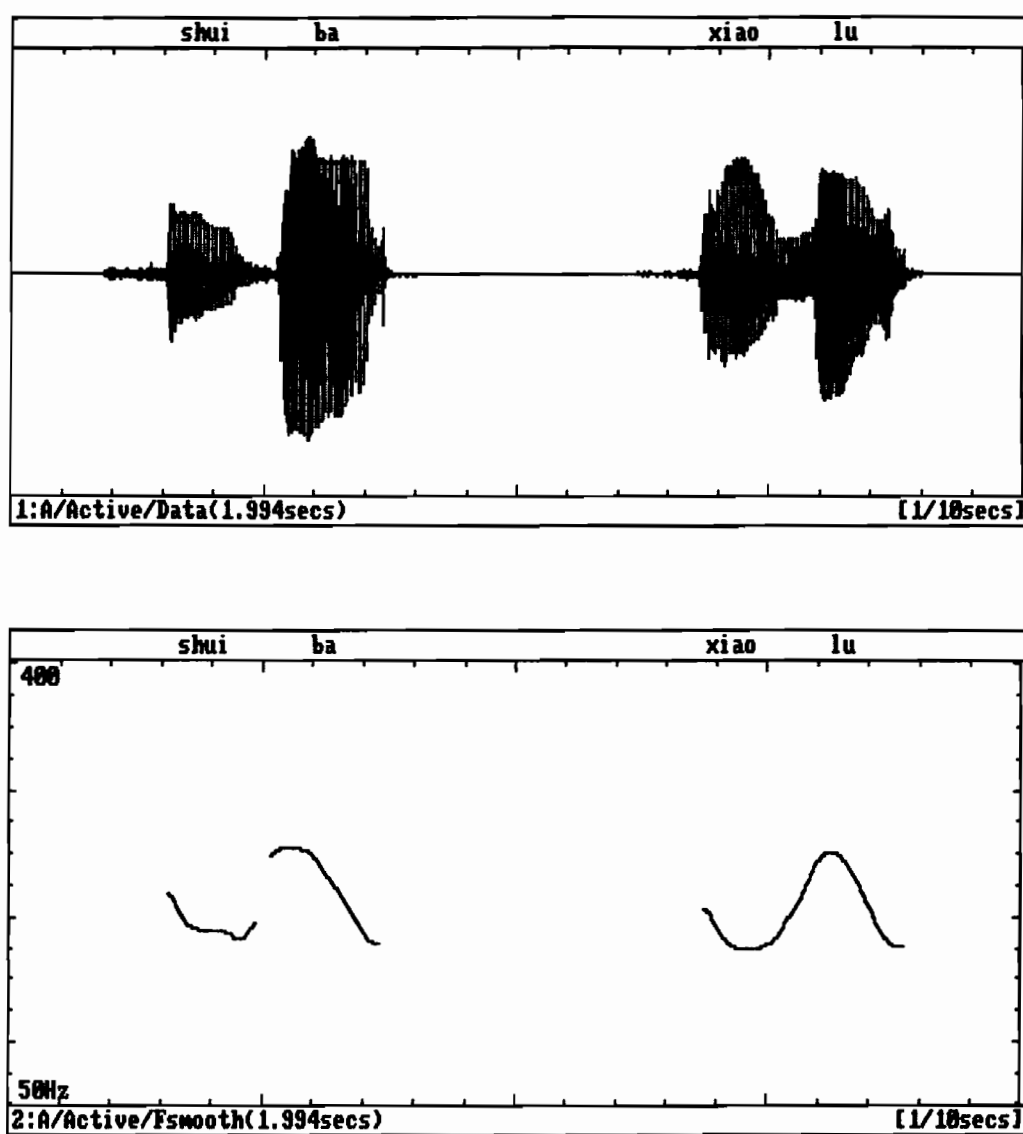


Figure 4.16 Waveform and pitch tracks of T3T4 in disyllabic words by speaker H.



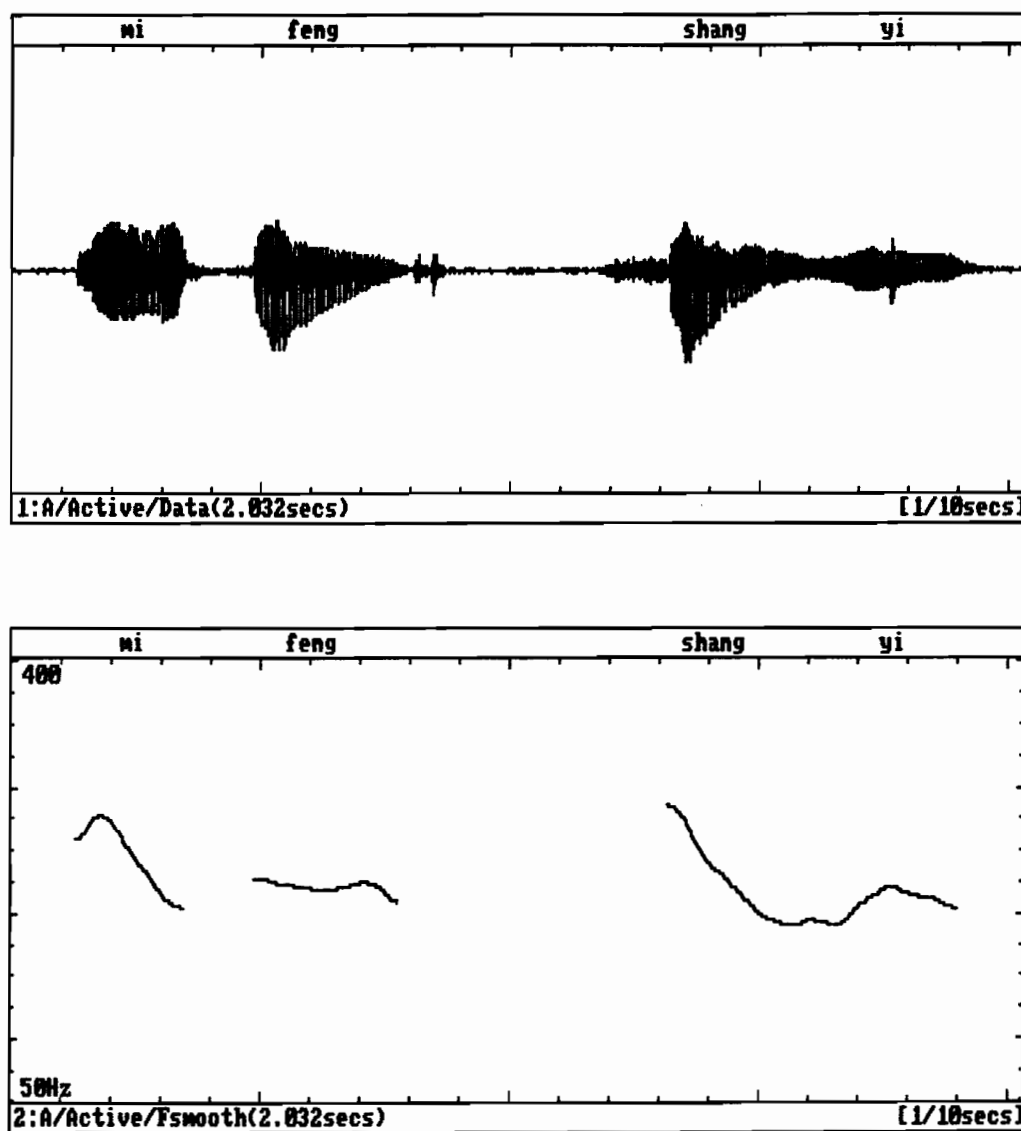


Figure 4.17 Waveform and pitch tracks of T4T1 in disyllabic words by speaker H.

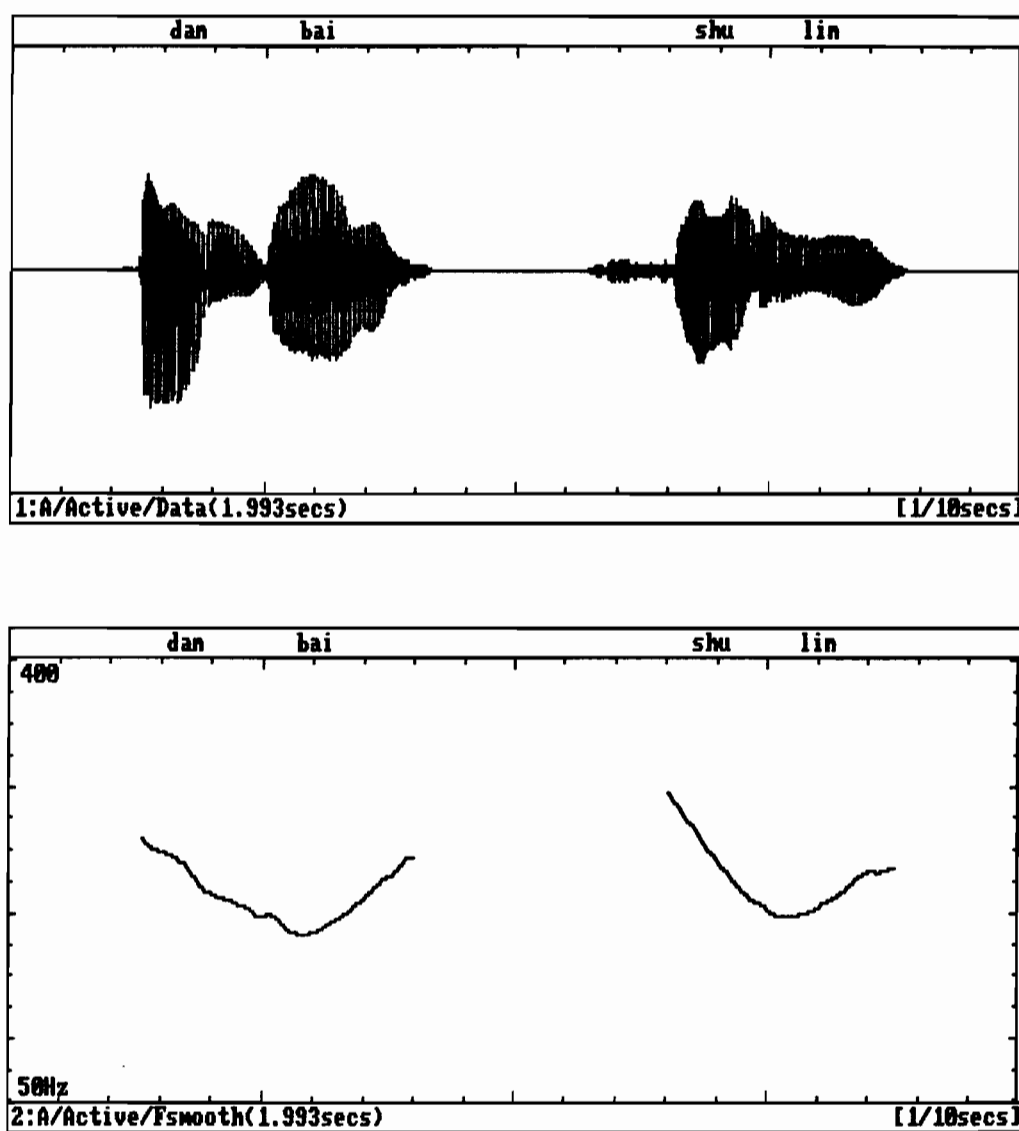


Figure 4.18 Waveform and pitch tracks of T4T2 in disyllabic words by speaker H.

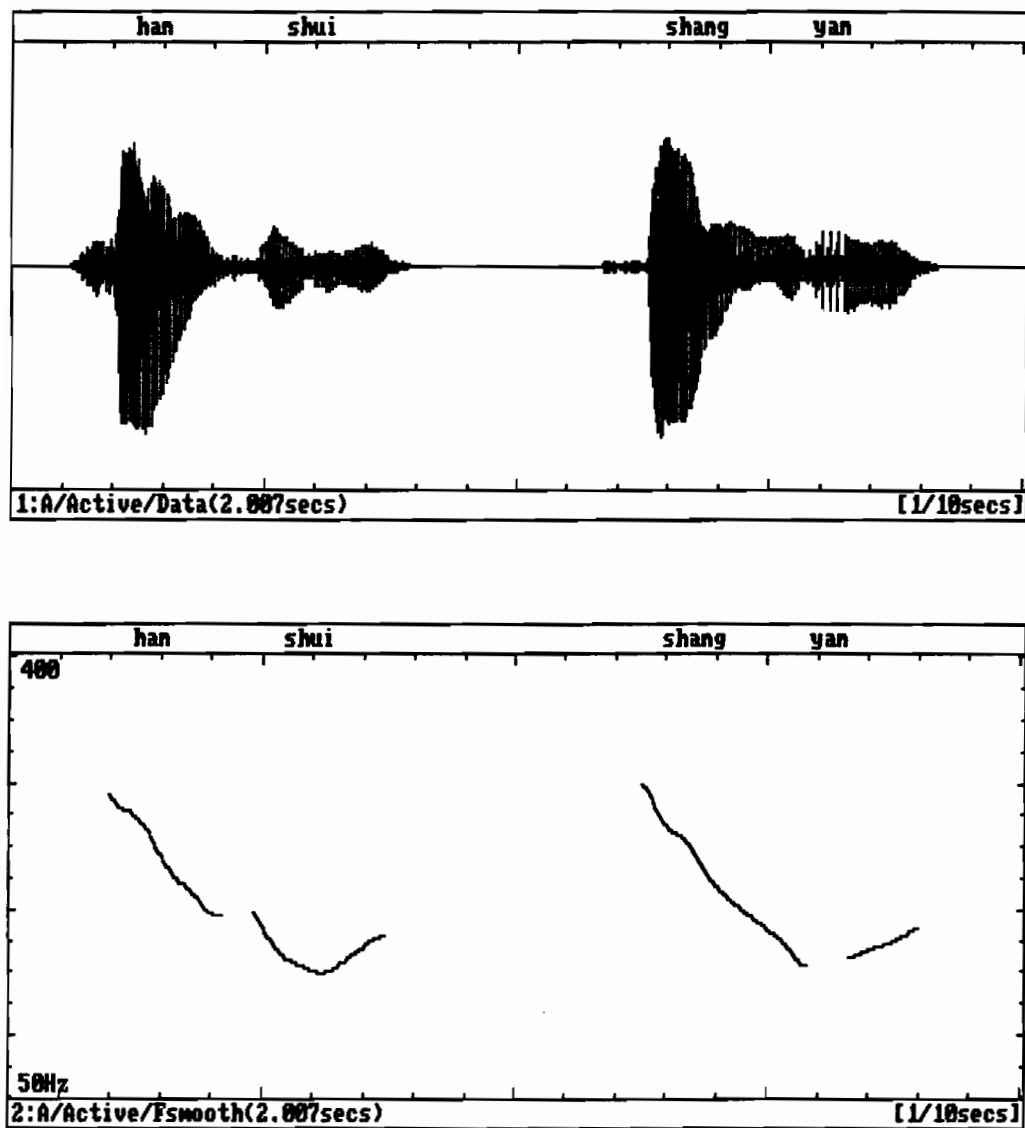


Figure 4.19 Waveform and pitch tracks of T4T3 in disyllabic words by speaker H.

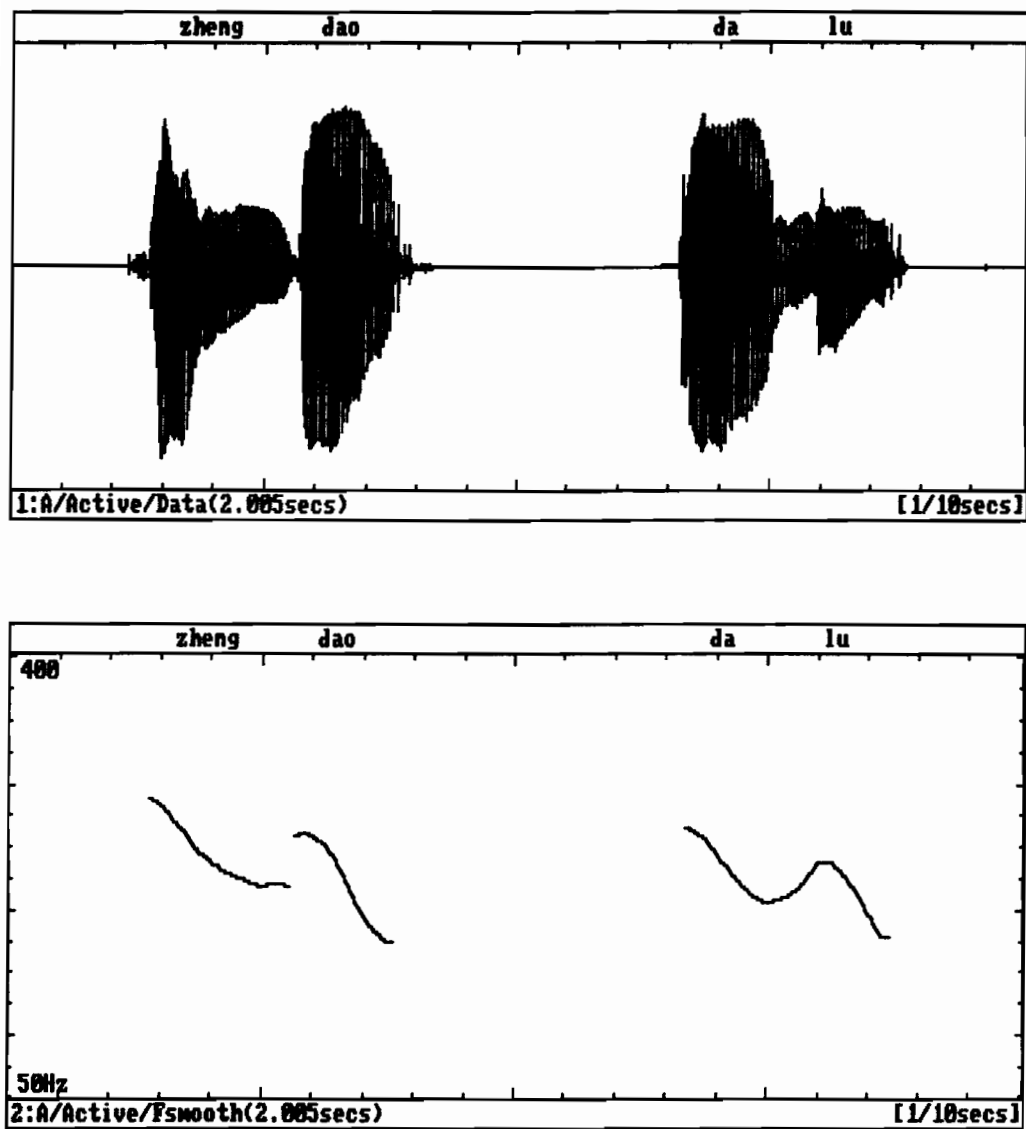


Figure 4.20 Waveform and pitch tracks of T4T4 in disyllabic words by speaker H.

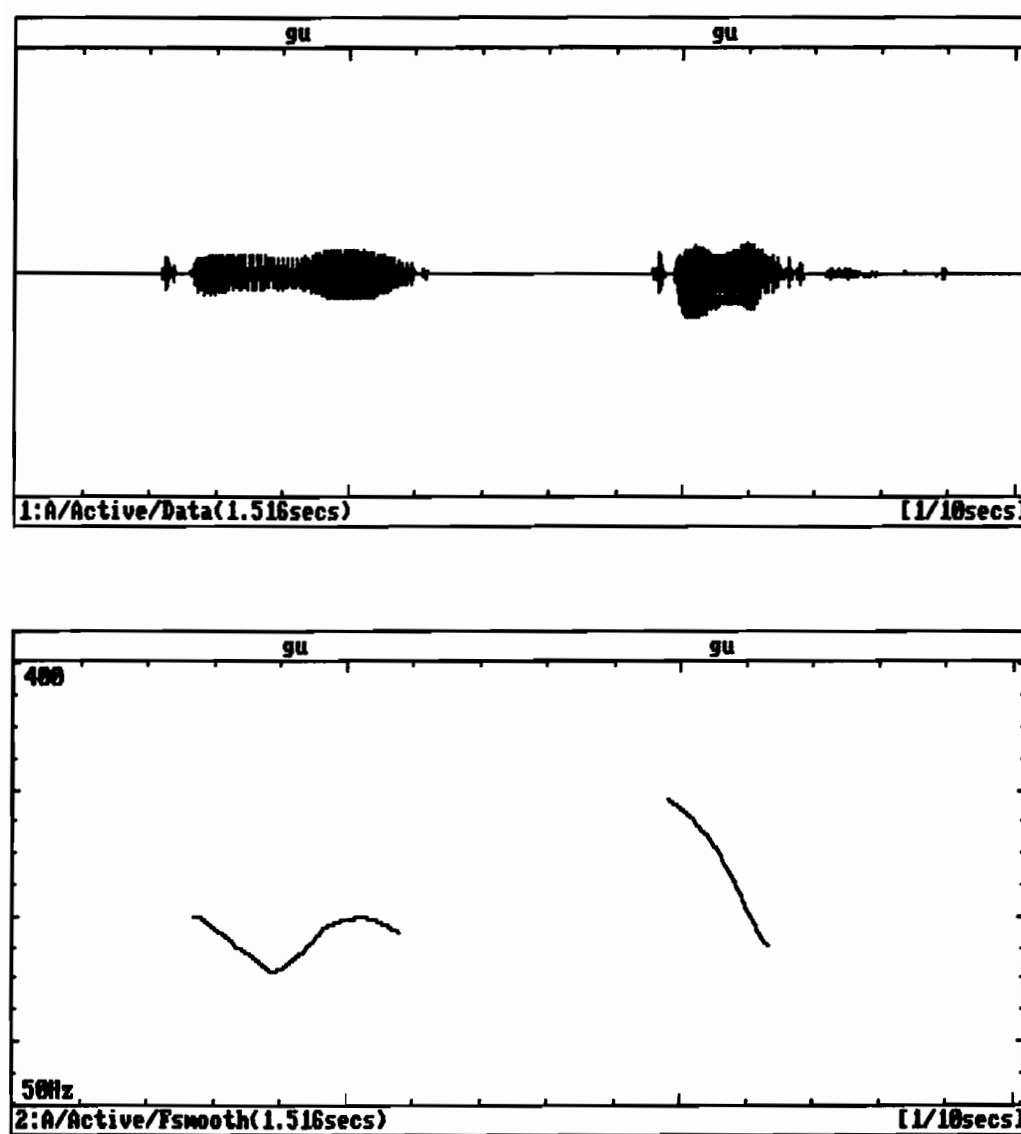


Figure 4.21 Waveform and pitch tracks of T3 and T4 in syllables gu produced by speaker (the second time).

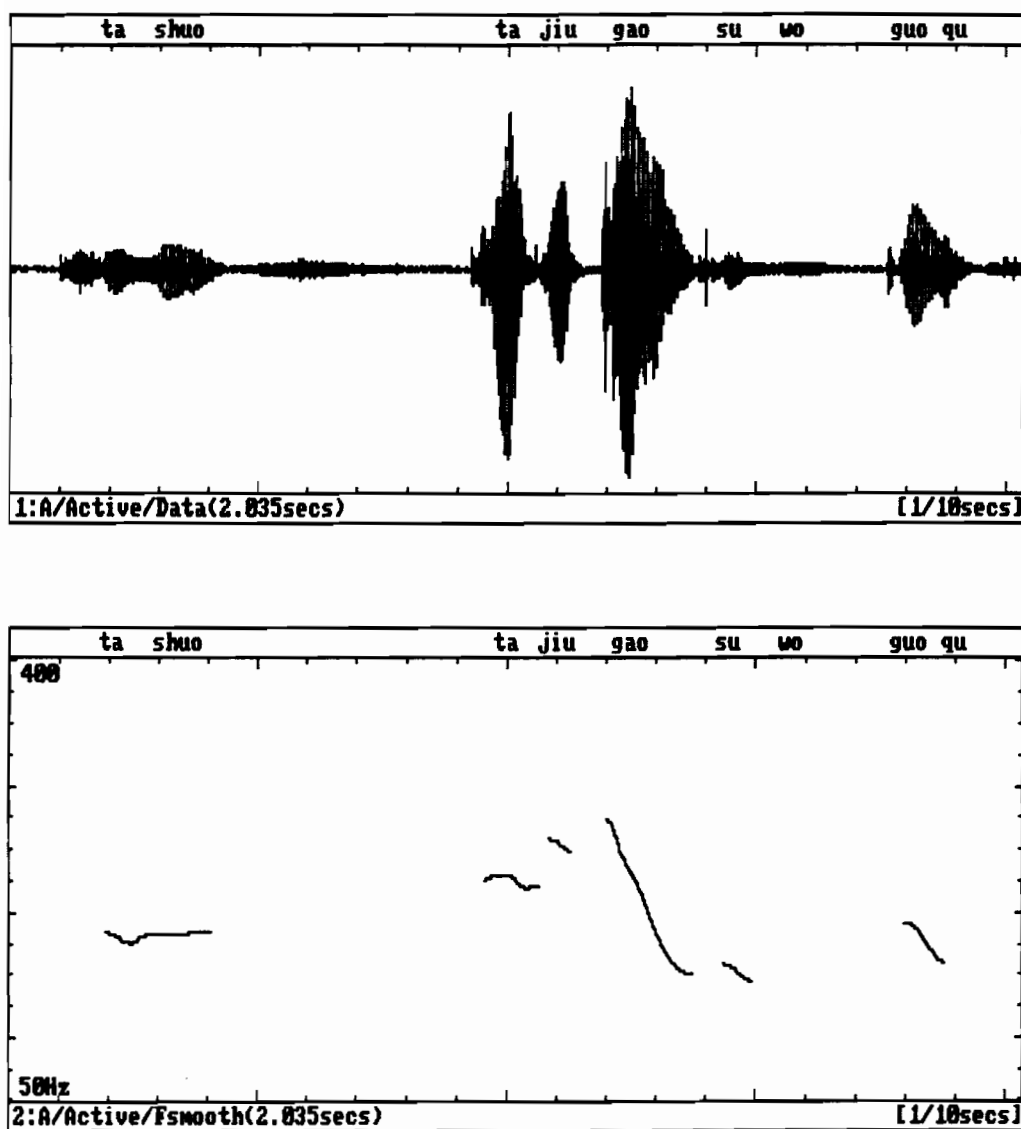


Figure 4.22 Waveform and pitch tracks of sentence ZJ14, Ta shuo, ta jiu gaosu wo guoqu , 'She said, she told me to drive through'.

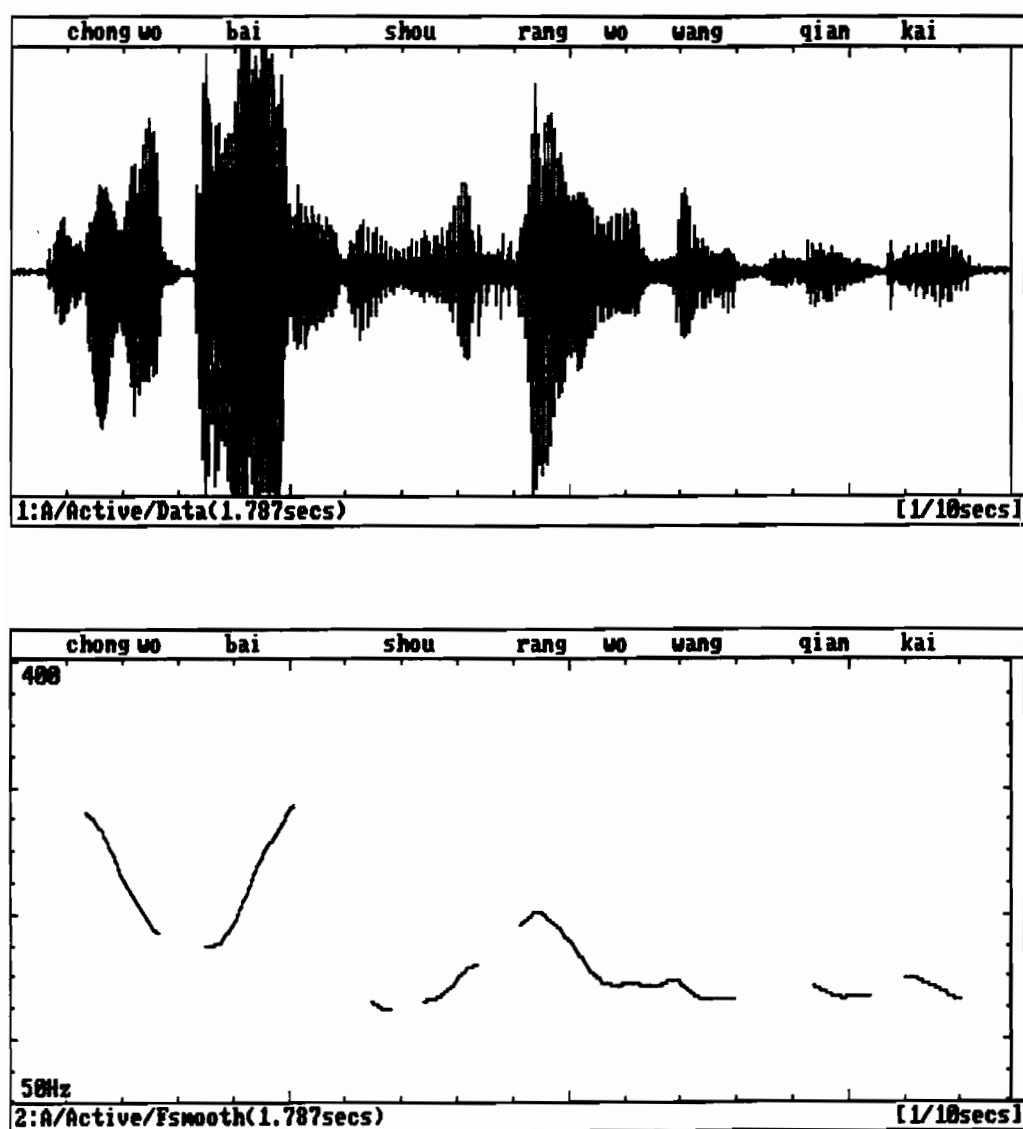


Figure 4.23 Waveform and pitch tracks of sentence ZJ15, Chong wo bai shou, '(She) waved her hand at me,' and ZJ16, Rang wo wang qian kai. '(She) let me drive forward.'

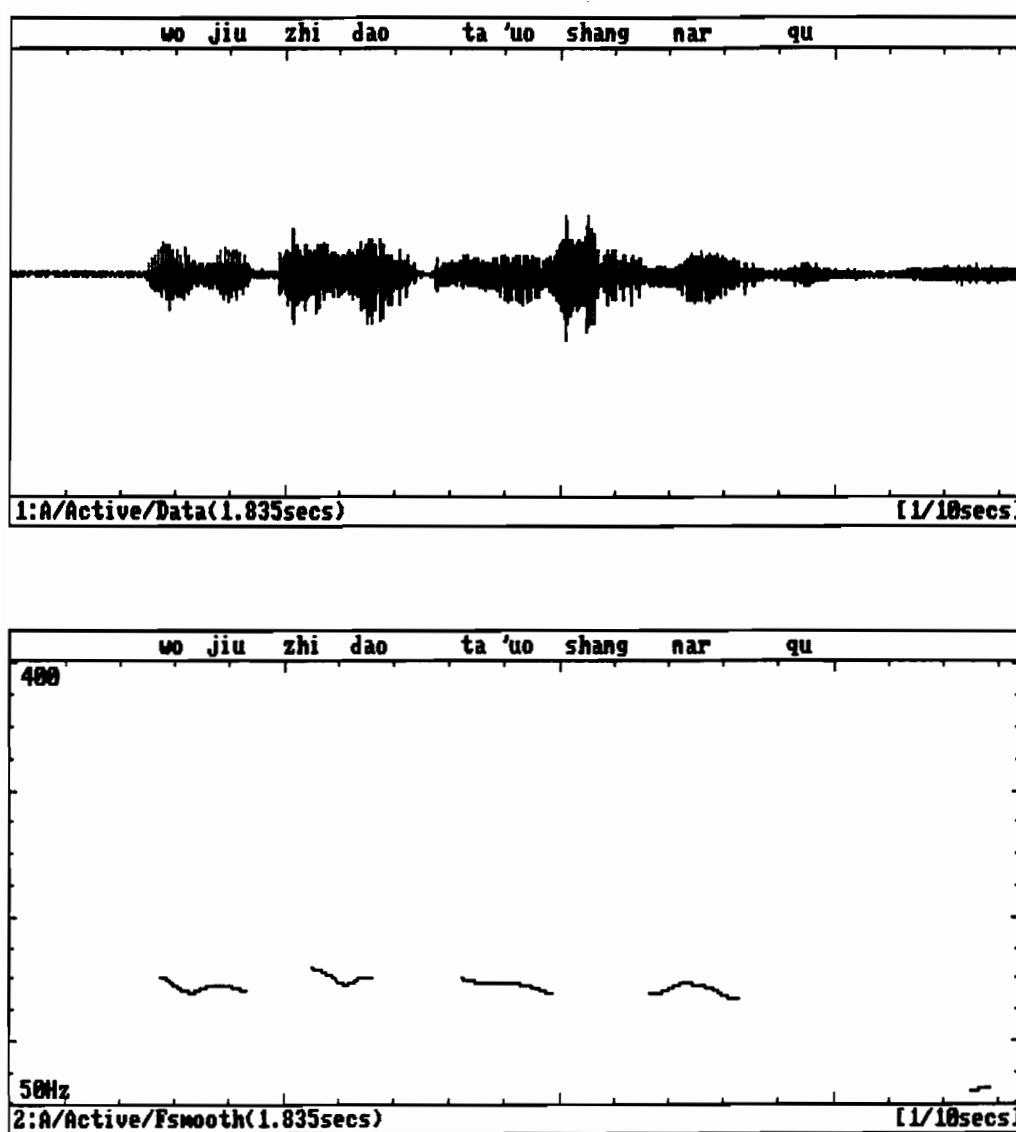


Figure 4.24 Waveform and pitch tracks of sentence ZJ17, Wo jiu zhidao ta shuo shang nar qu. 'I know that she wanted me to go there.'



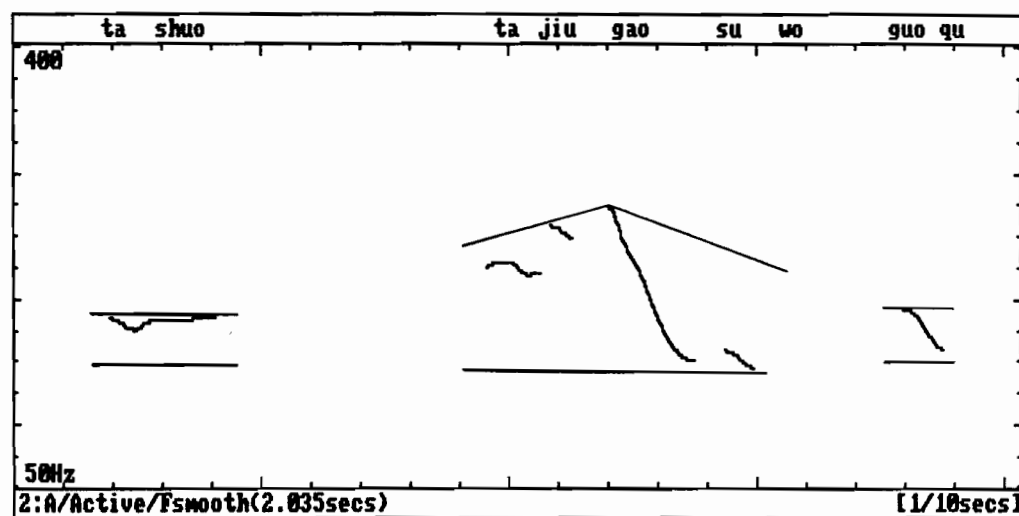
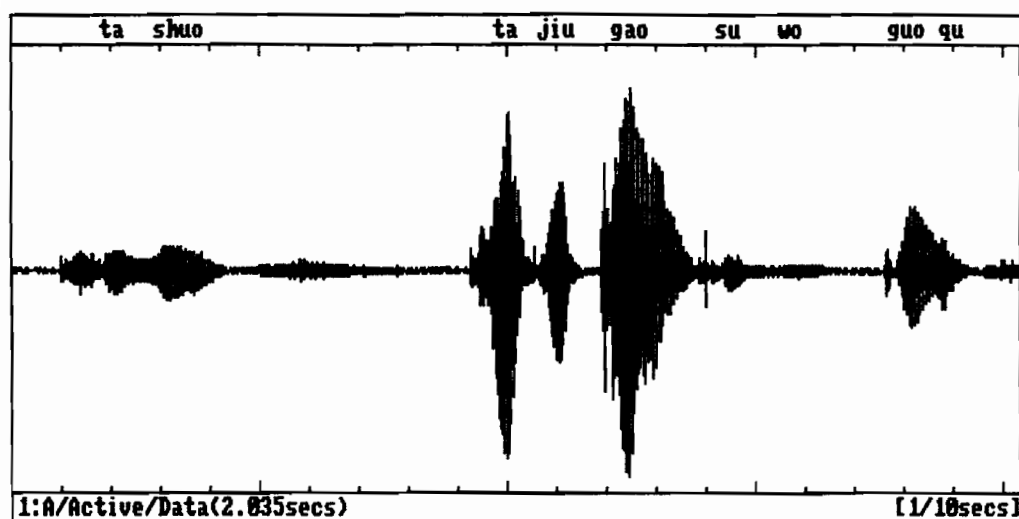


Figure 4.25 Outlined pitch range for sentence ZJ14, Ta shuo, ta jiu gao su wo guo qu, 'She said, she told me to drive through.'

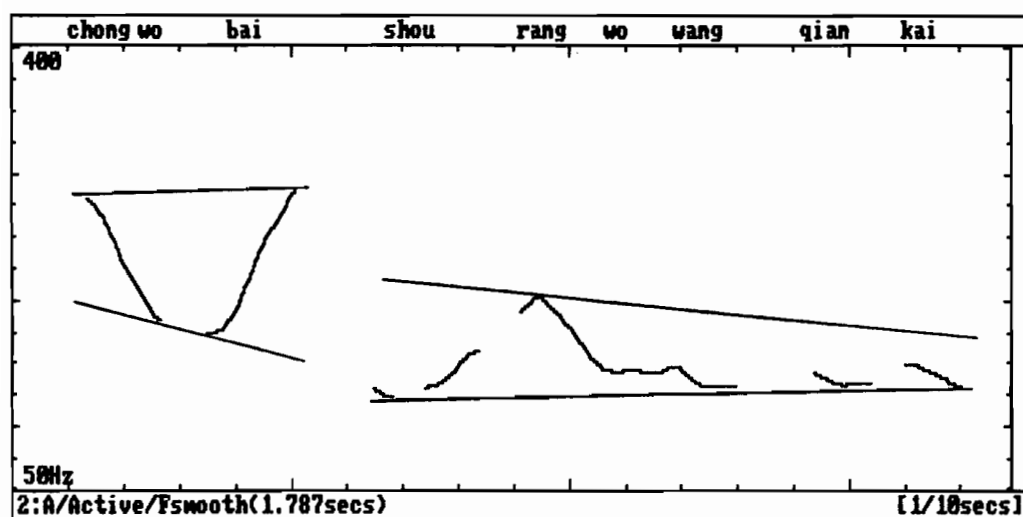
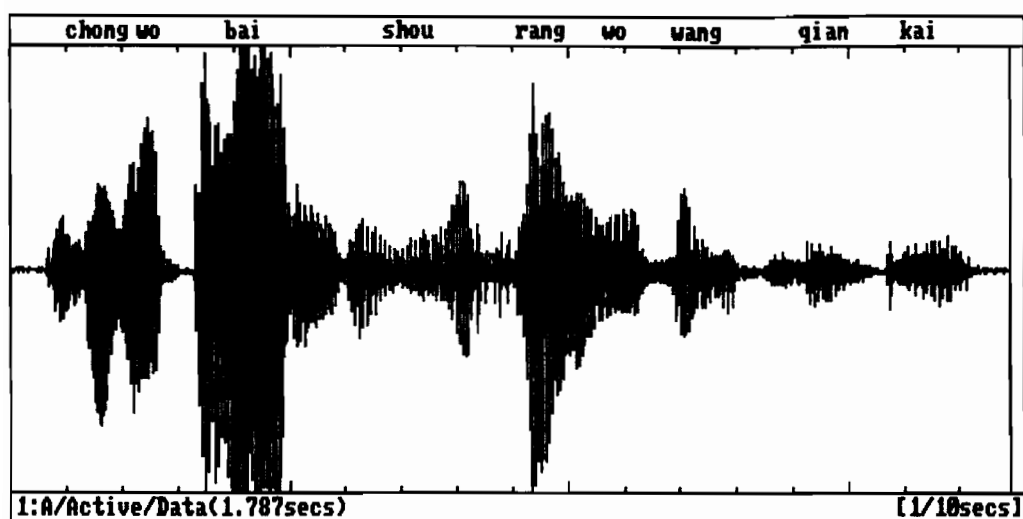


Figure 4.26 Outlined pitch range for sentence ZJ15, Chong wo bai shou, '(She) waved her hand at me,' and ZJ16, Rang wo wang qian kai. '(She) let me drive forward.'

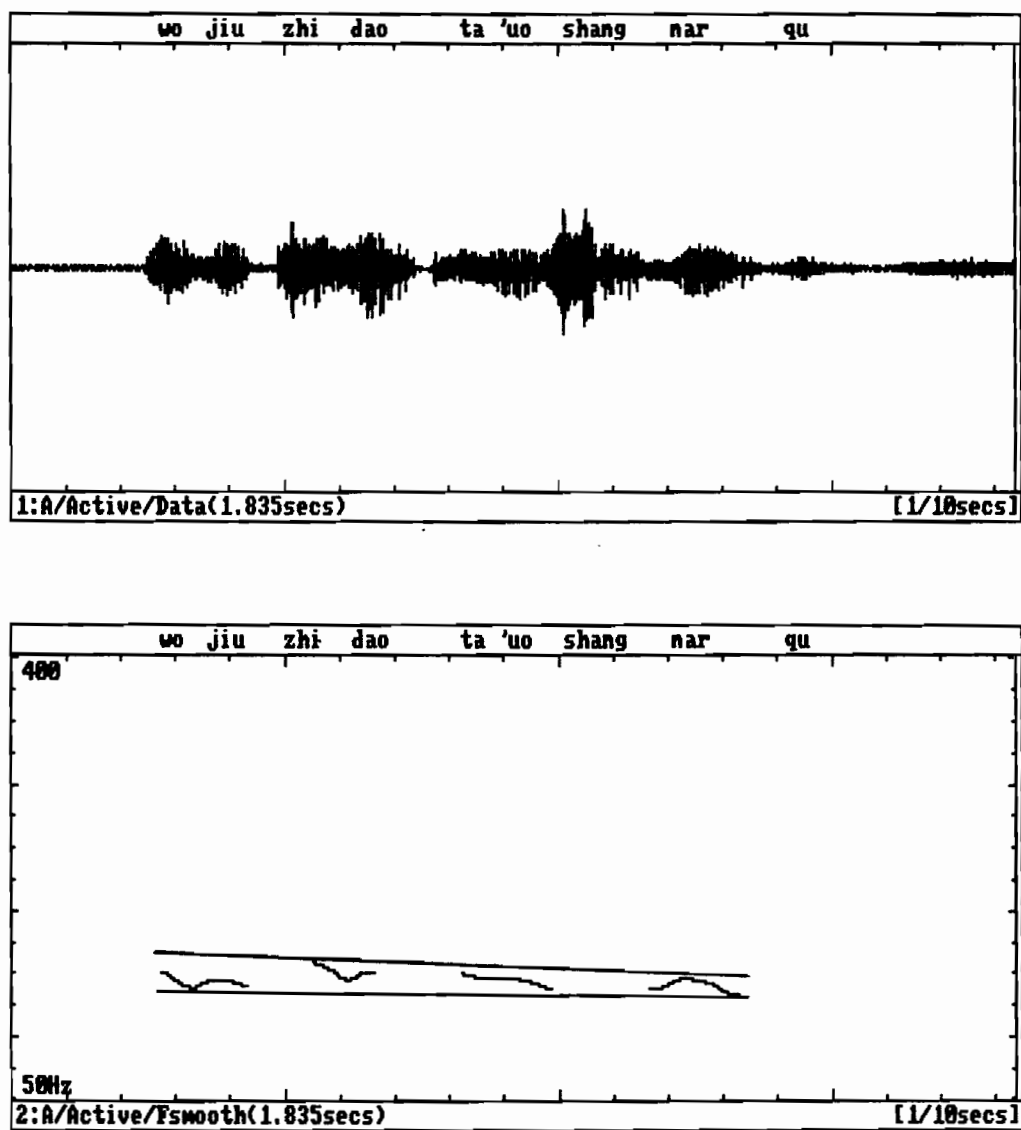


Figure 4.27 Outlined pitch range for sentence ZJ17, Wo jiu zhidao ta shuo shang nar qu. 'I know that she wanted me to go there.'

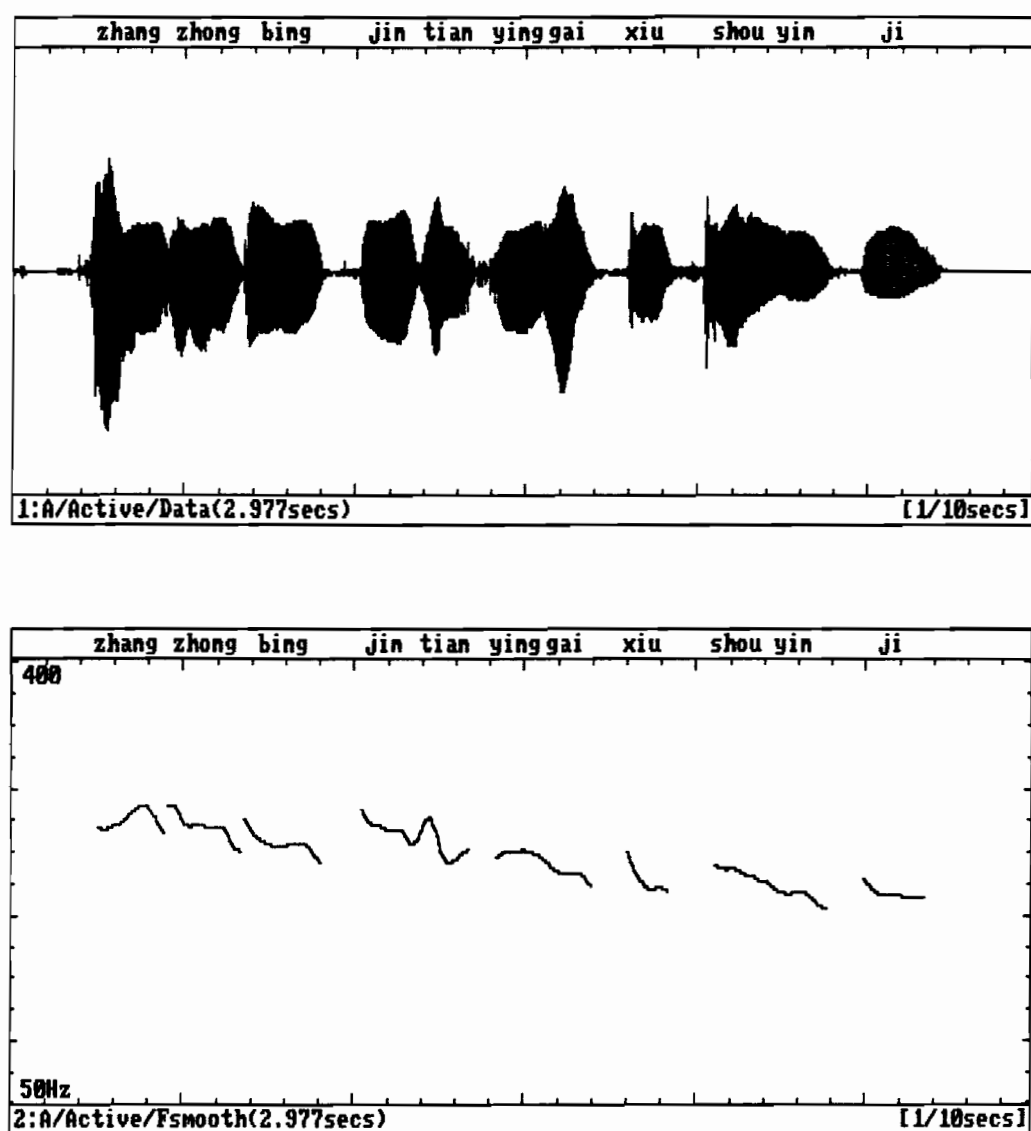


Figure 4.28 Waveform and pitch tracks of sentence  
S1a by speaker H, Zhang Zhongbing jintian yinggai xiu  
shouyinji. 'Zhang Zhongbing should repair a radio today.'

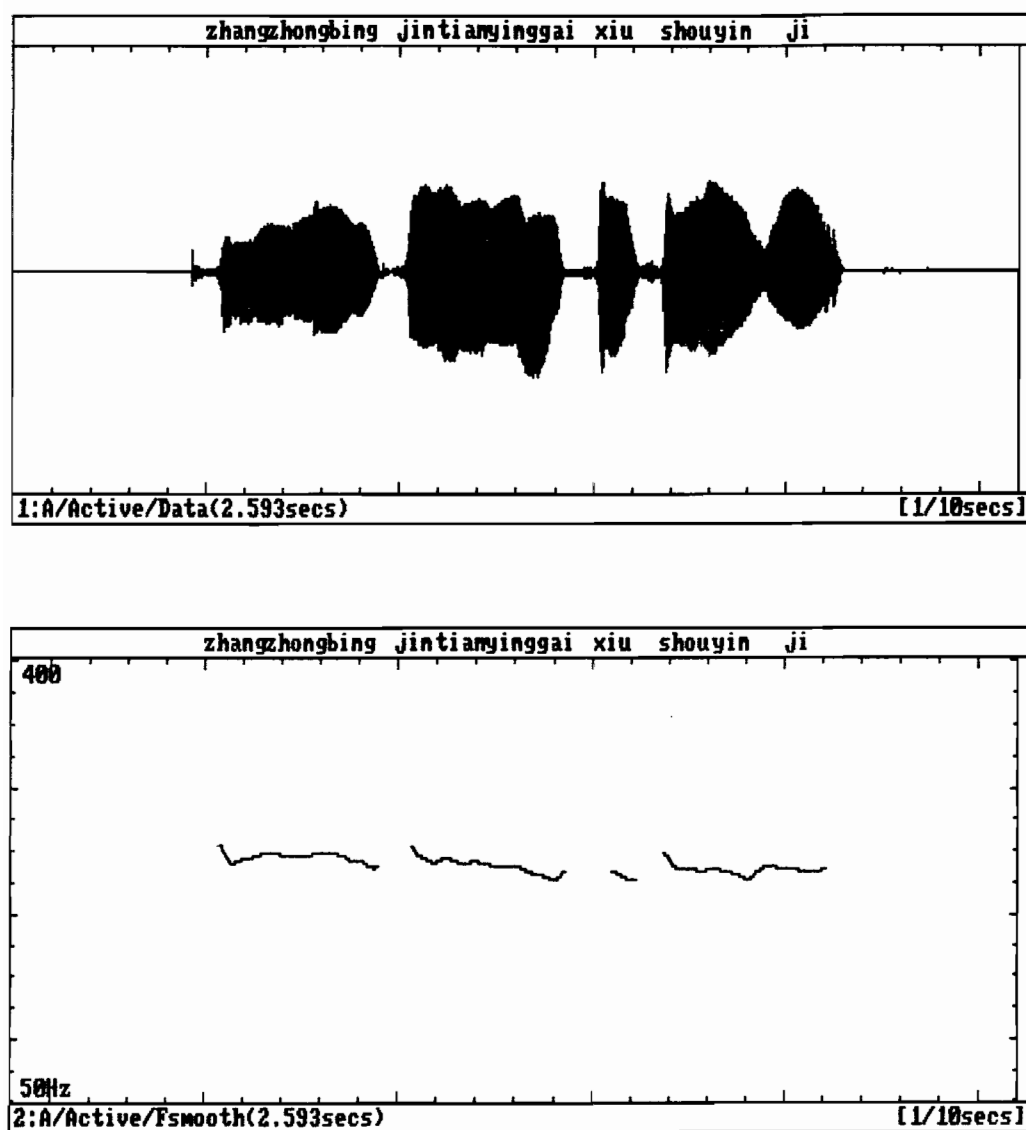


Figure 4.29 Waveform and pitch tracks of sentence S1b by speaker H, Zhang Zhongbing jintian yinggai xiu shouyinji. 'Zhang Zhongbing should repair a radio today.'

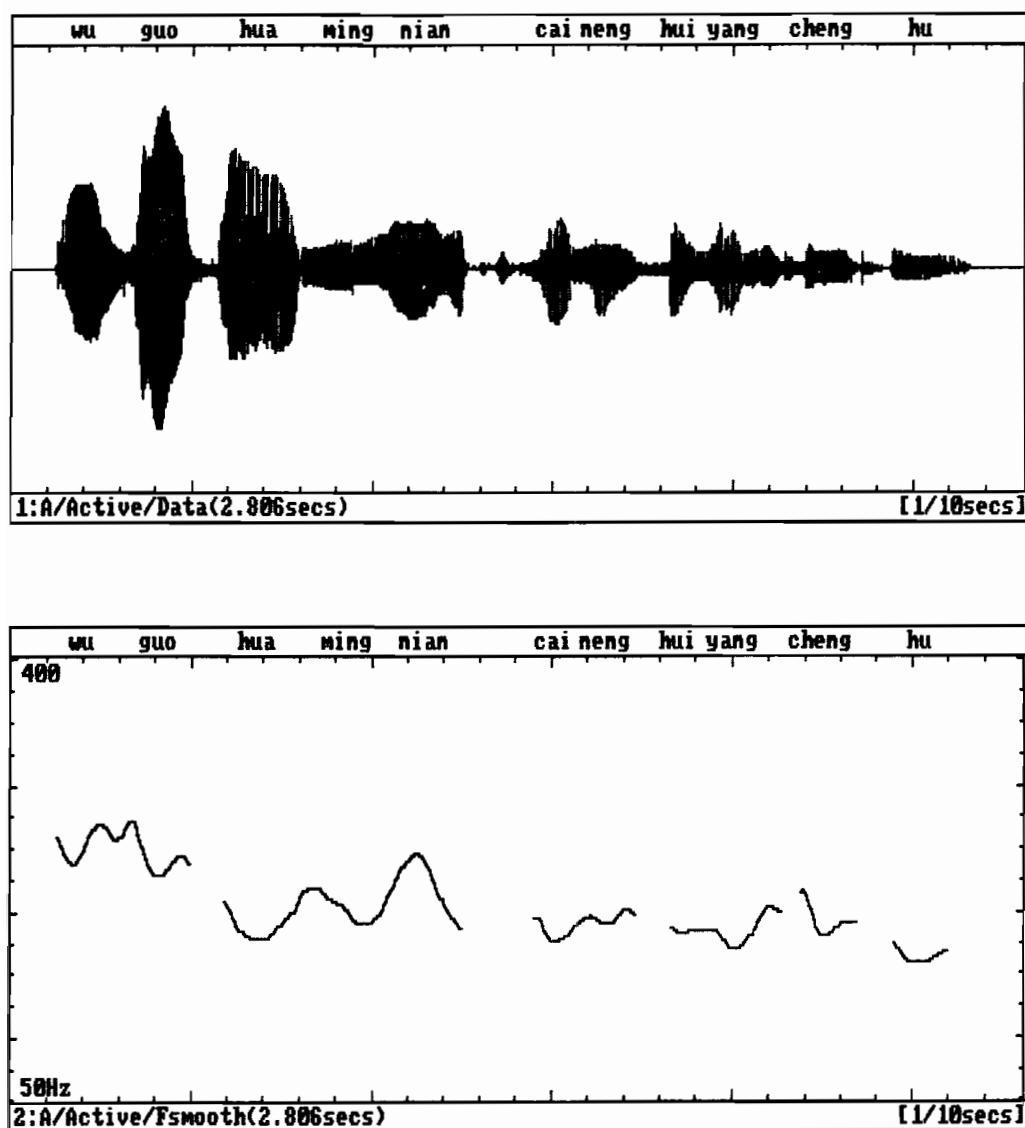


Figure 4.30 Waveform and pitch tracks of sentence S2a by speaker H, Wu Guohua mingnian cai neng hui Yangchenghu. 'Wu Guohua cannot go back to Yangcheng Lake until next year.'

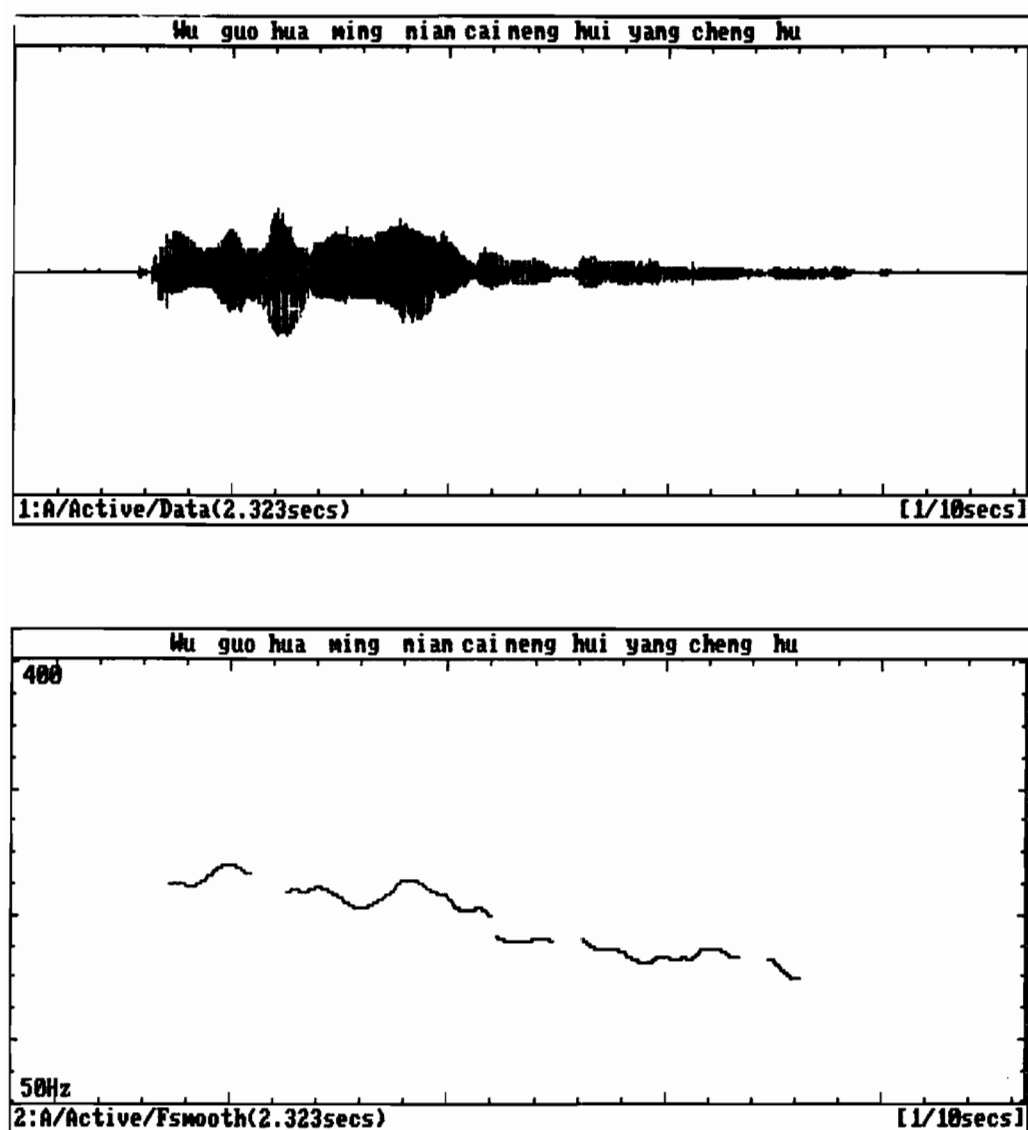


Figure 4.31 Waveform and pitch tracks of sentence S2b by speaker H, Wu Guohua mingnian cai neng hui Yangchenghu. 'Wu Guohua cannot go back to Yangcheng Lake until next year.'

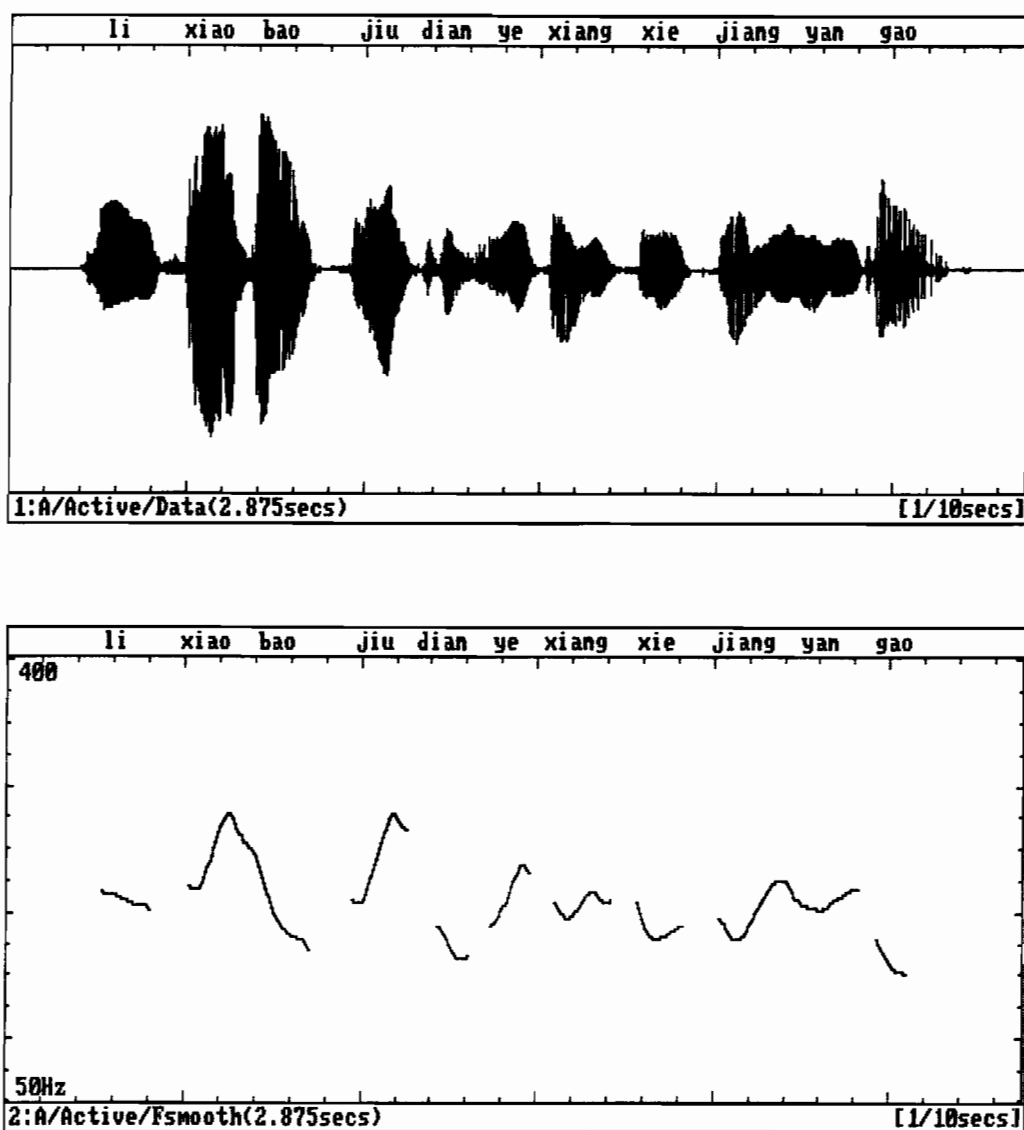


Figure 4.32 Waveform and pitch tracks of sentence S3a by speaker H, Li Xiaobao jiudian ye xiang xie jiangyanqao. 'At 9:00 Li Xiaobao wants to write a draft for a lecture too.'



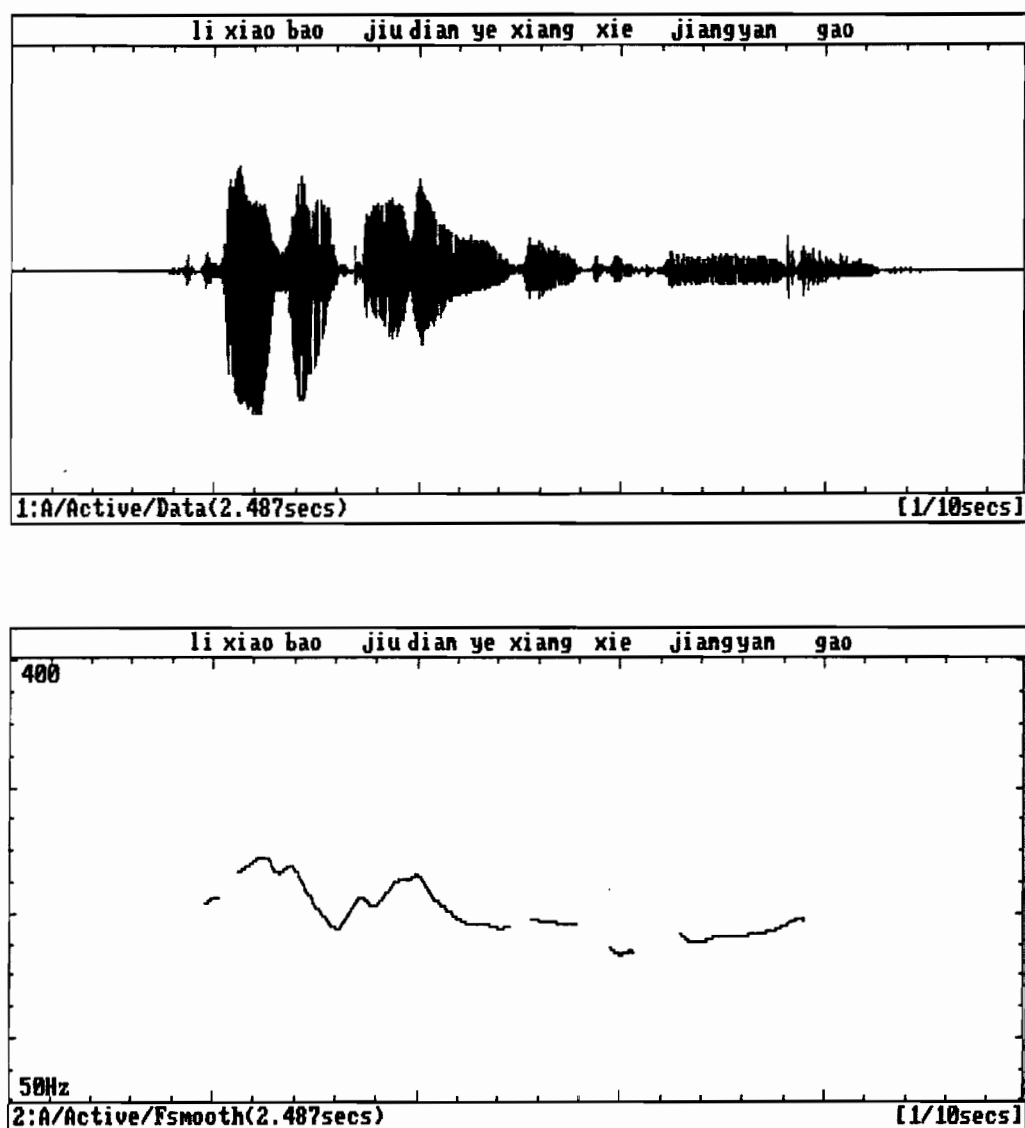


Figure 4.33 Waveform and pitch tracks of sentence S3b by speaker H, Li Xiaobao jiudian ye xiang xie jiangyangao. 'At 9:00 Li Xiaobao wants to write a draft for a lecture too.'

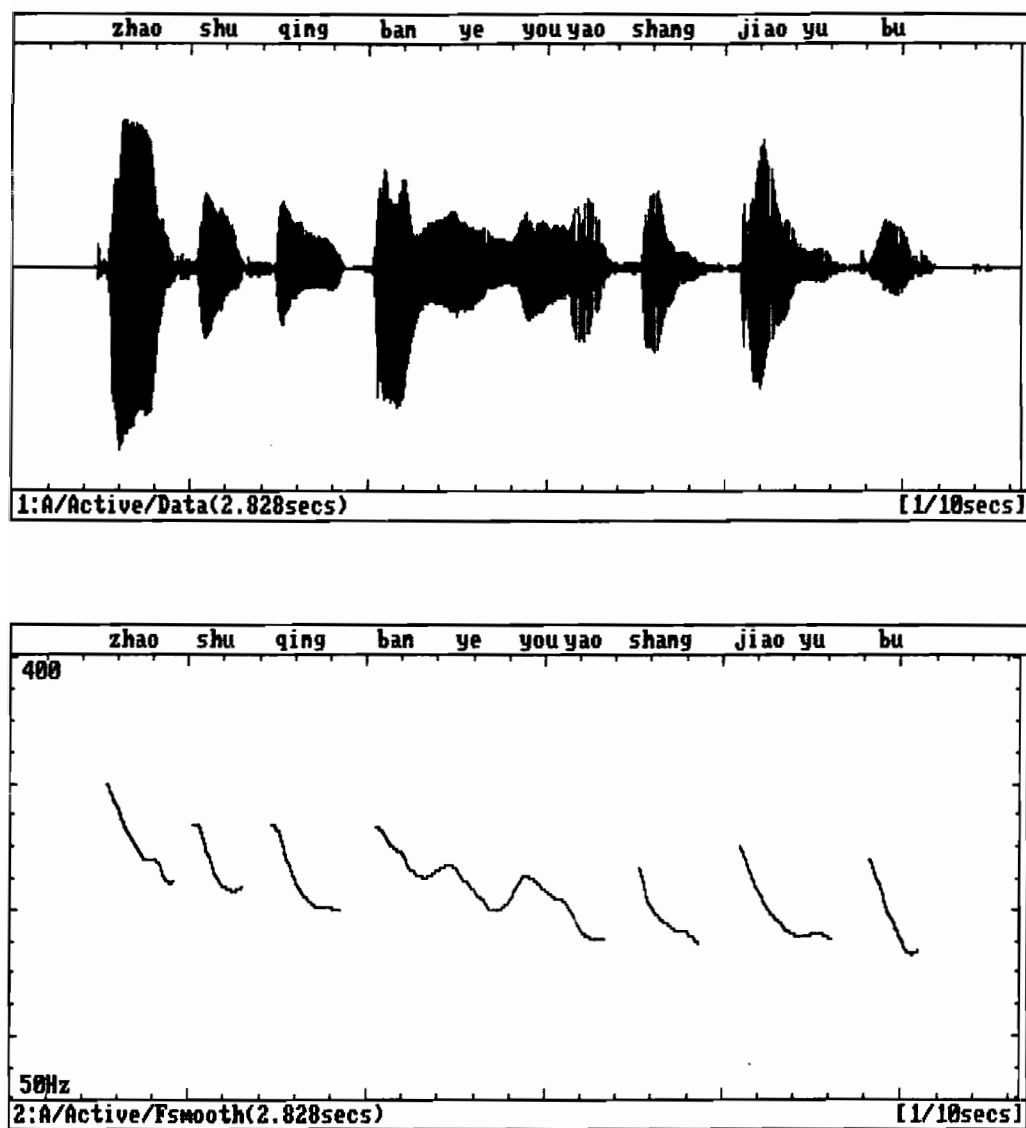


Figure 4.34 Waveform and pitch tracks of sentence S4a by speaker H, Zhao Shuqing banye you yao shang jiaoyubu. 'Zhao Shuqing will go to the Ministry of Education in the middle of the night again.'

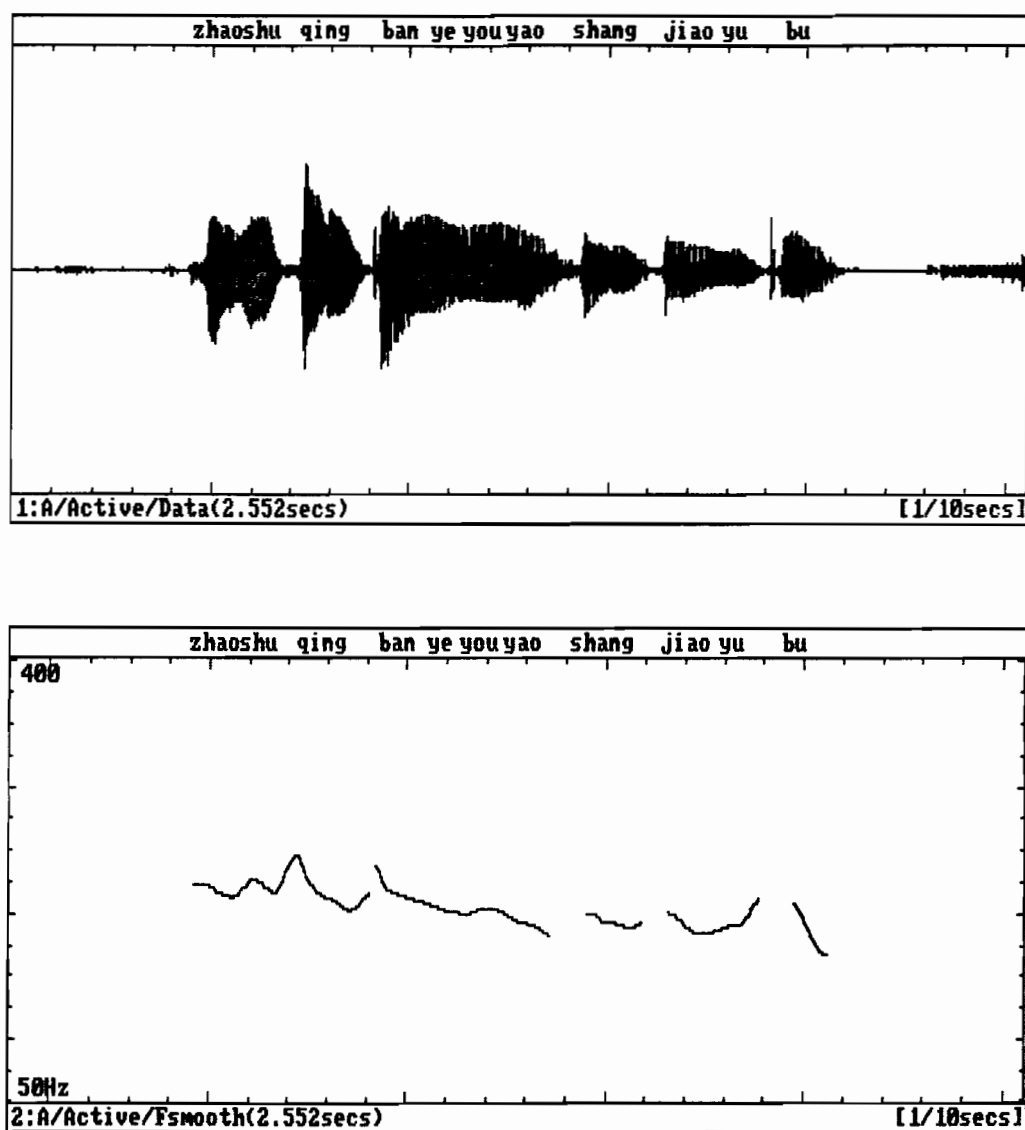


Figure 4.35 Waveform and pitch tracks of sentence S4b by speaker H, Zhao Shuqing banye you yao shang jiaoyubu. 'Zhao Shuqing will go to the Ministry of Education in the middle of the night again.'

## CHAPTER V

### TONAL REALIZATION AND PITCH UNDULATION

In this chapter, several hypotheses are presented to describe the realization of pitch contours of tones in both spontaneous and controlled speech. All of the hypotheses are introduced through one example in Section 5.1, and are explained by more evidence in the following sections.

#### 5.1. Overview of the major hypotheses

This section consists of an overview of the major hypotheses presented in this chapter. However, before the major hypotheses can be discussed, specific notions and terms used through out the remainder of the dissertation will be introduced. First of all, the underlying tones and tone sandhi rules used in Chapter 4 need to be modified.

### 5.1.1.1. Modification of underlying tones and tone sandhi rules

Hereafter, the low falling variant 21 is adopted as the underlying form of T3. However, the same underlying forms for T1, T2, and T4 are used as before. There are two reasons for adopting the low falling underlying T3. The first reason concerns the wide distribution of T3, which has been confirmed by data from other studies and data from this study, shown in Chapter 4 and beyond. Another reason concerns the physical constraints of T3 production, which is hypothesized due to the unusual behavior of T3 discussed in Chapter 6.

Where examples of pitch contour formation are necessary, I have provided predicted surface tones in conjunction with underlying tones for each sentence. This will aid in understanding the difference between phonological prediction and the actual pitch movement within the sentence. However, since I have adopted a different underlying form of T3, the tone sandhi rules of T3, therefore, must change. First of all, the Half-T3 Rule, which states that a T3 appears as a low falling contour when followed by T1, T2, or T4, does not apply. Also, the T3 Rule, which indicates that a T3 becomes a rising tone before another T3, needs to be reformulated as follows:

- (1)                      Revised T3 Rule:  
                             21 ---> 35 / \_\_\_\_ 21

In addition, a new "Final T3 Rule" has to be formulated. The low falling form is changed to a low falling-rising form when a T3 is followed by a stop or pause as indicated bellow:

- (2)                      Final T3 Rule:  
                             21 ---> 213 / \_\_\_\_      stop  
    pause

According to my data of both spontaneous and read speech, this rule is optional. Finally, the derivation of the surface form of a neutral tone which follows a T3 should also be reformulated as follows:

- (3)                      0 --> 4 / 21 \_\_\_\_

For the convenience of discussion about how tones behave in speech strings, the height and shape will be regarded as two basic, or underlying, features of each tone. The basic features of the four Mandarin tones are as follows:

- |        |  |       |        |         |         |
|--------|--|-------|--------|---------|---------|
| (4)    |  | T1    | T2     | T3      | T4      |
|        |  | ----- | -----  | -----   | -----   |
| Height |  | high  | low    | low     | high    |
| Shape  |  | level | rising | falling | falling |

### 5.1.2. Pitch undulation

I assume that pitch movement in a sentence has a tendency undulate rather than jump upward and downward. Only in very limited situations is it possible for a whole sentence to exhibit a flat line pitch track. The basis of the assumption stems from the fact that the rate of vocal cord vibration is limited to a certain range of frequency, and the vibration rate gradually changes in normal speech. For example, a typical undulation of the pitch movement is shown in Figure 5.1. The corresponding sentence is ZJ2526. In this figure, there are four peaks and three valleys in the whole pitch track. Hereafter, "pitch undulation" will be used as a term to refer to pitch tracks with peaks and valleys.

(5) ZJ2526:

Ta	ne	jiu	yiwei,	nei	kaoguan	jiu	yiwei	...	
55	0	51	21 35	51	21 55	51	21 35		UT
55	2	51	21 35	51	21 55	51	21 35		ST
*	*		*		*		*		
she PART then think that tester then think									
"She thought, the tester thought..."									

In order to clearly illustrate all the points, the syllables are delineated with vertical lines drawn from the upper to the lower portion of Figure 5.1. When comparing pitch curves with corresponding predicted surface forms, each unpredicted tone is marked by asterisk in the sentence.

Note, however, that some of the pitch contours, such as that of the T3 in the first yi, retain their basic tonal features. The corresponding tones are called "full tones". Some of the other pitch contours, such as that of the T1 in guan and that of T4 in the first jiu, partially or completely lose their basic tonal features. These tones are called "reduced tones". Neutral tones do not have specific underlying forms and hence, are not reduced tones. The definitions for "full tone" and "reduced tone" are relative, since there exists a continuum of change between the two. The degree of feature loss for each tone is judged only subjectively. A full tone might retain eighty, rather than one hundred percent of the basic features of the tone. Thus, the purpose of using these terms is only for the convenience of qualitative description.

#### 5.1.3. Importance of tones and their order of occurrence

It is important to note that the specific shape of a pitch undulation depends not only on the tones of the syllables but also the order in which these tones occur in the sentence. However, the pitch undulation is not just the simple connection of full tones or tones predicted according to the present phonological system. As noted in the previous section, some tones are fully realized and some are unexpectedly reduced in the utterance. The order in which their



tones occur in the utterance plays an important role in determining the overall shape of the pitch undulation.

This point is clearly illustrated in figure 5.1. The shape of the first portion of the pitch undulation, a high level-falling contour, is formed by the combination of the T1 and T0 in the first two syllables; however, the value of the T0 is not the same as that predicted by Chao (1968). The next portion of the pitch undulation, the falling-rising contour, is formed mainly by the T3 and T2 in the fourth and fifth syllables respectively. If the order of these two tones was reversed, then the pitch contour would be in a rising-falling shape. As a consequence, the entire pattern of pitch undulation in the sentence would be different. This fact reveals the importance of tonal order and occurrence in the sentence. However, it should be noted that the T4 in the third syllable does not function as expected. Instead of retaining a high falling shape, the T4 contour becomes a low curve serving as an anticipatory adjustment of pitch movement for the following T3. This unique behavior causes the actual shape of the pitch undulation to differ from the expected shape.

#### 5.1.4. Formation of pitch undulation

Some of the full tone build the frame of the pitch undulation, while other tones affect the final shape of the

pitch undulation. Reduced tones tend to adjust themselves when fit into the frame; and these tones provide an important contribution to the final formation of the pitch undulation.

In Figure 5.1, the frame of the pitch undulation is built on the full tones of the five syllables: ta, Kao, the first yi, and the second jiu and wei. Other syllables, however, fit differently in the frame. Along the pitch movement, the neutral tone in ne naturally realizes an instantaneous fall after the full T1 in ta. The T4 in jiu relinquishes both of its basic features in order to fit properly in the frame. Contrary to this phenomena, the T2 of the first wei fit into the frame without any change. Furthermore, the T4 in nei retains only a "high" feature when realized as the second peak of the undulation. The pitch curve in the consonant of the syllable serves as an anticipatory adjustment of this reduced T4. The pitch curve in guan fits in the frame in a quite similar way and hence, the T1 becomes a high rising curve. The T3 in the second yi retains its "low" feature and becomes concave in shape to fit the frame. After much adjustment in the tones, the final shape of the utterance's pitch undulation is finally formed.

### 5.1.5. Function of stress pattern

The stress pattern of a sentence is determined by how the speaker produces the sentence according to different linguistic and nonlinguistic factors. The same speaker may produce different stress patterns when repeated the same words. An interesting example is the phrase jiu yiwei 'thought' in sentence ZJ2526. This phrase occurs twice in the same sentence with different stress patterns and hence, different surface tones.

I hypothesize that the stress pattern of the utterance controls different tonal behavior in the formation of pitch undulation. Stronger stresses keep the corresponding tones full and make them build the frame of the pitch undulation. Weaker stresses make tones adjust to fit in the frame and contribute to the final shape of the pitch undulation. Tones in weaker syllables retain features which are compatible with the tendency of pitch movement, but partially or totally give up features which are not compatible with the tendency. Neutral tone or totally reduced tones obtain their pitch contours according to both tones of stronger syllables and the tendency of pitch movement in the intermediate phrase.

As reviewed in Chapter 2, the function of stress has been noted in previous studies. Some studies mention partial loss of tones in weakly stressed syllables. The loss is

usually treated as the disappearance of the second part of the tonal shape. However, according to my data, either feature (i.e. height or shape) of a tone could be lost. In previous studies, there is no general rule found concerning how pitch contours are realized after the partial loss. Furthermore, although there are many studies about how neutral tones and totally reduced tones realize their surface forms, a general rule which predicts these realizations in spontaneous speech is still yet unavailable. My hypothesis stated above provides the general principle for both.

In sentence ZJ2526 below, the stress patterns are marked by "s" and "w". An "s" indicates a strongly stressed syllable, while a "w" indicates a relatively weakly stressed or an unstressed neutral tone syllable.

(6) ZJ2526:

Ta	ne	jiu	yiwei,	nei	kaoguan	jiu	yiwei	...
s	w	w	s w	w	s w	s	w s	
55	0	51	21 35	51	21 55	51	21 35	UT
55	2	51	21 35	51	21 55	51	21 35	ST
	*	*		*	*		*	
she	PART	then	think	that	tester	then	think	
"She thought, the tester thought..."								

In this case, tones of the five stronger syllables all possess full tones and construct the frame of the pitch

undulation, and most of the weaker syllables have partially or totally reduced tones, which play active roles in finally forming the pitch undulation.

It must be made clear, though, that full tones may also occur in weakly stressed syllables. In other words, a relatively weak syllable may not lose its tonal feature. For example, in the above sentence, the weakly stressed syllable wei has a full T2. Why do this type of phenomena occur? The answer is that these phenomena are caused by an optimum match among several factors which influence surface realization of tones. These factors include the tones which occur in the utterance, the order of the occurrence, the stress pattern, and the tendency of the pitch movement. In this case, the local tendency of pitch movement favors a rise from the low ending point of the preceding T3 in the first yi, which is a low falling tone. In addition, the T4 of the next syllable nei, with the basic "high" feature, also requires the pitch to rise upward. The occasionally required pitch curve in this syllable, the first wei, is the same as a basic contour of the T2 -- a low rising curve. Therefore, the realization of this full T2 is not the same as that for many other full tones. Most full tones are reealized simply conditioned by strong stresses. This full T2 does not serve as a basic component of the frame. Rather, it functions the same as reduced tones, and contributes only

to the final shape of the pitch undulation

#### 5.1.6. Domain of tone sandhi: the intermediate phrase.

Syllables tend to group into intermediate phrases within a sentence, and each intermediate phrase is a prosodic constituent containing at least one stressed syllable and serves as a tone sandhi domain. In this study, the pitch track of each intermediate phrase is regarded as a "tune". The shape of a tune is based on at least one typical contour of a tone. In this analysis, three lowest prosodic levels are concerned, which are: prosodic word, intermediate phrase, and intonational phrase. The corresponding tonal constituents at these levels are called: tone, tune, intonation. The formation of tune is studied in this Chapter.

Sentence ZJ2526 shown below is divided into four intermediate phrases, the boundaries of which are marked by "|".

(7) ZJ2526:

	Ta	ne		jiu	yiwei,		nei	kaoguan		jiu	yiwei		...
	s	w		w	s	w	w	s	w	s	w	s	
	55	0		51	21	35	51	21	55	51	21	35	UT
	55	2		51	21	35	51	21	55	51	21	35	ST
	*			*			*		*		*		
	She PART then think that tester then think												
	"She thought, the tester thought..."												

Each intermediate phrase in this sentence has one or two strongly stressed syllables. Figure 5.1 shows the tonal change happens in each of the intermediate phrases. Moreover, the whole shape of pitch movement in each intermediate phrase reveals a relatively independent tune.

For each tune, the pitch contours of strongly stressed tones frase the basic shape, and pitch contours of weaker tones fit into the frame. In other words, the tendency of pitch undulation predominates over weakly stressed tones. In the first intermediate phrase, the neutral tone of the syllable ne serves as a falling extension of the T1, which belongs to the strong syllable ta. In the second intermediate phrase, the reduced T4 of the first jiu becomes an anticipatory adjustment of the T3 in the strong syllable yi. In the third intermediate phrase, both the T4 of nei and the T1 of guan sustain only the feature "high" to function as the anticipatory and carryover adjustment of the full T3 of the strong syllable kao. In the last intermediate phrase, the concave curve of the T3 in the weakly stressed syllable yi serves as a transition between the T4 and T2 in the strong syllables jiu and wei respectively. Major tonal changes occur inside an intermediate phrase rather than between two separate intermediate phrases. Even so, a pitch transition between two neighboring intermediate phrases often occurs. This transition may serve as the carryover

adjustment of the first tune, the anticipatory adjustment of the second tune, or the combination of both. The height of the ending point and the local tendency of pitch movement at the ending portion of a tune may affect the pitch curve at the starting portion of the successive tune.

For the convenience of discussion, I refer to the anticipatory or carryover pitch adjustment of a tone as "pre-extension" or "post-extension" of the tone, respectively. In the above example, the third tune can be regarded as formed by a low falling T3 and its pre- and post-extension. Sometimes, the pre-extension of one tone is also the post-extension of another tone in one intermediate phrase. This is referred to as a "transition" between the two tones. This phenomenon occurs in the pitch track of the fourth intermediate phrase, where the low concave T3 of yi serves as a transition between the T4 of jiu and the T2 of wei. At the same time, this T3 retains its feature "low" which is compatible with the tendency of the local pitch movement.

Tonal phenomena play crucial roles in defining the prosodic constituent intermediate phrase. I have been using the concept of intermediate phrase. However, a more detailed discussion of the concept is placed at the end of this chapter.



### 5.1.7. Principle of pitch contour formation in intermediate phrases

In summary, the following is the general principle which governs pitch contour formation in intermediate phrases.

#### (8) Principle of Pitch Contour Formation in Intermediate Phrases:

A pitch contour for an intermediate phrase forms a single tonal unit, tune. This pitch contour takes its shape by conforming to all features of strongly stressed syllables and some features of weakly stressed syllables. The contours of strongly stressed syllable build the frame of the tune. The contours of weakly stressed and unstressed syllables are adjusted to serve: (1) as transitions between pitch contours of stressed syllables; (2) as pre-extensions of pitch contours of stressed syllables; or (3) as post-extensions of pitch contours of stressed syllables along the tendency of pitch movement.

### 5.2. Pitch undulation

From this section on, I will explain in detail each of the previous overviewed hypotheses with additional more examples. In order to analyze the formation of pitch contour of individual tones in speech strings, the first item that needs attention is pitch movement within the whole sentence. The analysis raises a question: Is there any general manner of pitch movement for all Mandarin sentences? The observation of pitch tracks of sentences in the data of the present study and some other previous studies leads to the following

hypothesis: pitch undergoes undulations in a speech string, and the tendency of pitch undulation affects tonal realization. Evidence that supports this hypothesis will be discussed in this section.

#### 5.2.1. Sequence of TiT0

Evidence of pitch undulation and its affect on tonal contours comes from the surface realization of neutral tones. As reviewed in Chapter 2, scholars have different descriptions of surface heights or contours of neutral tones in TiT0 ( $i = 1, 2, 3$ , or  $4$ ) sequences, however, they do agree on the fact that the surface realization of neutral tones is conditioned by the preceding tones in "TiT0" sequences. In other words, neutral tones are realized as continued pitch curves of the preceding full tones. However, the following questions are raised: In a TiT0 sequence, why does a neutral tone usually curve downwards after the rising contour of a T2? Why does it curve upwards after a falling contour of a T3, rather than maintain the trend of the preceding tone? Why, contrary to this tendency, does the tone continue to fall rather than rise after the falling contour of a T4?

My answer to all three questions above is that because of physical constraint, pitch tends to undulate in the local pitch range. When the upward slope of a T2 reaches the

higher boundary of the pitch range, it must turn downward. This is the reason that a neutral tone is realized as a downward contour after a T2. For the similar reason, a neutral tone following a low falling T3 is realized as an upward contour, after the pitch movement reaches the lower boundary of the pitch range and changes direction toward the high boundary of the pitch range. However, the situation is different when a neutral tone follows a T4. Although phonologically the T4 is transcribed as "51", it is a phonetic fact that it never fall as low as the low falling T3 which is transcribed as "21". Therefore, the pitch movement after a T4 could continue downwards until it reaches the low boundary of the pitch range. The neutral tone which follows a T4 is then realized at the continued falling portion of the pitch undulation.

As noted previously, scholars have different descriptions of neutral tones, although most previous phonetic studies of tones have used a formal reading style. From the above analysis, it is apparent that all of the previous descriptions may be correct for certain data or under specific conditions. There is a common problem: the variables allowed for by previous descriptions are too limited. This is the reason that all the descriptions fail to reflect the dynamic relationship between a neutral tone and its preceding tone. Compared to those occurring in slow and formal

speech, neutral tones in fast and casual speech exhibit many more unpredicted variants.

The best way to describe the rule of the formation of the pitch track for a neutral tone is to regard it as realized along pitch undulation to serve as a transition between the surrounding tones, or a pre- or post-extension of the successive or preceding tone. In other words, the surface form of a neutral tone is decided by the neighboring tones and the tendency of pitch undulation.

If this analysis is correct, the rule should be able to apply in the surface realization of neutral tones not only in a single TiT0 sequence, but also in a sequence of TiT0's. As designed in Chapter 3, each of the sentences S7-S10 contains a sequence of several TiT0's ( $i=1, 2, 3$ , or  $4$ ). Let us examine the pitch tracks of these sentences produced by different speakers, see if the rule has been applied. The pitch tracks of sentences S7-10 produced by speaker Z are given in Figures 5.2-5.5. For comparison, a prediction of the surface tones in these sentences is provided in description of neutral tones of Chao's (1968) as follows.

- (9) ZJS7a:  
 | Gege        zhuo shang | ge    zhe    xin de | bolibei. |  
   55 0        55     0        55 0        55 0        55 0 55    UT  
   55 2        55     2        55 2        55 2        55 2 55    ST  
      brother desk top        put ASP new PART glass cup  
      "There is a new glass on my brother's desk."
- ZJS8a:  
 | Yeye        lou        shang | cang zhe lan de gezini. |  
   35 0        35        0        35 0        35 0        35 0 35    UT  
   35 3        35        3        35 3        35 3        35 3 35    ST  
      grandpa building top    hide ASP blue PART tartan  
      "There is some blue tartan hidden upstairs at my grand-  
      father's place."
- ZJS9a:  
 | Jiejie shou shang | you    ge zhi    de | labatong. |  
   21 0    21     0        21 0    21     0        21 0    21    UT  
   21 4    21     4        21 4    21     4        21 4    21    ST  
      sister hand top        have CL paper PART megaphone  
      "There is a paper megaphone in my sister's hand."
- ZJS10a:  
 | Didi        bei    shang | fang zhe sui        de | mutoukuai. |  
   51 0        51     0        51 0        51        0        51 0    51    UT  
   51 1        51     1        51 1        51        1        51 1    51    ST  
      brother quilt top        put ASP broken PART wood cube  
      "There are broken pieces of wood on my brother's  
      quilt."

Syllables in each of the above sentences produced by speaker Z are divided into intermediate phrases. However, the division is based on how the sentences are spoken, a criterion different from that of Zhang (1988). Note that in Figure 5.2-5.5, some of the pitch tracks are interrupted by voiceless segments or pause. If the pitch tracks are treated as a continuous line, it seems as though some portions of the line do not show up.

It is apparent that the pitch track for every utterance in Figure 5.2-5.5 as a whole is in an undulatory shape. When comparing the actual neutral tone curves with the predicted tones above, one fact becomes obvious: although the actual pitch curves of the neutral tones are not consistent with the phonological description reviewed in Chapter 2, these neutral tone curves can be predicted according to the rule that I describe in the above. The neutral tones obtain their surface curves preceding, following, or between the neighbouring tones along the pitch undulation. Most of the neutral tones have surface falling curves in T1T0's, T2T0's, and T4T0's, and rising curves in T3T0's. All of these shapes have been reported in previous studies. I refer to these neutral tone shapes as regular shapes. Most pitch curves of neutral tones in the sentences containing TiT0's produced by speaker H and C also exhibit the similar shapes.

If the rule that I described above is correct, it should be able to predict not only the regular shapes, but also the irregular curves of neutral tones. Now let us see if the irregular shapes of neutral tones in the same Figures 5.2-5.5 can be explained. For example, in Figure 5.3, the shape of the pitch track of T2T0 in the last three syllables gezini 'tartan' exhibits continuously descending slope rather than a regular rising-falling pattern. The neutral tone of the syllable zi is the post-extension of the pre-

ceding T2 syllable ge. In fact, the tones of the last four syllables form a continuous post-extension of the full tone T2 found in the syllable lan.

Two additional examples of T2T0's in S8 are shown in Figure 5.6 and 5.7, which are produced by speakers H and C respectively. The division of this sentence into intermediate phrases by H and C is slightly different from that produced by speaker Z (cf. ZJS8a above), in making gezini 'tartan' into a separate intermediate phrase:

(10) HJS8a & CJS8a:

	Yeye	lou	shang	cang	zhe	lan	de	gezini.	
	35 0	35	0	35	0	35	0	35 0 35	UT
	35 3	35	3	35	3	35	3	35 3 35	ST
	grandpa building top hide ASP blue PART tartan								
	"There is some tartan hidden upstairs at my grand-								
	father's place."								

In Figure 5.6, most T2T0's are all realized as regular rising-falling contours with the T0's serving as falling post-extensions of the T2's along the pitch undulation. However, the fourth T2T0 of syllables lan de 'blue' becomes a falling-rising-falling curve. The T0 has an unregular convex shape. However, this T0 is still realized along the pitch undulation to serve as the post-extension of the preceding T2, which has a low concave shape. Furthermore, a similar tonal realization is exhibited in Figure 5.7. All the T0's are realized along the tendency of pitch movement

to become post-extensions of their preceding T2's, or become transitions between the surrounding T2's in an intermediate phrase. All these examples confirm the rule of pitch contour formation in neutral tones described above. The sentences which contain TiT0's were also uttered by the same speakers in a casual style. Pitch tracks of the casually produced sentences also support the description of the rule.

In J. Shen (1985), five well-trained broadcasters read the same sentences S7-10. The pitch tracks of the utterances were averaged among the speakers and normalized in both time and frequency scales. When analyzing the sequences of "TiT0"s in both my data and that of J. Shen's, and considering descriptions of isolated "TiT0"s in the other studies, it is easy to see that in a formally produced sequence of TiT0's, the pitch track of each TiT0 forms a cycle on the whole pitch undulation. If each pitch undulation is treated as a sequence of sine waves, the "TiT0"s occur at different phases of the sine waves. This point is illustrated in Figure 5.8. In particular, the solid lines indicate pitch tracks that occur in vocalic segments of the syllables and the dotted lines indicate pitch tracks which might miss if the initial consonants in the syllables were voiceless.

Figure 5.8 shows that the pitch contour of each TiT0 sequence represents one complete cycle. The overall shape of



the pitch undulation for each sequence of TiT0's looks similar. However, the main difference among these normalized undulations of TiT0's is that they are out of phase with each other, (particularly in terms of the height along the vertical axis). A comparison among the first cycles on each of the four TiT0's, clearly indicates that the cycles gradually change shape from T1T0 to T4T0, and that the phases of the four tones are complementarily distributed on a cycle. The height and shape of a neutral tone pitch contour in a sequence of TiT0's is decided by both their preceding tones and the cycle (i.e., the tendency of pitch movement). Chao's (1968) phonological description of the heights of neutral tones cited in Chapter 2 conforms quite well to this relative description of pitch undulation.

In addition, there is a positive proportion correlation between the pitch tracks and sine waves: the shorter the strings and the more formal the reading style, the better the pitch tracks match the suggested sine waves. The averaged and normalized pitch tracks of J. Shen (1985) show a much better match to their respective sine waves than the pitch tracks of Figures 5.2-5.5 do.

In short, the above examples support the hypothesis that pitch tends to undulate within a speech string. Moreover, the above analyses also indicate that in any style of speech the realization of neutral tones always hints at

how pitch movement undulates.

### 5.2.2. Sequences of different tones

Evidence of pitch undulation and its effect on tonal contours are always exhibited in sequences of tones with random orders. In many cases it would seem that the formation of the undulation is due to the phonologically predicted shapes of the tones. In other words, the undulation is an coincident result of merely connecting the expected tones one after another. However, through the use of six examples, I attempt to disapprove this opinion. These examples are illustrated in Figures 5.9-5.14 which contains of pitch tracks of the spontaneously produced sentences uttered by three different speakers, H,C, and Z. That is, speaker H produced HJ2930 and HJ6566, speaker Z produced sentences ZJ2021 and ZJ33, and speaker C produced CJ2829 and CJ3031. As before, I will divide each sentence into several intermediate phrases; however, the manner in which I do this will be introduced later. Then I will derive the predicted surface tones and compare them with their actual pitch contours. In the sentences below, unpredicted tones that loses one basic feature are marked with a single asterisk and those that lose both basic features are marked with double asterisks (e.g., \*\*)

(11)

HJ2930

	Ni	yao	yuyan		zai	buhui	yunyong		na	jiu
	21	51	21 35		51	51 51	51 51		51	51
	21	51	21 35		51	35 51	53 51		53	51
	21	51	21 35		51	35 51	53 51		35	51
	*	**			*	**	*			

you if language also cannot use then just  
 "If you cannot speak the language either, then definitely

kending	hui		qifu	ni.!	
21 51	51		55 51	21	UT
21 53	51		55 51	21(4)	ST
21 35	51		55 51	21(4)	ST
*			*	*	

definitely will bully you  
 you will be bullied."

HJ6566

	Ta	de	baoxian	gongsi		pei	le	yiqian	duo	kuai
	55	0	21 21	55 55		35	0	55 55	55	51
	55	2	35 21	55 55		35	3	51 55	55	51
	*			*	*	*	*	*	*	*

She PART insurance company pay ASP 1000 more M  
 "Her insurance company paid more than one thousand

qian	a.!	
35	0	UT
35	3	ST
money	PART	
dollars.	"	

ZJ2021

	Kaishi	ma,		jingu	wang	qian		kai	de	shihou,	...
	55	21	0	51	51	21	35	55	0	35	51
	55	21	4	53	51	21	35	55	2	35	51
	*						*	*	**	**	

begin PART enter toward front drive PART time  
 "At the beginning, when I drove in and went forward ..."

(11) (continued)

ZJ33

	Ying	gai	zhijie		ni	jiu	guoqu	,		peng	le	jiu	peng	le	
55	55	35	55		21	51	51	0		51	0	51	51	0	UT
55	55	35	55		21	53	51	1		51	1	53	51	1	ST
55	55	55	55		21	53	51	1		51	1	53	51	1	ST
	*		*			**		*				**			

should directly you then go there hit ASP just hit ASP  
 "You should drive through directly, even if you had  
 hit it."

CJ2829

	Cong	lai	meiyou		kai	guo	che	,		ye	cong	lai	meiyou		...
35	35	35	21		55	51	55			21	35	35	35	21	UT
35	35	55	21		55	51	55			21	35	35	55	21	ST
35	55	55	21		55	51	55			21	35	55	55	21	ST
35	35	55	21		55	51	55			21	35	35	55	21	ST
	*				*		**			*	*		*		

hitherto not drive ASP car also hitherto not  
 "(I) have never driven a car, I have also never..."

CJ3031

...		zuo	dao	jiashi	yuan	de		na	weizi	shang		zuo	guo		
	51	51	51	21	35	0		51	51	0		51	51	0	UT
	53	51	51	21	35	3		53	51	1		51	51	1	ST
		*	**		*	*		*	*	*		*	*	**	

sit on driver PART that seat top sit PERF  
 "...sat on the seat for a driver."

In Figures 5.9-5.14, pitch undulation is quite obvious. These pitch undulations are not composed only of underlying or predicted surface forms of tones occurring in the sentences. Unpredicted tonal heights and/or contours are exhibited in each sentence. Why must many tones change their features, in either a predictable or an unpredictable

manner, to build a pitch undulation? I explain the phenomenon as being caused by physical constraints. For a given time duration and a given pitch range, the number of peaks and valleys of a pitch movement must be limited according to a specific speech rate and style. If all of the syllables in a sentence are articulated clearly and slowly, as though read in a rather formal and slow style, every tone has the chance to keep its underlying or predicted surface form to compose the whole pitch undulation. However, in spontaneous speech, the speaker often produces the sounds in a casual manner and at a faster rate. The duration of a sentence is much shorter, and the shape of the pitch undulation does not contain many sharp peaks and deep valleys. Therefore, not as many predicted risings and fallings can be realized. This phenomena forces many tones to alter some of their basic features to form a simplified pitch undulation.

In brief, pitch tracks of sentences containing tones with random orders confirm that pitch undulates in utterances. The formation of an pitch undulation affects the realization of word tones. Entering a sentence, a syllable may give up both of the basic features of its tones.

### 5.2.3. Sequences of Ti's

Evidence of pitch undulation is also given by different sequences of Ti's, where "i" (i=1, 2, 3, or 4) is the same in a particular utterance. When there is a sequence of unlevel Ti's, the amplitude of the pitch undulation is larger. Note again the pitch tracks of S1-S4 produced by speaker H in Figures 4.28-4.35.

The pitch undulations are quite clear in all of these figures. For sentences with as many as eleven syllables, not even one pitch undulation is formed when all of the tones are the same. In Figures 4.28 and 4.29, because of the basic features of T1, the pitch undulation is reduced to a rather flat line with several small curves. In Figures 4.30 and 4.31, even for a formal reading style, several T2's lose their basic features in forming the pitch undulation. In the casual reading style, most of the T2's become falling or level tones. These tones reduce the number of rising-falling variations in the pitch undulation. In Figures 4.32 and 4.33, in both styles, less than half of the T3's remain in low falling contours. The others changed dramatically to serve as the non-falling portions of the pitch undulation. The situation improves in Figures 4.34 and 4.35, because most of the T4's retain their basic shapes in the formation of the pitch undulation. However, several of the T4's lose the "high" feature.

Phenomena similar to the above observations are found in the same sentences produced by speakers Z and C. Since these sentences were originally designed and tested by J. Shen (1985), his data are also taken into consideration. The sentences in his study, however, contain two fewer syllables than those in mine (i.e. without the sixth and seventh syllables presented here). The tonal contours of the four sentences from J. Shen are shown in Figure 5.15. These tones correspond to the vocalic portions of the syllables in each sentence. Furthermore, the sentences are averaged among the five broadcasters using the formal reading style and are normalized in both time and frequency scales. Although these sentences were uttered with a very formal style and at a slow rate of speech, the shapes of their pitch undulations as well as the behavior of each type of tone, are very similar to those found in the formal versions in my data. For example, in the words Wu Guohua 'Wu Guohua', Yangchenghu 'Yangcheng Lake', Li Xiaobao 'Li Xiaobao' and Jiaoyubu 'Ministry of Education', the way in which the pitch contours adjust to fit in the pitch undulation is almost the same in J. Shen's data and in the formal examples of the data presented here.

The reason for this phenomenon warrants attention. Questions naturally would be raised such as: what causes the pitch to undulate in this manner and why, even in a

very formal reading style, do tonal changes similar to what is revealed in the Ti's still happen? These questions will be addressed in the following paragraphs.

The basic motivation for pitch undulation is physical constraints. It is known that, a pitch curve reflects a continued vibration of vocal cords. A broken line in the curve indicates that the fundamental frequency is changing abruptly. Such a jump is almost impossible in normal speech. As noted in Chapter Four, some consonants can cause small jumps in pitch movement. The rate of the vibration is limited to a certain defined range. Within this range, if the rate remains stable or changes slowly, it is reflected by a flat line in the pitch track. If the rate changes quickly, either increasing or decreasing, it has a tendency to reach one of the pitch range boundaries.

Since the rate of vibration cannot exceed this boundary, there are only two possible results if the vibration does not stop. One possibility is to keep the same rate after the rise or fall. In the pitch track, this results in a rising or a falling contour followed by a flat line. The other possibility is to change the speech rate from increasing to decreasing or vice versa, after the rate reaches the high or low limit. As shown in the pitch track, pitch moves toward the opposite direction, or the other boundary of the range, after reaching one boundary. This continuous change



of the vibrative rate of vocal cords is exhibited as a typical undulation in the pitch track between the two pitch range boundaries.

The basic pitch undulations of T2, T3, or T4's are formed due to this basic reason. As for T1's, ideally, the pitch track should be a flat line which is, in fact, a reduced undulation. However, there are naturally occurring minute changes in the rate of vocal cord vibration, because of various influences such as the production of segmental elements. This is the reason the pitch tracks of T1's in the data are often slightly curved.

During the production of a sentence (or a certain portion thereof), the effort or muscle strength expended, is determined by such factors as the speaker's mood, the importance of the information, and the type of the sentence. After the muscle strength is determined, a pitch range is then roughly given. If certain syllables are emphasized, they might be produced with a stronger effort; and hence, their pitch range, would become relatively larger. Normally, without any special effort, the rate of vocal cord vibration would not suddenly shift. Thus, the pitch tracks of normal speech usually do not contain any broken lines.

Though pitch tracks of speech strings have the general shapes of undulation that I have just discussed, they are not always smooth lines. Several factors can cause small

curves to appear on pitch undulation. One is the perturbation of some consonants at the onset of pitch tracks in many words. Another can be the tendency of the tone to keep its original shape when it fits in with a pitch undulation.

It must be a universal fact of languages that pitch movement in a speech string takes the shape of undulation. However, the specific principle which governs the formation of different shapes of undulations cannot be the same across languages.

To summarize, from all of the data discussed in the above, regardless of how different tones behave, pitch undulations of whole sentences predominate, and thus influence tonal realization. I assume that physical constraints motivate pitch to undulate continuously rather than to jump up or down suddenly in speech strings.

### 5.3. Formation of pitch undulation

A basic question regarding the formation of the pitch undulation in a sentence is: what is the general relationship between the tones and the pitch undulation? As noted in the last section, there are always some tones that keep their basic features in surface form and others do not. I regard these tones as "full tones" and "reduced tones" respectively. Questions relating to this fact are: what makes tones behave so differently? How is the frame of a

pitch undulation in a specific sentence formed? How does the pitch undulation influence the realization of both partially or totally reduced tones and neutral tones? Do these tones also actively contribute to the formation of the pitch undulation? In this section, I will provide my answers to these questions.

#### 5.3.1. Process of the formation of pitch undulation

After a careful analysis of the pitch tracks in the data, I reached the hypothesis that basic features of tones which occur in a sentence and the order of the occurrence of these tones, play important roles in the formation of pitch undulation. I suggest the following general process of its formation. First, the frame of the pitch undulation is built by some of the full tones, according to their order of occurrence. Second, other tones adjust themselves to fit in the frame. Reduced tones give up their features which are not as compatible with the tendency of pitch movement, and keep those which are, to decide the final shape of the pitch undulation. I will explain these points with two examples.

The first example is the sentence HJ73 as shown below with its underlying tones and predicted surface tones. The pitch track of this sentence is shown in Figure 5.16. As in the previous examples, intermediate phrases are divided by an "|".

(12) HJ73:

Ta	z	i	j		mei	shou		jiaotong	guize,		...	
55	51	21			35	21		55	55		55	35
												UT
55	51	21			35	21		55	55		55	35
												ST
He himself not abide traffic regulation												
"He himself did not abide by the traffic regulation..."												

According to pitch tracks in Figure 5.16, there are only three full tones which retain both of their basic features. These full tones are the T4, T2, and T1 in the syllables zi, mei, and tong respectively. Most of the other tones, the reduced tones, retain only one of their basic features. The T1 in ta, T3 in ji, and T1 in gui maintain their heights, but the shapes have slightly changed. On the other hand, T3 of shou and T2 of ze maintain their shapes but partially change in height. Only one tone, the T1 of jiao, loses both of its features.

I hypothesize that the process of the formation of pitch undulation in the sentence HJ73 is as follows. First, the pitch contours of the full tones and the order of the occurrence of these full tones decide the frame of the whole pitch undulation in the sentence. In this case, it is the pitch contours of the three full tones T4, T2, and T1 that frame the shape of the pitch undulation. Also, the order of the tones is very important for the shape of the frame. For instance, because the T4 occurs first and the T2 second, the first half of the undulation has a frame with a falling-

rising shape. However, if the T4 and T2 occurred in an reverse order (i.e., T2 first and T4 second), then the frame of the first half of the undulation would exhibit a rising-falling shape.

Second, the tendency of the pitch undulation forces pitch contours of other tones, which include reduced tones and neutral tones, to fit in. These tones are forced to retain the features that are compatible with the undulation but relinquish incompatible features. As a result, some of these tones function as transitions between full tones and some of them function as pre-extensions or post-extensions of full tones in the same intermediate phrase along the pitch undulation.

Referring back to Figure 5.16, the T1 of ta and T3 of ji are pre-extension and post-extension of the full tone T4 in the first intermediate phrase. The height of both tones do not change, but their shapes along the pitch undulation of the sentence do change. The pitch contour of the T3 of shou is the post-extension of the T2 in the second intermediate phrase. Theis T3 partially loses its feature "low", and is realized as a falling contour which starts high but ends low. The T1 of gui and T2 of ze are post-extensions of the T1 of tong in the last intermediate phrase. Retaining its basic "high" feature, the T1 of gui serves as a post-extension of the full tone T1 of tong along the pitch

undulation. Moreover, the T2 of ze serves as a continued post-extension of the T1 of tong. The T2 loses its "low" feature, but tends to retain its rising shape at the ending portion.

My third point is that the reduced tones not only are passively adjusted to fit in the pitch undulation, but also actively affect the formation of the pitch undulation. Since full tones only build the frame of the pitch undulation, these reduced tones have to complete the formation of the whole pitch undulation. They retain some of their features which are compatible with the tendency of pitch movement in the sentence. In order to fully explain this point, it is necessary to analyze in detail the formation of the final shape of the pitch undulation.

The frame of the pitch contour in the first intermediate phrase, ta ziji, has a falling shape which is formed by the pitch contour of the T4 in the syllable zi. Since this falling contour already starts rather high, according to the tendency of pitch undulation, the tone which precedes this T4 should not be a much higher falling contour. If this preceding tone, is a T1 or another T4 which has the "high" feature, it could only be a high level, rising or concave contour to serve as the pre-extension of the T4. Otherwise, if this preceding tone is a low T2 or T3 tone, it should be in a low rising or convex curve. Since the fact is that this

tone is a T1, the actual pitch track of this tone, shown in the vowel of the syllable ta, is an expected high concave curve. The low rising portion of the pitch track, in the T1 syllable, is the pre-extension of the pitch movement in the initial consonant, as we have seen in Chapter 4. For the same reason, the pitch curve after the T4 in zi could have different contours. The following tone determines its shape. By this analysis, it is clear that the final shape of the pitch undulation in the intermediate phrase of syllables ta ziji, is heavily dependent on reduced tones.

A different portion of the sentence further supports my third point. The frame of pitch undulation in the second intermediate phrase mei shou has a rising shape. The full tone T2 is found in the syllable mei. Since the T2 has risen high enough in the local pitch range, the pitch curve in the succeeding syllable cannot maintain a rising shape. However, there are several different ways, that the succeeding tone can become compatible with the tendency of the pitch movement. If this subsequent tone was a T1 or T2, it might pose a high convex or a level shape in this special tonal context. This is because previous studies have found that between a T2 and any non-neutral tone, a T1 or T2 may become a high level tone (see T2 Rule in Chapter 2). If this tone is a T3 or T4, it should have a falling shape, because a falling contour is very compatible with the tendency of

pitch movement in this portion. This is why in the actual situation, the following T3 remains in its basic falling shape. However, since it has to start high, it cannot avoid becoming a falling tone that partially retain its feature "low". I will treat this reduced T3 as the post-extension of the full tone T2 along the pitch undulation. The basic feature "falling" and the "low" of the T3 contributes much to determine the final shape of the pitch undulation in the intermediate phrase mei shou. Figure 5.17 shows the comparison between the real pitch track in sentence HJ73 with the possible pitch track in the following possible sentence HJX, which contains a T1 rather than a T3 in the last syllable of the second intermediate phrase. The dashed line illustrates the possible pitch undulation.

(13) HJX:

Ta ziji	meiting	jiaotong guize,   ...	
55 51 21	35 55	55 55 55 35	UT
55 51 21	35 55	55 55 55 35	ST
He himself not listen traffic regulation			
"He himself did not listen to (the reading of) the traffic regulation,..."			

It is also interesting to notice that the features "falling" and "low" of the T3 in syllable shou in sentence HJ73, also play an important role in affecting the shape of the pitch undulation in the third intermediate phrase and hence in the whole sentence. The low ending of the falling



contour of the T3 also causes the pitch undulation in the succeeding intermediate phrase to start low and to change shape. The T1 of jiao gives up both of its basic features "high" and "level" in order to serve as a low rising pre-extension of the full tone T1 in the intermediate phrase. However, if the last tone in the second intermediate phrase had been a T1 rather than a T3, and thus did not have the falling curve, then pitch contour in the second IP would have had a different shape with a higher ending. As a consequence, the pitch contour in the last IP would also have a different shape, such as a level-falling shown in Figure 5.17. As a result, the whole undulation would not have the second valley.

In short, although reduced tones are adjusted to fit in the frame built by full tones, they still play important roles in the formation of the pitch undulation of a sentence.

The second example of the formation of pitch undulation is shown in Figure 5.18 which illustrates the pitch tracks of the sentence HJ35. There exists a different situation of tonal realization in this entire sentence as described below.

(14) HJ35:

	Ta	shuo	na		ta	ye		yudao	guo	zhe	shi,	...	
	55	55	51		55	21		51	51	0	51	51	UT
	55	55	51		55	21		53	51	1	53	51	ST
	she	say	then	she	also	meet		ASP	this	thing			
	"She	said	that	she	had	also	come	across	this	kind	of		
	problem,	...											

In this sentence, every non-neutral tone is realized as a full tone. In the first intermediate phrase ta shuo na, the two T1's in ta shuo are realized as high curves which could be roughly classified into level shapes. The T4 na retains a typical high falling contour. The second intermediate phrase contains two syllables ta ye. The pitch track of the T1 in ta retains a high level shape. Because of the pause, the T3 has a small rising tail. However, the whole shape still has a low falling. There are five syllables in the third intermediate phrase. The first two T4's are realized as two falling curves, even though the first one ends higher and the second one starts lower. The neutral tone in the third syllable is realized as the post-extension of the preceding T4. The last two T4's are realized as parallel falling curves in the small local pitch range. The upper portion of the figure, shows strong aspirative energy between the second and third intermediate phrases of the waveform. However, these lines are caused by a heavy breath which does not affect the pitch movement in the sentence.

The pitch track in Figure 5.18 indicates a simple relationship between tones and pitch undulation: underlying tones are connected one after another to form the whole pitch undulation. However, I assume that the same process which was explained in the first example also forms the pitch undulation in this second example. The frame of the pitch undulation is built by some of the full tones, which are those in syllable na, ta, dao, and shi. Other tones realize their surface forms according to their basic features, the tendency of pitch movement, and other effects. They serve as the pre-extension, post-extension and transition along the tendency of pitch movement in the three intermediate phrases respectively. It is an optimal match among the features of the tones, their order of occurrence, and the frame of pitch undulation, that offers the chance for all of the syllables keep their tones full rather than reduced. How could I know which full tones have built the frame of the pitch undulation and which have only fit in? I will answer this question in the next section.

In short, the shape of a pitch undulation is determined by the basic features of tones that occur in the sentence, the order of the occurrence of these tones, and the tendency of pitch movement in the sentence. The frame of a pitch undulation is built by some of the full tones. Reduced tones also contribute importantly to the final shape of a pitch

undulation.

### 5.3.2. Pitch undulation and stress pattern

Tones function very differently in forming a pitch undulation? By listening carefully to the tape recorded, as well as analyzing the corresponding pitch tracks of the sentences, I notice that it was speaker's effort, which is reflected by the stress pattern that play the leading role. Strongly stressed syllables maintain full tones which build the frame of a pitch undulation, while those of unstressed syllables adjust their tones to fit within the frame. After different stresses are assigned (based on linguistic and/or nonlinguistic factors), it is decided which tones should be components of the frame of pitch undulation and which should not. Before explaining this point by examples, I need to introduce the conception of stress pattern first.

#### 5.3.2.1. Conception of stress pattern

As in other studies, "stress" is a relative concept based on auditory comparison. A syllable is considered "stressed" in a if it is stronger than the so called neutral tone syllable. I only distinguish two degrees of stresses: relatively stronger and weaker stresses. When describing stress pattern of a group of syllables, I use "s" and "w" to mark these two types of stresses respectively. A

very weak syllable, or neutral tone syllable, is also marked by a "w". By using this "w-s" system of stress marking, I only roughly indicate certain difference between strengths of stress and mark the relatively stronger stresses that maintain the basic tones in the corresponding syllables.

Whenever stress pattern is concerned, the strength of every syllable in a sentence is identified with either a "w" or an "s". Inside one sentence, if there is no special emphasis, the actual strength of syllables tends to be stronger at the beginning than at the ending portion. Stronger stresses in the ending portion of a sentence are often even weaker than weaker stresses in the beginning portion of the same sentence. HJ35 is such an example.

(15) HJ35:

	Ta	shuo	na		ta	ye		yudao	guo	zhe	shi,		...
	w	w	s		s	w		w	s	w	w		s
	55	55	51		55	21		51	51	0	51		51
	55	55	51		55	21		53	51	1	53		51
	she	say	then		she	also		meet	ASP	this	thing		
	"She said that she had also come across this type of problem,..."												

The stresses of the syllables ta and shuo are both identified as "w"'s when compared to the syllable "na" in the first group. If compared with the stresses of syllables in other groups, they would be identified as "s"'s, since they are stronger than most of the latter.

In this study, I compare stresses among neighboring syllables and pay attention to stress pattern at the level of the intermediate phrase. Since "stress" is a subjective concept which cannot be measured acoustically, it is not surprising that sometimes a stress pattern is hard to figure out. For example, in sentence spoken in a rather low voice, stress patterns are often difficult to figure out. However, under most situations of spontaneous speaking, stress pattern is readily identifiable.

In speaking, responses elicited under specific pragmatic situations or inside a context of discourse, often result in variabilities. For example, a strong command might be given with the following stress pattern:

(16)                   | Quai   ting   che! |  
                           s       s       s  
                           51       35       55                   UT  
                           51       35       55                   ST  
                           quick   stop   car  
                           "Stop driving immediately!"

Every syllable in this pattern is marked by an "s" which is natural for an anger tone. Even this is true for most cases, an "s-w-s" or "w-w-s" pattern is more likely for other situations. Frequently, though, a syllable which is usually stressed becomes totally unstressed in normal speech. Also, it is possible in every day speech that a normally un-

stressed syllable might become a strongly stressed one. For example, an aspect marker such as quo would be normally unstressed. However, when responding to a question, a speaker may emphasize that he/she had already done something in the following manner:

- (17)                    | Qu      quo    le. |  
                               w        s        w
- |    |     |      |    |
|----|-----|------|----|
| 51 | 0   | 0    | UT |
| 51 | 1   | 1    | ST |
| go | ASP | PART |    |
- "(I) had been there already."

In the utterance above, gou is strongly stressed which is natural for the context of this sentence. However, this utterance had produced surface tones which are not normally expected. The stronger syllable quo might obtain a high falling T4 contour and the weaker syllables qu and le might have a high convex curve and a low falling curve to serve as a pre- and post-extension respectively.

As explained in the above, stress patterns in sentences are basically determined by several factors. One factor is the speaker's mood at a particular time. Another factor is how the speaker emphasizes the meaning of the context. Other factors concern linguistic or non-linguistic influence. It is beyond the scope of this study to discuss in further detail about the assignment of stresses in each

sentence. However, the stress patterns of the sentences used in this study are clearly marked according to the tape recordings. This is done to provide a qualitative description of the formation of pitch undulation.

#### 5.3.2.2. Tonal contour and stress patterns

Returning back to the issue of pitch undulation formation, it is necessary to find the relation between stress patterns and tonal contours in real life speech. An analyses of both auditory impression of tape recordings and corresponding pitch tracks lead to the assumption that stress patterns determine the different functions that each tone plays in forming a pitch undulation. Stronger stresses indicate the existence of frame builder tones and weaker stresses indicate the presence of final shape former tones in the utterance. To illustrate the above phenomena, the examples in Section 5.3.1 will also be used in this section.

First, I listened to the tape recordings of sentence HJ73 and marked the stress pattern for each intermediate phrase as shown below:



(18) HJ 73:

	Ta	ziji		mei	shou		jiaotong	guize,		...
	w	s	w		s	w		w	s	w
	55	51	21		35	21		55	55	
	55	51	21		35	21		55	55	
										UT
										ST
	He himself not abide traffic regulation									
	"He, himself, did not abide by the traffic regulation,									
	..."									

Notice there is an apparent correlation between the stress patterns and the pitch tracks of Figure 5.16. The pitch contours of the T4, T2, T1 and T2 in the respective strong syllables zi, mei, tong and ze, construct the frame of the pitch undulation. The tones of other syllables adjust themselves to fit into this frame and complete the final shape of the pitch undulation. With the exception of the final syllable, syllables with stronger stresses have full tones, and syllables with weaker stresses have reduced tones.

The last syllable is an exception because it has a relatively strong stress in the intermediate phrase, with a reduced contour of T2. It seems that besides being influenced by the formation of the local pitch undulation, the fact that the T2 loses its feature "low" is also influenced by the status of the sentence. In this case, the utterance is a pending sentence. Studies have shown that the final tone of a pending sentence is often rather high (Chang 1958), similar to the rising tone at the end of a question.

This study focuses on the relationship between stress and tone in an utterance. Previous studies found that a heavily stressed syllable retains its original tone, while an unstressed syllable loses it (Chao 1968; Kratochvil 1968). A weakly stressed syllable loses part of its tone (Zhang 1988). It seems a logical deduction of these findings that for the syllables which are stressed in a degree between the extremes, the lower the degree of stress is, the fewer the percentage of tonal features retained. Most of my data support this deduction, but some do not.

There are two questions warranting attention. The first question concerns the pitch contour of a weakly stressed syllable. That is, how is the pitch contour realized for a weakly stressed syllable after losing part of its tone? Although previous studies have described the loss or retention of the tone, these studies did not provide a comprehensive description of how the reduced tone acquires its surface form in any position of a sentence. According to some studies, it seems that a reduced tone obtains a pitch contour that is the same as part of its underlying tonal contour. Some studies have analysed how neutral tone curves in the ending portion of sentences are influenced by both preceding tones and intonation. However, the fact how an intonation influence both totally and partially reduced

tones in other portions of sentences have not yet been described.

My answer to the first question has been presented in section 5.3.1. The manner in which partially reduced tones realize their surface forms depends on their compatibility with the pitch movement of the utterance. If the tendency of pitch movement and the partially reduced tone are compatible, then the surface forms retain their features. If there is incompatibility between the two, the surface forms relinquish their features. The tendency of pitch movement is determined by strongly stressed syllables. Tones of these syllables build the frame that the pitch undulates along. The way that totally reduced tones realize their surface forms is to give up all of their basic features and obtain their pitch contours in the same manner as neutral tones do.

The second question pertains to the correlation between syllabic weakening and tonal reduction. Is it a rule that tones must be reduced in weaker syllables? My answer to this question is no. There are many cases in my data that some tones in weakly stressed syllables tend to retain their basic features and hence are realized as full tones. This occurs rather often in connected speech, especially in relatively slow and formal styles. Sentence HJ35 shown below is a good example of this phenomenon. The pitch contours of this utterance are illustrated in Figure 5.18 example. Fur-

thermore, how might this type of phenomena be explained? The reader may wish to note that the same phenomena was explained in section 5.3.1. In that section an open-ended question was raised: Why are some full tones frame builders and others not?

The answer to the above questions is: the realization of full tones in weaker syllables is the result of an optimum match among several factors. These factors include: the tones which occur, the order of their occurrence, the stress patterns in the sentence, and the tendency of pitch movement. To help understand this answer, it is necessary to closely analyze the characteristics of the sentence HJ35. First, after listening to the tape recording, I marked the strength of stresses in this sentence and relate the stress patterns with tonal behavior.

(19) HJ35:

	Ta	shuo	na		ta	ye		yudao	guo	zhe	shi,		...
	w	w	s		s	w		w	s	w	w	s	
	55	55	51		55	21		51	51	0	51	51	UT
	55	55	51		55	21		53	51	1	53	51	ST
	she	say	then		she	also		meet	ASP	this	thing		
	"She said that she had also come across this type of problem,..."												

As noted from Figure 5.18, all of the tones, except the neutral tone, are full tones. There are only four syllables with relatively strong stresses. The tones of these stronger

syllables maintain their basic contours and build the frame of the whole pitch undulation. All the other syllables have weaker stresses, and their tones fit in the frame to form the final shape of the pitch undulation. However, even though these tones are weakly stressed, they are not reduced. This is because most of their features are compatible with the tendency of the pitch movement, which is determined by the occurrence and order of the tones and the stress pattern in the utterance. It is more convenient for weaker syllables retain their original contours rather than change. The realization of full tones in these weaker syllables is the result of an optimum match among the occurring tones, the order of their occurrence, the stress patterns in the sentence, and the tendency of pitch movement.

In the previous paragraphs, I have attempted to answer two very important questions about the relationship between tonal realization and stresses. Furthermore, I have also explained the role of stress patterns in the formation of pitch undulation. Another example which supports my analysis is the sentence HJ63 shown below. Its pitch track is given in Figure 5.19, and the stresses are marked as follows:

(20) HJ63

	Zuihou	jiu	rang	ta		pei	qian	a.	
	w	s	w	s		s	w	s	
	51	51	51	51		55	35	35	0
	53	51	53	51		55	35	35	3
	at	last	then	let		her	pay	reparation	PART
	"At last (he) let her pay the reparation."								

The above sentence was spoken with normal loudness, and the stress pattern can be easily identified from the auditory impression. The strongly stressed syllables are hou, rang, and ta in the first intermediate phrase, and qian in the second intermediate phrase. All of these syllables maintain the basic features of their tones to build the frame of the pitch undulation. Other syllables are all weaker. They adjust their tones along the tendency of pitch movement, and form the final shape of the pitch undulation.

In summary, there are four factors which play important roles in the formation of pitch undulation in a sentence. These include: the tendency of the pitch to undulate, stress patterns, tones and their order of occurrence. Stress pattern plays a role of selecting frame maker and final shape former tones for the pitch undulation. Stronger stresses identify tones which build the frame, while weaker stresses indicate tones that fit in the frame and decide the final shape of the pitch undulation. Syllables that are strongly stressed keep their original tones, and others adjust their features more or less, depending upon their

tonal environments and the tendency of the pitch undulation.

#### 5.4. The domain of the tone sandhi

In the previous sections, I explained the general process by which tones in an intermediate phrase realize their corresponding surface forms. Also, I marked in the example sentences the intermediate phrases to aid in my analysis. From this process, we can infer that the prosodic constituent intermediate phrase, forms the domain of tone sandhi.

Herein the term "tone sandhi" is used in a much broader sense than what is conventionally used. That is, it refers to noticeable change in either the height or the shape of a tone. More precisely, the intermediate phrase is the domain of surface tone realization provided that the pitch curve formation of neutral tone is also considered.

If correct, this point should be confirmed by examples from any of the three types of tonal sequences. These are tonal sequences of TiT0's, tonal sequences containing random Ti's, or those with the same Ti's. In Section 5.2, I presented data about how neutral tones obtain surface forms in sequences of TiT0's. In addition, I analyzed examples of surface tone realization in sentences with Ti's of a random tonal sequences in Section 5.3. It has been seen that for both types of sequences, if a stress pattern is given in an

intermediate phrase, tones of weak syllables fit in the frame that is built by tones of strong syllables. The surface forms of the tones within this intermediate phrase are completely arranged to form the tune. Therefore, the hypothesis that each intermediate phrase is the domain of tone sandhi is supported.

However, I have not yet confirmed whether sequences of the same Ti's support the hypothesis. These sequences are ideal for testing the tone sandhi domain, because in each of them, every tone has the same underlying form. If any tone does not realize its features in the surface form, the domain in which this realization occurs would be easily identified.

In the following subsections of 5.4.1-5.4.3, I will show that pitch tracks of these sequences also strongly support the hypothesis that the intermediate phrase is the tone sandhi domain. The examples that I will use again are, Figures 4.28-4.35. These figures illustrate the pitch tracks of the Ti's in S1-4a (formal speaking style) and S1-4b (casual speaking style) produced by speaker H. The intermediate phrases and stress patterns from the recorded sentences are marked below. The difference between the formal and the casual speaking styles of the same sentence often affect the division of intermediate phrases and the stress patterns. Correspondingly, the pitch undulations of the same



sentence with different speaking styles are often not the same. The underlying tones are given in each of the sentences. However, I will not attempt to predict the surface tones, because I already introduced the prediction according to Zhang's system in Chapter 4.

#### 5.4.1. Sequences of the T1's or T4's

The T1 change is the simplest, because only one or two T1's exhibit falling curves. The prosodic structure of the T1 sentence produced by speaker H is as follows:

(21)

HJS1a:

	Zhang	Zhongbing		jintian		yinggai	xiu		shouyinji.		
	w	w		s		s	w		s	w	s
	55	55		55	55	55	55		55	55	55
	Zhang	Zhongbing		today		should	repair		radio		UT

"Zhang Zhongbing should repair a radio today."

HJS1b:

	Zhang	Zhongbing		jintian		yinggai	xiu		shouyinji.		
	w	w		s		s	w		s	w	s
	55	55		55	55	55	55		55	55	55
	Zhang	Zhongbing		today		should	repair		radio		UT

"Zhang Zhongbing should repair a radio today."

In the above utterances, there are four intermediate phrases in the formal style (HJS1a), but only three in the casual style (HJS1b). The T1 sandhis occur more in the formal than casual style version. Most of pitch contours in Figure 4.28 curve slightly in the on-glide or off-glide, and

they reflect a general tendency of declination across the sentence. However, they do not lose their basic features. As noted in Chapter 4, the T1 in the syllable zhang has a rising curve, and the T1's of those in the syllables tian and xiu exhibit typical falling contours. All the T1's, though, should be treated as the pre- and post-extensions of the strongly stressed T1's within the same intermediate phrases. Here again, the domain of the T1 sandhis is the intermediate phrase.

T4 sandhi is also not very complex; however, it does occur more often than the T1 sandhi. The T4 sequences uttered by speaker H exhibit similar prosodic structures between both the versions of the formal style and the casual style.

(22)

HJS4a:

Zhao Shuqing	banye	you	yao	shang	jiaoyubu.
s    w    s	s    w	s	w	s	s    w    s
51    51 51	51 51	51	51	51	51    5151    UT
Zhao Shuqing	midnight	again	will	go	Ministry of Education

"Zhao Shuqing will go to Ministry of Education in the middle of the night again."

HJS4b:

Zhao Shuqing	banye	you	yao	shang	jiaoyubu.
w    w    s	s    w	w	w	s	s    w    s
51    51 51	51 51	51	51	51	51    5151    UT
Zhao Shuqing	midnight	again	will	go	Ministry of Education

"Zhao Shuqing will go to Ministry of Education in the middle of the night again."

In Figure 4.34, which is the pitch track of the T4 string produced in the formal style, slight tonal changes occur within each intermediate phrase, except the first one. The last two weaker T4's are realized as a continuous pitch curve of the preceding stronger T4. Figure 4.35 provides the pitch track of the same T4 string in the casual version. In this case, there are more weakly stressed syllables, most of which partially maintain their falling shapes. However, the last weak T4 becomes a rising contour along the pitch undulation. They serve as pre-extensions, post-extensions, and the transition of stronger T4's in the first, second and third intermediate phrases respectively. In both versions, it is quite obvious that the changes in T4 occur inside the domain of the intermediate phrase.

#### 5.4.2. Sequences of T2's

Unfortunately, tone sandhi of T2 has not received enough attention in previous studies. The only phonological rule about the T2 sandhi is found in Chao (1968), where the T2 may become T1 in some trisyllabic environments. As reviewed in Chapter 2, Wu (1984) noted that falling variants of T2 are also possible in some trisyllabic sequences. In my data, a T2 was often produced by all speakers as a falling tone as well as a level tone by. Speaker H's S2 in each style contains four intermediate phrases.

(23)

HJS2a:

	Wu	Guohua		mingnian		cai	neng	hui		Yangchenghu.	
	w	w	s		s	w		s	w	w	s
	35	35	35		35	35		35	35	35	35
	UT										

Wu Guohua next year only can go back Yangcheng Lake  
 "Wu Guohua cannot go back to Yangcheng Lake until next year."

HJS2b:

	Wu	Guohua		mingnian		cai	neng	hui		Yangchenghu.	
	s	w	w		s	w		s	w	w	
	35	35	35		35	35		35	35	35	35
	UT										

Wu Guohua next year only can go back Yangcheng Lake  
 "Wu Guohua cannot go back to Yangcheng Lake until next year."

The pitch track of the T2 sequence read in the formal style is shown in Figure 4.30. All strongly stressed syllables have basic low rising T2's. Other syllables have had their T2's adjusted in height and/or shape. In the first intermediate phrase, the high curves of the first two weaker T2's are realized along the pitch undulation which precedes the low curve of the stronger full T2. In both the second and third intermediate phrases, the weaker T2's become falling or quasi-level curves after the stronger T2's. In the last intermediate phrase, the weaker T2 between the stronger T2's changes only slightly in both height and shape, and serve as a transition between the two stronger t2's along the pitch undulation. Thus, the T2 sandhi domain is again the intermediate phrase.

The casually spoken S2 sequence is shown in Figure 4.31. The speaker uttered this sentence with a contrastive emphasis on the word mingnian, 'next year'. All syllables after this word (i.e., those in the last two intermediate phrases), become very weak, and their pitch contours are obviously affected by the sudden weakening in the pitch. The general rule that applies in this case is that the stronger syllables retain their basic tones and weaker syllables become adjusted correspondingly, seems to be overridden by the contrastive stress. I will discuss this specific phenomenon in the Chapter 7. However, in the first two intermediate phrases, the pitch contours are realized as in other examples. The T2's in stronger syllables keep their basic contours and the T2's in weaker syllables exhibit a change in their curves along the pitch undulation. Hence, the fact that intermediate phrases function as the tone sandhi domain is readily apparent.

Pitch tracks in sentences S5a-d provide more evidence to confirm that in sequences of T2's, the tone sandhi domains are in fact the intermediate phrases. The pitch tracks of these sentences produced by speaker H are shown in Figures 5.20-5.23

(24)

HJS5a:

| Guohua lai chan Guoping | wanr qiaopai. |  
 w s w s w s s w s  
 35 35 35 35 35 35 35 35 35 UT  
 Guohua come pester Guoping play Bridge  
 "Guohua comes to pester Guoping into playing Bridge."

HJS5b:

| Guohua chang lai chan Guoping | wanr qiaopai. |  
 w s s w w w w s w s  
 35 35 35 35 35 35 35 35 35 UT  
 Guohua often come pester Guoping play Bridge  
 "Guohua often comes to pester Guoping into playing  
 Bridge."

HJS5c:

| Guohua he Guoping | chang wanr pai. |  
 w s w s w s w w  
 35 25 35 35 35 35 35 UT  
 Guohua and Guoping often play Bridge  
 "Guohua often plays Bridge with Guoping."

HJS5d:

| Guohua chang lai wanr pai. |  
 w s w s w w  
 35 35 35 35 35 35 UT  
 Guohua often come play Bridge  
 "Guohua often comes to play Bridge."

Referring to Figure 5.20, there are six syllables groups in the first intermediate phrase. When the second, fourth, and sixth syllables are strongly stressed and the basic features of their respective T2's does not change. However, the T2's of the other syllables, the first and fifth, do change to serve as pre-extensions or transitions. The second intermediate phrase contains three syllables. The T2's of the first and last syllables sound stronger and retain the

basic T2 features. Furthermore, the T2 between these syllables is treated as a transition, although it does not change very much. The two intermediate phrases of these utterances are tone sandhi domains. Also, the pitch level of the whole sentence decrease from the beginning to the end and most likely keep the basic T2's from rising in the utterance. This same phenomenon occurs in the other three sentences spoken by the same speaker.

The T2 strings of Figures 5.21-5.23 clearly indicate that the intermediate phrases function as the tone sandhi domains. Thus, I will not describe the behavior of the T2's in detail.

#### 5.4.3. Evidence from sequences of T3's

A sequence of T3's often exhibits complicated tone sandhi and stress pattern functions I will discuss the stress pattern functions of T3's later in the paper. At this point, I want to address the question: Is the sandhi domain still an intermediate phrase in the sequence of T3's? The answer will become clear in the next few paragraphs. The answer is "yes".

The tone sandhi domain of the T3 sequence in sentences a and b of S3 produced by speaker H are as follows:

(25)

HJS3a:

| Li Xiaobao | jiudian| ye xiang xie | jiangyangao.|  
 w w s s w s s w s w s  
 21 21 21 21 21 21 21 21 21 21 21 UT  
 LiXiaobao 9:00 also want write draft for a lecture  
 "At 9:00 Li Xiaobao wants to be writing a draft for a  
 lecture, too."

HJS3b:

| Li Xiaobao| jiudian|ye xiangxie| jiangyangao.|  
 w w s s w s w w s w w  
 21 21 21 21 21 21 21 21 21 21 21 UT  
 Li Xiaobao 9:00 also want write draft for a lecture  
 "At 9:00 Li Xiaobao wants to be writing a draft of a  
 lecture, too."

Both the causal and formal spoken versions of the sentences contain four intermediate phrases. The casual version of the utterance, HJS3b has a contrastive emphasis on the time word jiudian '9:00'. As a result of this contrastive strength, the syllables in the last two intermediate phrases become very weak.

A brief analysis of Figures 4.32 and 4.33 shows that the relationship between the stress and pitch contour formation for T3 sequences is not the same as it is in the situations for other tonal sequences. On one hand, basic low falling T3's occur not only in strongly stressed syllables, but also in weakly stressed syllables. On the other hand, T3 sandhis occur not only in weaker syllables, but also in stronger syllables. There seems to exist fixed patterns for the shapes of pitch movement in each intermediate phrase. I



will discuss these phenomena of the T3 changes in the next chapter.

The tone sandhi domain for the T3 sequence, however, is still the intermediate phrase. For the formal reading style, HJS3a, the pitch tracks are shown in Figure 4.32. The T3 sandhis occur in each of the intermediate phrases. Although there are unpredicted T3 curves, tone sandhis never cross the boundaries of intermediate phrases. The rising tail of the third tone and the falling curve initiating the fourth tone should be treated as post- and pre-extensions of the major portions of the corresponding tunes respectively. They can also be treated as transitions between the tunes, but never as tone sandhis across intermediate phrases. In Figure 4.33, despite the influence of contrastive emphasis, it is still obvious that the intermediate phrases serve as tone sandhi domains.

In conclusion, tonal changes exhibited in all sequences of the same tones, like those sequences of different tones or TiT0's, also support the hypothesis that the tone sandhi domain in an Mandarin sentence is an intermediate phrase.

#### 5.4.4. A general principle of pitch contour formation in intermediate phrases

This section is a summarization of the above analyses. I hypothesize that a pitch undulation is built in each intermediate phrase according to a general principle given the following factors: tones, the order of the tones, the stress pattern, and the tendency of pitch undulation. The general principle is stated in below:

##### (26) Principle of Pitch Contour Formation in Intermediate Phrases:

A pitch contour for an intermediate phrase forms a single tonal unit, tune. This pitch contour takes its shape by conforming to all features of strongly stressed syllables and some features of weakly stressed syllables. The contours of strongly stressed syllable build the frame of the tune. The contours of weakly stressed and unstressed syllables are adjusted to serve: (1) as transitions between pitch contours of stressed syllables; (2) as pre-extensions of pitch contours of stressed syllables; or (3) as post-extensions of pitch contours of stressed syllables along the tendency of pitch movement.

This principle governs tonal changes in intermediate phrases, and partially answers the question about how surface tones are realized in a sentence. All of the examples observed in the above sections support the hypothesis of this principle. However, there are other effects which may override this principle and hence, result in more complicated tonal phenomena. I will discuss the influence of

different factors on the application of this principle in the next chapter.

### 5.5. Intermediate phrase

In the previous sections, the concept "intermediate phrase" was introduced and discussed in some detail. Also, the sentences in the examples examined were appropriately divided into intermediate phrases. Through my analysis of tonal phenomena in the previous sections, the existence of this intermediate prosodic unit was much easier to understand.

#### 5.5.1. Conception of the intermediate phrases

The intuition of native-Mandarin speakers have lead Chinese linguists to believe that there are groups of syllables inside a sentence. These groups of syllables form an intermediate unit in a sentence which is defined as a foot or a super-foot in phonological studies. (Refer to Chapter 2 for a review of these studies). In order to analyze the number of feet or super-feet in a sentence, the sentence is scanned according to the rules of foot and super-foot formation. The mechanism of the rules, originally devised for analyzing Chinese poetry (Chen 1979), is based on intuition expressed by native Chinese speakers. If the speaker considered a sequence of surface tones to be

acceptable, the corresponding scanning would be accepted. Otherwise, the scanning would be considered incorrect. Because this analysis was based on each author's intuition of formal speech and carefully designed sentences, most of which contained a sequence of T3's, the conclusion is limited to only that type of data. Despite this limitation, these studies represent pioneer work in the field.

From the review of previous phonetic studies of Chinese tones in Chapter 2, we see that the prosodic structure in an utterance has not yet received serious attention in the phonetic analyses of tonal phenomena. Among the articles mentioned, only those by Wu (1982, 1984, 1990) acknowledged a group of pitch contours of tones as a single unit (i.e., a prosodic constituent). Wu stated that disyllabic and polysyllabic sequences are one type of basic tonal constituents in an utterance. However, he maintained that these constituents have fixed tonal patterns within any utterance.

I hypothesize the prosodic constituent, intermediate phrase, does exist. It is defined as a group of syllables in an utterance which contains at least one stressed syllable and serves as a tone sandhi domain. The characteristic form of the prosodic unit is a pitch contour, or pitch undulation based on at least one typical contour of the four Mandarin tones. As previously introduced, I refer to this pitch contour as the "tune" of the intermediate phrase.

The term "intermediate phrase" is used in studies of English to identify a prosodic unit which groups words together with at least one accented syllable exhibiting a particular prosodic form (Beckman and Pierrehumbert, 1986). I use this term as well to refer to a similar prosodic unit, however, in Mandarin.

By adopting the concept of the intermediate phrase, I consider the prosodic phenomena in Mandarin at three distinct levels: the level of the prosodic word, the intermediate phrase, and the intonational phrase. Each level has a corresponding unit of pitch movement; the tone, tune, and intonation.

An intermediate phrase may be equal to different syntactic units in size, i.e. one or more words, or one or more phrases. Sometimes it is the same as Chen's (1979) foot or super-foot, but in spontaneous speech, it is usually larger. Examples in the previous sections have already shown this point clearly.

#### 5.5.2. Division of sentences into intermediate phrases

The division of a sentence into intermediate phrases is determined by how the sentence is spoken. Both linguistic and nonlinguistic factors contribute to the division. For example, the placement of boundaries for intermediate phrases is strongly influenced by some linguistic factors,

such as the integrity of a low level syntactic unit or the emphasis on the meaning of an utterance. Nonlinguistic factors, such as a speaker's mood and speech style, often affect the number of intermediate phrases in a sentence. An analysis of the factors involved, however, is not the focus of this study. However, this study does provide some evidence to show the existence of the linguistic effects in the following paragraphs.

One linguistic effect which influences the division of a sentence into intermediate phrases is the integrity of the low level syntactic or semantic unit. With the exception of certain nonlinguistic effects, such as hesitation or sudden realization, boundaries of intermediate phrases always overlap with boundaries of a word or a short phrase which is usually also a semantic unit. In the data concerning both designed sentences and spontaneous sentences, an intermediate phrase boundary never occurs within a word or short phrase under normal nonlinguistic conditions. We can see this regularity in the following two sets of contrasting sentences with S6b versus S6c in Set 1, and S6d versus S6e in Set 2:

(27)

Set 1:

S6b:

| Li Bao | jiudianzheng | xie jianggao. |  
 21 21 21 21 21 21 21 UT  
 Li Bao 9:00 sharp write a draft for a lecture  
 "At exactly 9:00, Li Bao was writing a draft for a  
 lecture."

S6c:

| Li Bao | jiudian | ye xiejianggao. |  
 21 21 21 21 21 21 21  
 Li Bao 9:00 also write a draft for a lecture  
 "At 9:00, Li Bao will also be writing a draft for a  
 lecture."

Set 2:

S6d:

| Wo jiudianzheng | xiang xie( ) jianggao. |  
 21 21 21 21 21 21 21 21 UT  
 I 9:00 sharp want write a draft for a lecture  
 "At exactly 9:00, I want to be writing a draft for  
 a lecture."

S6e:

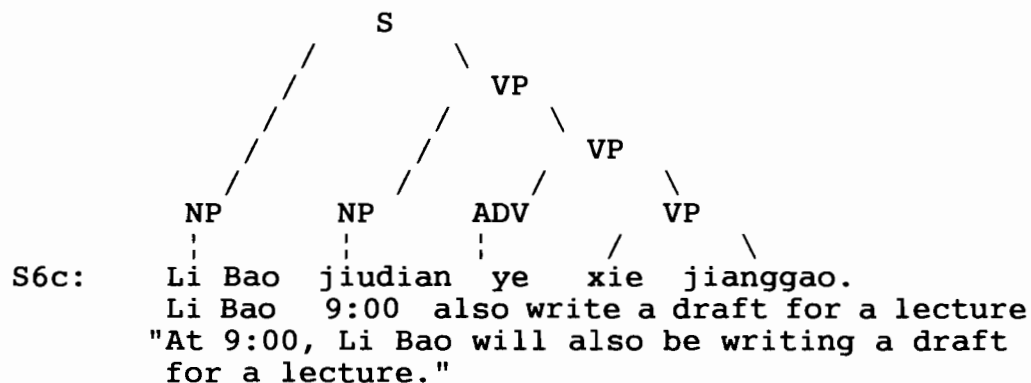
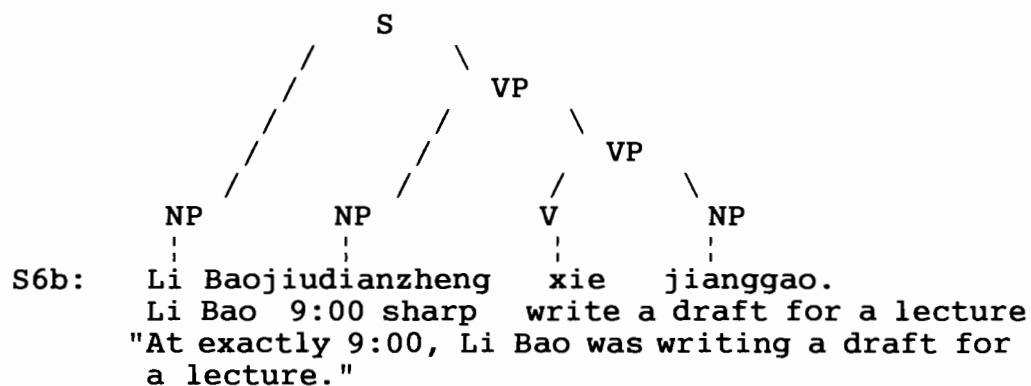
| Wo jiudian | zong xiang xie | jianggao. |  
 21 21 21 21 21 21 21  
 I 9:00 always want write a draft for a lecture  
 "At 9:00, I always want to write the draft for a  
 lecture."

In each set, the contrasting sentences have similar syntactic structures and, except for one, contain the same syllables. The contrasting syllables are ye 'also' and zheng 'sharp' in Set 1, and zong 'always' and zheng 'sharp' in Set 2. In all of the sentences produced by the three speakers, both ye and zong are grouped into the second intermediate phrase, but the contrasting syllable "zheng" always belongs

to the first intermediate phrase. Apparently, the different grouping is due to syntactic or semantic effects. Following are the syntactic structures of the sentences.

(28)

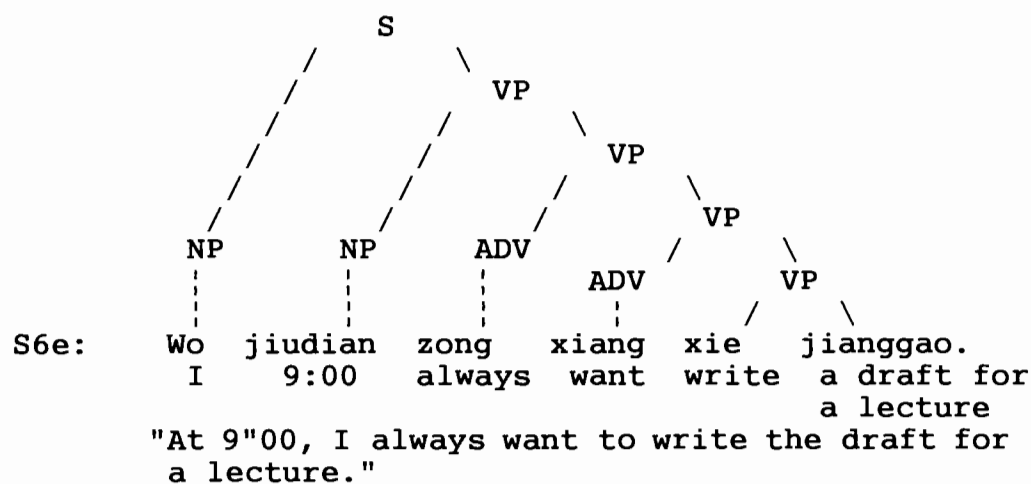
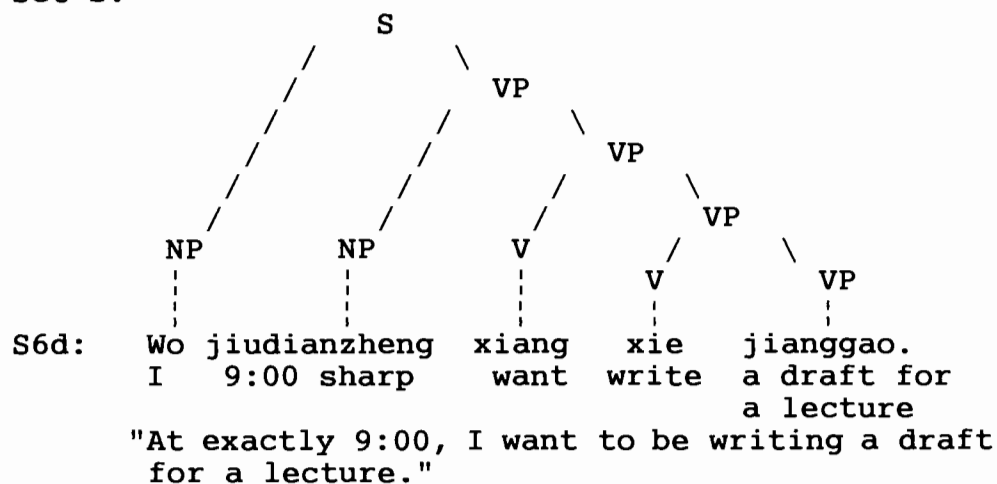
Set 1:





(28) (continued)

Set 2:



I will first consider zheng 'sharp' in the nominal phrase or semantic unit jiudianzheng 'nine o'clock sharp'. Because of the integrity of this syntactic phrase or semantic unit, zheng is not grouped into the next intermediate phrase as zong 'always' or ye 'also' does in the

contrasting sentences.

Second, consider the syllables ye 'also' and zong 'always'. If they had been put into the first intermediate phrase, the division of intermediate phrases in S6c and S6e would be the same as that for S6b and S6d respectively. The comparison is expressed as follows:

(29) Set 1:      S6c: | \$\$ | \$\$ | \$\$ (|) \$\$ |  
                   S6b: | \$\$ | \$\$\$ | \$\$\$ |  
                   Set 2: S6e: | \$\$\$ | \$\$\$ | \$\$ |  
                       S6d: | \$\$\$\$ | \$\$\$\$ |

The division for S6b or S6d is simpler than that for S6c or S6e because the number of intermediate phrases is smaller. However, neither ye nor zong is grouped into the first intermediate phrase as zheng is. All the speakers produced ye and zong in the second intermediate phrase. The explanation for this can only come from the fact that, either syntactically, ye and zong are more closely related to the following syllables than to the preceding ones. Semantically, the two syllables belong to the same units of the following words. It is, again, the integrity of the short verbal phrase or semantic unit that influences the division of the intermediate phrase.

Another linguistic effect comes from a pragmatic or discourse factor, which is the emphasis of meaning. That

is, the discourse factor could change the number or organization of the intermediate phrases in a sentence. In my data, Sld, Sle, and Slf are contrasted by different positions of emphasis (emphasized words are underlined) that occur in different contexts.

(30)

Sld: | Zhang Zhongbing| jintian yinggai xiu| shouyinji.|  
-----

Sle: | Zhang Zhongbing| jintian | yinggai xiu| shouyinji.|  
-----

Slf: | Zhang Zhongbing| jintian yinggai xiu| shouyinji.|  
-----

55 55 55 55 55 55 55 55 55 55 55 55 UT  
Zhang Zhongbing today should repair a radio  
"Zhang Zhongbing should repair a radio today."

The questions to which these sentences responded are as follows.

(31)

Question for Sld:

Shei jintianyinggai xiu shouyinji?  
who today should repair radio  
"Who should repair the radio today?"

Question for Sle:

Zhang Zhongbing shenme shihou yinggai xiu shouyinji?  
Zhang Zhongbing what time should repair radio  
"When shouldZhang Zhongbing repair the radio?"

Question for Slf:

Zhang Zhongbing jintian yinggai xiu shenme?  
Zhang Zhongbing today should repair what  
"What shouldZhang Zhongbing repair today?"

To answer these questions, the emphasis in S1e makes the time word jintian 'today' a separate intermediate phrase. In S1d and S1f, however, the same time word is only part of the longer intermediate phrase.

One nonlinguistic factor is the length of the prosodic unit. In the data, most intermediate phrases are between 250 and 1000 milliseconds. There must be effect of physical constraints that make these sizes relatively convenient for production. According to speech rate, there could be fewer or more syllables in each intermediate phrase. The utterance could be divided into more intermediate phrases containing fewer syllables when the speaking rate becomes faster. When a sentence or a long phrase is produced longer than one second, usually it is divided into two or more intermediate phrases. Below are two examples, one is a complicated sentence HJ44-46, and the other is a sentence HJ5 containing a long phrase.



speaker's hesitation or sudden break in the sentence (perhaps in the realization of something), resulting in a pause within a short phrase. If the speaker was uncertain when to write the draft, for example, at nine o'clock sharp or nine thirty, it is hypothetically possible that S6d could be uttered in the following way:

(34)

S6d:	:	Wo	jiudian	:	zheng	:	xiang	xie	:	jianggao.	:	
	:	Wo	jiudian	:	zheng	:	xiang	xie	:	jianggao.	:	
		21	21	21		21		21		21		21
		I	9:00		sharp		want	write		a	draft	for
										a	lecture	
		"At nine o'clock sharp I want to be writing a										
		draft for a lecture.										

In this case, the single syllable zheng 'sharp' might stand out as an intermediate phrase if it was produced between two pauses caused by hesitation. The speaker could possibly produce the sentence at a quick pace, and the hesitation would result in an intermediate phrase boundary after jiudian '9:00', but not after zheng. Both of these two ways of speaking show how nonlinguistic effects prevail over grammatical effects. However, our speakers did not produce these variants, so I will use another example from spontaneous speech.

(35)

HJ35:

	ta	shuo	na		ta	ye		yudao	guo	zhe	shi.		
	55	55	51		55	21		51	51	51	51	51	UT
	she said then she also meet ASP this thing												
	"She said that she also experienced this kind of thing."												

The boundary after ye breaks the verbal phrase ye yudao guo, into two intermediate phrase. The speaker hesitated after saying ye. Perhaps the speaker was uncertain about what to say or how to say it. This nonlinguistic effect causes the occurrence of one more boundary. This type of pause is often exhibited in spontaneous speech and results in different divisions and an increased number of intermediate phrases in a sentence. However, when the speaker read the sentence without hesitation, there was no pause between ye and yudao. As a result, the phrase ye yudao guo retained its integrity, and became grouped with the single syllable ta. In this study, the division of intermediate phrases was judged by listening to the tape recordings. Since the all information including tonal changes was given, the division is usually easy to figure out. My attention was concentrated on analyzing tonal phenomena inside prosodic constituents at different levels, especially at the level of intermediate phrase. Based on the data, I discussed general phenomena of pitch contour formation in the intermediate phrases in this and in the previous chapter. In the next chapter, I have

provided a detailed analysis of more complicated phenomena of pitch movement related to T3 at the intermediate level.



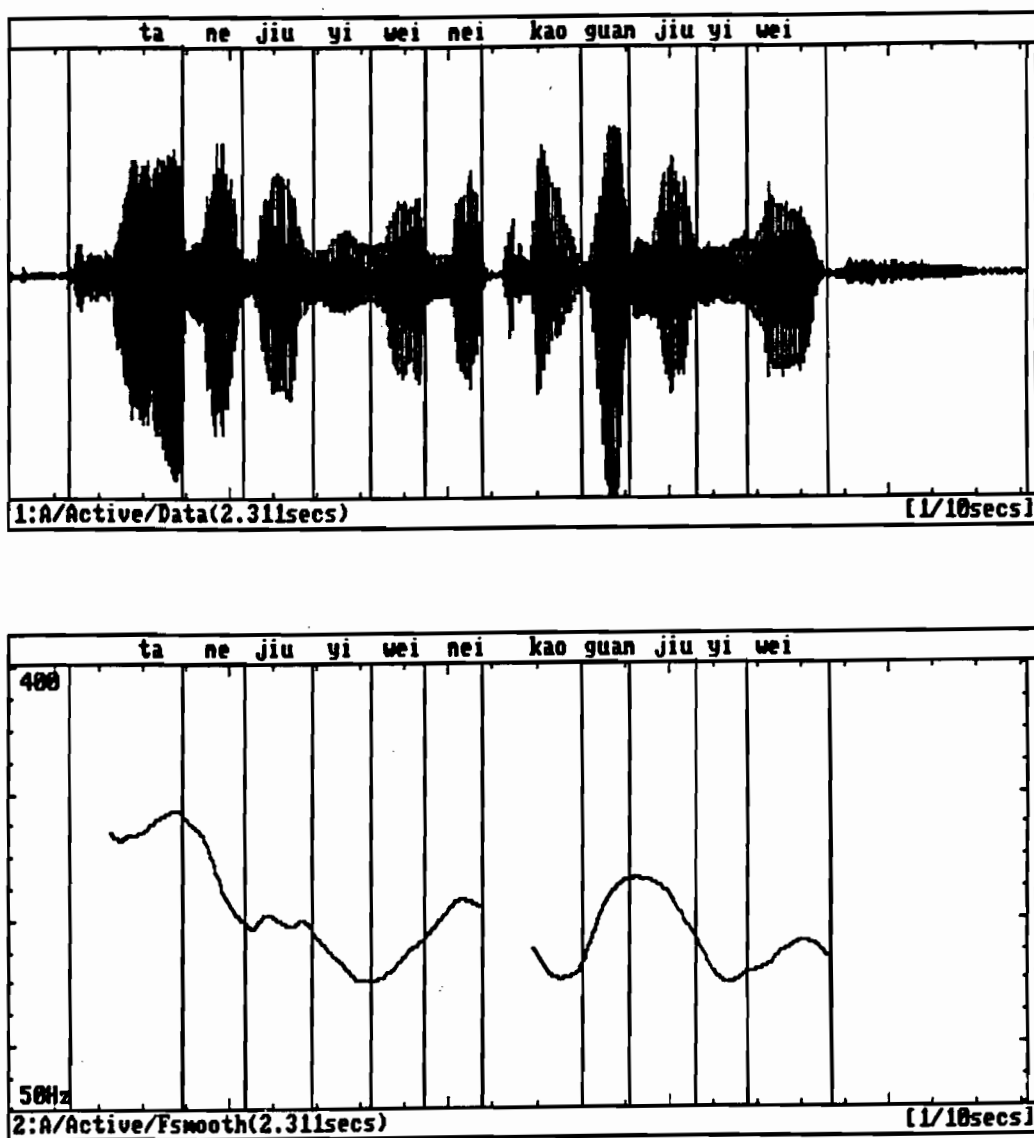


Figure 5.1 Waveform and pitch tracks of sentence ZJ2526, Ta ne jiu yiwei, nei kaoquan jiu yiwei... 'She thought, the tester thought...'

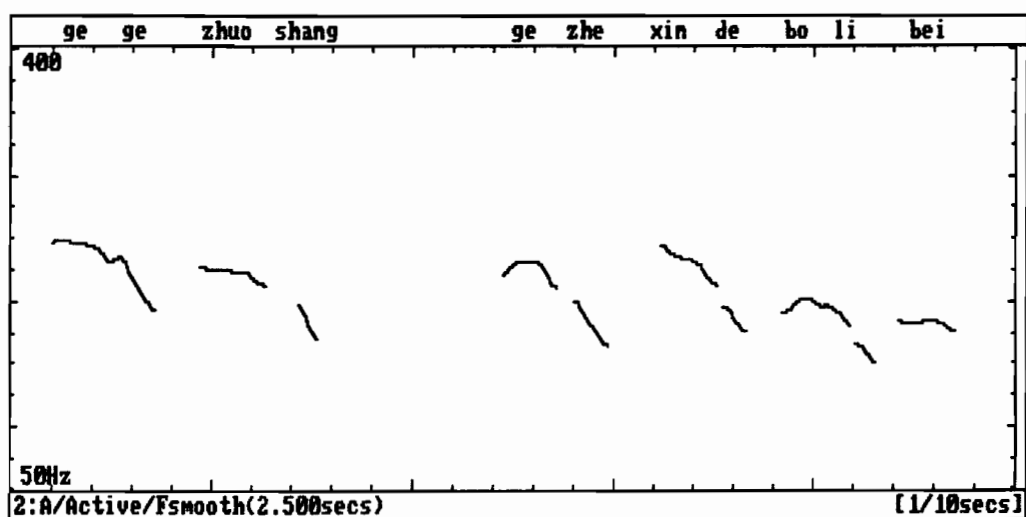
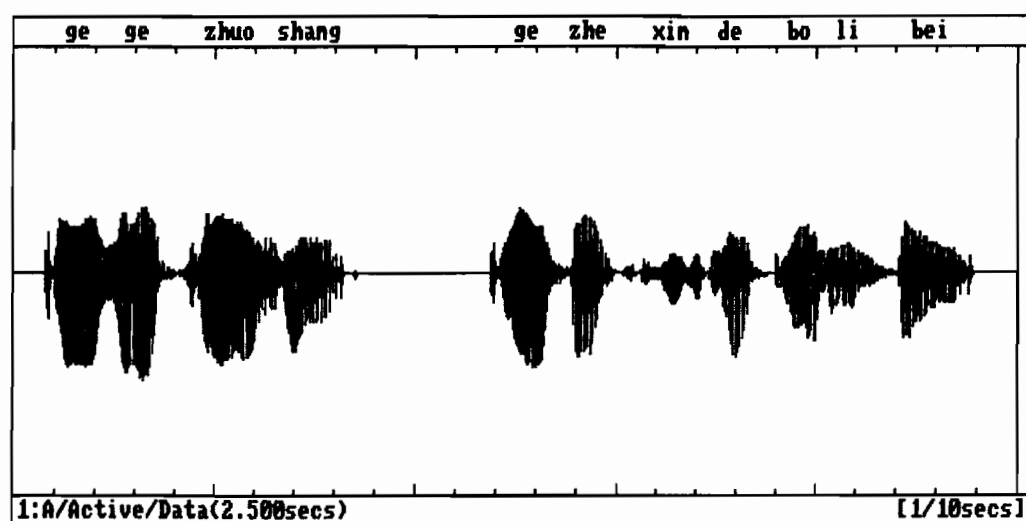


Figure 5.2 Waveform and pitch tracks of sentence ZJS7a, Gege zhuoshang gezhe xinde bolibei. 'There is a new glass on my brother's desk.'

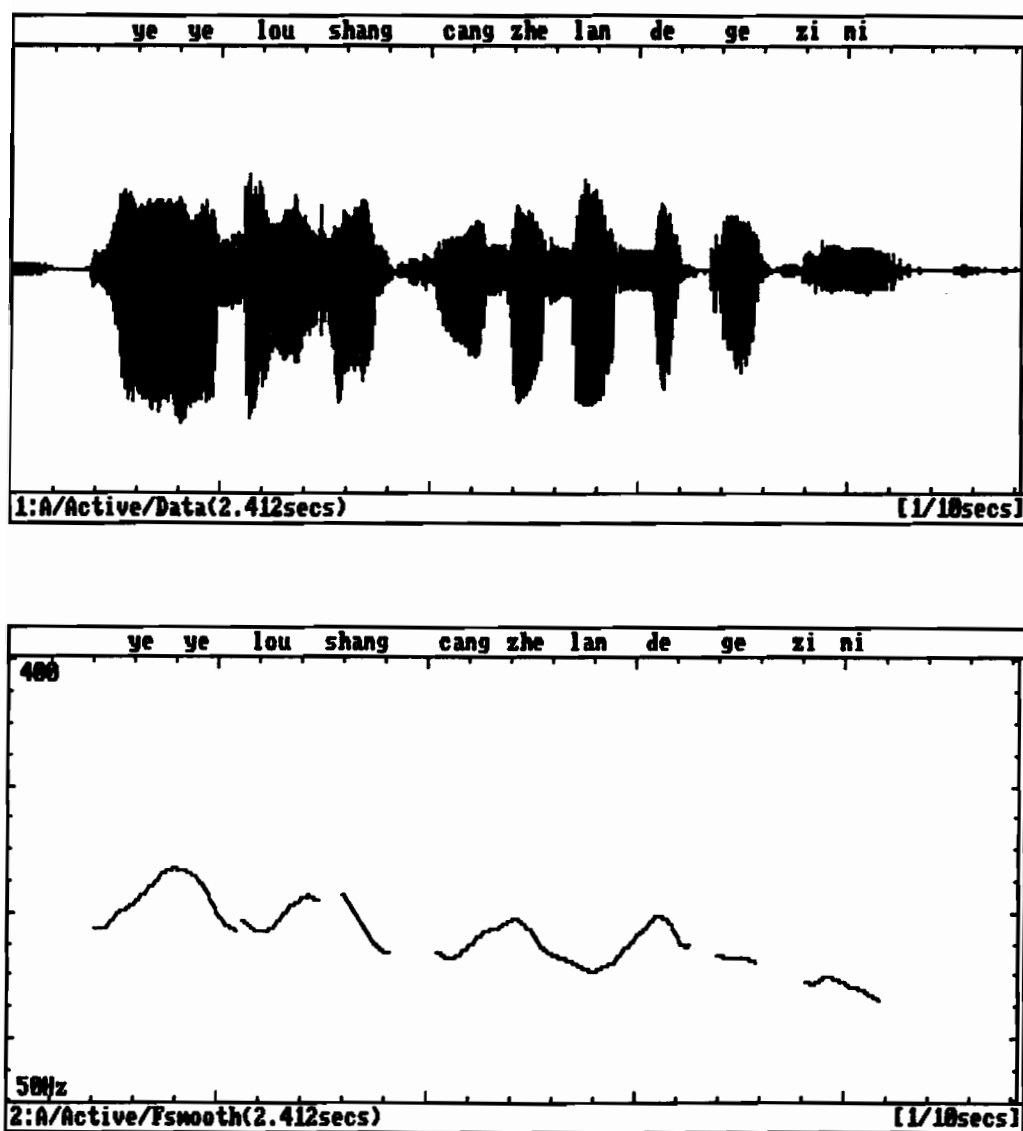


Figure 5.3 Waveform and pitch tracks of sentence ZJS8a, Yeye loushang cangzhe lande gezini. 'There is some blue tartan hidden upstairs at my grandfather's place.'

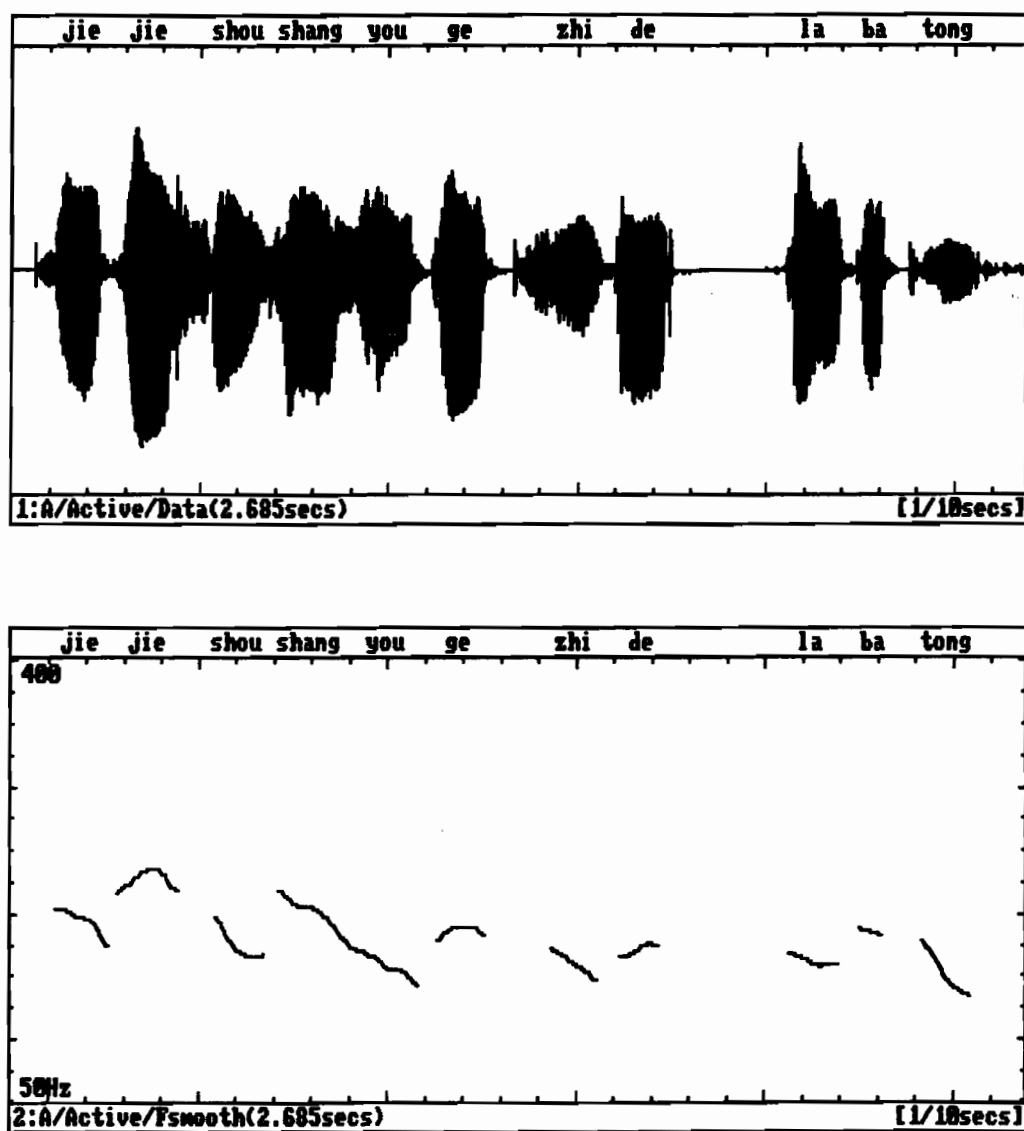


Figure 5.4 Waveform and pitch tracks of sentence ZJS9a, Jiejie shoushang youge zhide labatong. 'There is a paper megaphone in my sister's hand.'

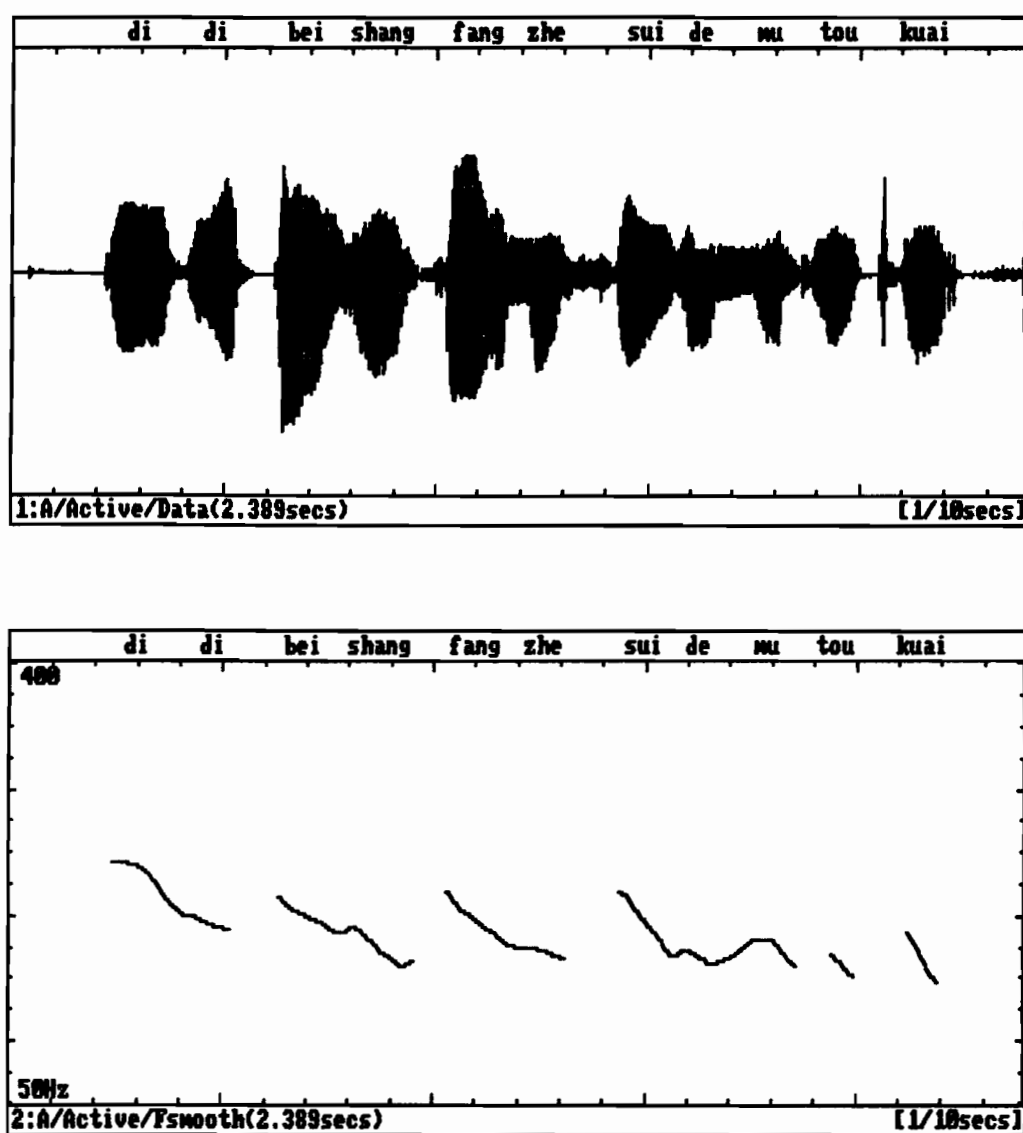


Figure 5.5 Waveform and pitch tracks of sentence ZJS10a, Didi beishang fangzhe suide mutoukuai. 'There are broken pieces of wood on my brother's quilt.'

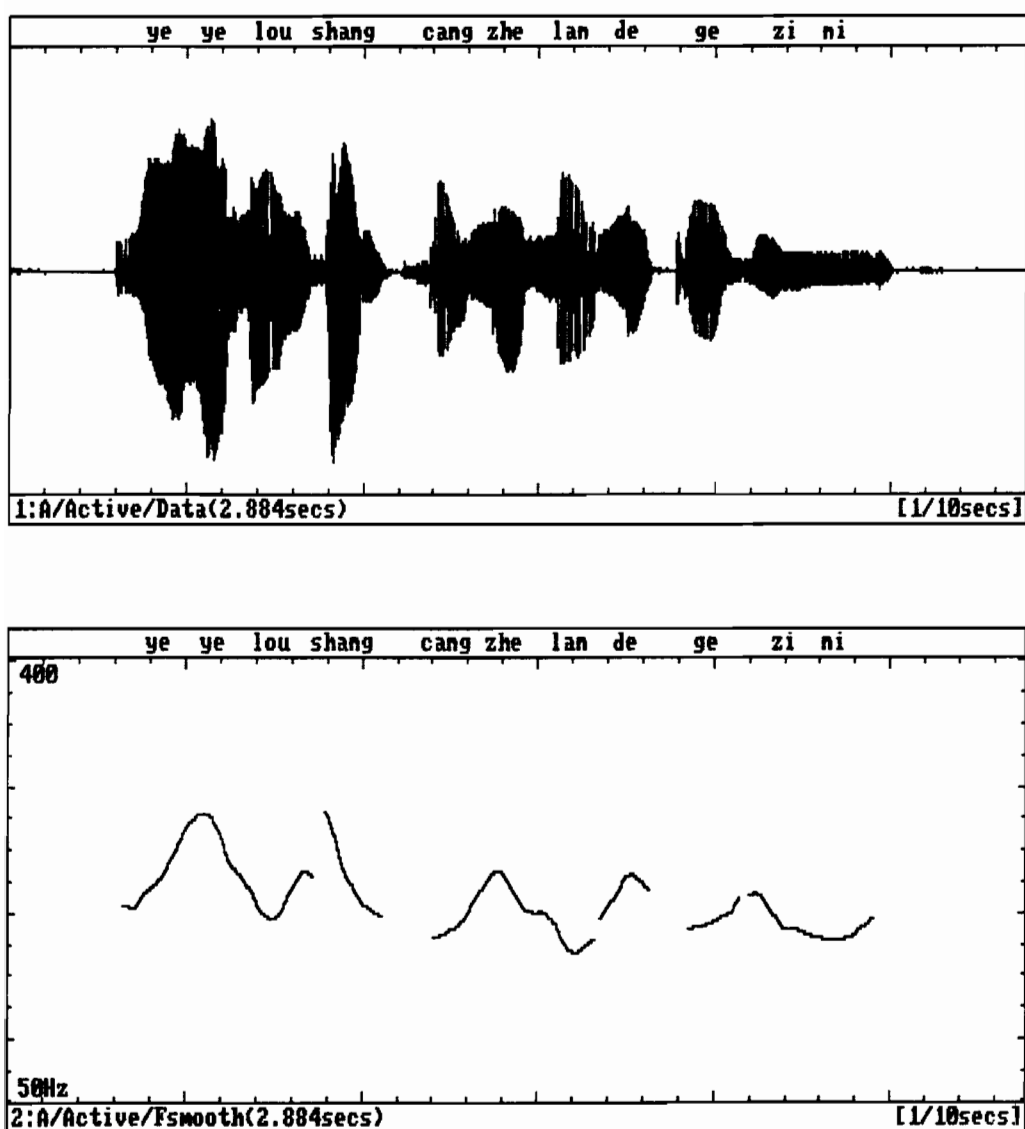


Figure 5.6 Waveform and pitch tracks of sentence HJS8a, Yeye loushang canqzhe lande gezini. 'There is some blue tartan hidden upstairs at my grandfather's place.'

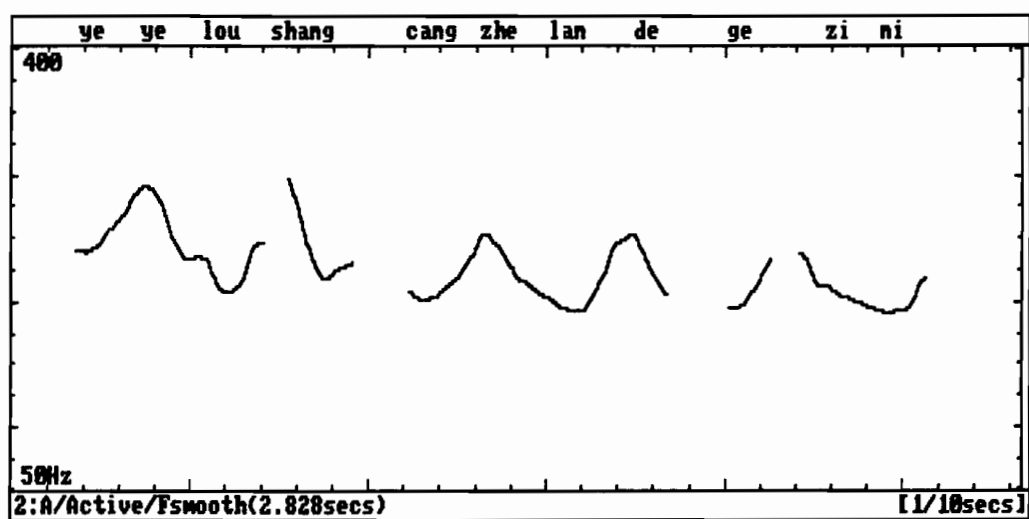
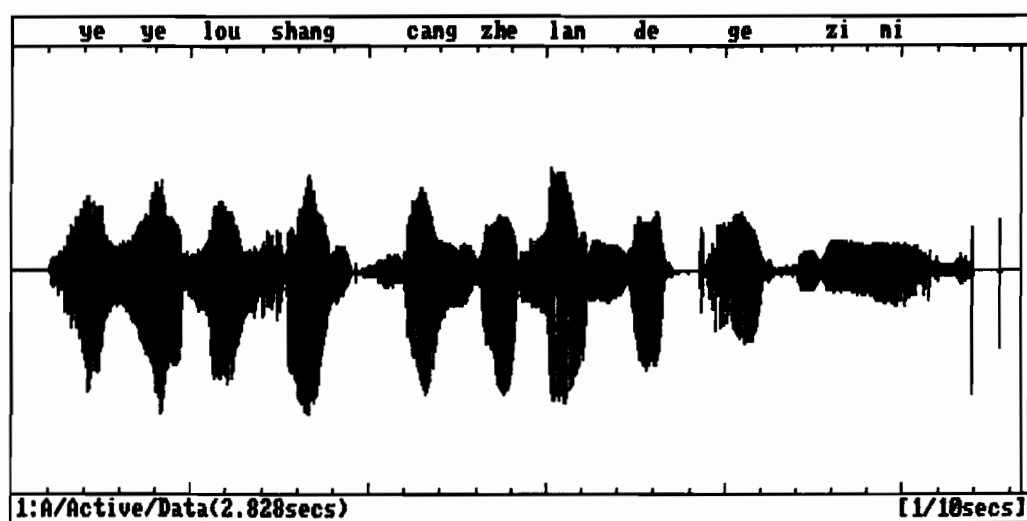
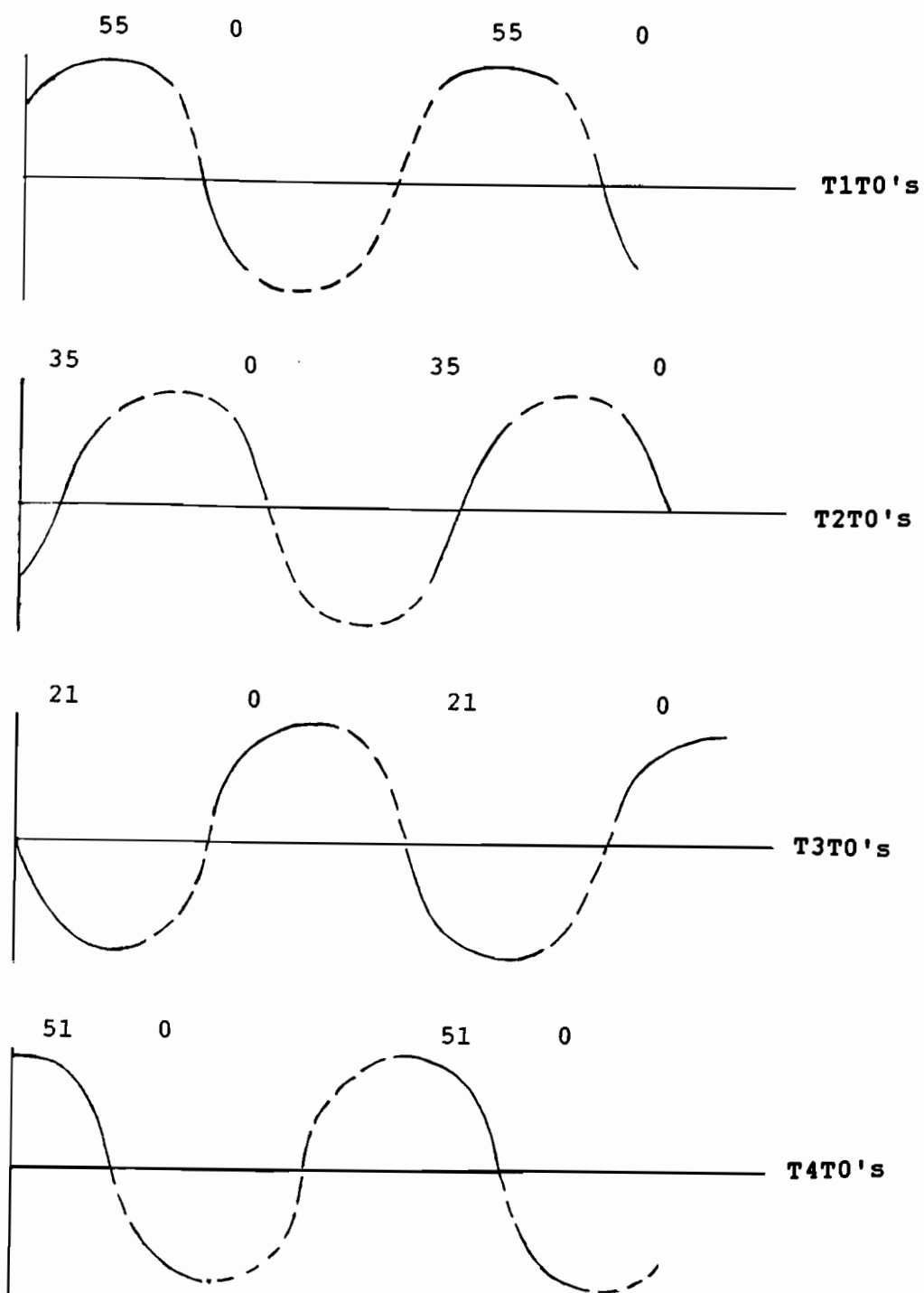


Figure 5.7 Waveform and pitch tracks of sentence CJS8a, Yeye loushang cangzhe lande gezini. 'There is some blue tartan hidden upstairs at my grandfather's place.'



**Figure 5.8** Sine waves illustrating pitch undulations of TiT0's. Solid lines indicate pitch curves corresponding to vocalic portions of syllables, broken lines indicate those corresponding to other portions of syllables.



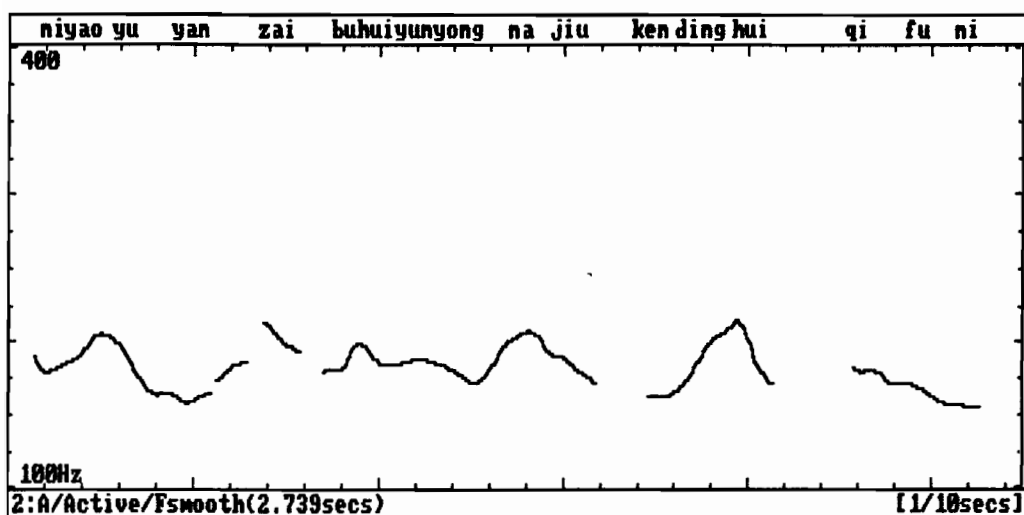
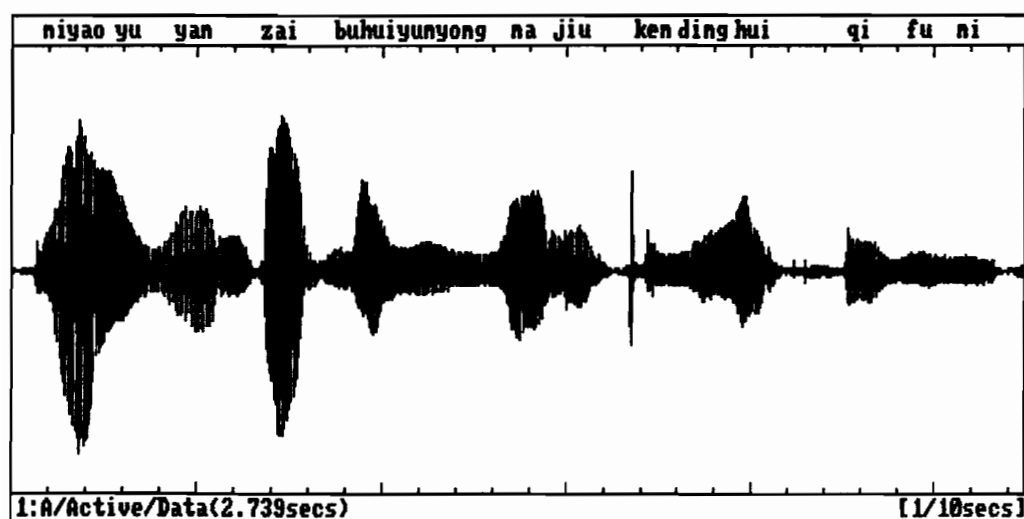


Figure 5.9 Waveform and pitch tracks of sentence HJ2930 Ni yao yuyan zai bu hui yunyong, na jiu kending hui qifu ni. 'If you cannot speak the language either, then definitely you will be bullied.'

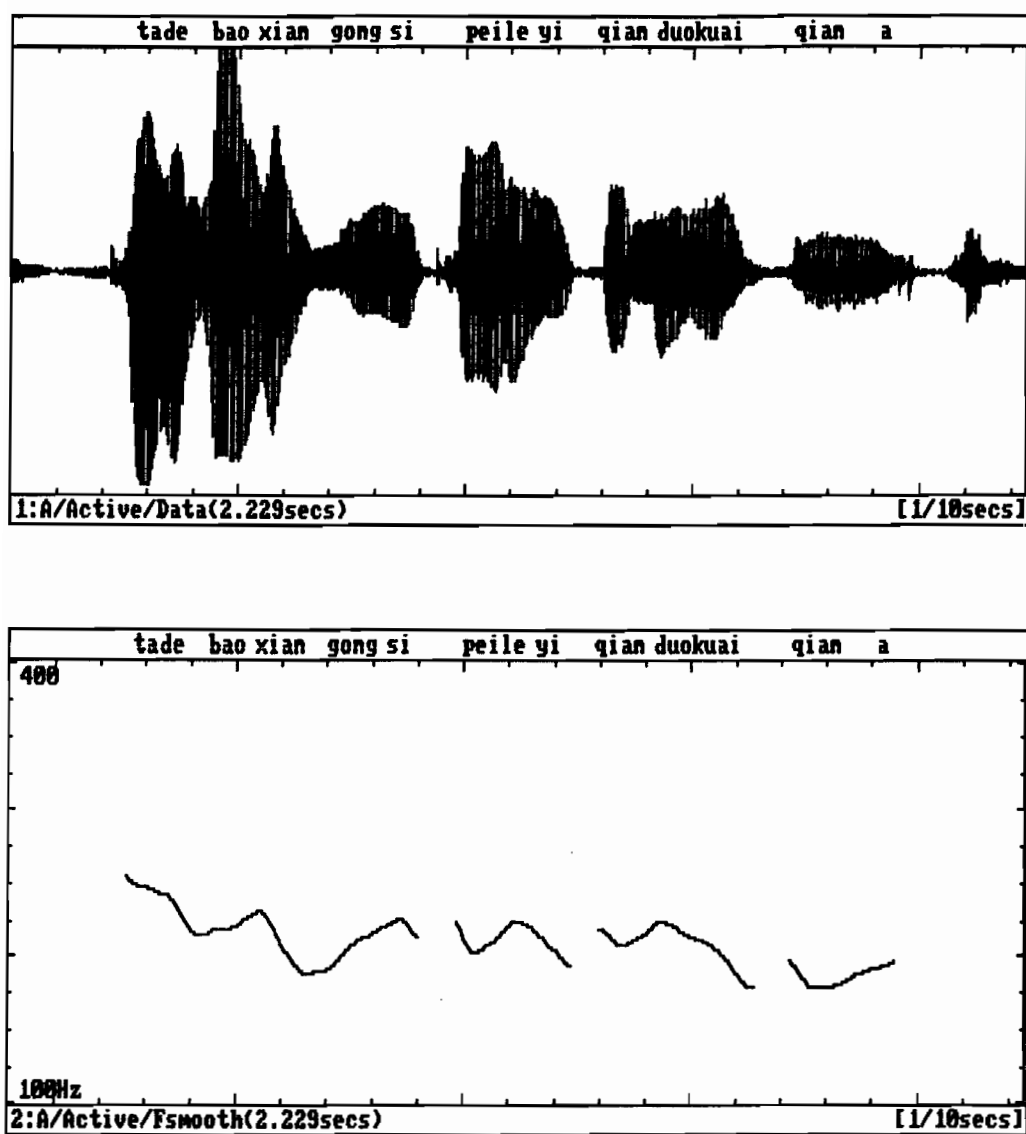


Figure 5.10 Waveform and pitch tracks of sentence HJ6566 Ta de baoxian gongsi pei le yiqian duo kuai qian a. 'Her insurance company paid more than one thousand dollars.'

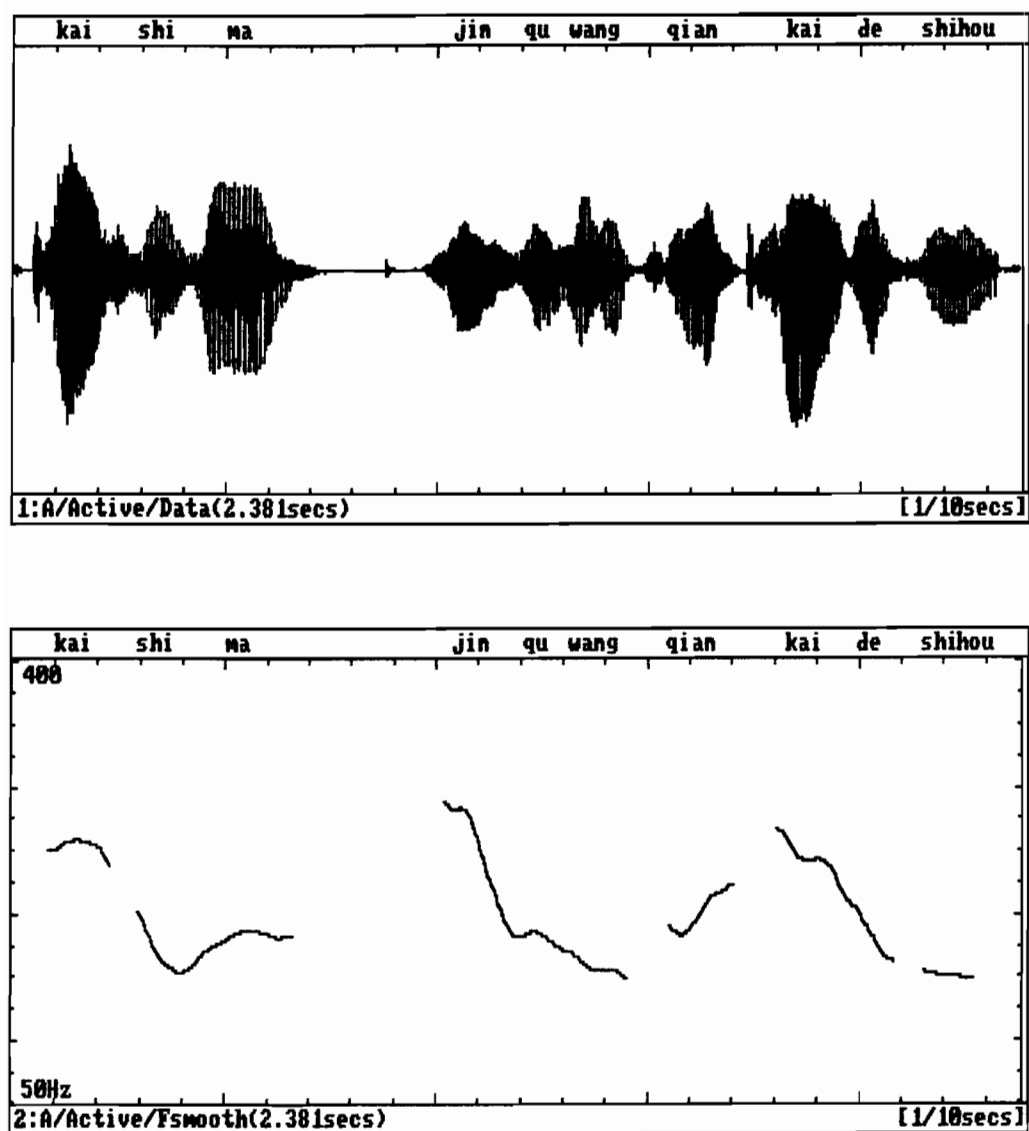


Figure 5.11 Waveform and pitch tracks of sentence ZJ2021 Kaishi ma, jinqu wang qian kai de shihou,... 'At the beginning, when I drove in and went forward ...'

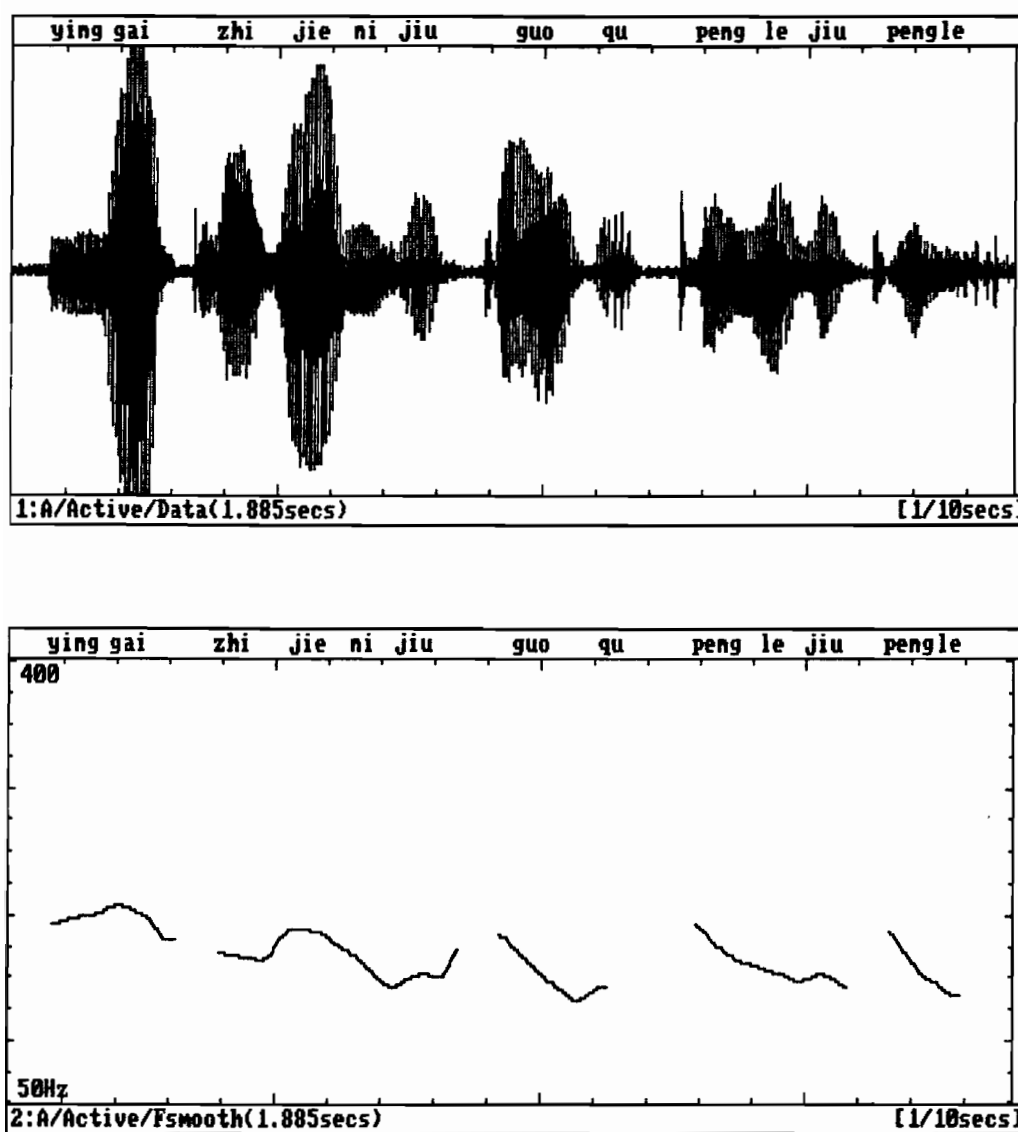


Figure 5.12 Waveform and pitch tracks of sentence ZJ33 Yinggai zhijie ni jiu guoqu, peng le jiu peng le. 'You should drive through directly, even if you had hit it.'

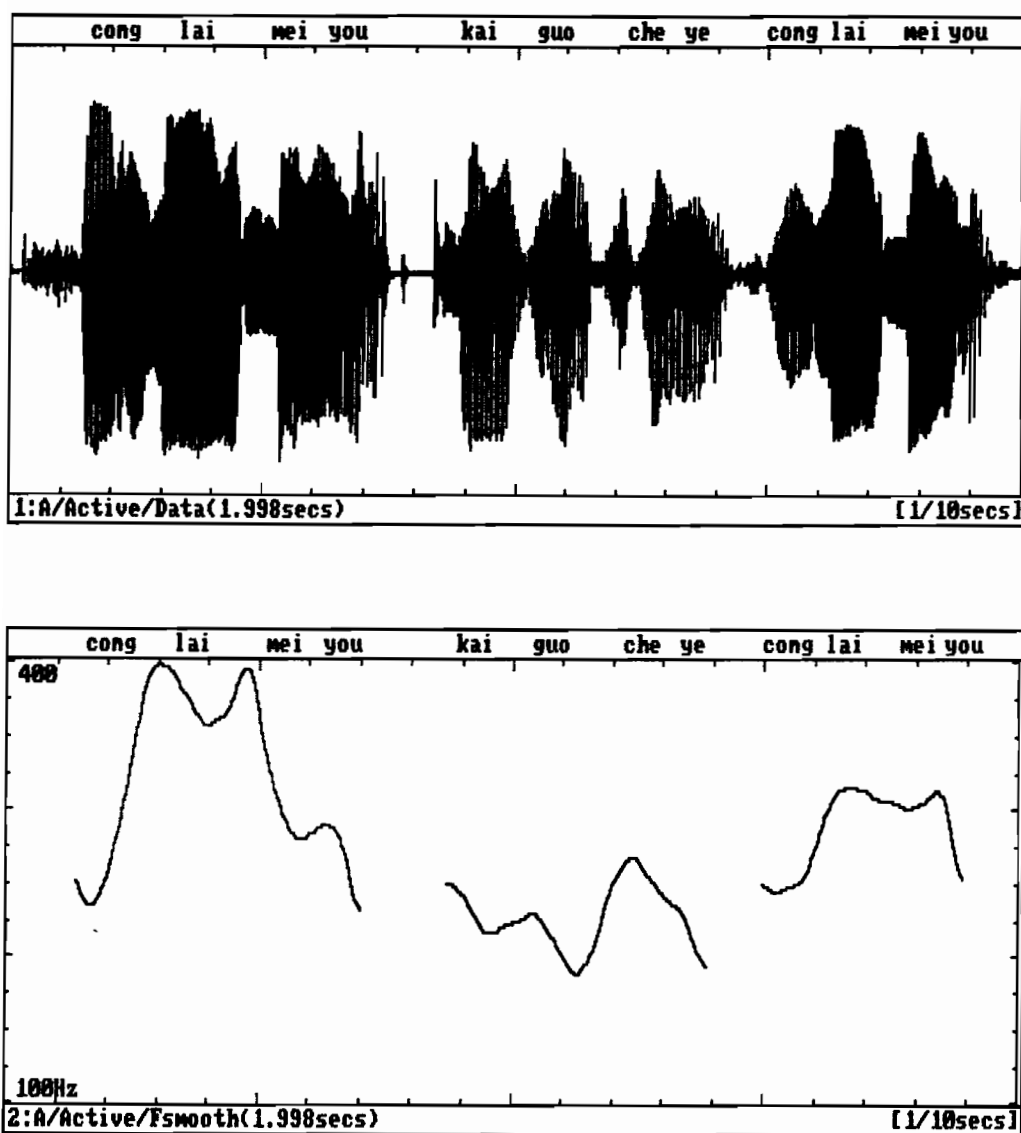


Figure 5.13 Waveform and pitch tracks of sentence CJ2829 Conglai meiyou kai quo che, ye conglai meiyou... '(I) have never drive a car, also I have never...'

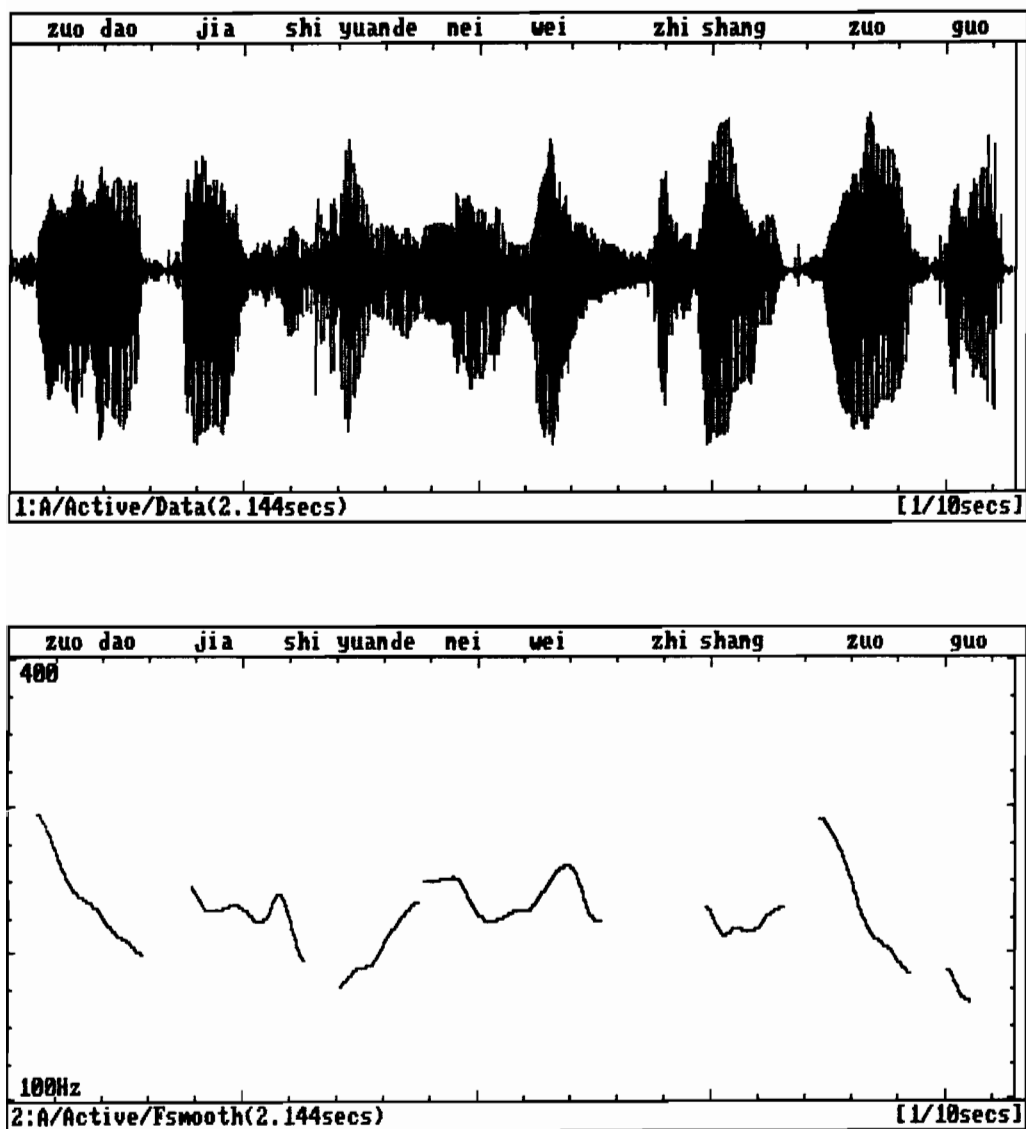


Figure 5.14 Waveform and pitch tracks of sentence CJ3031 ...zuo dao jiashiyuan de na weizi shang zuo guo. '...sat on the seat for a driver.'

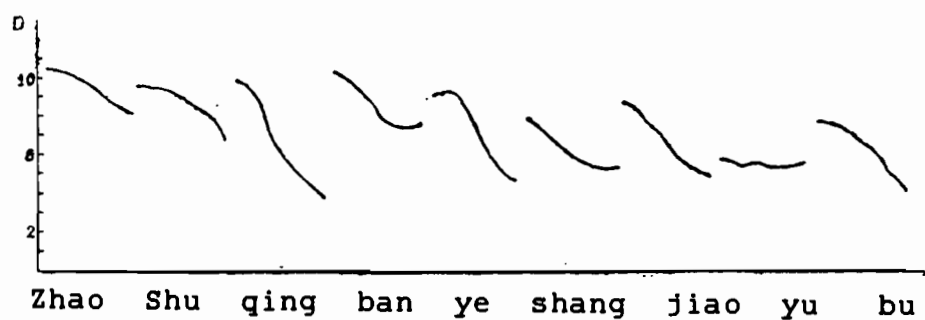
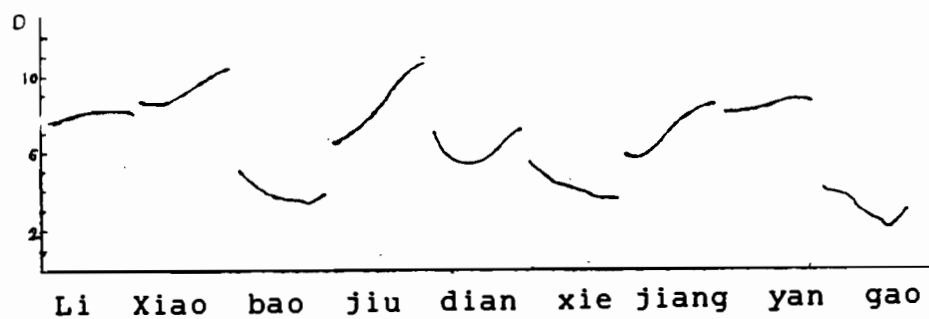
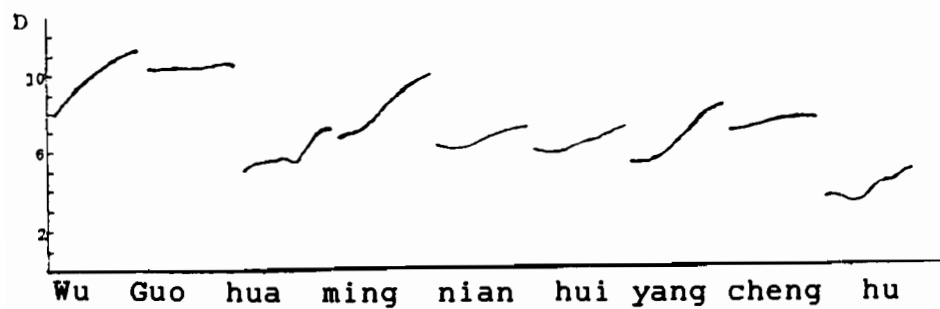
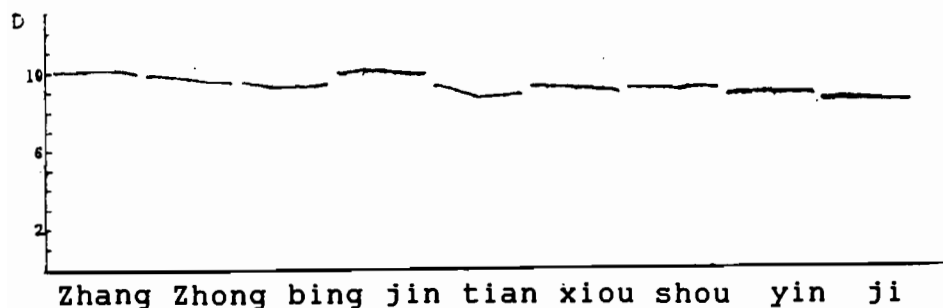


Figure 5.15 Tonal contours of Ti's in four sentences from J. Shen (1985). The vertical scale is standerdized measure of frequency among speakers.

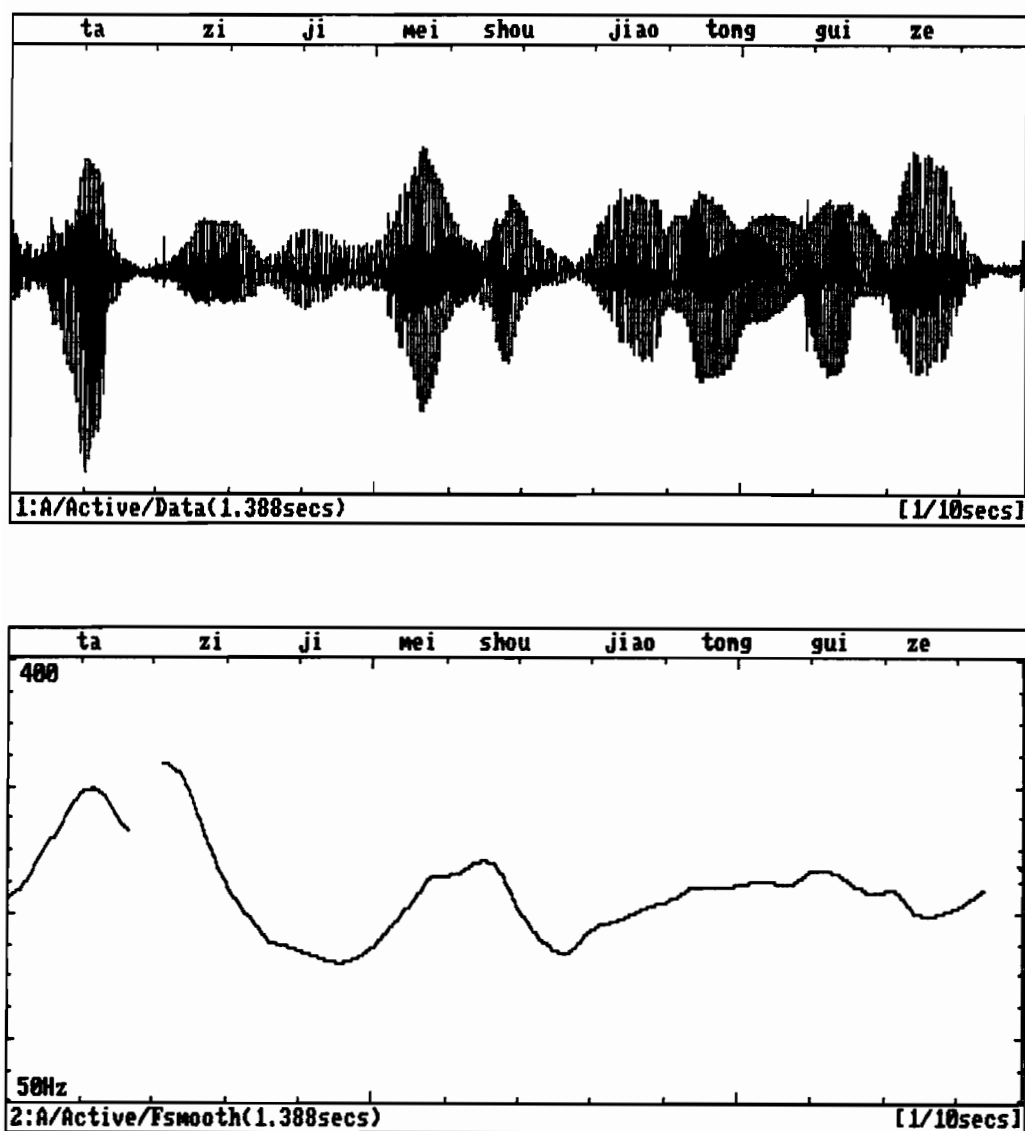


Figure 5.16 Waveform and pitch tracks of sentence HJ73, Ta ziji mei shou jiaotong quize, 'He himself did not abide by the traffic regulation...'



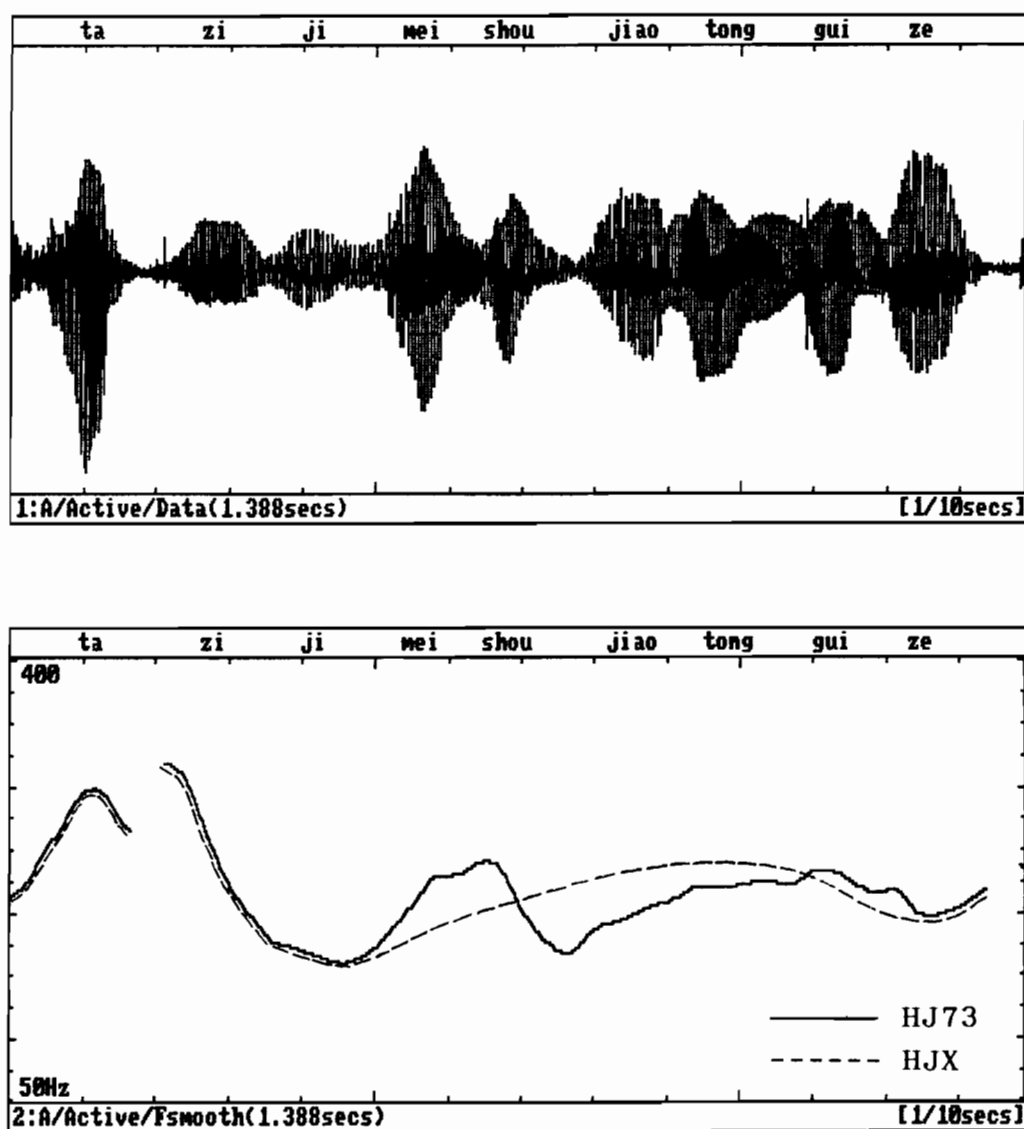


Figure 5.17 Comparison of pitch tracks between sentence HJ73 and HJX. HJ73: Ta ziji mei shou jiaotong guize,... 'He himself did not abide by the traffic regulation,...' HJX: Ta ziji mei ting jiaotong gize,... 'He himself did not listen to the traffic regulation,...'

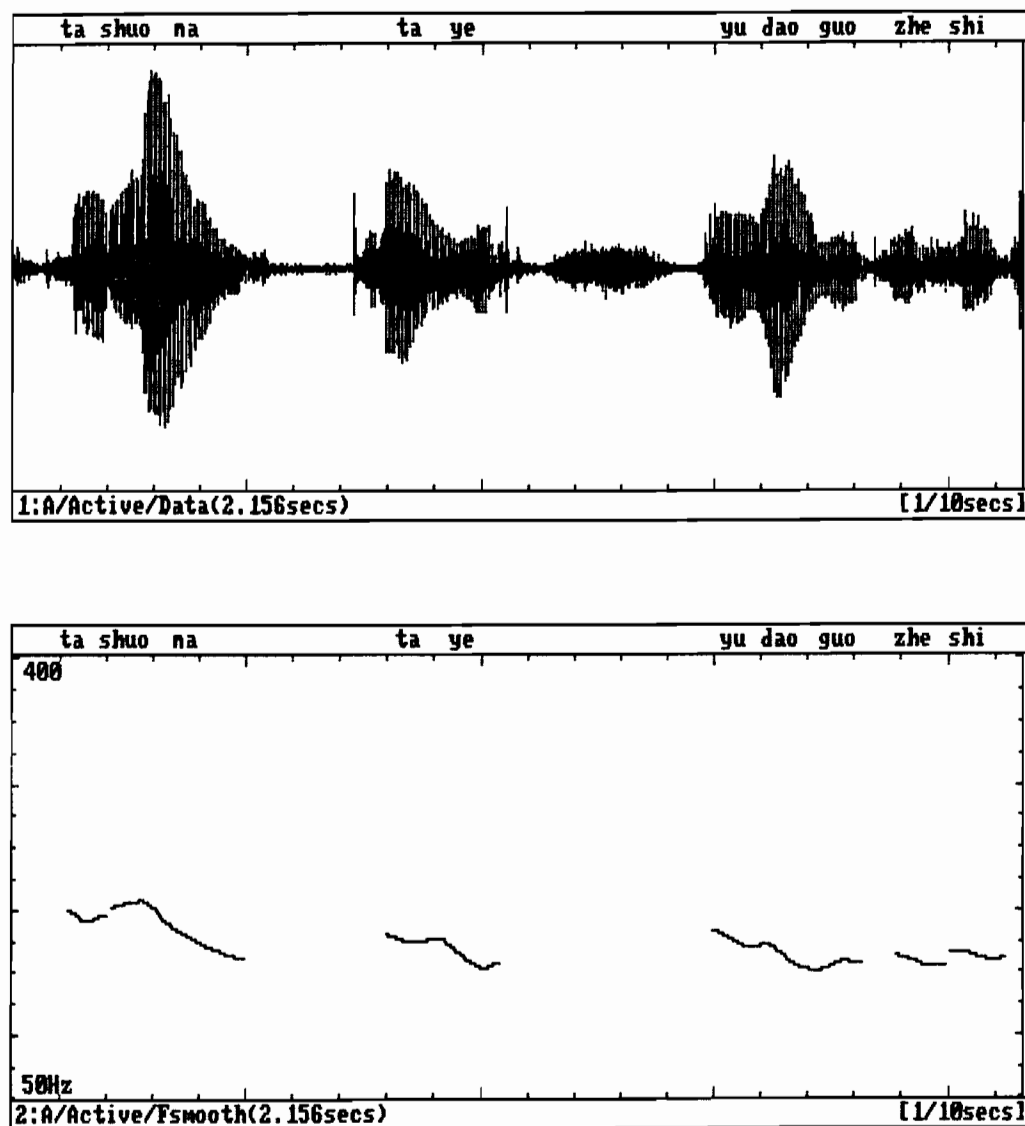


Figure 5.18 Waveform and pitch tracks of sentence HJ35, Ta shuo na ta ye yudao guo zheshi,... 'She said that she had also come across this kind of problems...'

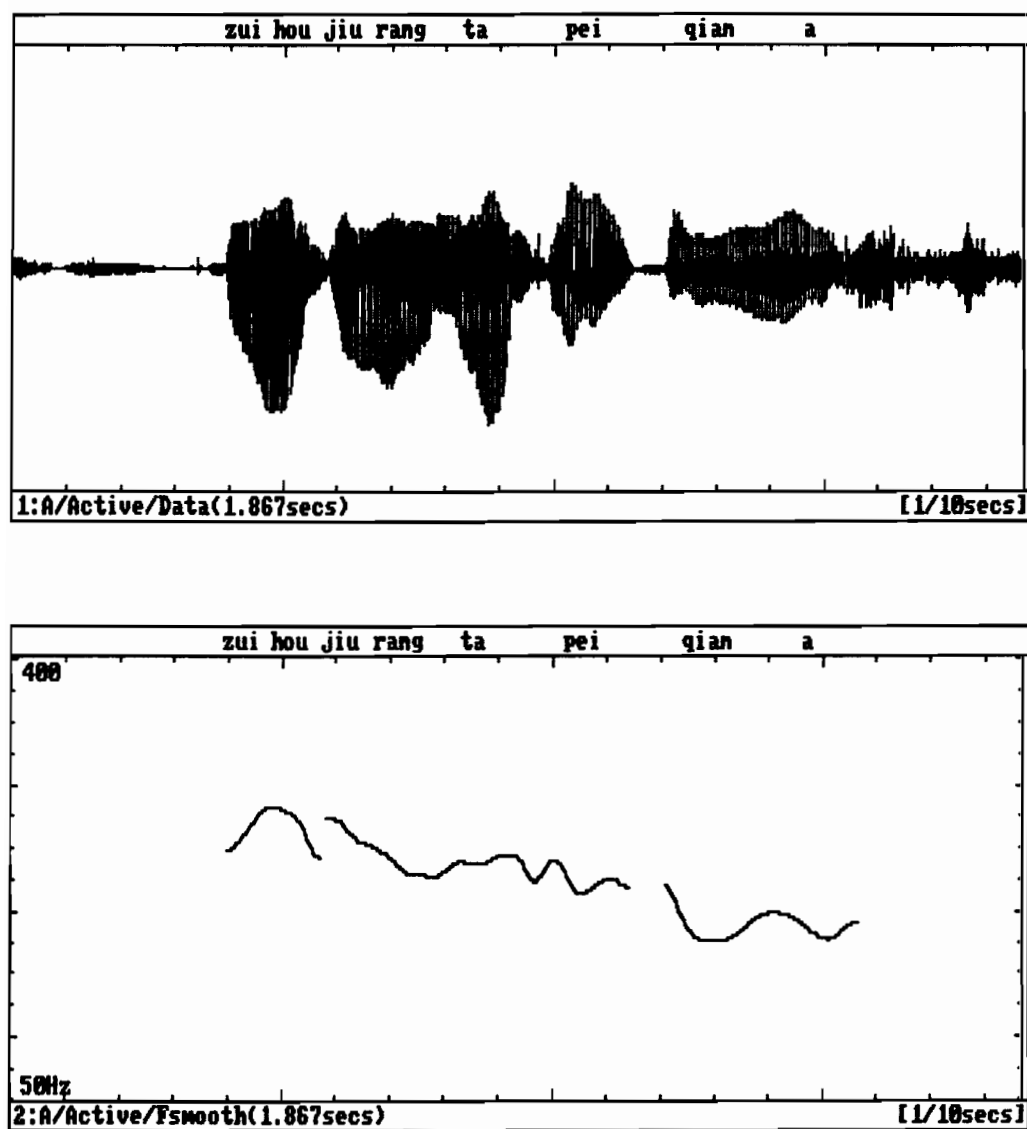


Figure 5.19 Waveform and pitch tracks of sentence HJ63, Zuihou jiu rang ta pei qian a. 'At last (he) let her pay the reparation.'

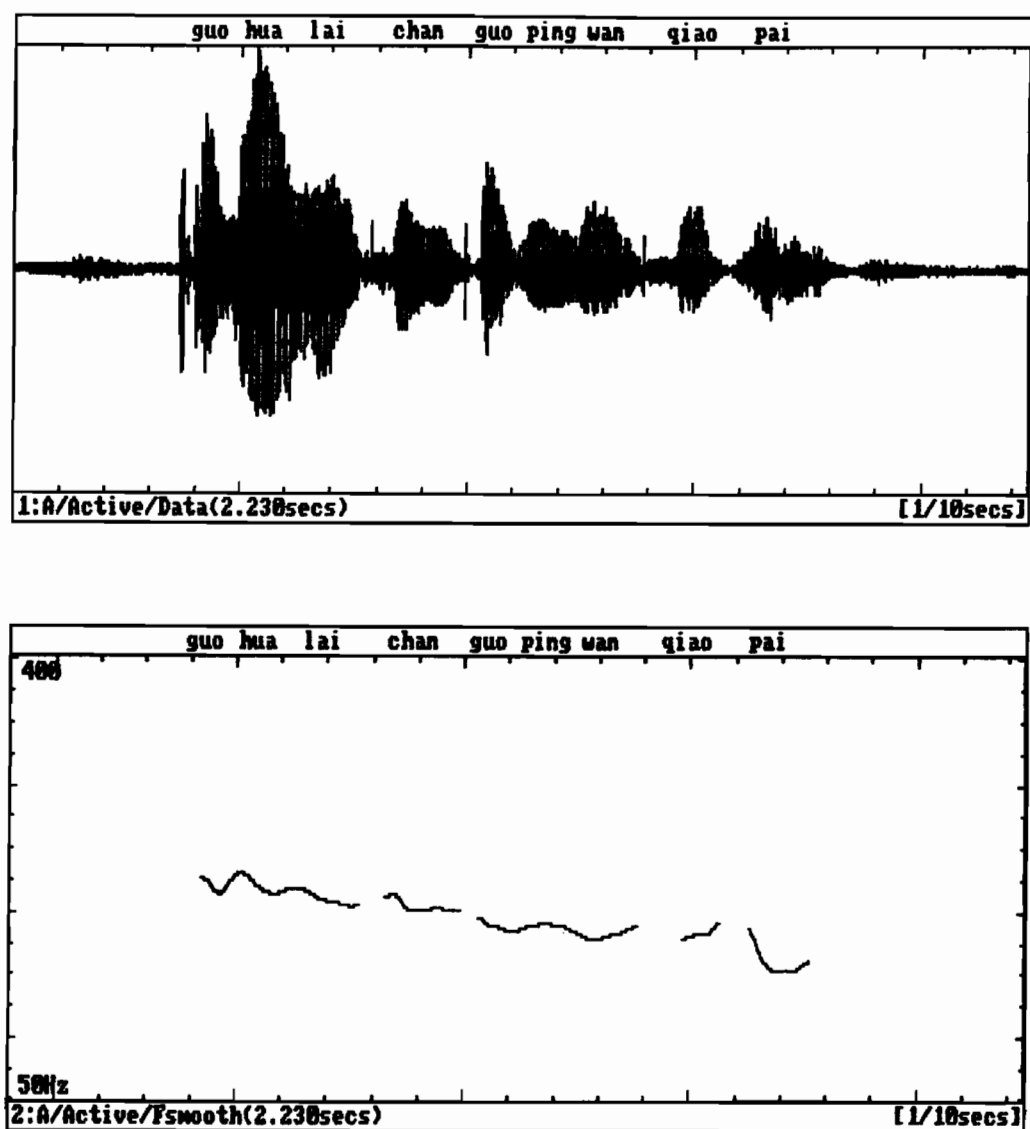


Figure 5.20 Waveform and pitch tracks of sentence HJS5a, Guohua lai chan Guoping wanr qiaopai. 'Guohua comes to pester Guoping into playing Bridge.'

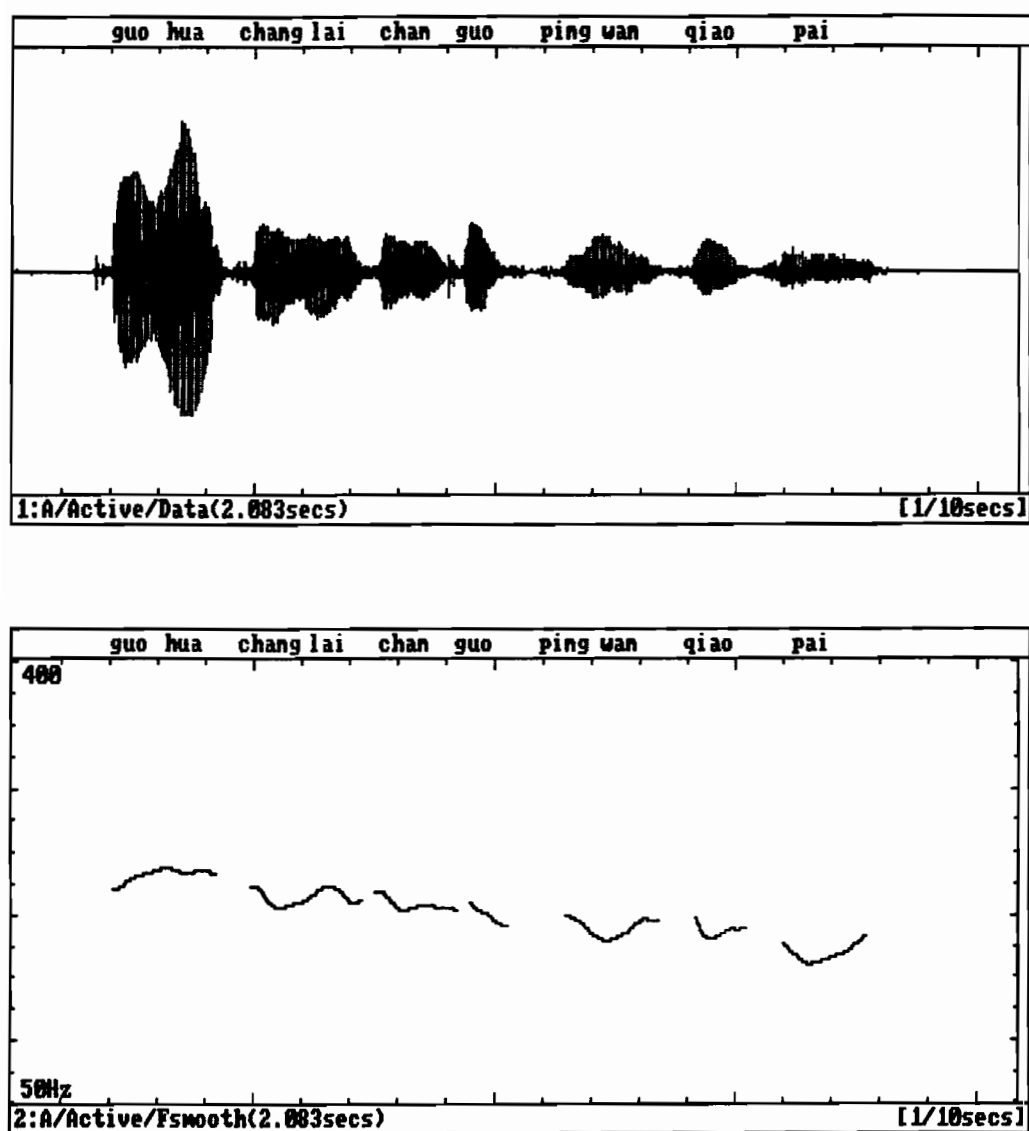


Figure 5.21 Waveform and pitch tracks of sentence HJS5b, Guohua chang lai chan Guoping wanr qiaopai. 'Guohua often comes to pester Guoping into playing Bridge.'

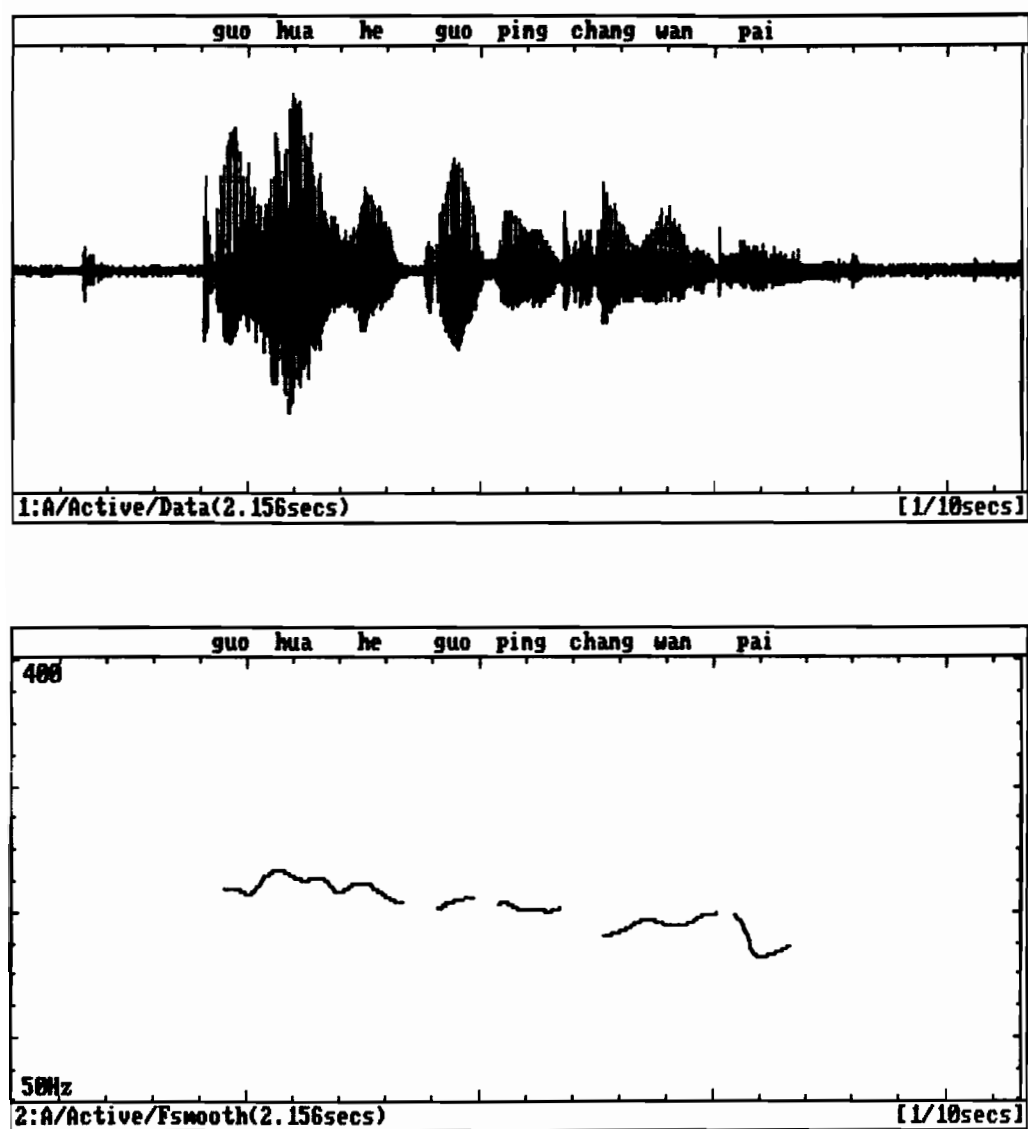


Figure 5.22 Waveform and pitch tracks of sentence HJS5c, Guohua he Guoping chan wanr pai. 'Guohua and Guoping often plays Bridge.'

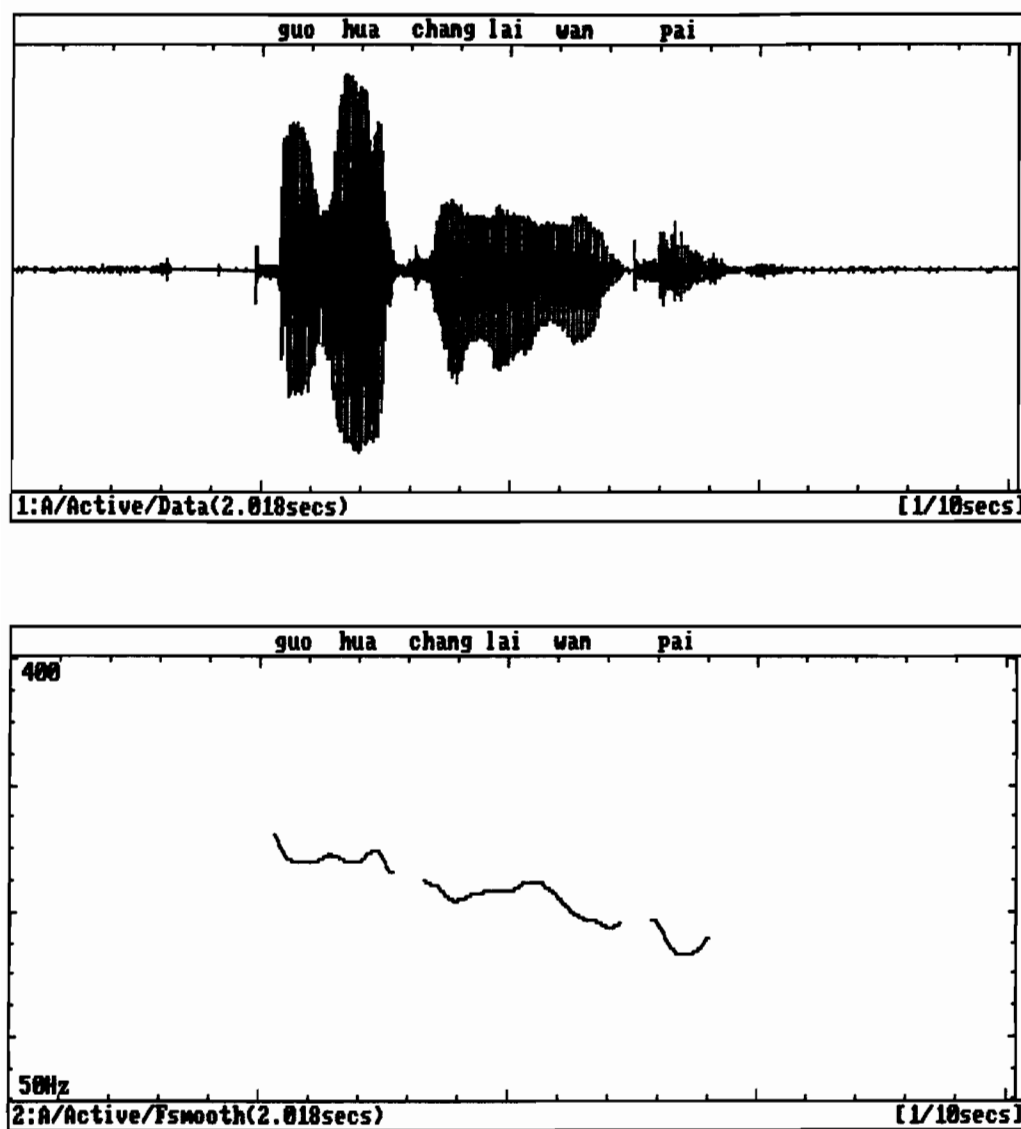


Figure 5.23 Waveform and pitch tracks of sentence HJS5d, Guohua chang lai wanr pai.  
'Guohua often comes to play Bridge.'

## CHAPTER VI

### PRODUCTION OF SEQUENCES OF T3'S

Unusual phenomena of tonal realization are exhibited in sequences of T3's. In this chapter, the specific patterns of pitch undulation in T3 sequences are observed. To help explain this phenomena, physical constraints concerning the production of the tones are hypothesized. It is assumed that the effects of producing the T3's override the principle of pitch contour formation in intermediate phrases.

#### 6.1. Strengthening nature of tone sandhi within a T3 sequence

As analyzed in the previous chapter, pitch tracks of controlled sentences produced by three speakers show that an intermediate phrase is a tone sandhi domain for any  $T_i$  ( $i=1, 2, 3$ , or  $4$ ) sequences. However, stress patterns do not affect T3 sandhi in the same way that it affects sandhis of other tones.

Chinese linguists have paid attention to how stress affects tone sandhi. A strongly stressed syllable is



expected to keep its underlying tone, while a weak syllable is expected to lose it. In previous studies, tone sandhi rules are reformulated with the condition of stress. Zhang (1988) referred to tone sandhi rules, such as Half-T3 Rule and Half-T4 Rule, as weakening rules. He hypothesized a general process of weakening for tones in a weak position. Zhang defines weakening only as the loss of part of an original tone. However, few scholars have noted that the general weakening rules cannot apply to T3 sequences. Zhang (1988) is the first to state that the T3 Rule is "counterintuitive" because it applies to syllables with emphasis or contrastive stress. In fact, before him, Wu (1982) had discussed how a T3 becomes a rising tone when bearing a contrastive stress in a non-final position of a sequence of T3's, but he did not comment on the unusualness of the phenomenon. I refer to the "unweakening" nature of T3 sandhi as "strengthening" nature in this study, although it often happens that the change, that a low T3 becomes to a rising tone, is not a process of strengthening.

Until now, the strengthening nature of T3 sandhi has not received enough attention in Chinese tonal literature, although the fact that tone sandhis are conditioned by stress is frequently noted. Zhang's (1988) focus on the strengthening nature of T3 sandhi is important for a deeper understanding of tonal phenomena in Mandarin. However, he

does not provide further suggestions on the motivation of the phenomenon apart from acknowledging the unusual fact.

The corroboration of the strengthening nature of T3 sandhi is found in the data. Whenever a sequence of two or more Ti's are produced in the same intermediate phrase, tone sandhis are optional for other tones, but obligatory for T3's. I assume that there must be a strong effect which makes a T3 change whenever it occurs in a T3 sequence. This effect overrides the effect of stress pattern, hence making T3 sandhi an strengthening process.

In the tonal literature, T3 sequences are always used as the best examples to explain tone sandhis. Considering the contrast between the weakening and strengthening nature of different tone sandhis, as well as the possible effect which motivates tonal changes inside a sequence of T3's rather than other Ti's, it is reasonable to assume that T3 production is rather different from other tones. What are the special characteristics of T3 production? I will offer an hypothesis, after observing pitch contours of sequences containing a T3 or T3's.

## 6.2. Pattern of pitch movement in sequences of T3's

It seems that there are specific patterns of pitch movement in sequences of T3's. In order to know more about how T3 changes in sequences, I examined both spontaneous

and controlled data.

### 6.2.1. Two shapes of tunes in T3 sequences

First, I observed controlled data, which are the sentences S3 a-f and S6 a-h. Within the sentences, S3 d-f are designed to contain contrastive stresses. When considering T3 sandhis in these sentences, I ignored T3's following contrastive stresses, which are discussed later.

Different speakers often produce the same sentence with different stress patterns and tone sandhi forms, even for the controlled data. Pitch tracks of S6a's, shown in Figures 6.1-6.3, are used as examples.

(1)

HJS6a:

Li Xiaobao	jiudianzheng	ye xiang xie	jiangyangao.
w w s	w w s	s w w	w w s
21 21 21	21 21 21	21 21 21	21 21 21 UT
Li Xiaobao	9:00 sharp	also want write	draft for
			a lecture
"At 9:00 Li Xiaobao also wants to write a draft for a			
lecture."			

ZJS6a:

Li Xiaobao	jiudianzheng	ye xiang xie	jiangyangao.
w w s	w w s	s w w	w w s
21 21 21	21 21 21	21 21 21	21 21 21 UT
Li Xiaobao	9:00 sharp	also want write	draft for a
			lecture
"At 9:00 Li Xiaobao also wants to write a draft for a			
lecture."			

**CJS6a:**

```

Li Xiaobao | jiudianzheng | ye xiang xie | jiangyangao.|
W W S      W W S      W S      W      W W S
21 21 21    21 21 21    21 21    21    21 21 21 UT
Li Xiaobao  9:00 sharp    also want write draft for a
                                lecture
  "At 9:00 Li Xiaobao also wants to write a draft for a
  lecture."

```

As illustrated, all speakers produced the sentence with four intermediate phrases, each containing three syllables. In three of the intermediate phrases, the last syllable is stronger than others. However, the stronger stress in the third intermediate phrase is produced on the first syllable ye by speaker H and Z, but on the second syllable xiang by speaker C.

According to the phonological rules, the first T3 in each tone sandhi domain of three syllables could only be a low rising tone. The second T3 should be either a low rising or a high level tone. Also, the third T3 is expected to be a low falling tone or a low falling-rising tone when it is followed by a pause. However, the figures show that for an intermediate phrase, the first T3 is realized as a low falling, low falling-rising, or a low rising curve. The second T3 becomes a high tone with various shapes: rising, level, falling, falling-rising. The last T3 has a low falling or low falling-rising curve, despite whether it is in front of a pause or not.

It is difficult to find a general rule of the tone sandhis when dealing individually with the changes of each T3 contour. I think T3 sandhis should be studied in local groups. The tone sandhi domain for T3's, as for other tones, is an intermediate phrase. T3 adjustment should always serve the formation of a tune, which is the pitch contour, or undulation, of an intermediate phrase. With this consideration, I observe the pitch contour of each tune as a whole, ignoring small curves.

An interesting finding is that, with the exception of the third tune produced by speaker C, the overall shapes of all tunes are similar: a major rising(-level)-falling cycle with or without a pre-extension and/or a post-extension, along the pitch undulation. I will call this type of overall shape "Shape 1". The third tune produced by speaker C contains two rising-falling cycles, because the T3 of the second syllable is realized as a falling-rising curve. This type of general shape, with or without a pre-and/or a post-extension, will be referred to as "Shape 2".

The pitch tracks in Figures 4.32 and 4.33, exhibit both shapes of tunes. In Figure 4.32, the first and second intermediate phrase, i.e. Li Xiaobao and jiudianzheng respectively, have tunes with Shape 1. However, the first tune has a pre-extension, in syllable Li, but the second tune does not. The third tune has Shape 2, because of the

major rising contour of the second T3. The shape of the fourth tune is between Shape 1 and Shape 2. However, I will treat it as a Shape 1, since the concave curve of the second syllable "yan" is rather high, giving the tune have an overall contour similar to a rising-level-falling shape. In fact, there is a continuum of shapes between Shape 1 and Shape 2. A tune of T3's could be realized as any specific shape between the two typical patterns, i.e. Shape 1 and Shape 2.

In Figure 4.33, all of the four tunes are in Shape 1, although the contrastive stress in the second intermediate phrase influences the shape of the third tune. As often happens to low T3 variants, the falling T3 in the last syllable gao does not show up in the pitch track of Figure 4.33, although in the tape recording it sounds similar to the last T3 shown in Figure 4.32. Scholars have noted that a low T3 often causes a creaky voice in the syllable. The fact that sometimes a pitch curve does not show up in the output of the sound analysis system CECIL must be related to this voice quality. When a portion of a syllable is produced by a creaky voice, the fundamental frequency of the whole syllable becomes difficult for the system to discern. For many T3 sentences, the system shows all of the low T3's on the output pitch tracks only once or twice among several repetitions of its operation. For the illustrations in this

study, I have chosen the pitch tracks in which these low T3s show up.

The regular shapes of tunes are exhibited in all of the data of controlled T3 sequences. More examples are provided in Figure 6.4-6.10, which are pitch tracks of sentences S6 b-h produced by speaker Z.

(2)

ZJS6b:

```
| Li Bao | jiudianzheng | xie   jianggao.|
  w  s      w  w  s      w      s      w
  21 21      21 21  21      21      21  21      UT
  LiBao  9:00 sharp      write draftfor a lecture
  "At exactly 9:00 Li Bao was writing a draft for a
  lecture."
```

ZJS6c:

```
| Li Bao | jiudian | ye   xie | jianggao.|
  w  s      w  s      s      w      s      w
  21 21      21 21      21  21      21  21      UT
  LiBao  9:00      also write draftfor a lecture
  "At 9:00 Li Bao will also be writing a draft for a
  lecture."
```

ZJS6d:

```
| Wo jiudianzheng | xiang xie | jianggao.|
  s  w  w  s      s      w      s      w
  21 21 21  21      21  21      21  21      UT
  I  9:00 sharp      want write draft for a lecture
  "At exactly 9:00 I want to be writing a draft for a
  lecture."
```

ZJS6e:

```
| Wo jiudian | zong   xiang xie | jianggao.|
  w  s  w      s      w      w      s      w
  21 21 21      21  21  21      21  21      UT
  I  9:00      always want write draft for a lecture
  "At 9:00 I always want to write the draft for a
  lecture."
```

ZJS6f:

| Wo ye | zong xiang xie gao. |  
 s w w s w w  
 21 21 21 21 21 21 UT  
 I also always want write draft  
 "I always want to write the draft, too."

ZJS6g:

| Wo zong xiang xie gao. |  
 w s s w w  
 21 21 21 21 21 UT  
 I always want write draft  
 I always want to write the draft."

ZJS6h:

| Wo jiudian xie gao. |  
 w s s w w  
 21 21 21 21 21 UT  
 I 9:00 write draft  
 "At 9:00 I will write the draft for a lecture."

Despite the stress patterns, the shapes of the tunes in these examples are all Shape 1: each of which has a major rising-level-falling contour with or without a pre- and/or a post-extension. The pre- or post-extension is realized either in the whole length or only in a portion of a syllable. A basic low falling T3 occurs only at either the initial or final position of an intermediate phrase.

In the controlled data of T3 sequences, an intermediate phrase of normal size contains two or three syllables. The longest intermediate phrase of a T3 sequence has five syllables, which occurs in sentence S3c produced by speaker H. The contour of the tune formed by the five T3's is in Shape 1. The pitch track of the sentence is shown in Figure 6.11.



## (3) HJS3c:

|Li Xiaobao | jiudian ye xiang xie | jiangyangao?|  
 w w s s w w w w w w s  
 21 21 21 21 21 21 21 21 21 21 21 21 UT  
 Li Xiaobao 9:00 also want write draft for a lecture  
 "DoesLi Xiaobao also want to write the draft for a  
 lecture at 9:00?"

To summarize, the general rule for tone sandhi, in a sequence of T3's, is that all T3's in each intermediate phrase form a contour with a given pattern. This pattern is a typical rising-falling or rising-falling-rising-faling shape or an shape between these two, with or without a pre-and/or a post-extension along the pitch undulation.

## 6.2.2. Function of stress patterns in T3 sequences

Does stress pattern still have any influence over the pitch contour formation of T3 sequences, even though it is overlapped by some other effects? A close observation leads to a positive answer. In an intermediate phrase, the pitch curve of the stronger syllable is usually longer or spans a larger pitch range than that of any other syllable.

However, an important fact is that the stronger T3 is always realized as a curve with at least one low target rather than a purely high curve. Its pitch contour composes

a major rising, falling, or falling-rising portion of a tune. In an intermediate phrase, when the stronger stress is on the first syllable in an intermediate phrase, the pitch contour of that syllable is realized as the rising portion of the tune, and those of other syllables compose the latter portion. The pitch contours of the third intermediate phrase in Figures 6.1 and 6.2 are formed by this method. When the last syllable has the strongest stress, its T3 serves as the major falling on the tune; other T3's compose the preceding rising or rising-level portion. The formation of the first two tunes in Figure 6.4 are examples of this stress pattern.

When the second T3 is stressed stronger than others in a trisyllabic intermediate phrase, there are two options of pitch contours for the tune. One option is that this T3 appears as the rising portion on a Shape 1 tune, as long as the preceding T3 is in a low falling or low level curve. This option is exhibited in the last tune in Figure 6.4. Another option is that the stronger T3 is realized as the middle falling-rising portion on a Shape 2 tune, assuming that the preceding T3 is also rather strong and shows a rising contour. The third tunes shown in Figures 4.32 and 6.3 are two examples of this option. In all of my data, most tunes of T3 sequences are in Shape 1, and only the two shown in the above figures are in Shape 2.

In short, for an intermediate phrase of a sequence of T3's, stress pattern affects the detailed arrangement of how a fixed shape for the tune is formed by T3 pitch curves.

### 6.2.3. Evidence from data of uncontrolled sentences

The above analysis is based on the data of controlled sentences. I will take a look at the data of spontaneous speech and the reading of the transcriptions to see if pitch contours of T3 sequences actually have the shapes previously described. In the spontaneous sentences there are fifteen sequences of two T3's, four sequences of three T3's, and only one sequences of four T3's. However, since there is a intermediate phrase boundary in one of the three T3 and in one of the four T3 sequences, there are in fact sixteen tone sandhi groups containing two T3's, four such groups containing three T3's, and none containing four T3's. Observing pitch contours of these T3 sequences in both spontaneous speech and the reading of the corresponding transcript, I see that all of their pitch contours, except one, are in Shape 1. The exception is in Shape 2. Figures 6.12-6.13 and 6.14-6.15 are examples of pitch tracks from the spontaneous speech and read transcript respectively. The sentences are as follows, and sequences of T3's are marked by "\*"s.

(4)

ZJ4243

| Wang na lushang zou, | Xiao Shen zai neibianr kanzhe, |  
 S W S W S S W S W W S W  
 21 51 51 51 21 21 21 21 51 55 51 0

toward that street drive Xiao Shen at there watch  
 "When I was driving toward that street, Xiao Shen

| ta shuo: "Ei... |"

W W S  
 55 55 55 UT  
 he say Oh  
 was watching there and he said: "Oh..."

ZJ65

| Guai guoqu yihou | ye keyi. |  
 S W S W S S S W  
 21 51 51 21 51 21 2121  
 \* \* \*

turn around after still O.K.  
 "It is still O.K. after turning around."

ZD80

| Wang zuo guai huilai, | ...  
 S W S W W  
 21 21 21 35 35  
 \* \* \*

from left turn back  
 "(I) turned back from left, ..."

ZD85

| Wo zhe chetou zhenghao | cai le yixia chuqu le. |  
 S W S W S W S W W S S W W  
 21 51 55 35 21 21 21 0 55 51 55 51 0  
 \* \* \*

My the car-head just step PART once out PART  
 "I just stepped on the accelerator, and the head of the  
 car crossed the stop line."

In Figure 6.12, there are four T3's in a sequence. The corresponding syllables are zou, xiao, shen, and zai, which belong to the first and second intermediate phrases. The pitch contour in the last three T3, which belongs to the second intermediate phrase, forms a typical rising-falling cycle as part of the tune. The word zai, 'at', usually has a T4, but it also has an optional colloquial pronunciation with a T3 by many native Beijing speakers. Here this syllable is uttered with a T3 by Z.

The whole pitch undulation of this example is very interesting for various reasons. A main reason is due to sequence of T3's, but also because of the change of other tones. Preceding the sequence of T3's are one T3 and three T4's, in the first intermediate phrase. Following the T3's is the sequence of T4T1T4T0, in the second intermediate phrase. Next occurs the third intermediate phrase which begins with three T1's. There is not even one T2, the rising tone. However, the whole pitch movement in the example is a very well shaped undulation with four peaks and three valleys. Function of stress patterns in both T3's and other tones is clearly illustrated in Figure 6.12.

This utterance is a valuable example, since it shows a combination of several interesting phenomena, which occurs naturally and rarely produced in spontaneous speech. Among the pitch tracks of sentences I have examined, this is the

only one which is formed by such an optimal match with several factors. The factors include: first, nine syllables, containing underlyingly falling tones T3's and T4's, occurring together, is rare. Secondly, the order of four T4's followed by four T3's, is hard to come by in spontaneous speech. Thirdly, the stress patterns, formed by "s" and "w" alternately, is desirable. Fourthly, the pitch undulation of a long sentence, keeps such a large and stable pitch range is unusual. The optimal match of these four factors allows the pitch undulation to have a shape similar to a natural sine wave.

Figure 6.13 shows another rare example of spontaneous speech. Again, there is a long sequence of T3's and T4's which is seen as a typical undulation of pitch movement. The shape of the tune formed by the three T3's is neither a typical Shape 1 nor a typical Shape 2. Generally speaking, with the level-falling-rising-falling shape, it is similar to Shape 2. As usual, the syllable ye is quite strongly emphasized, and the emphasized stress can be judged by auditory impression. However, in addition to personal impressions, the figure confirms this emphasis by reflecting an especially long duration. The pitch contour of the T3 in the vocalic portion of the syllable has an unusually low falling shape. However, referring to the duration of the waveform of the syllable in the upper

portion of Figure 6.13, it is seen that only a short portion of the pitch contour shows up in the figure.

The interesting point concerning example 6.13 is that the T3 in ye is realized in a very low falling contour. It is a rare phenomenon that T3 occurs in such a low value. The lowest point of the pitch contour, only less than 70 Hz in frequency, is about an octave lower than the normal minimum value in the speaker's data. Is such a low pitch track in this portion of the T3 caused by an octave error of the output from the CECIL system? Although this type of error occurs quite often in the output of some sound analysis systems, in this case, the answer is "no." To confirm this point, the pitch track of the T3 is enlarged in Figure 6.16. In the portion of waveform which corresponds to the low pitch track, durations between pulses, which are shown as long vertical lines, are between 13 to 15 milliseconds. This means that the portion of the T3 pitch track in the figure is correctly abstracted by the computer analyzing system. This observation and confirmation is significant for understanding the production of a T3, which will be discussed later. Also the fact that the feature of a T3 is very low and in falling shape is confirmed in this case.

Now let us come back to the examination of pitch contours of sequences of T3's. In Figure 6.14, pitch tracks

of the three T3's in wang zuo guai form a contour of Shape 1 in the main portion of the tune. In Figure 6.15, as in Figure 6.12, the T3's in zheng hao cai belong to two intermediate phrases; the first two T3's form a Shape 1 contour in the first intermediate phrase, and the last T3 sustains a low falling in the second.

In short, data of both spontaneous speech and the reading of a transcript support my hypothesis concerning the shape of pitch contour for a T3 sequence when it occurs in one intermediate phrase.

### 6.3. Condition of T3 sandhis

The following questions are raised in regards to T3: what makes T3's behave so differently from other tones in response to the effect of stress? In addition, why does tone sandhi in a sequence of T3's results in similar pitch patterns of tunes? I suggest that it is the physical constraint which makes a T3 hard to produce, hence causing the above phenomena. In order to support my idea, I will provide a discussion of pitch range. Then I will analyze the position of a pitch range in which a basic T3 normally occurs and the circumstances required by the production of a T3.



### 6.3.1 Pitch range

For convenience of explanation, several concepts of pitch range will be used. I will refer to the largest possible pitch range for a speaker as "the possible pitch range". The pitch range physically shown in the pitch track will be referred to as "the actual pitch range". Assuming that other factors remain the same for a specific portion of a sentence, and if all of the four Mandarin tones were fully realized in the stressed syllables, the pitch range for the tones will be referred to as "the imagined pitch range". The relationship among the three pitch ranges are: The actual pitch range of an intermediate phrase is contained in the imagined pitch range which in turn is contained by the possible pitch range. The possible pitch range for normal speaking is given for each speaker and can be roughly figured out from his or her speech data produced in various moods. An imagined pitch range or actual pitch range is often reduced or expanded suddenly across intermediate phrases, while its variation inside an intermediate phrase is usually rather small.

The pitch track of sentence HJ64, shown in figure 6.17, illustrates the relationship among the three types of pitch ranges.

(5) HJ64:

	Genben		jiu	bu	shi	ta	de		shiqing.		
	s	s		w	w	w		s	w		s
	55	21		51	55	51		55	0		51
	simply		then		is	not	her	PERF	fault		UT
	"This is simply not her fault."										

The dotted lines, dashed lines, and solid lines indicate the possible, imagined, and actual pitch ranges respectively. The possible pitch ranges are decided according to both the speaker's spontaneous and controlled speech. The highest and lowest pitch values which occur in the data, are the maximum and minimum boundaries of the possible pitch range. The imagined pitch range remains a normal size in the second and third intermediate phrases, but is largely expanded in the first intermediate phrase due to its contrastive stress. The actual pitch range has a size similar to the imagined pitch range in the first and last intermediate phrases. However, it is smaller than the imagined pitch range in the second intermediate phrase. This is because the fully realized tone is a high tone, T1, in the vocalic portion of the syllable ta. All weakened tones keep only the "high" feature. Therefore, no low target is realized in the intermediate phrase.

In the data of both spontaneous and controlled speech, an actual pitch range is usually overlapped with the corresponding imagined pitch range. Although in some cases, such as in the second intermediate phrase of the sentence HJ64, the actual pitch range is smaller than the imagined pitch range. An actual pitch range and the corresponding imagined pitch range usually occur at a low position in the possible pitch range. The minimum of these pitch ranges are either close to each other or overlapped. The distance between the maximum boundary of an actual or imagined pitch range and that of the possible pitch range is determined by their size, since the size of the possible pitch range is fixed. For an ordinary sentence in either controlled or spontaneous speech, this distance is much larger than the distance between the corresponding minimum boundaries. The maximum and minimum boundaries of an actual or imagined pitch range for short, plain, speech usually occur in a middle or rather low position in the possible pitch range.

Therefore, more effort is required in order to lower the minimum boundary than to raise the maximum boundary the same amount. This is because that a physical constraint must exist: the production of a tone which is close to either boundary of a possible pitch range must be harder to produce than a tone in the middle of the pitch range. The means by which a contrastive stress expands a pitch range may serve

as evidence for this physical constraint. As found in other studies (J. Shen 1985, Shih 1989), the expansion of the actual pitch range is primarily reflected in the rising of the high pitch, i.e. the maximum boundary. The low pitch, or the minimum boundary of the pitch range, either lowers minimally to contribute to the expansion or remains unchanged. This fact indicates that the lowering of an already low tone is difficult.

In Figure 6.16, the emphasized low tone greatly lowers down the minimum boundary of both the imagined and actual pitch range greatly. Such a phenomenon has never been reported in previous studies. It is also the only case that I have ever see. The duration of the emphasized T3 syllable ye is two and a half times as long as the durations of the two strong syllables hou and ke, which surround ye. Obviously, it must require much more effort, and hence much more time, to produce such a low tone.

Based on this analysis of pitch ranges and the production of tones in different positions in the pitch ranges, I will discuss the production of T3's.

### 6.3.2. Production of T3's

I assume that it takes special effort to produce a basic T3. This is because a basic T3 not only occurs at the minimum portions of imagined pitch range, but also continues to descend toward the minimum possible boundaries. Producing such a low falling tone must require much more effort than producing other Mandarin tones in the same actual or imagined pitch range.

This assumption is supported by the fact that in the data of both controlled and spontaneous sentences, a T3 often transforms into a T1, T2, or T4. However, a T1, T2, or T4 never becomes a T3. Although each of the three tones may change to any one of the other two tones, it never falls as low as a typical T3 in the local pitch range. This fact hints at the difficulty of the producing of a T3.

A sequence of the same tones also supports this assumption; no matter how short it is, tone sandhi is obligatory for T3's, but not for any other Ti's. Two T3's can never occur parallel to each other in a low falling shape, but two T1's, T2's or T4's often occur parallel to each other in their basic shape. If the sequence for a Ti is rather extended, tone sandhis occur more frequently in T3's than in other Ti's. A basic nature of sandhi is applicable to pronunciation. Obligatory tone sandhi must be motivated by a high degree of difficulty in production.

As already noted, T3 is the only tone which is not affected by stress patterns in the same way as other tones. However, when a T3 is not adjacent to another T3, it behaves the same as other tones. This can be seen from examples in chapter 5 which contain several such T3's. None of those T3's exhibit tone sandhi when stressed strongly, and the T3 reduces when stressed weakly or completely unstressed.

Why is T3 sandhi not affected by stress when the T3 is adjacent to other T3's? Why in all other environments, T3 sandhi behaves like other tones? The resolution must lie in the difference between the productive characteristics of a T3 and those of other tones. A common difference between a T3 to a T1, T2, or T4 is that a basic T3 is a purely low tone with low targets for both the beginning and ending. None of the other tones are purely low, they all have at least one high target. Additionally, the second target of T3 is much lower than those low targets of other tones. Only in a sequence of T3's may a tone sandhi happen in a strongly stressed syllable. This must be due to the unique low feature of a T3 and the difficulty in producing such a low tone.

I have suggested above that there must be an effect which overrides the effect of stress pattern and renders T3 sandhi an unusual process. What is this effect? I assume that it is the physical constraint on the production of

extreme tones. This physical constraint makes the production of a low falling T3 rather difficult and inhibits successive occurrence. A T3 descends toward the minimum boundary of the possible pitch range for a speaker, and this boundary represents the threshold frequency value of vocal cord vibration in speech. When a speaker slows, but does not suddenly stop the rate of vocal cords vibration enough to close the threshold value, what happens? It is my assumption that a strong tendency of releasing muscular tenseness exists, and this resilience, or springing-back process of muscle movement is necessary. Therefore, acoustically, after the low falling T3, the pitch movement would tend to change along the direction of a returning spring and toward a much higher value.

This assumed tendency can also be seen by analyzing phonological rules. According to the T3 Rule, a T3 should have a low falling contour only when it precedes a T1, T2, or T4, namely a tone with at least one high target. This assumes that a low falling T3 contour must be followed by a tone with a high target.

Evidence for the above assumption exists in my data. It is possible to see that a low falling T3 is always followed by a contour leading to a high pitch target for the local pitch range, when the absent portion of a pitch curves is imagined. If the low-falling T3 occurs before a

pause or is strongly affected by contrastive stress, the situation may change, and this will be seen later. As exhibited in the data, a T3 may be realized as a low level or low falling-rising contour in front of a T1, T2, or T4 in a speech string to form the whole pitch undulation. The exact shape of this T3 is not important; what is important is its "low" feature.

It is seen that a high pitch target always shows up after the low T3. In most cases the target is realized in the next syllable, although sometimes it may also be realized in the syllable following the next syllable. This occurrence is based upon different factors of the speech. This is especially true when the next syllable is a neutral tone. The high target, following the low T3, may develop in the next intermediate phrase, just like what happened in most examples of T3 sequences in this chapter.

The high target may be under-shot in different environments, which often happens if the syllable following the low T3 is a neutral tone. When a T3 is followed by a pause, the springing-back process belongs to the same syllable of the T3. This high target is also often under-shot, thus the tail following the low falling portion rises less. In addition, the spring-back process could become very weak or even stop suddenly for some reasons. Therefore the spring-back process explains why a T3



preceding a pause can be produced as either a low falling-rising contour, or as a purely low falling contour. The major portion of the T3 is the low falling curve, and the rising tail is optional, even at the end of a sentence.

Why then does a T3 lose its low falling properties in front of another T3? I believe that this happens because the first T3 sustains a basic low falling contour, the muscles cannot be relaxed after production, but also must increase tenseness in order to produce the second T3. The Physical constraints make this impossible. Therefore, one T3 must lose its basic contour in order to ease production of the other T3. Logically, there are two possibilities since either T3 could change. Mandarin is a language which favors anticipatory sound change, and the solution is seen in the first T3 which, rather than the second one, becomes a rising tone. A high target will then be realized after the low curve of the second T3.

The above analysis explains how the physical constraint influences pitch production after a low falling portion of a T3. Now, consider pitch movement before the basic low falling portion of a T3. Since it requires special effort to produce a low falling T3, I assume that the muscles must prepare for the production by spending effort in the opposite direction. This preparatory effort results in a high pitch before the low T3 in the pitch track. If the T3

is at the initial position of a sentence, this preparatory effort may be spent before the beginning of vocal cord vibration and hence may not be reflected as a high target in the pitch track.

Reviewing the T3 rule, the requirement of a high target in front of a low T3 is again seen. According to the rule, the purely low tone T3, rather than any other tone, is obligated to change whenever it precedes another T3. This change is caused by the following low T3, and results is the purely low tone obtaining a high target. It is therefore reasonable to assume, that a low T3 requires a high preceding target.

My data also strongly supports another assumption: a low T3 also need a high pitch target occurs preceding the low target. For a sequence containing only two syllables, when the first tone is a T1, T2, or T4, its high target serves as the necessary high target before the low falling T3. When the preceding tone is another T3, it must be changed to allow the realization of the high target. This obligation forces the first T3 to adjust its shape according to both the tendency of pitch undulation and its basic feature. Since the pitch movement before a low falling curve of the T3 prefers a rising contour, the result of this adjustment can only be a rising tone, if there are no other strong influences. This is why T3 sandhi may occur in a

strongly stressed syllable in the T3 sequence. Despite the strength of each, the first T3 of the two always becomes a rising tone.

As illustrated in the data, for an intermediate phrase containing three or more T3's, the pitch contour formation is affected by various factors. Therefore, there are different methods of realizing the high target before a low T3. Using an intermediate phrase of three T3's as an example of this happening, it is seen that the last T3 must be a low contour, and the second T3 may have various shapes. If it becomes a high tone with any shape, the first T3 may either keep its low falling shape or become a rising contour, depending on the stress pattern. Then the tune obtains a Shape 1 contour. If the second T3 is seen as a low rising or falling-rising contour, then the first T3 must have a rising contour before it. The rising contour happens for the same reason as the first T3 in a sequence of two must rise, The whole shape of the pitch contour of this tune is Shape 2.

For a low falling T3 in a polysyllabic intermediate phrase, it is possible for the preceding high target to be realized in a syllable not directly preceding the T3. An example of this is shown in Figure 6.11, on the pitch track of HJS3c. The second intermediate phrase of the sentence contains five T3 syllables: jiudian ye xiang xie,

`also wants to write...at 9:00'. The tune is in a contour of Shape 1; The last T3 retains a low contour, and its preceding high target is realized in the second T3.

In the data, a low T3 contour usually occurs as a valley in a continuous pitch track as long as the pitch range does not change extensively before or after the T3. This is consistent with the two assumptions that a low T3 contour is expected to be surrounded by two high pitch targets.

In summary, because T3 has a very low target, I assume that the physical constraint of its production causes a speaker to make special effort. Acoustically, the special effort needed for producing a T3 is reflected in the obligatory high pitch targets preceding and following it. The tone sandhi of a strongly stressed syllable in a sequence of T3's can be explained by such obligatory high pitch targets.

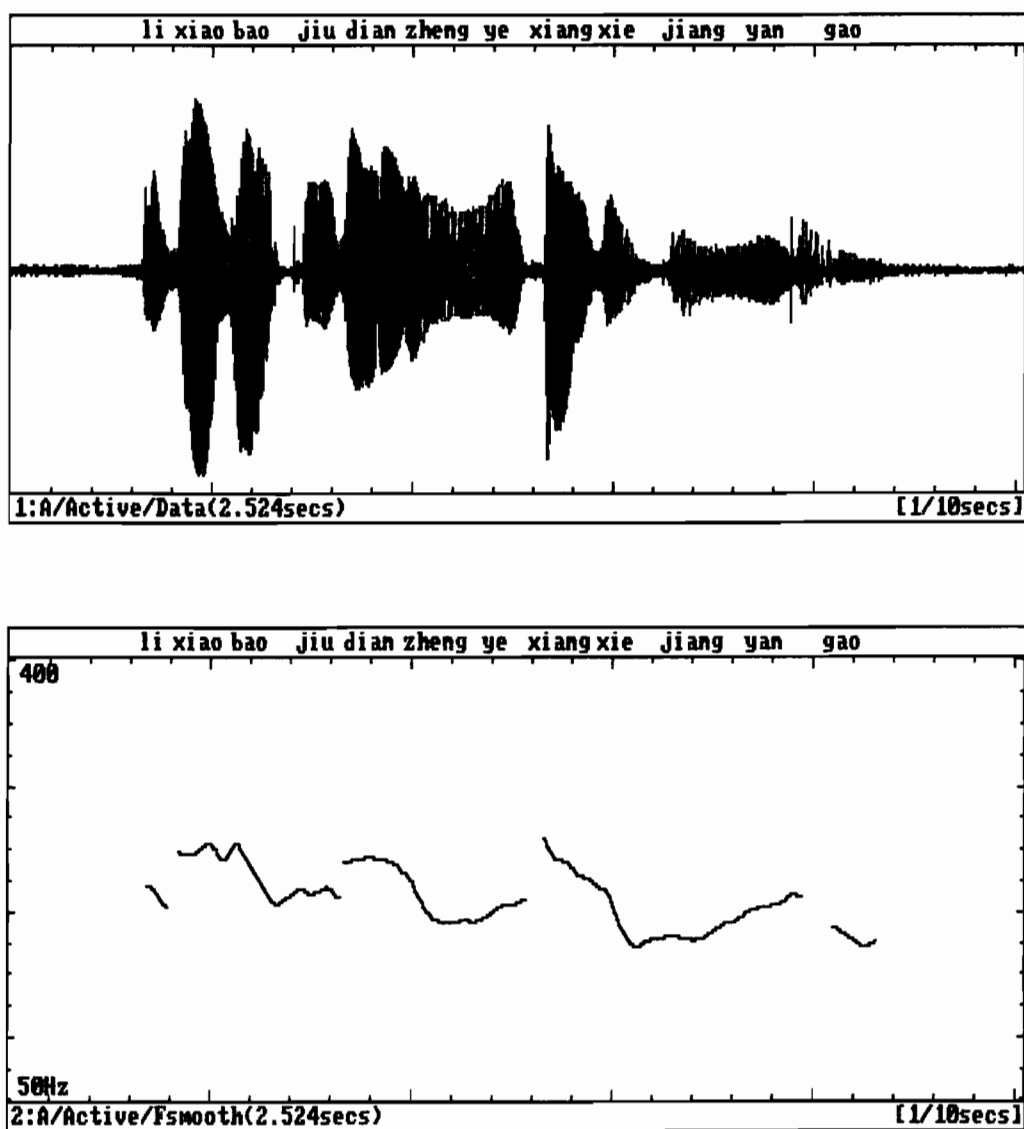


Figure 6.1 Waveform and pitch tracks of sentence HJS6a, Li Xiaobao jiudianzheng ye xiang xie jiangyangao. 'At 9:00, Li Xiaobao wants to write the draft for a lecture.'

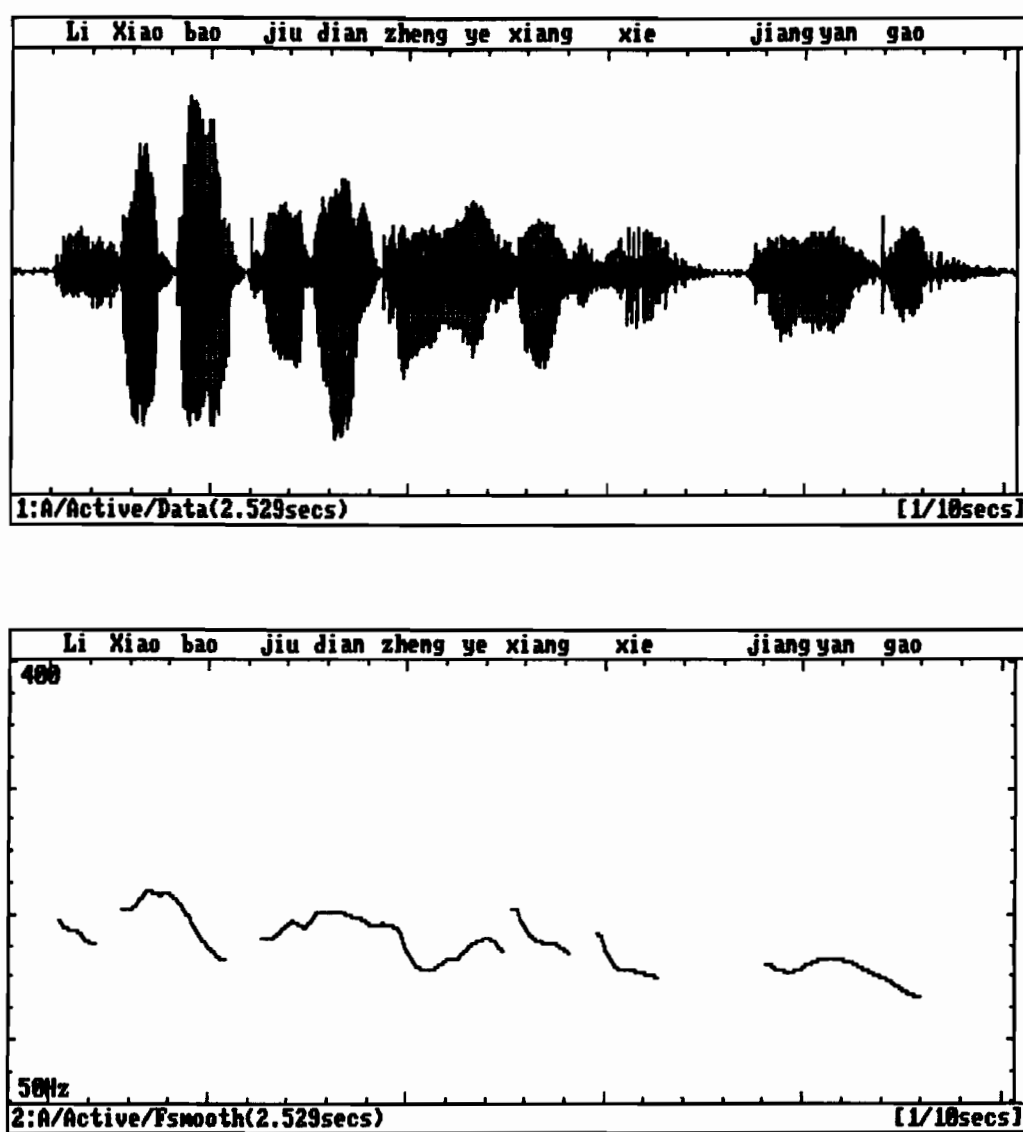


Figure 6.2 Waveform and pitch tracks of sentence ZJS6a, Li Xiaobao jiudianzheng ye xiang xie jiangyangao. 'At 9:00, Li Xiaobao wants to write the draft for a lecture.'

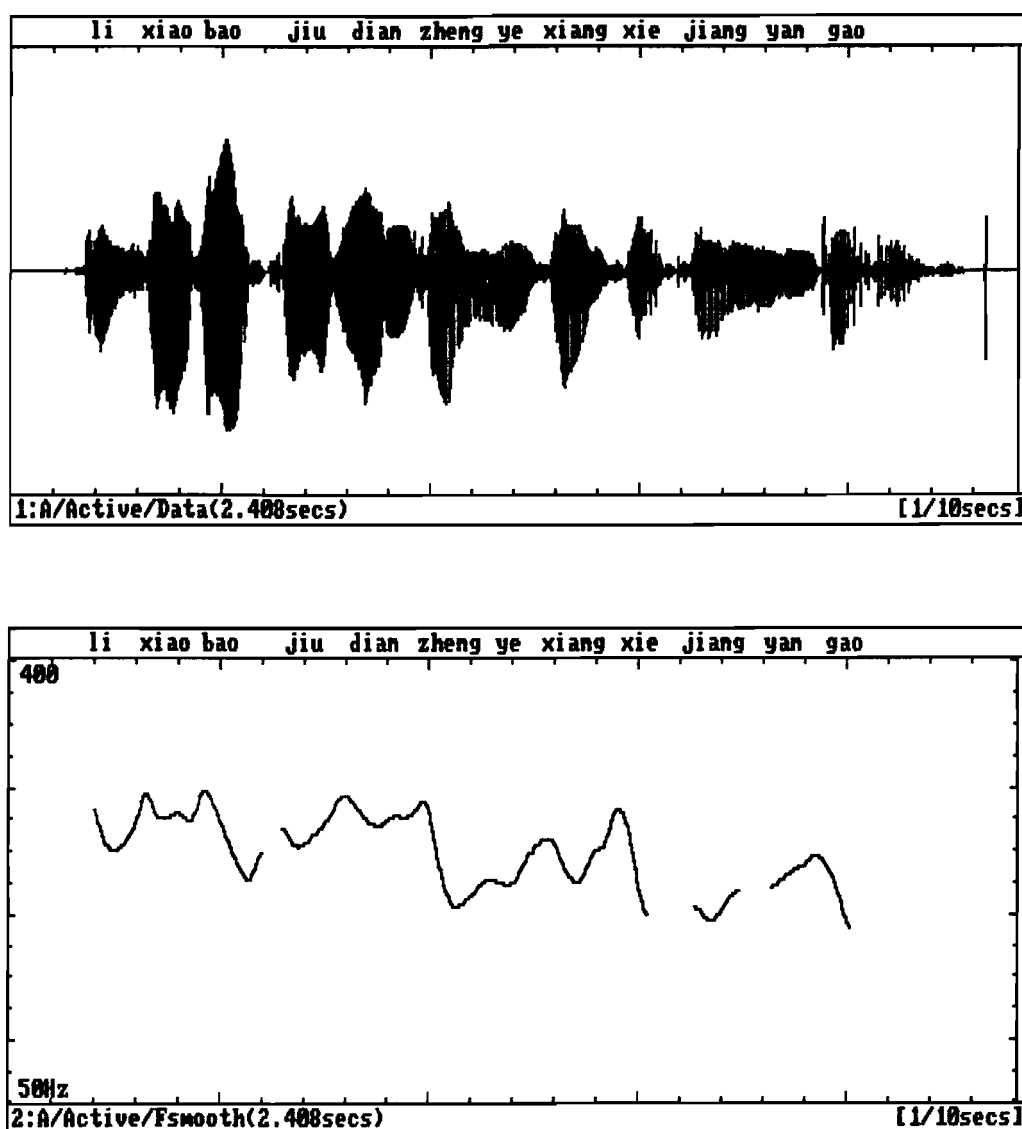


Figure 6.3 Waveform and pitch tracks of sentence CJS6a, Li Xiaobao jiudianzheng ye xiang xie jiangyangao. 'At 9:00, Li Xiaobao wants to write the draft for a lecture.'

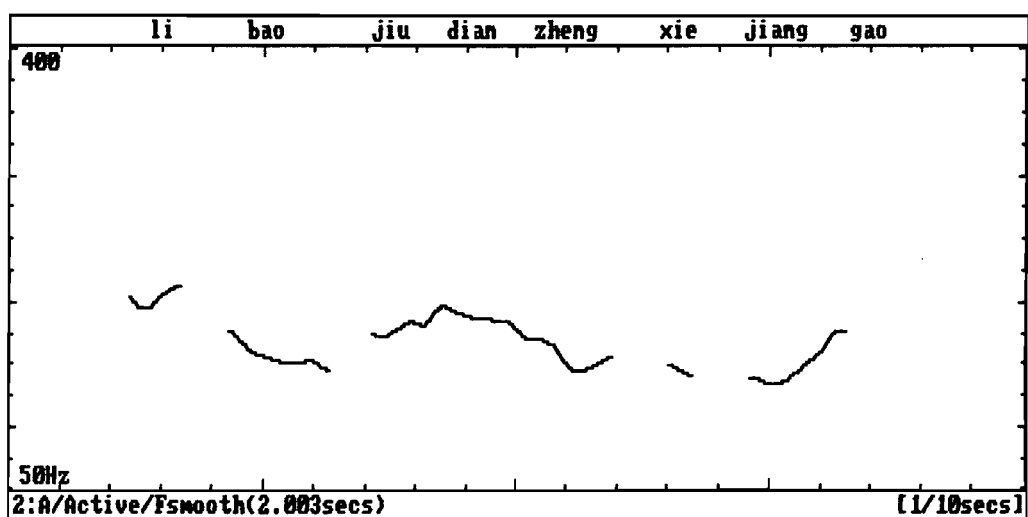
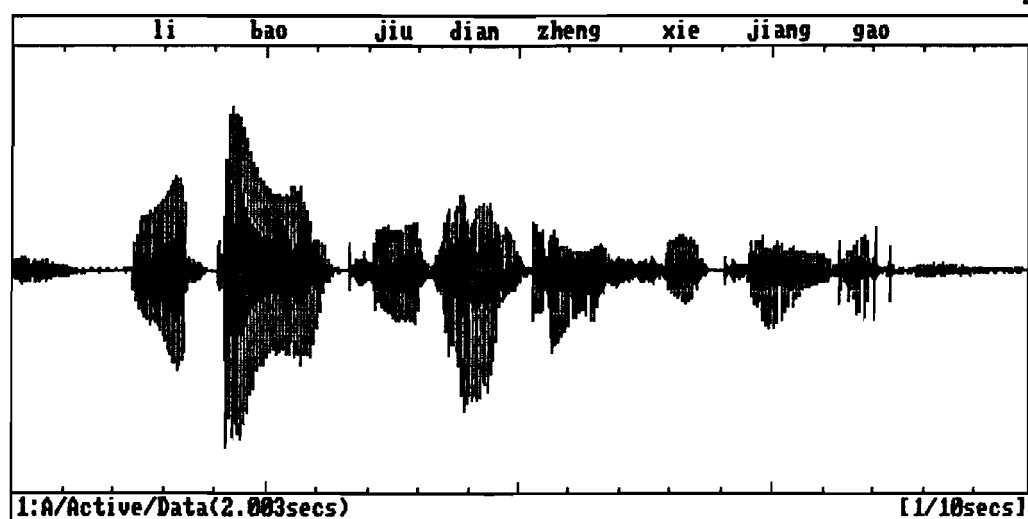


Figure 6.4 Waveform and pitch tracks of sentence ZJS6b, Li Bao jiudianzheng xie jianggao. 'At exactly 9:00, Li Bao will be writing a draft for a lecture.'



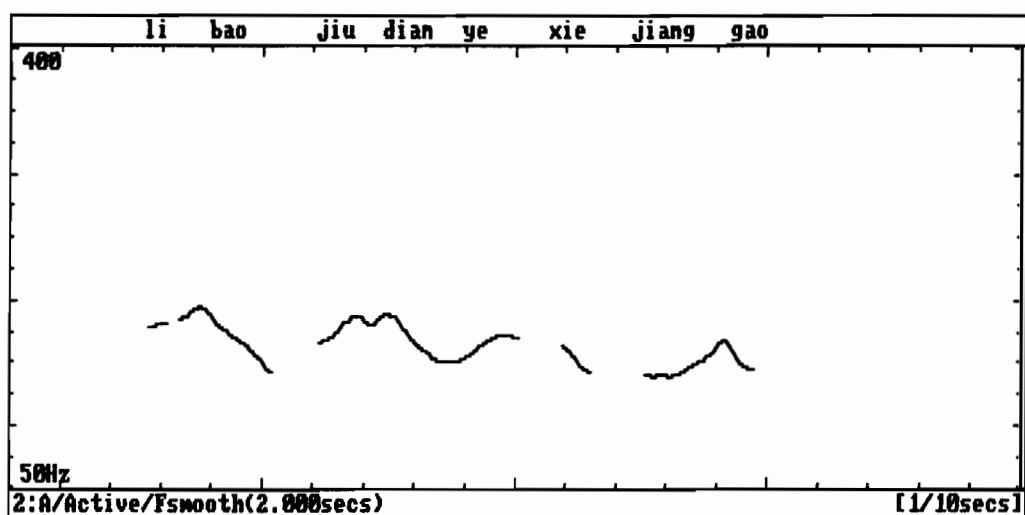
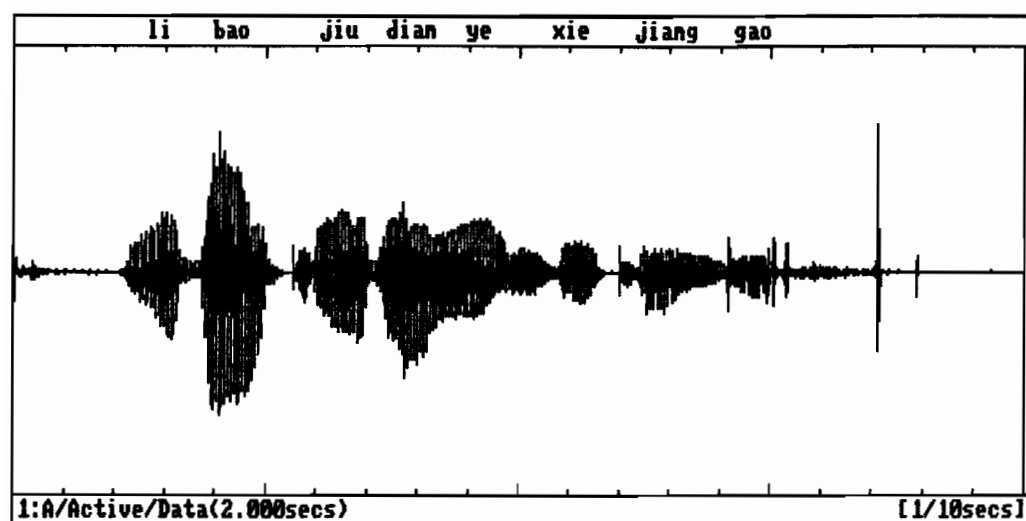


Figure 6.5 Waveform and pitch tracks of sentence ZJS6c Li Bao jiudian ye xie jianggao. 'At 9:00, Li Bao will also be writing a draft for a lecture.'

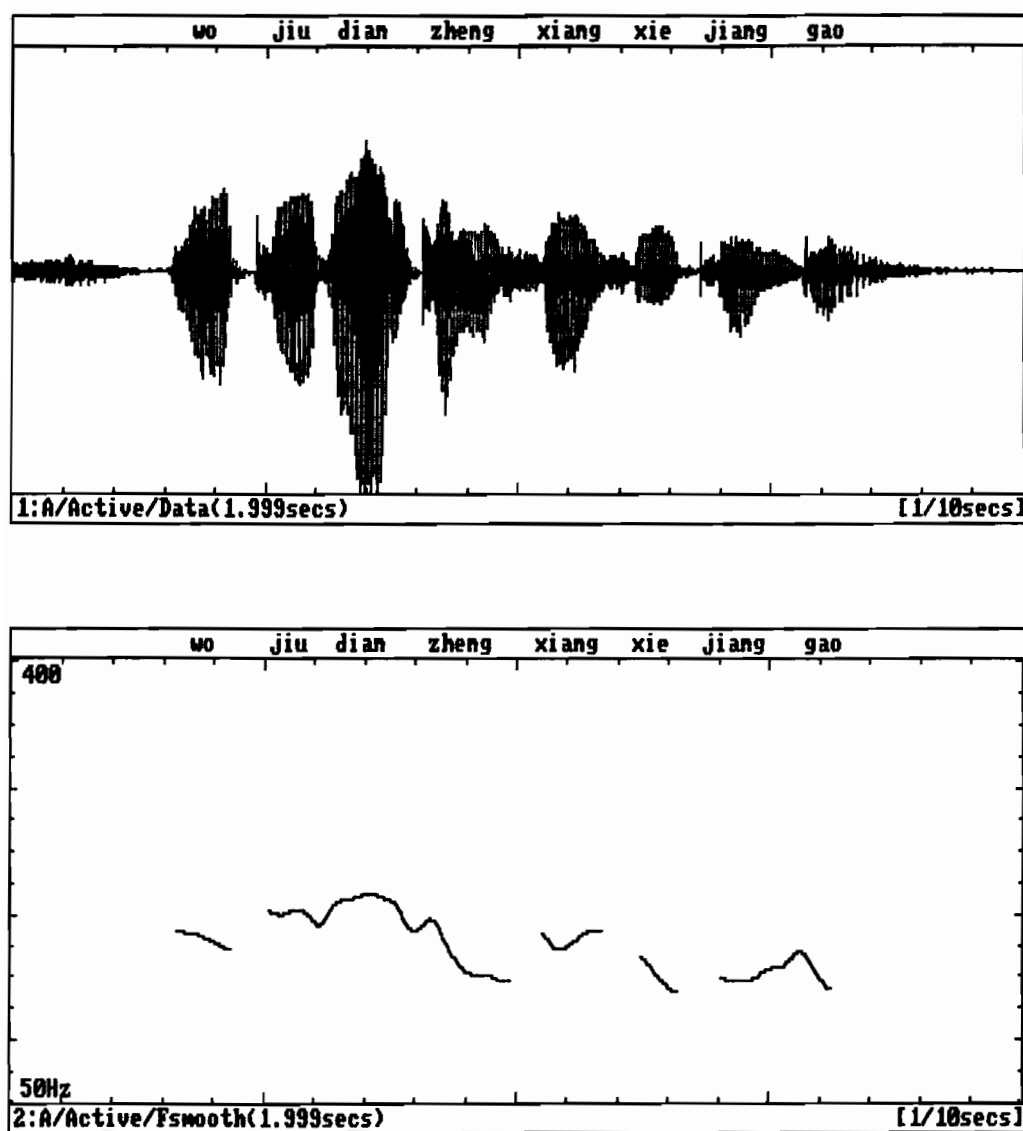


Figure 6.6 Waveform and pitch tracks of sentence ZJS6d Wo jiudianzheng xiang xie jianggao. 'At exactly 9:00, I want to be writing a draft for a lecture.'

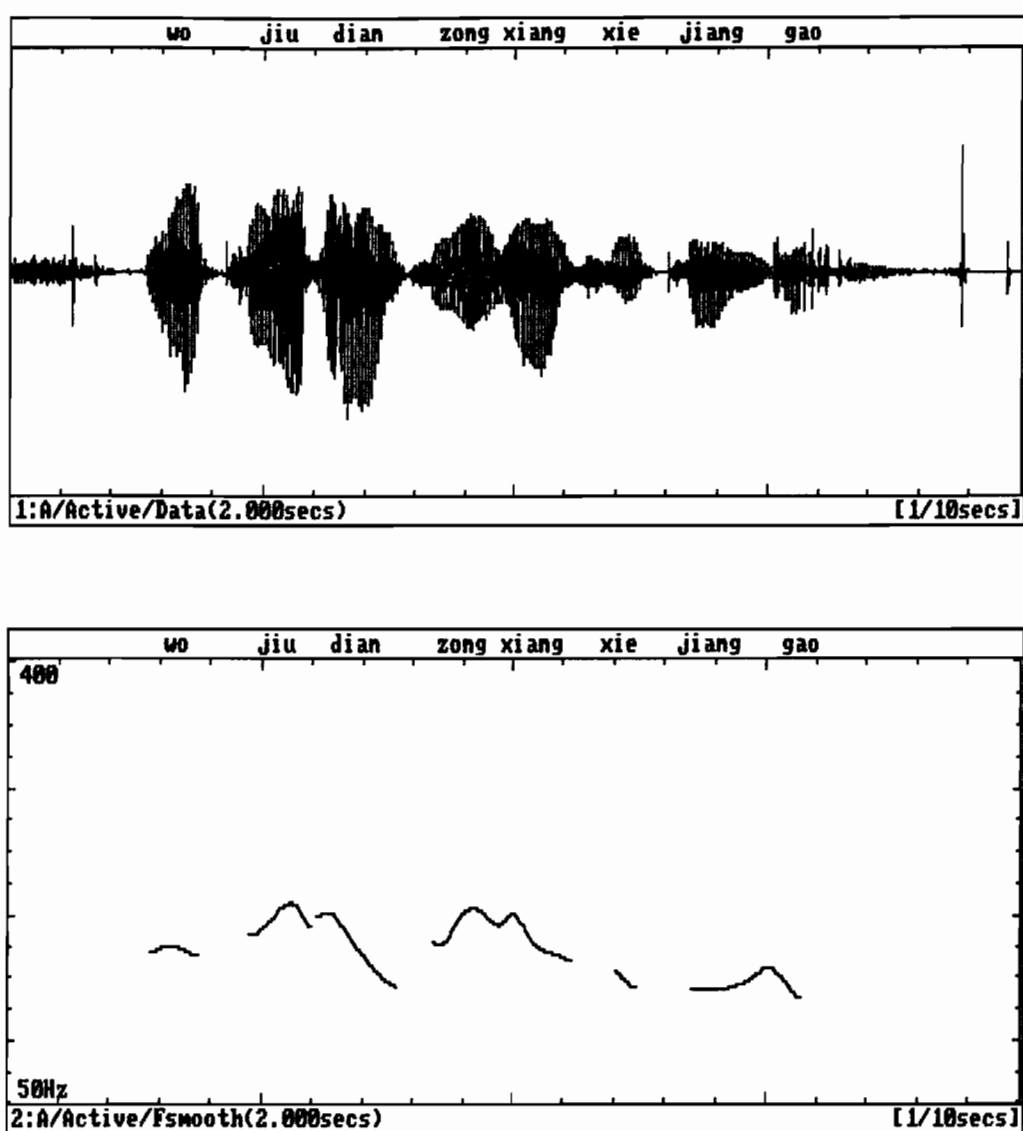


Figure 6.7 Waveform and pitch tracks of sentence ZJS6e Wo jiudian zong xiang xie jiangqao. 'At 9:00 I always want to write the draft for a lecture.'

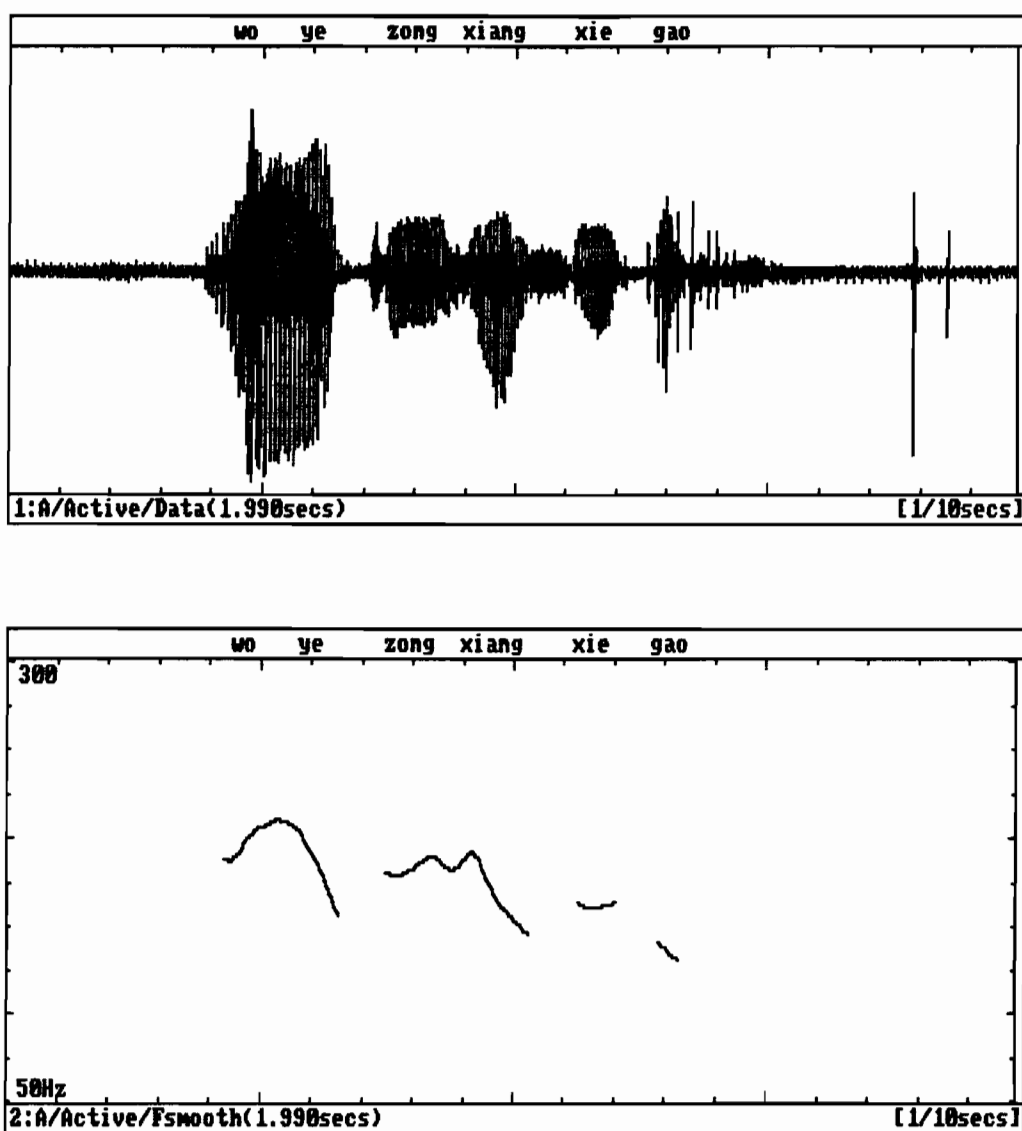


Figure 6.8 Waveform and pitch tracks of sentence ZJS6f, Wo ye zong xiang xie gao.  
'I always want to write the draft, too.'

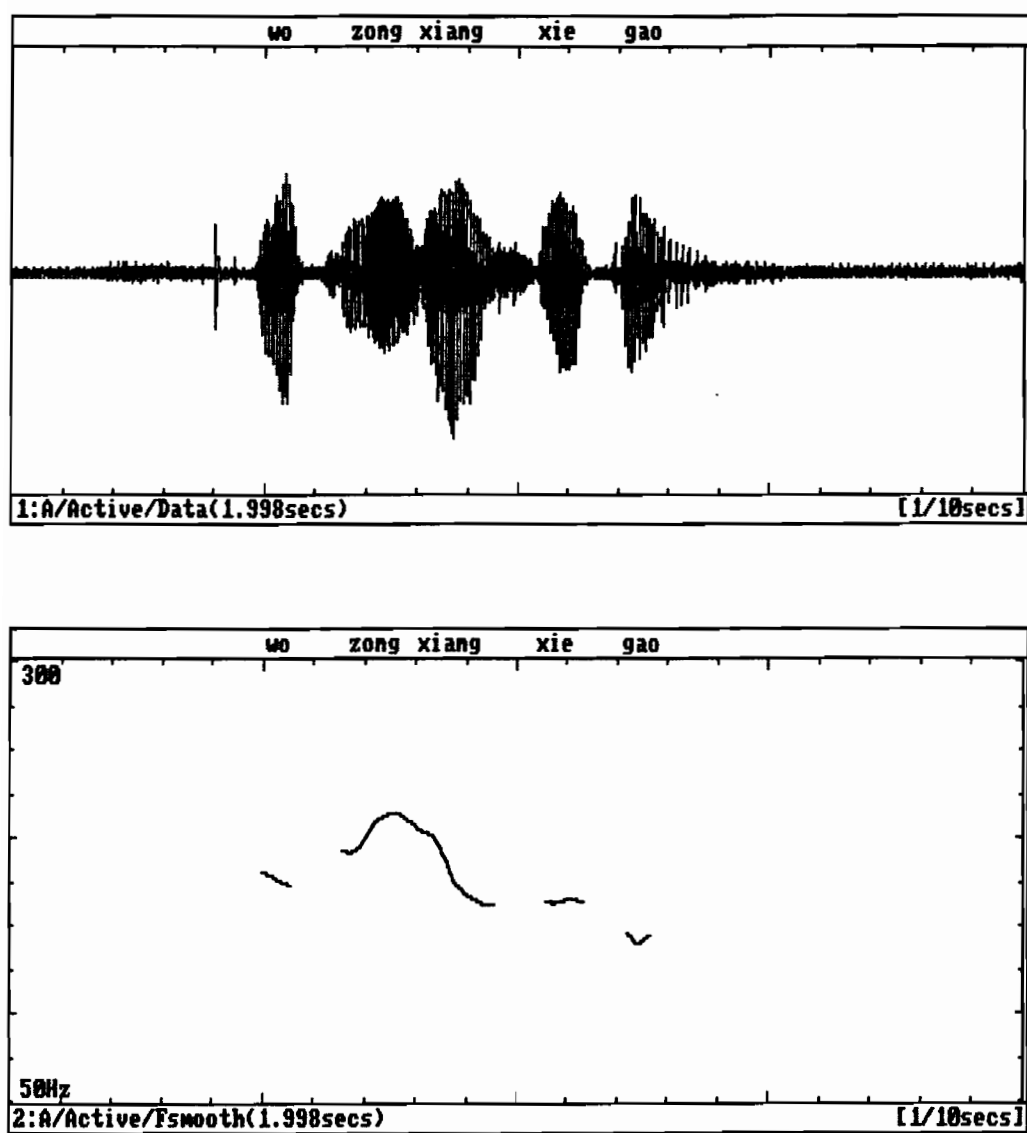


Figure 6.9 Waveform and pitch tracks of sentence ZJS6g, Wo zong xiang xie gao. 'I always want to write the draft.'

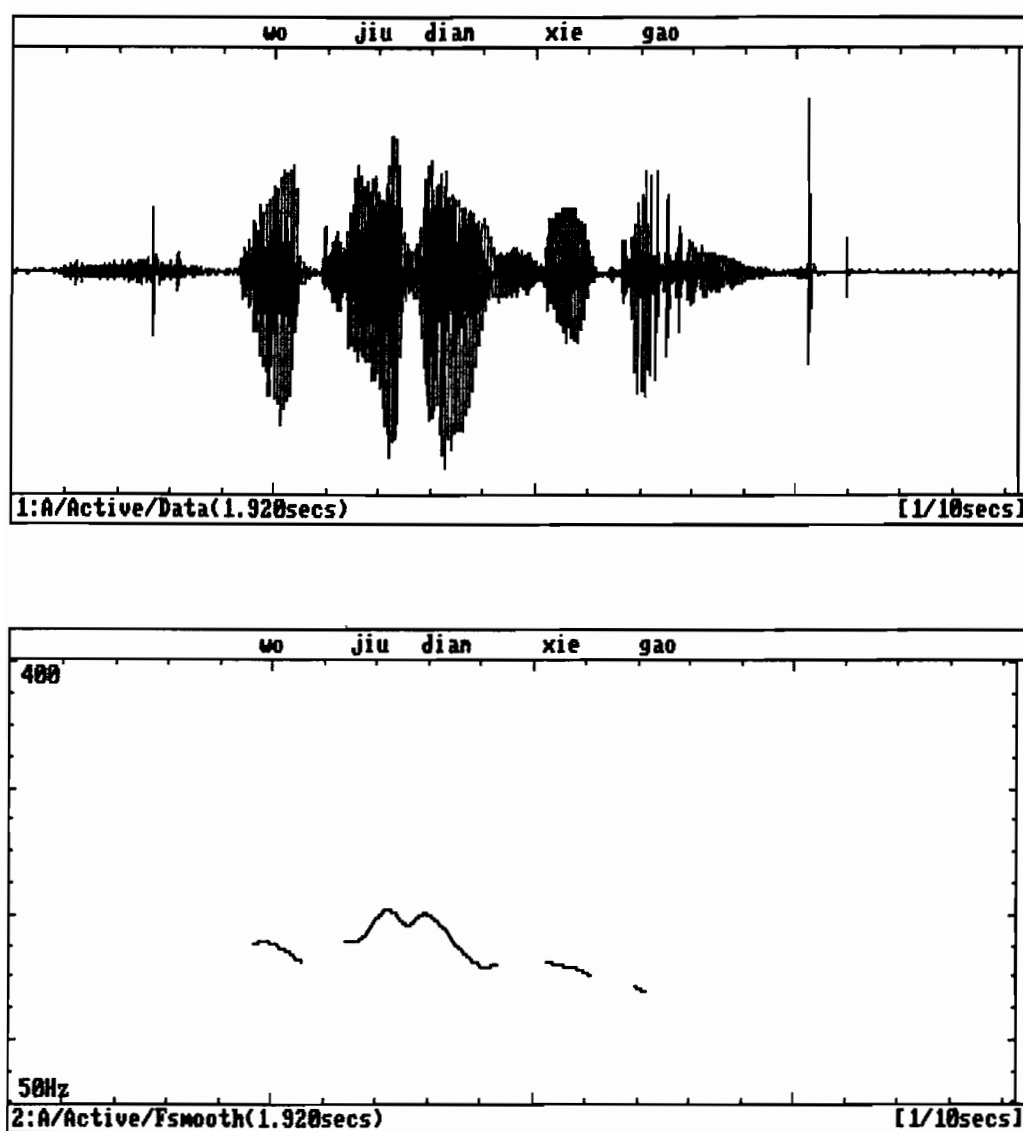


Figure 6.10 Waveform and pitch tracks of sentence ZJS6h, Wo jiudian xie gao. 'At 9:00 I will write the draft for a lecture.'

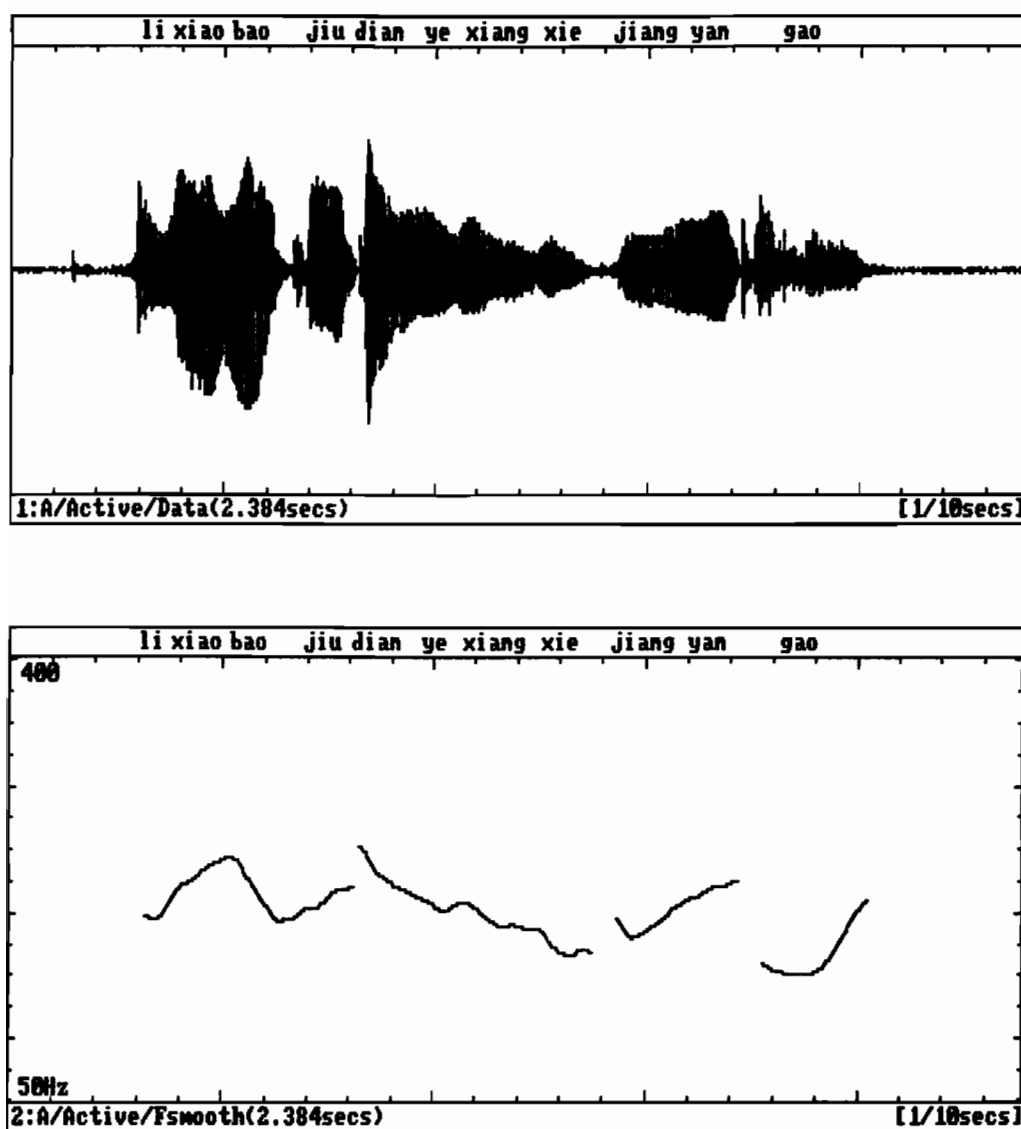


Figure 6.11 Waveform and pitch tracks of sentence HJS3C, Li Xiaobao jiudian ye xiang xie jiangyangao? 'Does Li Xiaobao want to write a draft for a lecture at 9:00, too?'

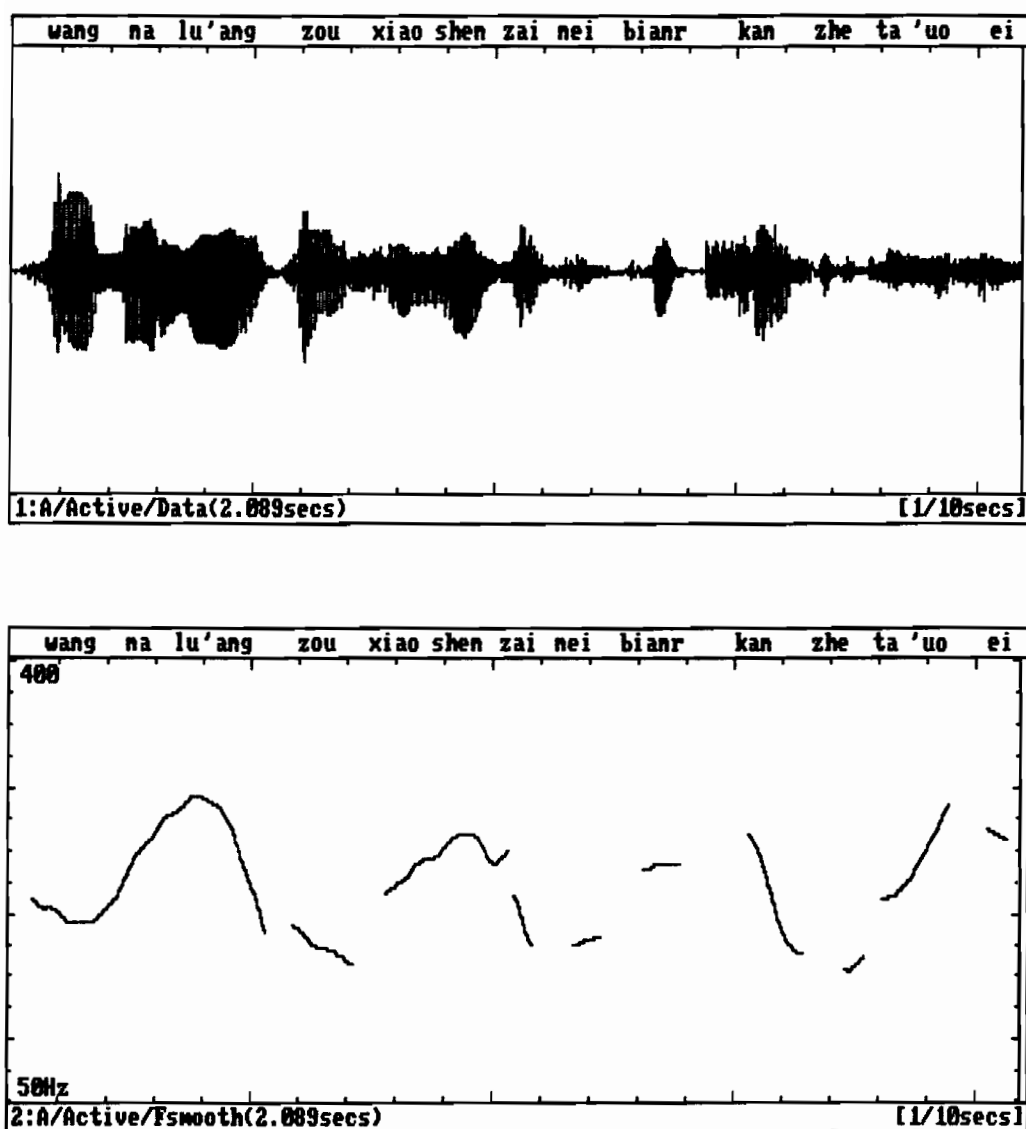


Figure 6.12 Waveform and pitch tracks of sentence ZJ4243, Wang na lushag zou, Xiao Shen zai neibianr kanzhe, ta shuo: 'Ei... ' 'When I was driving toward that street, Xiao Shen was watching there, he said: "Oh..."'



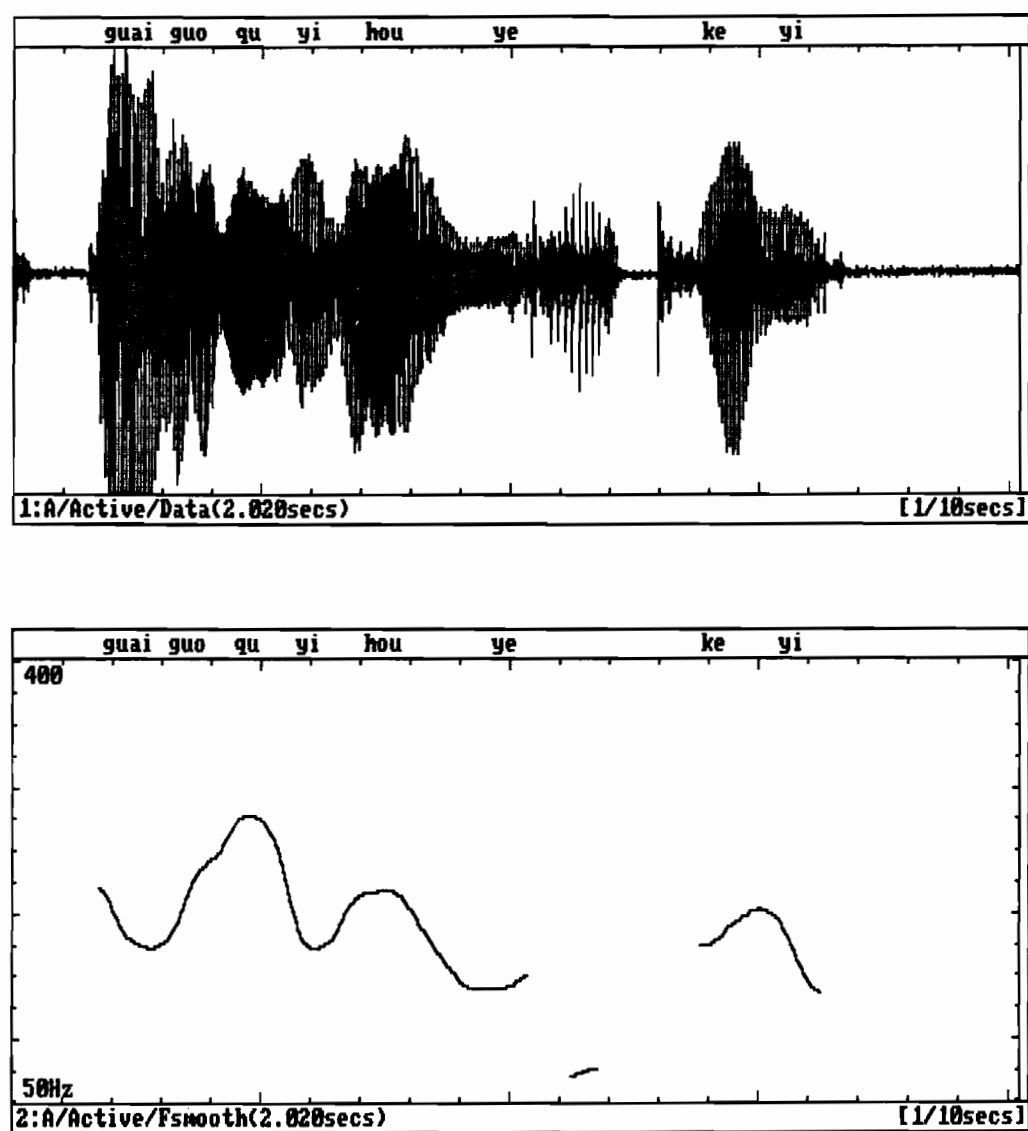


Figure 6.13 Waveform and pitch tracks of sentence ZJ65, Guai guoqu yihou ye keyi. 'It is still O.K. after turning around.'

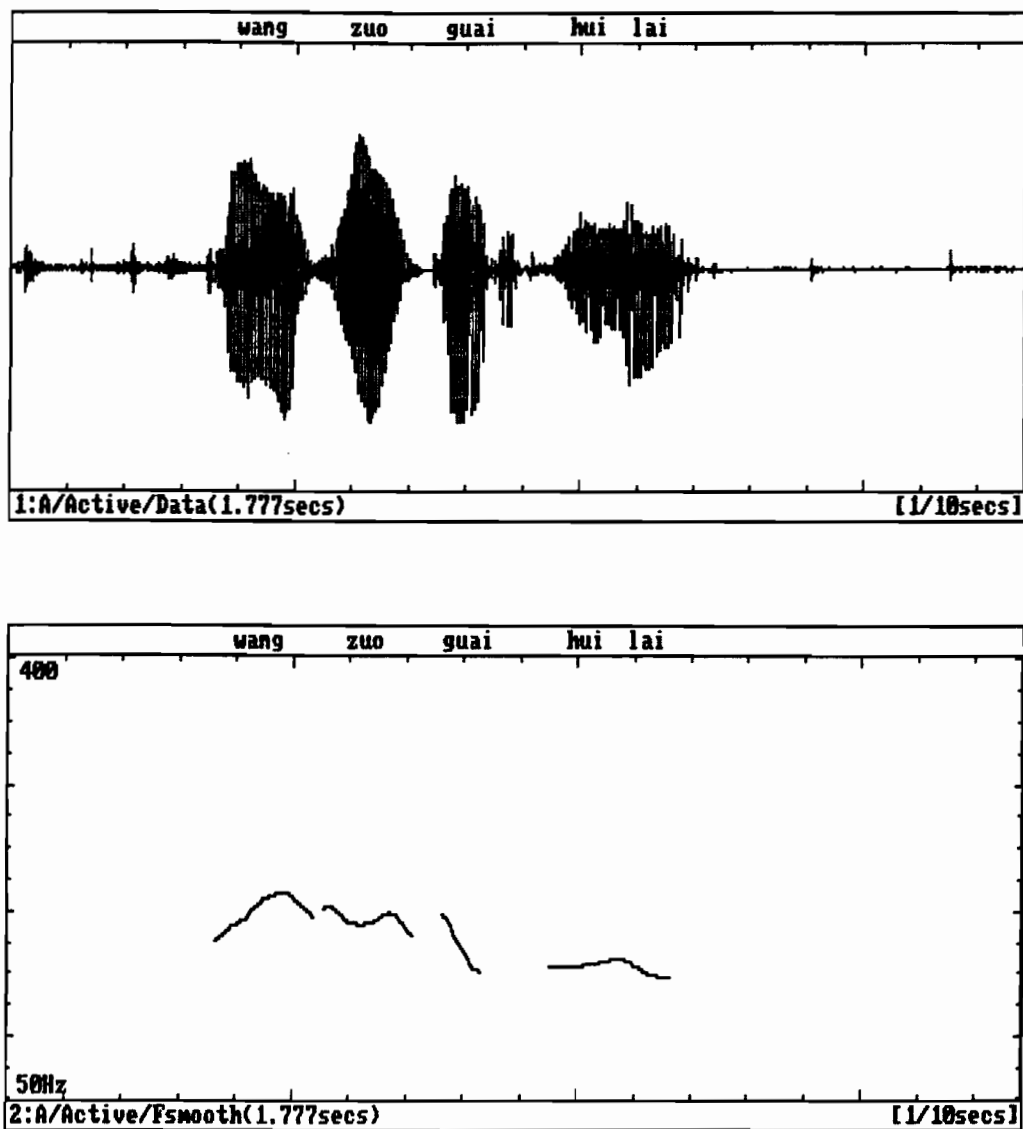


Figure 6.14 Waveform and pitch tracks of sentence ZD80, Wang zuo guai huilai,... '(I) turned back from left, ...'

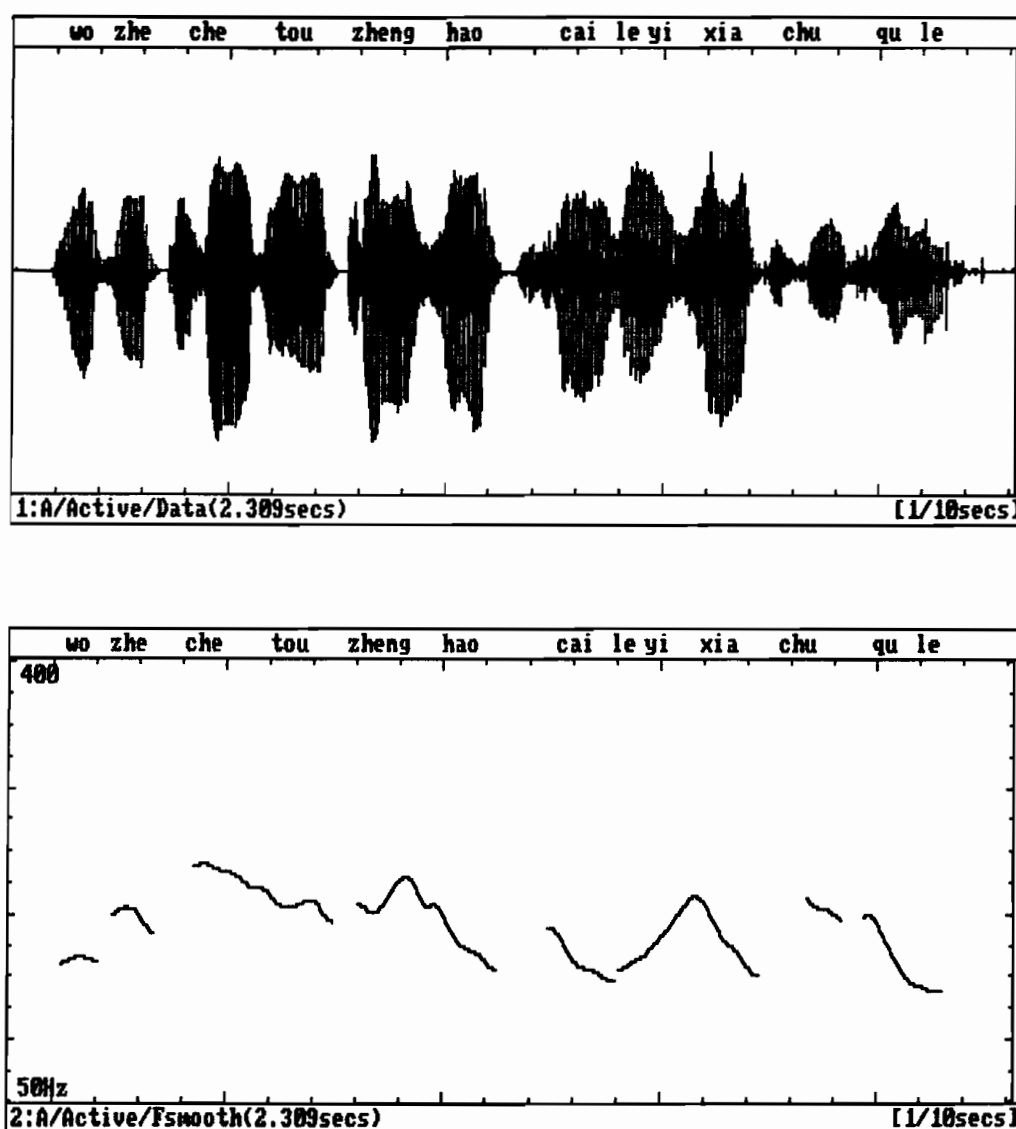


Figure 6.15 Waveform and pitch tracks of sentence ZD85, Wo zhe chetou zhenghao cai leyixia chuqu le. 'I just stepped on the accelerator, and the head of the car crossed the stop line.'

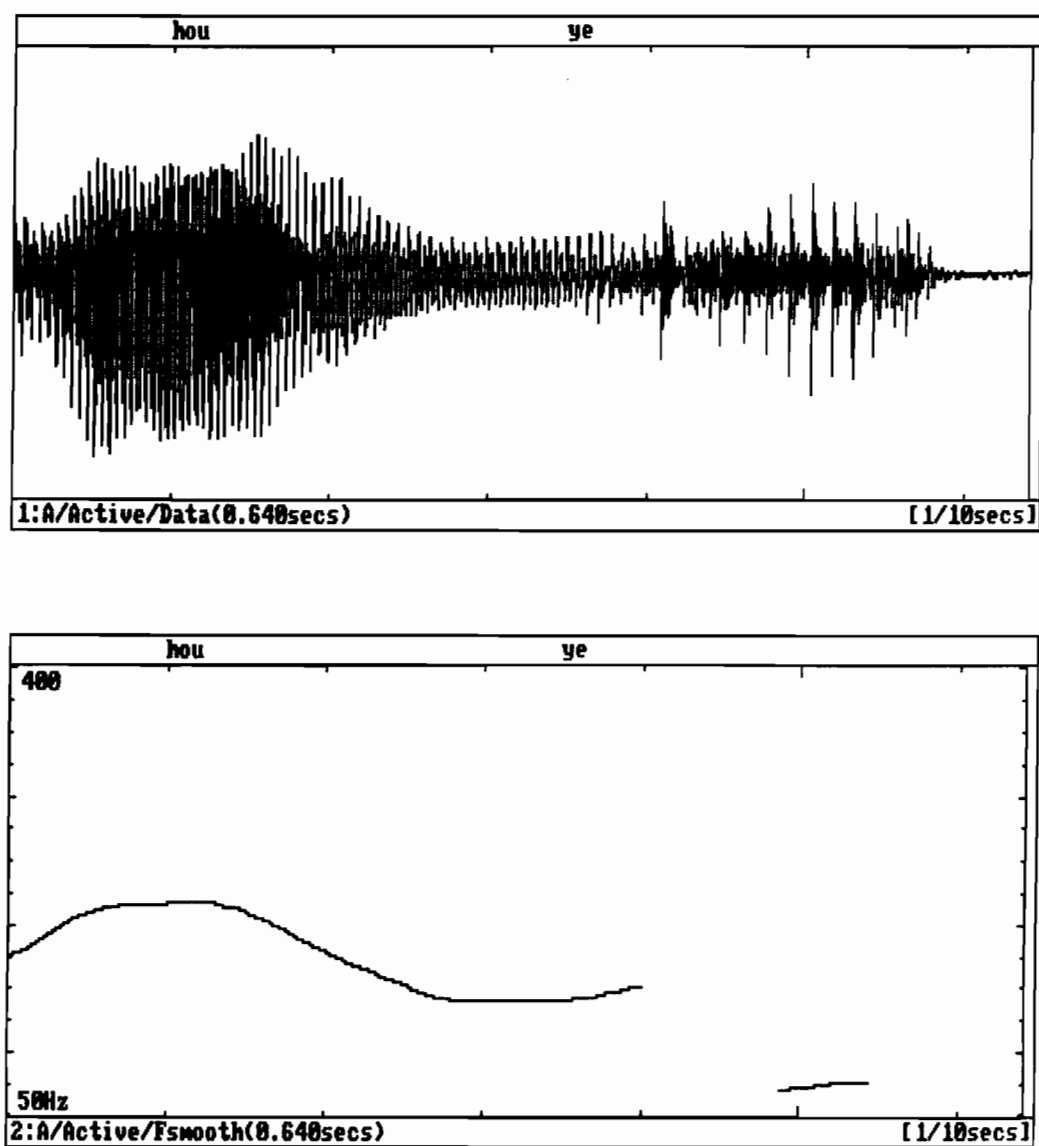


Figure 6.16 Waveform and pitch tracks  
of syllable hou 'after' and ye 'also' in  
sentence ZJ65.

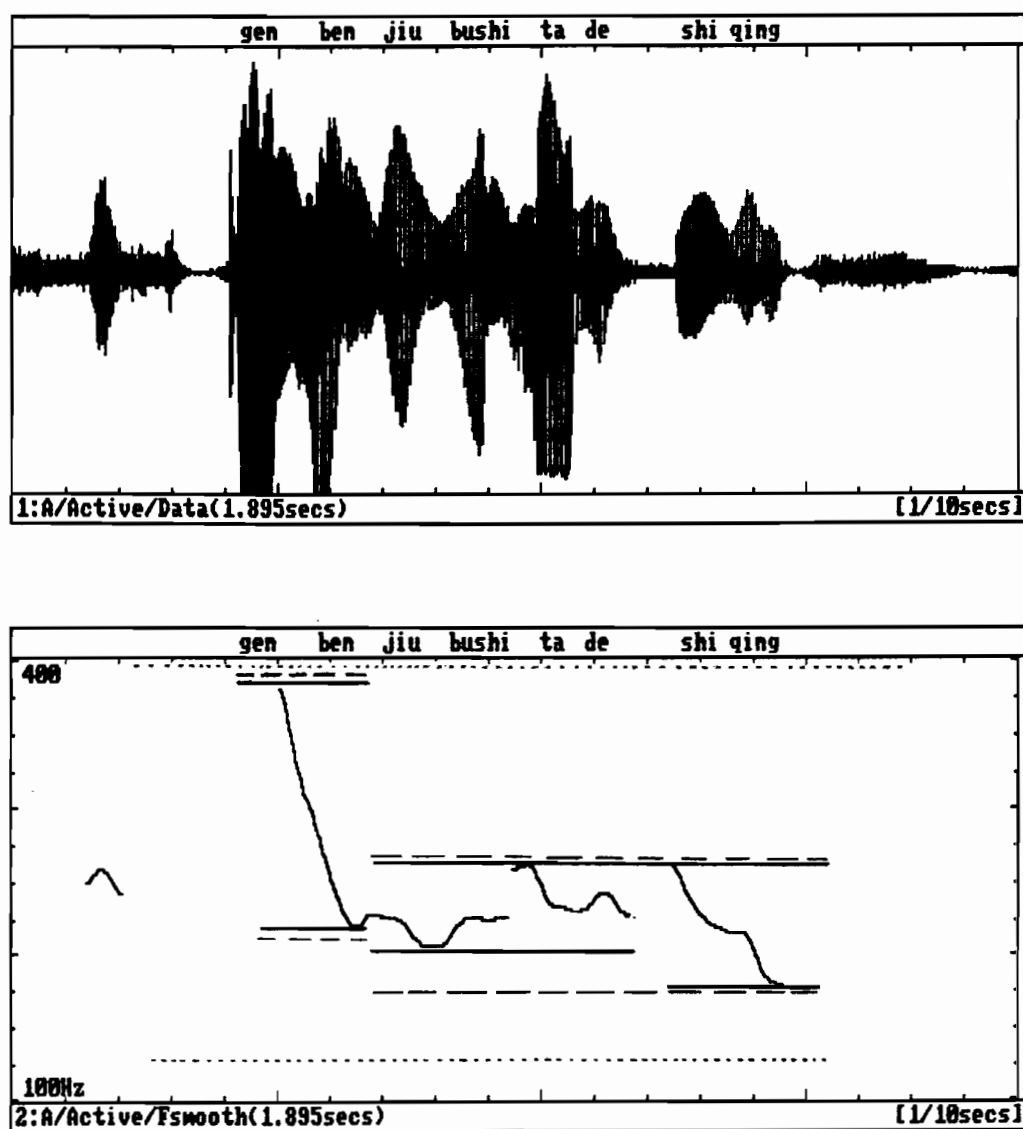


Figure 6.17 Waveform and pitch tracks of sentence HJ64 Genben jiu bu shi ta de shi qing. 'This is simply not her fault.'

— actual pitch range, ---- imagined pitch range, ..... possible pitch range.

## CHAPTER VII

### OTHER EFFECTS ON PITCH CONTOURS

In this chapter I will discuss the influences of catathesis, strong emphasis, sentence type, and speech style on pitch movement in a sentence. Each of these effects changes some aspects of the shape of a pitch undulation. Some of them may affect pitch contour realization of certain tones, and result in unexpectable shapes, according to the Principle of Pitch Contour Formation in Intermediate Phrases. Some of the influences may affect only the averaged frequency value rather than the actual shape of the pitch contours.

#### 7.1. Effect of catathesis

As defined in Chapter 2, catathesis refers to a downtrend of fundamental frequency, triggered by a sequence of target tones HLH. In the data of pitch tracks, a downtrend in the peak value over an pitch undulation is often obvious. However, for the uncontrolled data, it is impossible to confirm whether or not it is triggered by the effect of catathesis, since other causes exist. I will

discuss the effect of catathesis according to the pitch tracks of the tonal controlled sentences produced by the speakers.

#### 7.1.1.1. The test material

As introduced in Chapter 3, the design of the test is: to use T1, T3, or T4 in syllables wu and yao in the following sentence in order to form seven test sentences. These sentences are identified as WiYj (i or j = 1, 3, or 4) in declarative mood and as RWiYj in interrogative mood ("R" identifies interrogative mood).

- (1)            Zhang Wu-yi yao maomi.  
                  55        ?   55 ?       55 55            UT  
                  Zhang Wu-yi V       cat  
                  "Zhang Wu-yi V    a cat."

The assumption for this design is: all syllables, except wu and yao, have a T1. When a T3 occurs in either of the two syllable positions within the tonal environment of T1's, a high falling-rising pitch contour with the target sequence HLH should be formed. The effect of catathesis should be triggered, if this effect exists in Mandarin Chinese. T4 already has an "HL" feature by itself. A falling-rising contour should also be formed by a T4 and the following T1 whenever the T4 occurs in either of the two syllables in the test sentence. Again, the effect of catathesis should also

be triggered, if it exists. Due to the test's design, the magnitude of the possible catathesis triggered by different tones in different places, and the difference between single effect and chained effect, can be roughly tested.

The sentences uttered by four speakers are produced in a casual reading style and containing only one intermediate phrase. The formation of their pitch undulations reflects the Principle of Pitch Contour Formation in Intermediate Phrases. The two test syllables wu and yao are strongly stressed and hence keep the basic contours of their tones. Usually the middle syllable of a trisyllabic name Zhang Wu-yi would be stressed weakly. However, in this experiment, since the test tones occur in the middle syllable of this name, the speakers unconsciously place a rather strong stress on that middle syllable. Some of the other syllables are weakly stressed in the sentences, and therefore their T1's are changed in shape and lowered in height. For example, the T1 in syllable yi or mao is often realized as a low rising contour in order to serve as the transition between tones of stronger syllables.

I have measured frequency values of most T1's at the middle point of the syllable. However, for the T1 of syllable yi in a sentence containing two T3's, the measurement has been taken at the peak of the pitch contour. This is because the T1 is usually realized as a



rising-falling contour between the two T3's, and the peak value, is often quite different from the frequency value at the middle point of the syllable. The importance of the pitch value is due to its usage in testing the chained effect of catathesis. The measurement of a T3 or T4 is taken at both the starting point of the syllable and the lowest point of the falling portion of the pitch contour. Because of the voiced consonants, most sentences exhibit a continuous pitch track. However, the pitch track is often broken in sentences with a T3, and a part of the T3 may not appear. In these cases, the measurement has been taken on the lowest point of the shown portion of the T3.

Figures 7.1-7.14 show one pitch track of each test sentence produced by speaker Sh. The averaged measures (in Hz) for each speaker and among speakers are listed in Table 7.1 in the appendix. "SPK1"-"SPK4" indicates speakers Q, Zh, J and Sh. "Wuh" and "wul" or "yaoh" and "yaol" refer to the two measurements for a T3 or T4 in the syllable wu or yao respectively. The coding "h" and "l" indicate the higher and lower portions on the measured tone respectively. As designed, "WiYj" indicates a declarative sentence, and "RWiYj" an interrogative sentence. Each sentence has a  $T_i$  ( $i=1, 3, \text{ or } 5$ ) and a  $T_j$  ( $j=1, 3, \text{ or } 5$ ) in the syllables wu and yao.

### 7.1.2. Declination and catathesis in declarative sentences

To begin with, I will discuss catathesis in declarative sentences. Sentence W1Y1 contains six T1's. Since there are no low targets for these tones, the effect of catathesis does not exist. Pitch tracks of the sentence are straight lines, shown in Figure 7.1, when the syllables are equally stressed. The lines often undulate somewhat because of the different strength of stresses. The averaged measurements show that the amplitude of the undulation is as large as about 20 Hz for some speakers. In order to see if there is a general tendency to increase or decrease in frequency values, I will compare measured values of relatively strongly stressed syllables. The stress pattern of the sentence is produced as follows.

(2)		Zhang	Wu-yi	yao	mao	mi.		
		S	S	W	S	W	S	
		55	?	55	?	55	55	UT
		Zhang	Wu-yi	V		cat		
		"Zhang	Wu-yi	V		a cat."		

For three of the four speakers, the frequency changes among strongly stressed syllables is one of decrease. For speaker 1, the highest frequency value always occurs in syllable yao, so the decreasing starts late. Listening to the tape, yao is produced as a stress that somewhat stronger than the other syllables.

The size of the declination can be roughly counted by using the normalized value of frequency in syllable zhang as the reference, i.e. 100%. Frequency values of other measurements are normalized as percentages according to this reference. The averaged percentages of the declination for each speaker and for all speakers are shown in Table 7.1. The average is 10%, and differences exist among the speakers.

Table 7.2 Normalized frequency values in sentence W1Y1 produced by each speaker

-----					
W1Y1    zhang wu yi yao mao mi					
	zhang	wu	yao	mi	declination
-----					
SPK1	100	99	102	94	6
SPK2	100	100	92	85	15
SPK3	100	102	95	92	8
SPK4	100	100	99	88	12
-----					
Average(%)	100	100	97	90	10
-----					

Now, I will discuss the effect of catathesis which may exist in sentences containing tones with low targets. The first step requires deciding the domain of the HLH sequence in pitch undulation of each test sentence, i.e. discovering which two syllables contain the high targets H's. The second step is to compare the frequency values of

their tones to see if the effect of catathesis exists, and also to see what is the extent of the effect if it does exist.

When locating the high targets of a HLH sequence, one phenomenon is worthy of attention. This phenomenon occurs when a weakly stressed T1 follows a T3 or T4, it is often realized as a low rising contour, and its frequency value is rather low, and consequently should not be treated as a high tone. The high target should be identified in the proceeding stronger syllable. For example, in Figure 7.4, the sentence is:

```
(3)   W3Y1:
      ; Zhang Wu-yi yao mao mi.;
      S      S  W  S      W  S
      55      21 55 21   55  55           UT
      Zhang Wu-yi V   cat
      "Zhang Wu-yi V   a cat."
```

Both wu and yao have a T3, and each of the other syllables has a T1. The average frequency value (176 Hz) of the T1 in the syllable yi is much lower than that (203 Hz) of the following T1 in the stronger syllable yao. The high target is in syllable yao rather than yi, although yi is immediately following the syllable wu which contains the low target of the HLH sequence.

Keeping in mind that these similar phenomena occur in different sentences, I will test the effect of catathesis

by comparing frequency values of high targets in strongly stressed syllables. Since almost all utterances of the seven sentences contain the same stress pattern, the targets of the HLH sequence are identified in the sentences as follows.

(4)

W1Y3	zhang	wu	yi	yaoh	yaol	mao	mi	
		H			L		H	
W1Y4	zhang	wu	yi	yaoh	yaol	mao	mi	
			H		L		H	
W3Y1	zhang	wuh	wul	yi	yao	mao	mi	
		H		L		H		
W3Y3	zhang	wuh	wul	yi	yaoh	yaol	mao	mi
		H		L	H		L	H
W4Y1	zhang	wuh	wul	yi	yao	mao	mi	
		H		L		H		
W4Y4	zhang	wuh	wul	yi	yaoh	yaol	mao	mi
		H		L		H	L	H

There are other means of identifying the HLH sequence for some of these sentences, such as according to placement of stresses. For example, Speaker 1 produces sentence W1Y3 with a stronger stress on syllable yi rather than wu. As shown in Figure 7.2 and the averaged values, the T1 in yi is slightly higher than that of wu, so the HLH sequence starts from syllable yi. However, because the difference in frequency value is very small and all of the other speakers produce a stronger stress and hence a higher T1 in syllable

wu, I still consider wu as the syllable for the first H. For the same reason, the targets in a HLH sequence will still be marked as shown in the above manner.

The only irregular identification of a high target is in sentence W3Y3, where the weakly stressed syllable yi is treated as having an H. Normally, it may not be marked by an H, since it is in a weak syllable. Its "high" feature may be lost when it serves as a transition between the surrounding tones, as happens between the two T4's in sentence W4Y4. However, the T1 of yi is between two stronger T3's. Assuming that there must be a high target before or after a low T3, this T1 could not be realized as a low transition between the two T3's. Rather, It is expected to realized as a pitch contour with a high target. In actuality, the T1 does obtained a high target to keep its "high" feature, though the shape of its pitch contour is changed. Comparing the averaged frequency value in this yi and that of the yi in sentence W4Y4 or W3Y1, the difference is easily seen. The corresponding high target in W4Y4 or W3Y1 is in the following stressed syllable yao, therefore rendering T1 of yi much lower than that in W3Y3.

Having found the domain of the HLH sequence in each sentence, I then normalize the averaged measurements for each of the three targets by using the value of the first H as a reference, i.e. 100%. Next I measured the decrease

between the two H's and treat the resulting positive values (in percentage) as rough estimates of the size of the catathesis in the HLH sequence. Following is the formula:

$$(5) \quad \text{Catathesis} = \frac{H1 - H2}{H1} \times 100\%$$

"H1" and "H2" indicate the first and the second H's in the HLH sequence respectively. In fact, the decrease may be caused by both declination and the effect of catathesis. However, I will ignore declination as a cause for the decrease for three reasons: first, the relationship between the two is yet unclear to me; secondly, the amount of declination is very small; and thirdly, the amount of the declination that I measured in the above examples may not be accurate due to the small sample size. Table 7.2 lists the normalized averages of measurements for each of the three targets and the values of catathesis.

Table 7.3 Normalized averages of frequency measurements for each of the three targets and the value of catathesis in each sentence WiYj

W1Y3 zhang wu yi yaoh/yaol mao mi  
H L H

	wu	yaol	mi	catathesis
SPK1	100	63	82	18
SPK2	100	54	88	12
SPK3	100	49	80	20
SPK4	100	47	85	15
Average(%)	100	53	84	16

W1Y4 zhang wu yi yaoh/yaol mao mi  
H L H

	yaoh	yaol	mi	catathesis
SPK1	100	77	82	18
SPK2	100	70	85	15
SPK3	100	78	80	20
SPK4	100	74	74	26
Average(%)	100	75	80	20

W3Y1 zhang wuh/wul yi yao mao mi  
H L H

	zhang	wul	yao	catathesis
SPK1	100	66	95	5
SPK2	100	60	87	13
SPK3	100	51	84	16
SPK4	100	59	90	10
Average(%)	100	59	89	11



Table 7.3 (continued)

W3Y3    zhang wuh/wul   yi yaoh/yaol   mao mi  
               H                L   H                L                H

              zhang    wul    yi    catathesis 1

SPK1	100	66	85	15
SPK2	100	61	94	6
SPK3	100	55	82	18
SPK4	100	70	92	8
Average(%)	100	63	88	12

              yi        yaol    mi    catathesis 2

SPK1	100	71	92	8
SPK2	100	56	89	11
SPK3	100	55	84	16
SPK4	100	56	88	12
Average(%)	100	60	88	12

W4Y1    zhang wuh/wul   yi yao mao mi  
               H                L                H

              wuh        wul    yao    catathesis

SPK1	100	78	98	2
SPK2	100	78	88	12
SPK3	100	63	80	20
SPK4	100	78	89	11
Average(%)	100	74	89	11

Table 7.3 (continued)

W4Y4	zhang		yao		mao	
	H	L	H	L	H	
		wuh	wul	yaoh	catathesis 1	
SPK1		100	79	103	/	
SPK2		100	72	97	3	
SPK3		100	60	80	20	
SPK4		100	78	97	3	
Average(%)		100	72	94	6	
		yaoh	yaol	mi	catathesis 2	
SPK1		100	78	87	13	
SPK2		100	70	83	17	
SPK3		100	63	74	26	
SPK4		100	71	82	18	
Average(%)		100	71	82	18	

-----

The above results show that the effect of catathesis exists in all of the HLH sequences for all the speakers. The only exception is one case, occurring in the first part of W4Y4 by speaker 1. A chained effect of catathesis is expected in W4Y4, however, the effect (20% in size) in the first part of the sentence is obvious only in speaker 3's data. The averaged size (3%) of the effect is quite small in Speaker 2's and 4's data. The fact that most of the speakers read the test sentence with a stronger stress on the second test syllable presents the main reason why this phenomenon

occurs. If the first test syllable is stressed stronger, the size of catathesis in the first part of the sentence might be much larger.

In the data, the size of catathesis varies according to speakers. For the same sentences, speaker 3 always has the largest size of catathesis. Speaker 1 often has the smallest effect of catathesis, especially when the effect occurs in the first part of a sentence.

Therefore, the size of a catathesis is not influenced by the frequency value of the low target L or the difference between a T3 and T4. Rather, it is affected by its position in a sentence. This point is evident when comparing the above normalized percentage values in W3Y1 or W1Y3 with those in W4Y1 or W1Y4 respectively. Although the low target of a T3 is obviously lower (15-22 Hz) than that of a T4, the catathesis triggered by the two tones are similar in size when they both occur in the first or second part of a sentence. The differences among speakers are also quite consistent in the comparison. The comparison of catathesis between W3Y3 and W4Y4 is different than the previous ones. As discussed before, the high target between the two low targets in W3Y3 is assumed to be triggered by both T3's that surround it, however this situation does not occur in W4Y4. Therefore, the effect of position on the size of catathesis cannot be discovered by comparing W3Y3 to

W4Y4.

Chained effects of catathesis exist in sentences W3Y3 and W4Y4. The sizes of the effects are similarly triggered by two T3's (12Hz and 12 Hz) but also differently triggered by two T4's (6Hz and 18Hz). This difference is probably related to the nature of the triggering tones.

### 7.1.3. Catathesis in interrogative sentences

Both pitch tracks and the averaged measurements in interrogative sentences show that the frequency of T1's continually increases in the second portion of the interrogative sentence RW1Y1. The declination over the declarative sentence W1Y1 is exhibited only in the first portion of some utterances in the data of speaker 2 and 3. Thenormalized measurements of each stressed syllable in RW1Y1 are shown in Table 7.3.

Does the rising tendency in frequency of interrogative sentences override the effect of catathesis? To answer this question, I first normalized the averaged measurements of targets in the HLH sequence for each interrogative sentence. I then compared the values of the high targets and counted the value of the available catathesis, using the formula which was set up in the previous section. All of the results are shown in Table 7.3. The stress pattern and the domain of an HLH sequence for each interrogative sentence are the

same as those for the corresponding declarative sentences.

Table 7.4 Normalized averages of frequency measurements for each of the three targets and the value of catathesis in each sentence RW1Yj

RW1Y1 Zhang wu yi yao mao mi

	zhang	wu	yao	mi
SPK1	100	97	106	114
SPK2	100	102	92	96
SPK3	100	103	99	103
SPK4	100	99	105	117
Average(%)	100	100	101	108

RW1Y3 zhang wu yi yaoh/yaol mao mi  
H L H

	wu	yaol	mi	catathesis
SPK1	100	69	101	/
SPK2	100	57	92	8
SPK3	100	50	99	1
SPK4	100	64	127	/
Average(%)	100	60	102	/

RW1Y4 zhang wu yi yaoh/yaol mao mi  
H L H

	yaoh	yaol	mi	catathesis
SPK1	100	85	101	/
SPK2	100	72	93	7
SPK3	100	81	111	/
SPK4	100	82	125	/
Average(%)	100	78	102	/

Table 7.4 (continued)

RW3Y1    zhang wuh/wul    yi yao mao mi  
               H                L                H

	zhang	wul	yao	catathesis
<hr/>				
SPK1	100	66	99	1
SPK2	100	60	90	10
SPK3	100	55	93	7
SPK4	100	53	98	2
<hr/>				
Average(%)	100	60	95	5

RW3Y3    zhang wuh/wul    yi yaoh yaol mao mi  
               H                L    H                L                H

	zhang	wul	yi	catathesis 1
<hr/>				
SPK1	100	69	89	11
SPK2	100	64	94	6
SPK3	100	61	92	8
SPK4	100	62	97	3
<hr/>				
Average(%)	100	65	93	7

	yi	yaol	mi	catathesis 2
<hr/>				
SPK1	100	73	108	/
SPK2	100	60	102	/
SPK3	100	57	110	/
SPK4	100	58	121	/
<hr/>				
Average(%)	100	63	109	/

Table 7.4 (continued)

RW4Y1    zhang   wuh/wul   yi   yao   mao   mi  
                               H        L                H

	wuh	wul	yao	catathesis
SPK1	100	78	100	/
SPK2	100	77	89	11
SPK3	100	61	85	15
SPK4	100	76	95	5
Average(%)	100	74	92	8

RW4Y4    zhang   wuh/wul   yi   yaoh/yaol   mao   mi  
                               H        L                H        L                H

	wul	wu2	yaol	catathesis 1
SPK1	100	81	102	/
SPK2	100	77	96	4
SPK3	100	64	89	11
SPK4	100	80	100	/
Average(%)	100	76	97	3

	yaoh	yaol	mi	catathesis 2
SPK1	100	83	98	2
SPK2	100	75	99	1
SPK3	100	84	104	/
SPK4	100	76	113	/
Average(%)	100	80	102	/

The lack of catathesis in the second portion of sentence RW1Y3, RW1Y4, RW3Y3, or RW4Y4 indicates that the

effect is strongly overridden by the rising tendency of frequency in that part of an interrogative sentence. On the other hand, it is still obvious in the first portion of the sentences RW3Y1, RW3Y3, RW4Y1 or RW4Y4, although the size is smaller than that in the corresponding declarative sentence. Speakers' differences are exhibited again, since for speaker 2, catathesis is still visible in the second portion of a sentence, such as in RW1Y3 or RW1Y4.

To summarize, the data supports the hypothesis that catathesis exists in Mandarin Chinese. The size of catathesis is affected by the speaker and the position of occurrence in a sentence. Also, the rising tendency of fundamental frequency in an interrogative sentence reduces or overrides the effect of catathesis.

## 7.2. Effect of strong emphasis

Strong emphasis on the meaning of certain words expands local pitch range. As previously reviewed, the expansion is mainly reflected in the rising of the maximum limit of the pitch range. The questions that I am concerned with in this section are: how is pitch range expanded in strongly emphasized words? How does the expansion influence the formation of pitch contours of tones and that of the whole undulation of a sentence? I analyzed controlled sentences first, and then observed spontaneous data, to see



if the same general results can be obtained in spontaneous speech.

As described in Chapter 3, there are four basic controlled sentences which are in the same syntactic structure and contain a sequence of eleven of the same  $T_i$  ( $i=1, 2, 3, \text{ or } 4$ ). Each  $T_i$  sequence in sentence  $S_i$  is produced by each of the three speakers H, Z, and C in six different methods:

(6)

Sia: plain formal statement  
 Sib: plain casual statement  
 Sic: casual question  
 Sid: casual statement with emphasis on the subject  
 Sie: casual statement with emphasis on the time word  
 Sif: casual statement with emphasis on the object

Comparing pitch movement in a sentence produced four ways, Sib, Sid, Sie, and Sif, by the same speaker, the influence of strong emphasis is clear. Various similar characteristics of the influences among speakers are discussed in the following paragraphs. As examples, pitch tracks of Sib's produced by speaker H have been shown in Figures 4.8.i.2 ( $i=1, 2, 3, \text{ or } 4$ ), and those of Sid-Sif produced by the same speaker are provided in Figures 7.15-7.26.

As noted in Chapter 5, emphasis affects how a sentence is divided into intermediate phrases. When the time word is strongly emphasized in the sentences of  $S_i$ 's, it is never

grouped with the proceeding words in the same intermediate phrase. Using sentences S1d-S1f again as examples, this point can be seen easily.

(7)

```

S1d: |Zhang zhongbing |jintian yinggai xiu |shouyinji.|
S1e: |Zhang zhongbing |jintian |yinggai xiu |shouyinji.|
S1d: |Zhang zhongbing |jintian yinggai xiu |shouyinji.|
      Zhang zhongbing today      should repair a radio
      "Zhang zhongbing should repair a radio today."

```

The strongly emphasized words in S1d-S1f are underlined. In these sentences, an intermediate phrase boundary always immediately follows these words. The division of sentences S2d-S2f, S3d-S3f, and S4d-S4f into intermediate phrases are the same as what we have seen in S1d-S1f.

The effect of the strong emphasis on pitch range variation is obvious. Let us compare pitch tracks of sentences Sid-Sif ( $i=1, 2, 3$ , or  $4$ ) with those of Sib ( $i=1, 2, 3$ , or  $4$ ) in the corresponding figures. It is a general phenomena that the size of the pitch range for a strongly emphasized intermediate phrase in Sid-f is larger than that for the corresponding intermediate phrase in Sib, which contains no emphasis. Pitch range reduces gradually over the course of the sentence in Sib, while it reduces suddenly after the strongly emphasized intermediate phrase in Sid-Sif. Before the intermediate phrase in each sentence containing emphasis, the pitch range has a stable size. This

means that a strongly emphasized word stands out by contrasting the size of its pitch range with the those of the following words.

Further analysis indicates that the size of pitch range is a function of the position of its occurrence in a sentence, if other factors are given. The earlier the strong emphasis occurs, the larger the pitch range expands. This point is clearly demonstrated in Figures 7.15-7.26. For example, the size of the expanded pitch range of the strongly emphasized word Li Xiao-bao, 'Li Xiao-bao', in Figure 7.21 is larger than that of the strongly emphasized word jiudian, 'nine o'clock', in Figure 7.22, and which is in turn larger than that in the strongly emphasized word jiangyangao, 'a draft for a lecture', in Figure 7.23. Pitch range keeps a stable size over an entire sentence when a word in the last intermediate phrase is strongly emphasized.

The general shape of pitch undulation for a sentence is also affected by the existence of strong emphasis. When this strong emphasis occurs early in a sentence, it causes an abrupt prominence in pitch track at the emphasized portion and a long flattened tail in the following portion. When a strong emphasis occurs in the middle of a sentence, pitch movement exhibits fluctuation for a certain length, after which pitch undulation reduces. A strong emphasis in the final portion of a sentence does not cause obvious

prominence in the pitch track; usually it keeps pitch undulating without a large, but stable size of amplitude over the sentence. Pitch tracks of each set of sentences Sid-Sif can serve as examples of this regularity.

Tonal realization of syllables after a strong emphasis is obviously affected. Again the degree of effect is determined by the position in a sentence. The earlier the strong emphasis occurs, the stronger the effect is. For the principle of pitch contour formation in intermediate phrases and the production effect of a T3 sequence, the function is weakened in intermediate phrases after the strong emphasis.

For example, in pitch tracks of sentences Sid, shown in Figure 7.2.i.1, when the contrastive stress is in the first intermediate phrase, the function of the principle and the effect exhibit themselves clearly in this intermediate phrase. In Figure 7.21, which shows pitch tracks of sentences with T3's, the pitch contour of the three T3's in the first intermediate phrase is realized as a general rising-falling cycle because of the productive effect in a sequence of T3's. In each of the Figures 7.15, 7.18, and 7.24, which show pitch tracks of sentences with T1's, T2's and T4's respectively, the principle makes the last syllable keep the basic tone this is because of the strongest stress being in the intermediate phrase and consequently makes the preceding tones change in production

to serve as pre-extension along the pitch undulation. However, for all of the four sentences, the pitch contours, form a rather flattened line, in a low and narrow pitch range. These pitch contours are all in intermediate phrases after the first intermediate phrase. These flattened lines can be regarded as a long post-extension of the preceding tune. In most of the sentences, from the second intermediate phrase on, the principle of pitch contour formation in intermediate phrases and the production effect of T3 sequence are totally overridden by the effect of the strong emphasis. Only in some sentences are the principle and the production effect still visible. The tune in the second intermediate phrase shown in Figure 7.21 and those in the last intermediate phrase shown in Figure 7.18 and 7.24 are such examples.

The effect of strong emphasis on the pitch contour formation is weaker when it occurs in the second, rather than the first, intermediate phrase. This can be seen from pitch tracks in the sentences Sie's, which are shown in Figures 7.16, 7.19, 7.22, and 7.25. After the contrastive stress in the second intermediate phrase, pitch undulation has a larger amplitude in Sie's than in the same portion of the corresponding Sid's.

As described before, the controlled sentences that I am discussing are all produced based on the manner in which

a speaker answers a question like "Who is going to repair the radio?" "When is Zhang Zhong-bing going to repair the radio?" or "What is Zhang Zhong-bing going to repair?" The only new information in the answer is the name Zhang Zhong-bing 'Zhang Zhong-bing', the time mingtian 'tomorrow', or the object shouyinji 'radio'. Therefore, these words are produced with a rather strong emphasis. The other information in the sentence is already known, and hence is uttered very weakly. This strong contrast between strength of words, or intermediate phrases, in a sentence reflects a typical type of strong emphasis.

There are many cases containing strong emphasis in the data of spontaneous speech and phenomena similar to those found in the controlled sentences are exhibited. Figure 7.27 provides an example. The sentence is:

(8) ZJ32

	Ta	bu	yinggai		ting	che.	
	s	w	w	s	w	s	
	55	51	55	55	35	55	
	she	not	should		stop	car	
	"She should not stop the car."						

The first intermediate phrase of the sentence is strongly emphasized and hence has an expanded pitch range. The realization of tones reflects the principle of pitch contour formation in intermediate phrases. The second

intermediate phrase of the sentence is very weak; its pitch range is contrasted and tonal shapes are unexpected, according to this principle. In other words, the principle is overridden by the effect of the strong emphasis. As exhibited in the controlled sentences, the pitch curve of this occurrence is a low and flattened tail, or post-extension of the first tune.

In my data of spontaneous speech, an emphasis in one intermediate phrase is often not much stronger than stronger stresses in other intermediate phrases in the same sentence. This could be because the latter provides new information. Examples of this type of emphasis have been given in previous chapters. Figure 5.1 which shows pitch tracks of sentence ZJ2526, is such an example. The first intermediate phrase contains a strong emphasis on the first syllable ta. The pitch range is obviously larger than those of other intermediate phrases. However, strong stresses in the proceeding intermediate phrases are still rather strong, and the pitch ranges are also still quite large. Strong emphasis may affect, but does not override the effect of the principle of pitch contour formation in intermediate phrases.

Also, quite often seen in spontaneous speech is that the stress pattern following the strong emphasis is still clear and functions well in controlling tonal realization.

One example of this occurrence is in Figure 7.28, which shows pitch tracks of sentence HJ45.

(9) HJ45

	Genben	jiu		meiyou	weifan		jiaotong	guize	,				
	S	W		W	S	W	W	S		S	W	S	W
	55	21		51	35	21	35	21		55	55	55	35
	simply	then		not		violate	traffic	regulation					
	"(She) simply did not violate the traffic regulation,												
	ye	meiyou ...											
	W	S	W										
	21	35	21	UT									
	also not												
	also did not..."												

Pitch range of the first intermediate phrase is largely expanded because of the contrastive stress. Although the range is quite narrow in other intermediate phrases, the function of the principle of pitch contour formation in intermediate phrases is clearly visible. Figure 7.29 provides another similar example. The sentence is:

(10) HJ8

...		kao	neige	jiazhao			shenmede	shiqing	ha	,			
		S	W	W	S	S		W	W	W	S	W	W
		21	51	0	51	51		35	0	0	51	0	0
		test	that	driver's	license		so	on	things	PART			
	"...things like taking road test for driver's license."												

The word jiazhao is strongly emphasized, and the pitch range of the first intermediate phrase is thus much larger



than that of the second one. There is only one strongly stressed syllable in the second intermediate phrase, so it retains the basic tonal features of its T4. Tones of other syllables are all rather weak, hence serving as pre- and post-extensions of this T4. The second tune does not take shape as a post-extension of the first tune, as what happens in the controlled sentences. In other words, if the proceeding intermediate phrases are not totally weakened, the effect of strong emphasis does not override the principle of pitch contour formation in these intermediate phrases.

Apparently, strong emphasis in the above three examples only expands the local pitch range, and does not seriously affect the pitch contour formation in the following syllables. As pointed out in Chapter 5, I marked stress patterns only inside each intermediate phrase, namely, only at the level of intermediate phrase. In fact, the above analysis shows the effect of strong stress at the high level. The stress pattern at that level will be roughly discussed in Chapter 8.

Combining the phenomena observed in both controlled and spontaneous speech, the general effect of a strong emphasis acts to expand the local pitch range and contrast. Specifically, when the proceeding intermediate phrases are very weak, a strong emphasis may seriously affect tonal

realization in the following intermediate phrases. This is seen by overriding the principle of pitch contour formation in intermediate phrases and the productive effect of T3 sequence.

### 7.3 Effect of speaking style

There are two major styles of speaking: formal and casual style. People may falsely assume that reading aloud must be in the formal style, and spontaneous speaking in the casual style. However, in a continuum of style between the two extremes, reading does not have to only be in the extreme formal style, but can also be in a rather casual style. However, spontaneous speaking can be in an extreme casual style as well as a rather formal style.

In my data, only eight controlled sentences are read by the speakers in a rather formal style. Among these sentences, four of them are S1a, S2a, S3a, and S4a, which contain sequences of the same T1's, T2's, T3's, and T4's respectively. The other four sentences are S7a, S8a, S9a, and S10a, which contain sequences of the same T1T0's, T2T0's, T3T0's, and T4T0's respectively. For convenience, I will call the style for these sentences "Extremely Formal Style".

Other controlled sentences in my data are all read or uttered much more casually. I would refer to this style as

"Quasi-casual Style". The transcribed stories are read in a style between these two, and hence are treated as "Quasi-formal Style". The spontaneous story telling is in the most casual style, so it is labeled as "Extremely Casual Style". In fact, this classification of styles is still rough and a more detailed analysis should be the subject of further studies. In order to make this classification explicit to readers, a list is provided in the following.

(11)

Styles:	Data:
Extremely Formal	Controlled: S1a-S4a, S7a-S10a
Quasi-formal	Uncontrolled: story-reading
Quasi-casual	Controlled: all sentences except S1a-S4a & S7a-S10a
Extremely Casual	Uncontrolled: story-telling

How do these speaking styles affect pitch movement in sentences? The answer is that they mainly do so through adjusting pitch range, speech rate, and stress pattern. First, compare the same isolated plain sentences produced in Quasi-casual Style with those in Extremely Formal Style. For Quasi-casual Style, the pitch range is narrower, the speech rate is faster, and there are less strongly stressed syllables. As a result, less tones keep their basic features, and pitch undulates in less cycles. Figures 4.32 and 4.33 provide a comparison between pitch tracks of the

same T3 sequences produced by speaker H in the two styles. Pitch undulation in Figure 4.33 has smaller amplitude, shorter duration, and less peaks and valleys, because of the Quasi-casual Style.

In the story telling and reading sections, sentences are produced in a continuous narration. The general difference of pitch movement, for the same content, between Quasi-formal Style and Extreme Casual Style is as follows. In Quasi-formal Style, pitch range for each speaker changes much less, and keeps a much more stable size, than that in Extreme Casual Style. For example, in the data of speaker H's story reading, i.e. in Quasi-casual Style, pitch range varies from 80 Hz to 130 Hz. However, in story telling, i.e. in Extreme Casual Style, there are three types of pitch ranges. First, about 40% of the utterances have the smaller range, from 30 Hz to 80 Hz. Second, about 45% of the utterances have the larger range, from 80Hz to 120 Hz. Third, the rest of the utterance have the largest range, which reaches 200 Hz.

In my data, speech rate is also an important aspect of speaking style which also may affect contourformation. Speech rate is rather stable in the data for Quasi-formal Style, but keeps changing in the Extreme Casual Style. Sometimes, the spontaneous speech, which is in Extreme Casual Style, is slow, but in most cases it is faster than

the reading speech, which is in Quasi-formal Style. For the climax of a story, the spontaneous speech is usually at a high rate, which often combines with a large pitch range. In this situation, the result of pitch contour formation in the same sentences may be quite different in the two styles. Figure 7.30 and Figures 7.31-7.32 provide one comparison between pitch tracks of the same sentences which are uttered in the two styles.

(12)

	Jiu kai,   jiu wang nar kai,   dagai ye jiu   ...									
ZJ4041	w	s	w	s	w	w	w	w	s	w
ZD4041	w	s	s	s	w	s	w	s	w	s
	51	55	51	21	51	55	51	51	21	51
	*	*				*	*	*	*	*

just drive just toward there drive maybe also only  
 "(I) just drove, drove forward, maybe only..."

ZJ4041 is spontaneously spoken, and JD4041 is the read speech. The pitch tracks of ZJ4041 are given in Figure 7.30, and those of ZD4041 are given in Figures 7.31-7.32.

Differences in the durations, pitch ranges, stress patterns and overall shapes of pitch undulations for the two versions is obvious. First, the sentence is much longer in the read version than that in the spontaneous speech. Second, the largest pitch range is around 70 Hz in Figures 7.31-7.32, the read version, but 130 Hz in Figure 7.30, the

speaking version. Third, different stress patterns are exhibited in the second and third intermediate phrases of the two versions. It is seen that there are more strong stresses in read speech. Fourth, most pitch contours of the same tones realized in the two versions are also rather different. These tones are marked by a "\*" under the syllables.

One point worthy of attention is that no tone in the last intermediate phrase keeps its basic contour in Figure 7.30. The formation of the tune is based on the tonal feature height. This violates the principle of pitch contour formation in intermediate phrases, since according to the principle, the frame of a tune has to be built on basic tones rather than by features only. The combined effect of fast speaking rate and wide pitch range overrides the function of the principle. In the data, it often occurs that the principle functions well when a fast rate combines with a narrow pitch range, or when a slow rate combines with a wide pitch range. An interesting topic for further research would be to test how a single factor, such as speech rate or pitch range, influences the function of the principle. In fact, we have already seen some examples which show the effect of an expanded pitch range on pitch contours. The shape of a T1 is very sensitive to large pitch ranges. The high falling shape of a T1 in the first syllable

of the strongly emphasized word genben, 'simply', in Figure 7.28, is a typical example.

Another example showing that pitch contours are quite different in Extreme Casual Style and in Quasi-formal Style is provided in the comparison between Figure 7.33 and Figures 7.34-7.35. The sentences of the two styles are produced differently in terms of the division of intermediate phrases.

(13) HJ4041

	Zenme	hui	shi,		ta	jiushi	mai	le	
	S	W	S		S	W	W	S	W
	21	0	35		55	51	51	21	0
			*		*			*	
	how	M	thing		she	is	buy	PERF	
	"What has happened? It is that								
	neige	baoxian	yihou,		...				
	W	W	S		S	W	W		
	510	21	21		21	51			UT
	*	*	*		*	*			
	that insurance after								
	after she bought the insurance,..."								

(14) HD4041

	Zenme	hui	shi,		ta	jiushi	mai		le	neige	
	S	W	W		S	W	S		S	W	W
	21	0	35		55	51	51		21	0	51
			*		*				*	*	*
	how	M	thing		she	is	buy	PERF	that		
	"What has happened? It is that after she bought										
	baoxian	yihou,		...							
	S	W			W	S					
	21	21			21	51					UT
	*				*	*					
	insurance after										
	the insurance,..."										

In Figure 7.33, the fast speech rate shortened the durations of several syllables, and the rather large pitch range forces the pitch to undulate in fewer cycles within the short duration of the whole sentence. However, in Figures 7.34-7.35, although the pitch range is also large, the speech rate is much slower, and therefore the pitch is allowed to undulate more. Consequently, instead of containing only one peak, the tunes of the first two intermediate phrases contain two peaks.

Also, it is commonly seen in the data that stress patterns differ for the same sentence when produced in different styles, even though the speech rates for the two are similar. This difference between stress patterns may result in different pitch contours in two versions of the same sentences. As reviewed in Chapter Two, Chao (1968) holds that the last syllable of a short phrase is usually stressed the strongest. This opinion seems to be more reasonable in read rather than in spontaneous speech. In HJ4041, and many other sentences in spontaneous speech, weak stresses are exhibited at the end of sentences or before a pause, unlike strong stresses at the end of read speech.

The various effects of the two styles on the formation of pitch contours are also shown by the fact that when



reading, the speaker may lengthen the duration of a syllable. The increased length may be caused by the unfamiliarity with the reading material. In sentence HD4041, the syllable le in the third intermediate phrase is lengthened for this reason. This type of lengthening must partly contribute to the different shapes of pitch tracks in the second half of the sentence in both styles. In fact, the speaker also adds one syllable shi in the second intermediate phrase when reading the sentence, but this does not change the basic shape of the tune.

In most of my data on spontaneous speech, if the pitch range is not expanded or contracted greatly, and the speech rate is not too fast, the basic shape of pitch undulation in a sentence, as a whole, is rather similar to that of the same sentence produced in read speech. Such a large difference, as presented in the above examples, does not represent the majority of cases.

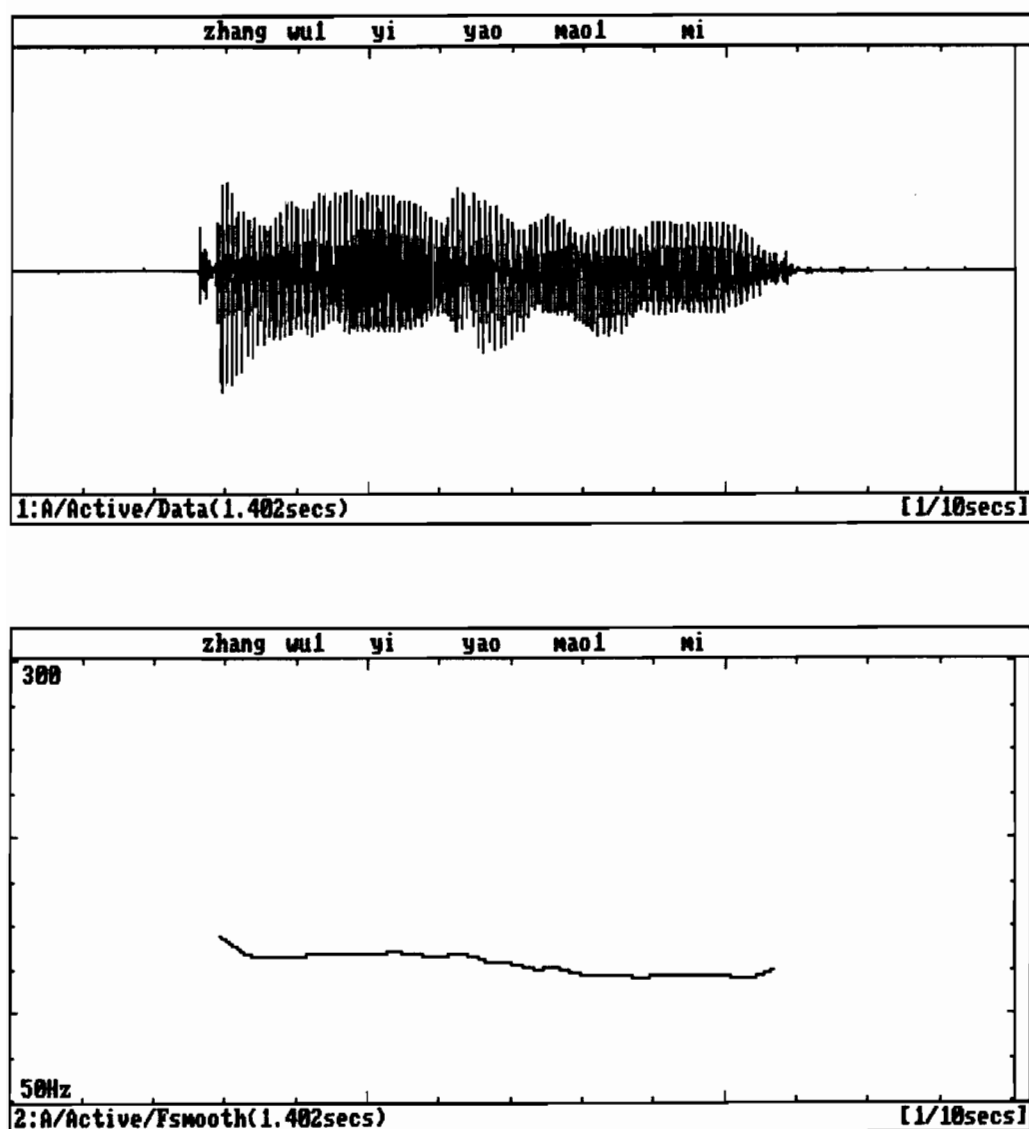


Figure 7.1 Waveform and pitch tracks  
of sentence W1Y1 by speaker SH, Zhang  
Wu-yi yao maomi. 'Zhang Wu-yi invites a  
cat.'

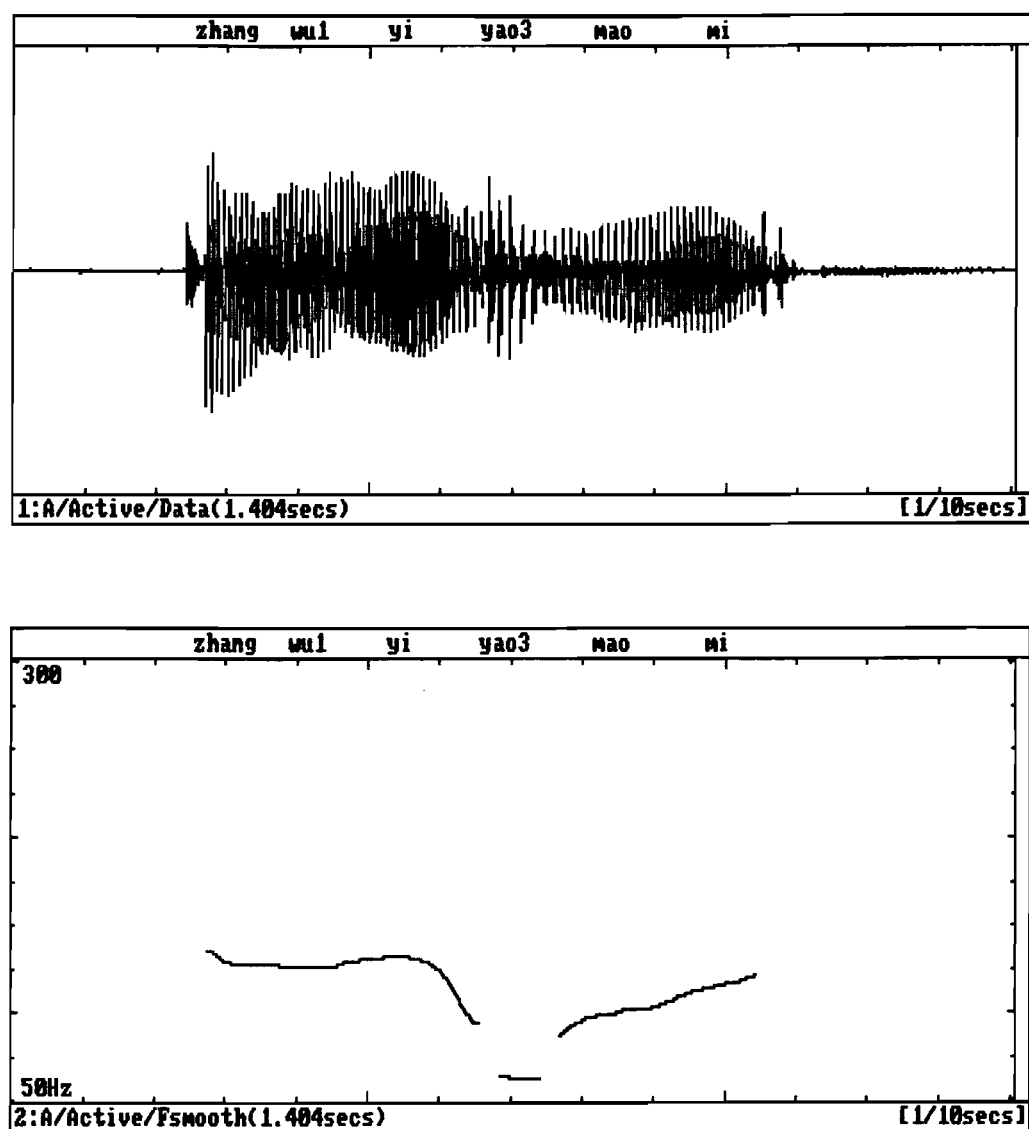


Figure 7.2 Waveform and pitch tracks of sentence W1Y3 by speaker SH, Zhang Wu-yi yao maomi. 'Zhang Wu-yi bites a cat.'

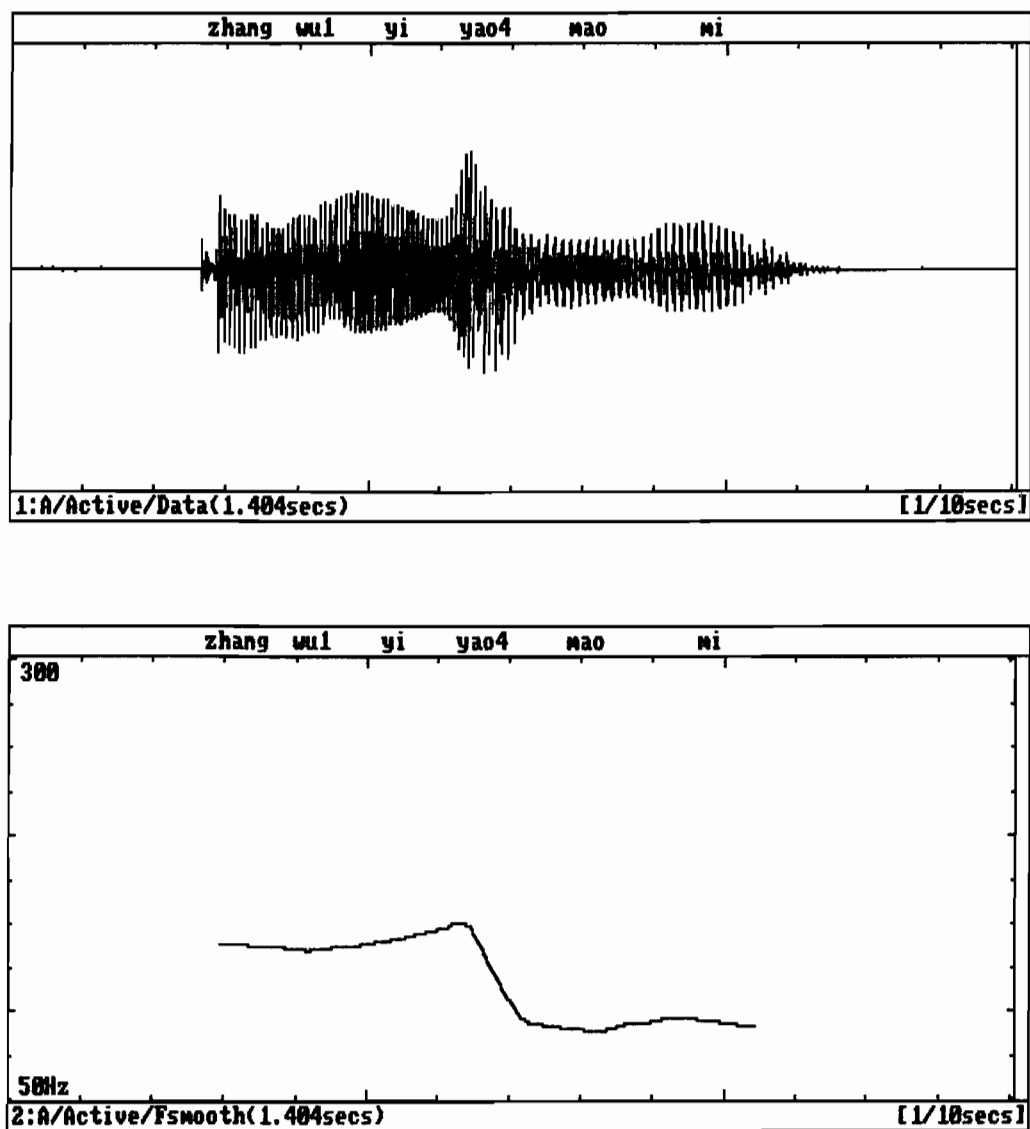


Figure 7.3 Waveform and pitch tracks  
of sentence W1Y4 by speaker SH, Zhang  
Wu-yi yao maomi. 'Zhang Wu-yi wants a cat.'

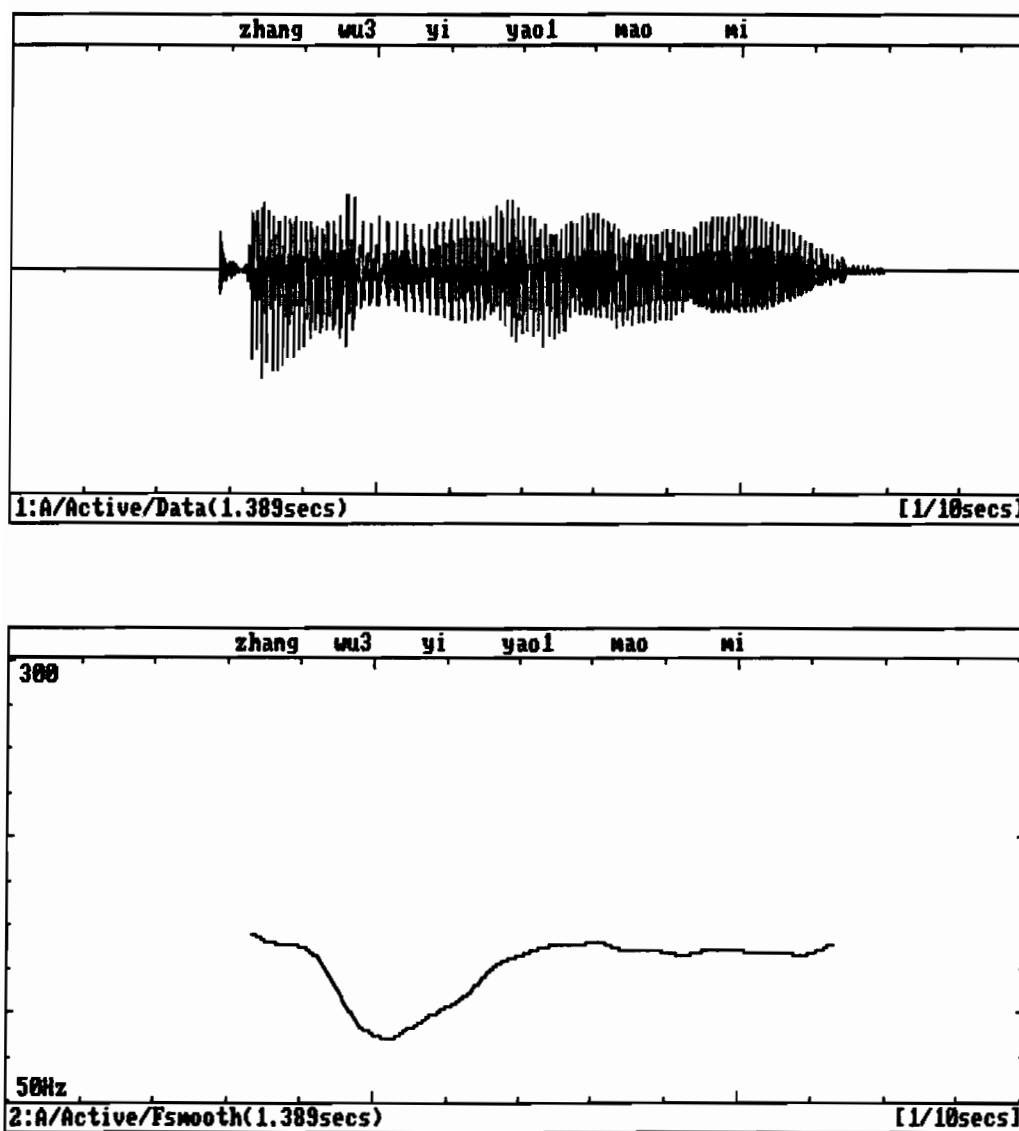


Figure 7.4 Waveform and pitch tracks  
of sentence W3Y1 by speaker SH, Zhang Wu-yi  
yao maomi. 'Zhang Wu-yi invites a cat.'

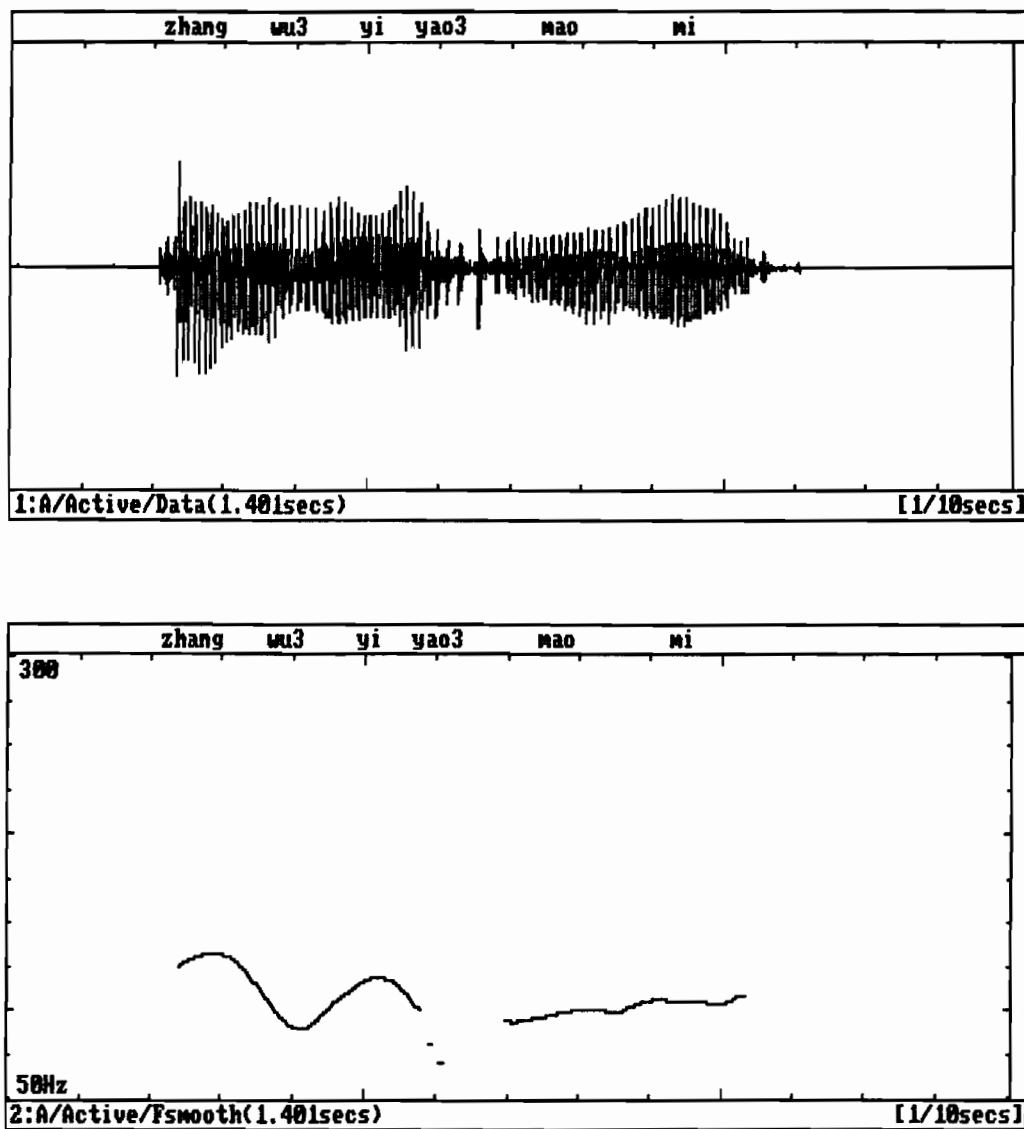


Figure 7.5 Waveform and pitch tracks of sentence W3Y3 by speaker SH, Zhang Wu-yi yao maomi. 'Zhang Wu-yi bites a cat.'

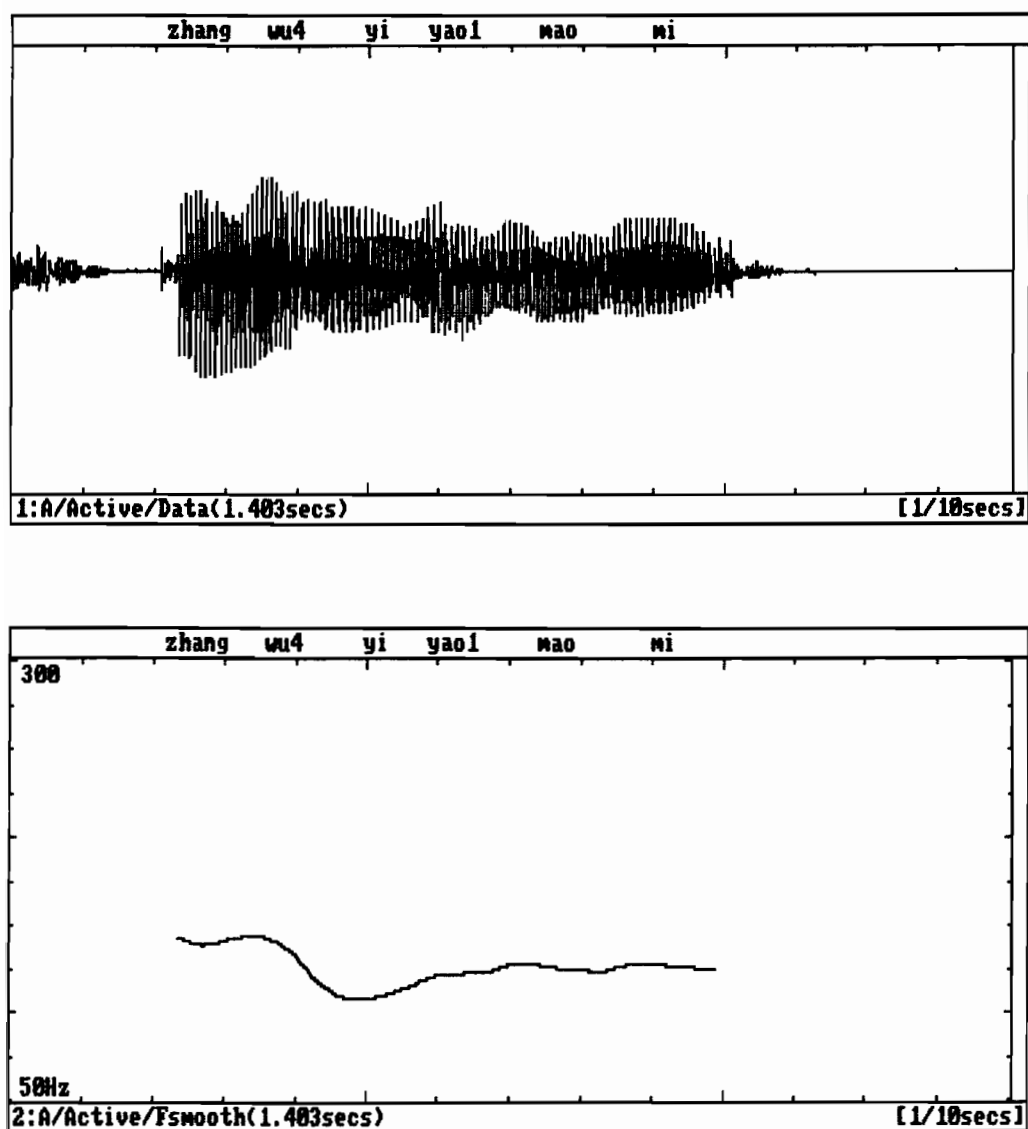


Figure 7.6 Waveform and pitch tracks of sentence W4Y1 by speaker SH, Zhang Wu-yi yao maomi. 'Zhang Wu-yi invites a cat.'

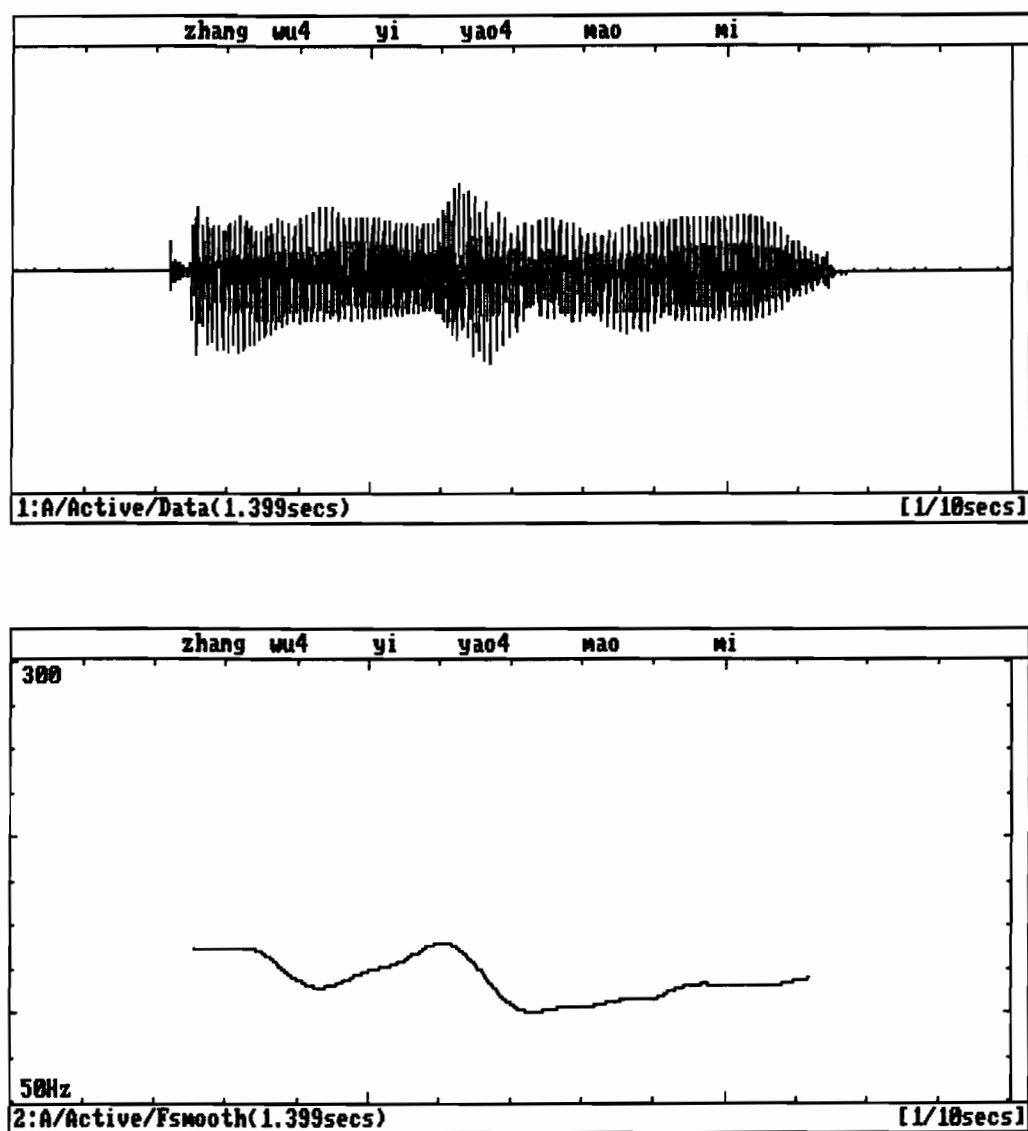


Figure 7.7 Waveform and pitch tracks of sentence W4Y4 by speaker SH, Zhang Wu-yi yao maomi. 'Zhang Wu-yi wants a cat.'



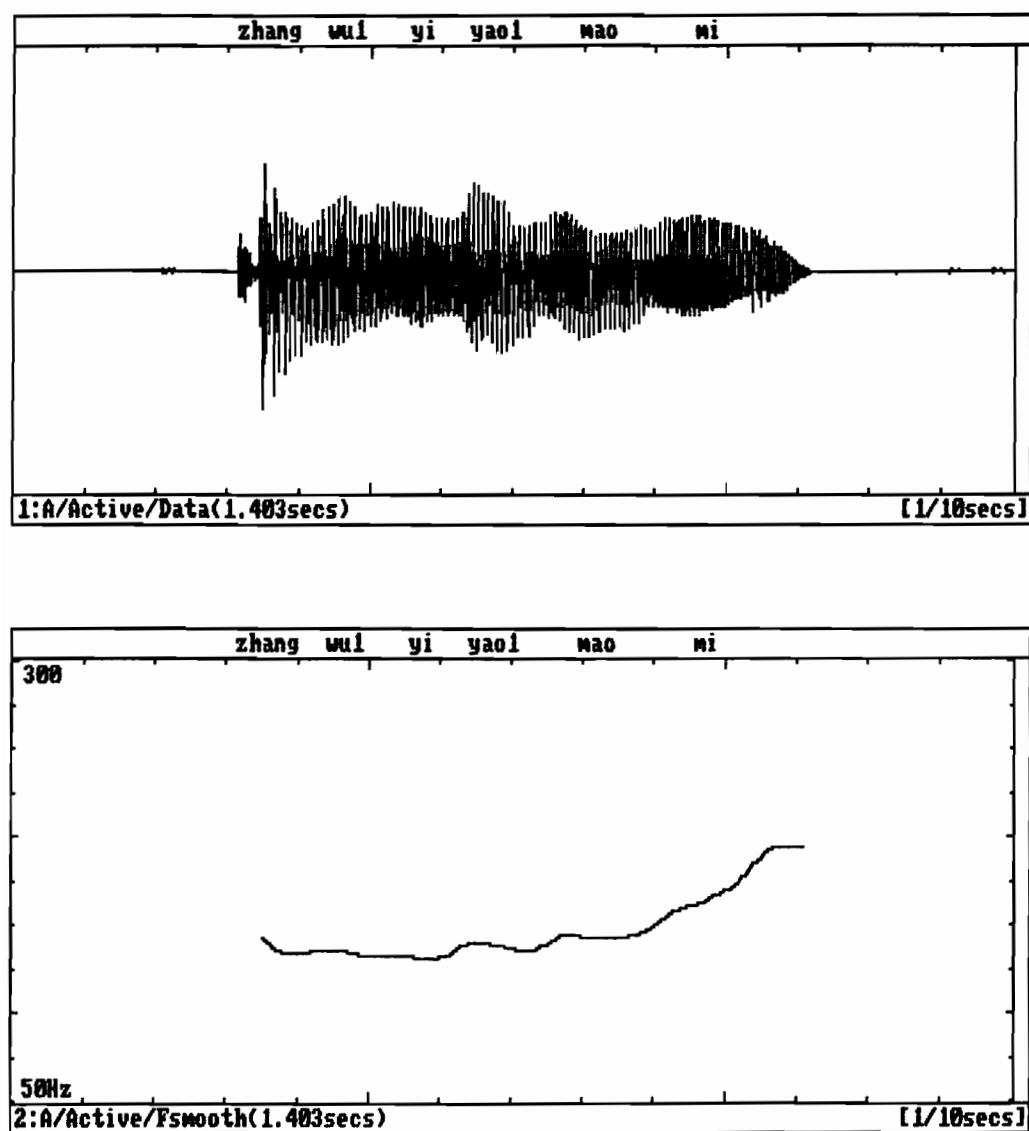


Figure 7.8 Waveform and pitch tracks of sentence RW1Y1 by speaker SH, Zhang Wu-yi yao maomi? 'Does Zhang Wu-yi invite a cat?'

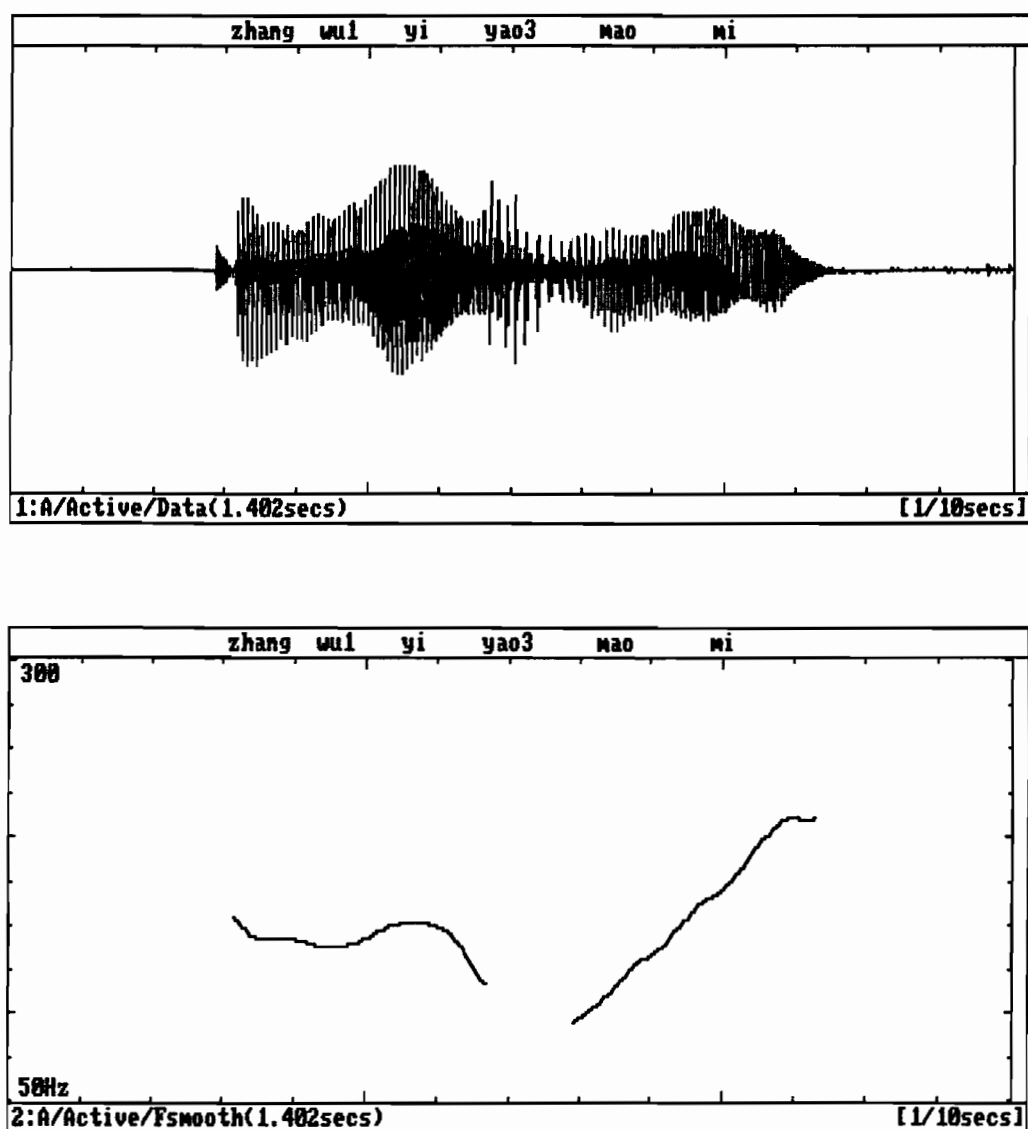


Figure 7.9 Waveform and pitch tracks of sentence RW1Y3 by speaker SH, Zhang Wu-yi yao maomi? 'Does Zhang Wu-yi bite a cat?'

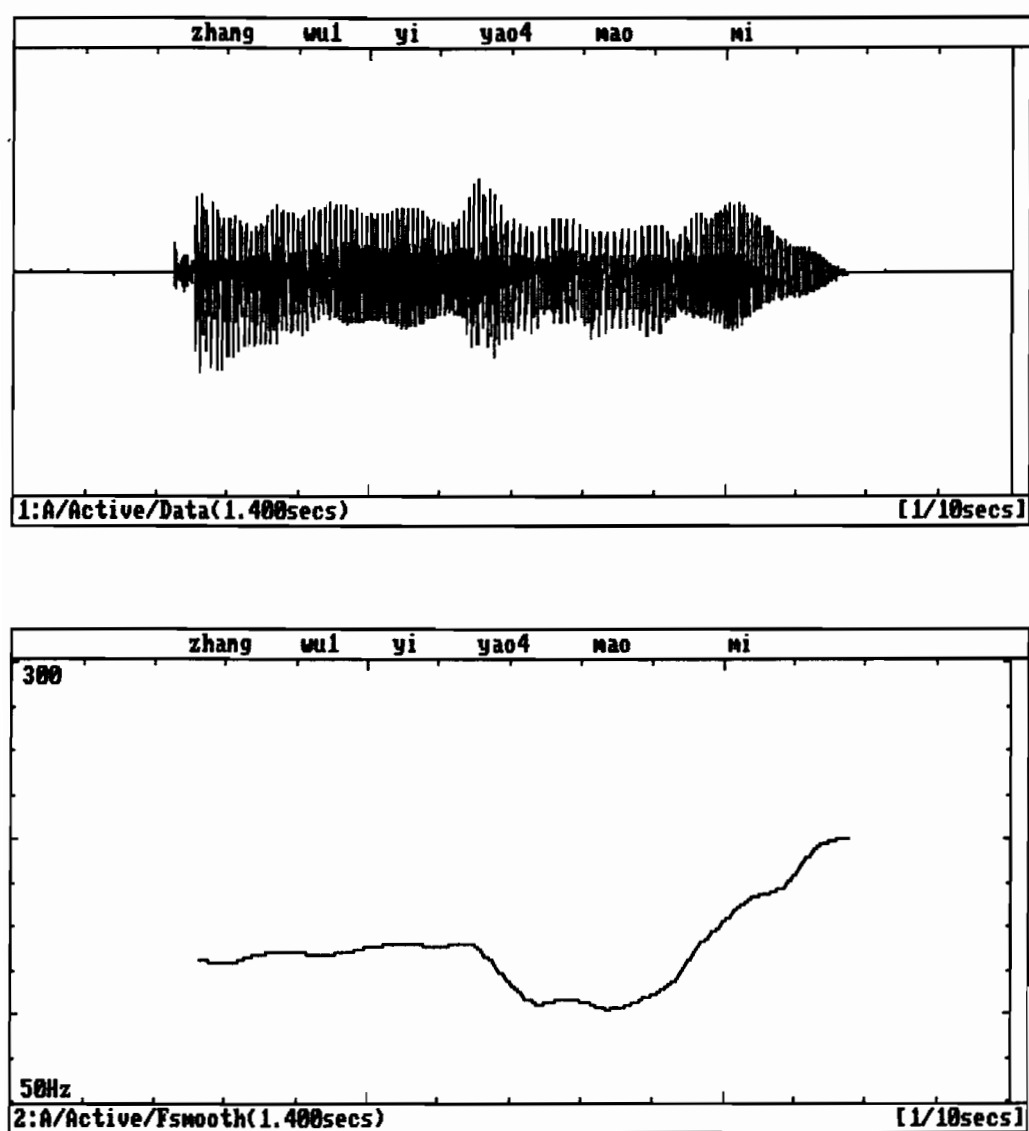


Figure 7.10 Waveform and pitch tracks of sentence RW1Y4 by speaker SH, Zhang Wu-yi yao maomi? 'Does Zhang Wu-yi want a cat?'

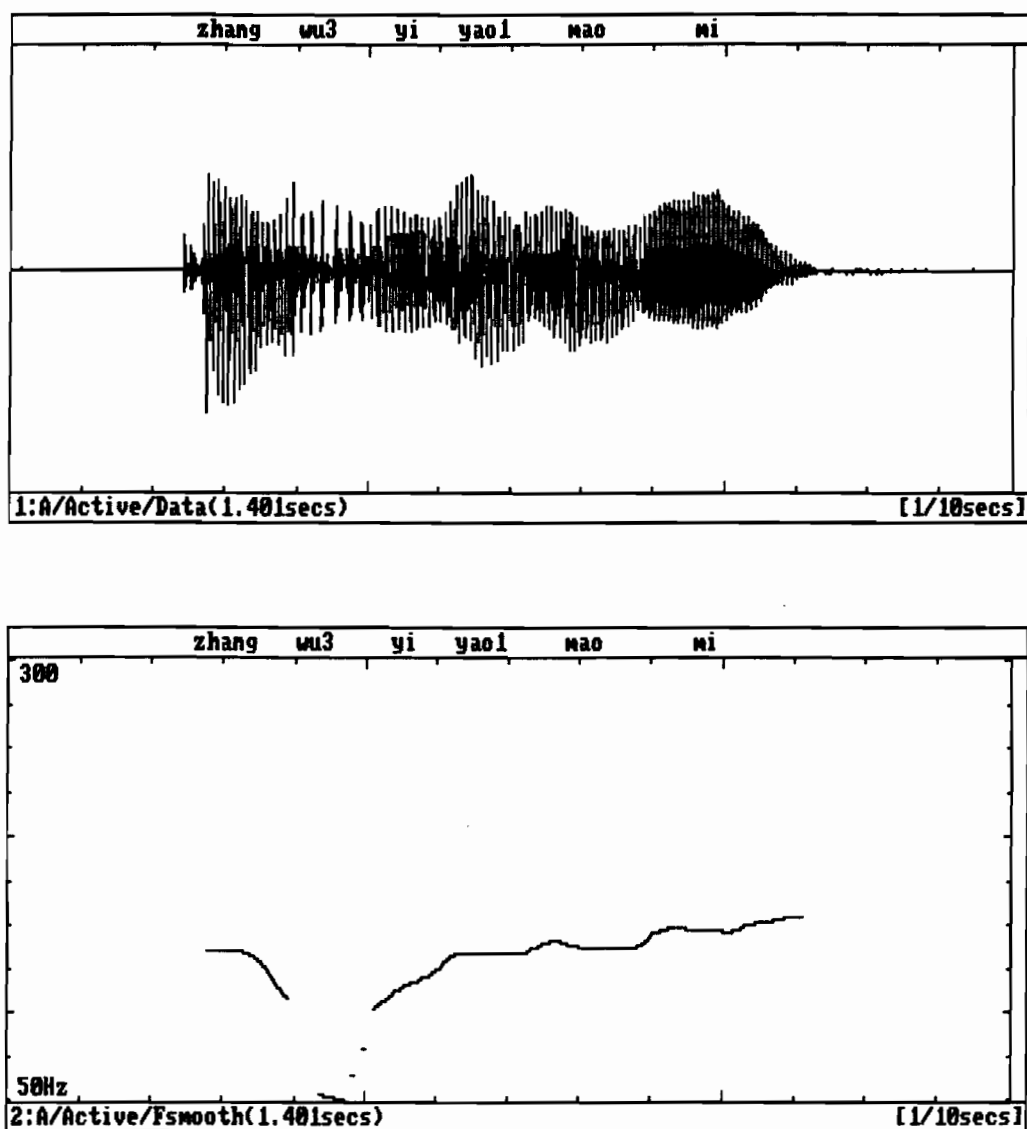


Figure 7.11 Waveform and pitch tracks of sentence RW3Y1 by speaker SH, Zhang Wu-yi yao maomi? 'Does Zhang Wu-yi invite a cat?'

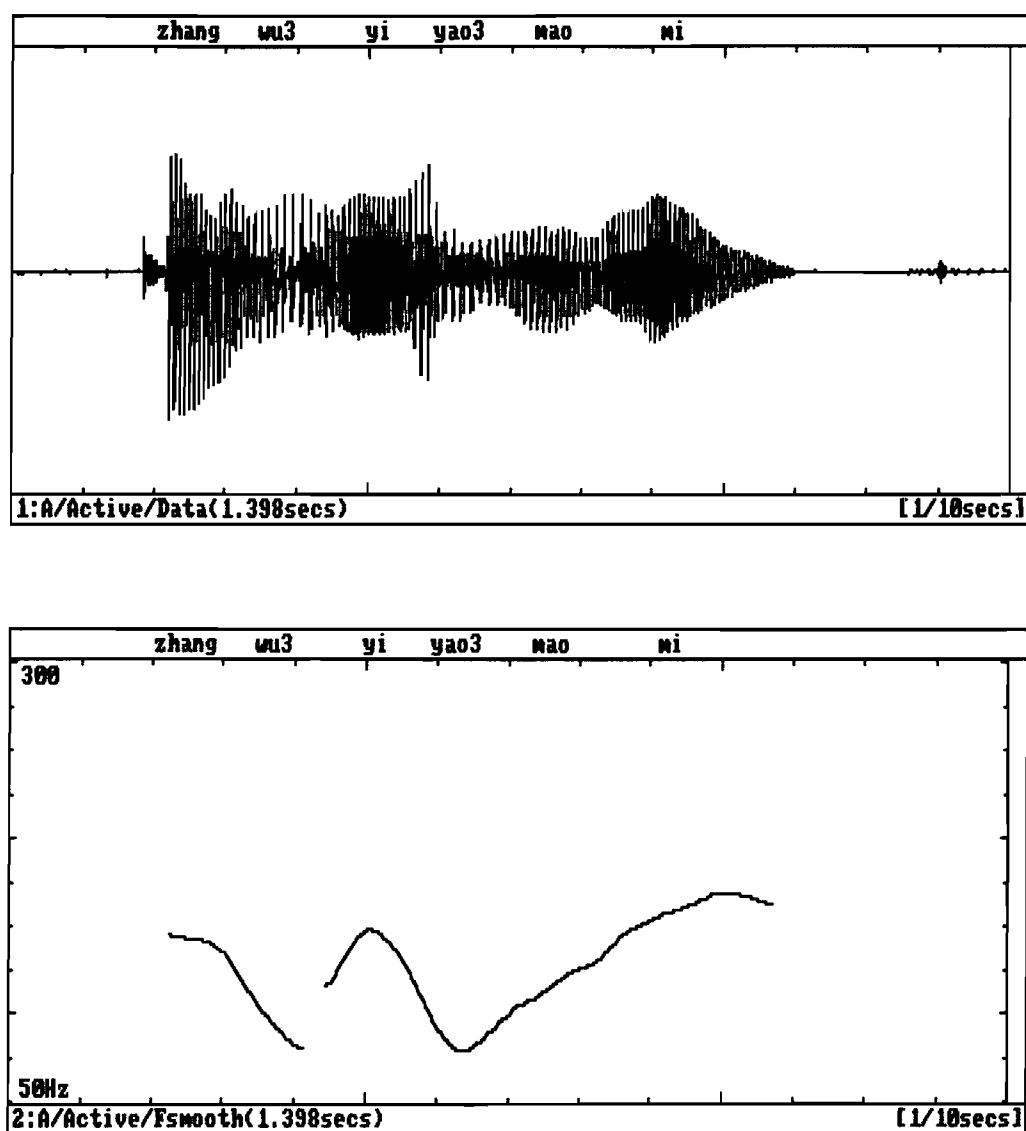


Figure 7.12 Waveform and pitch tracks of sentence RW3Y3 by speaker SH, Zhang Wu-yi yao maomi? 'Does Zhang Wu-yi bite a cat?'

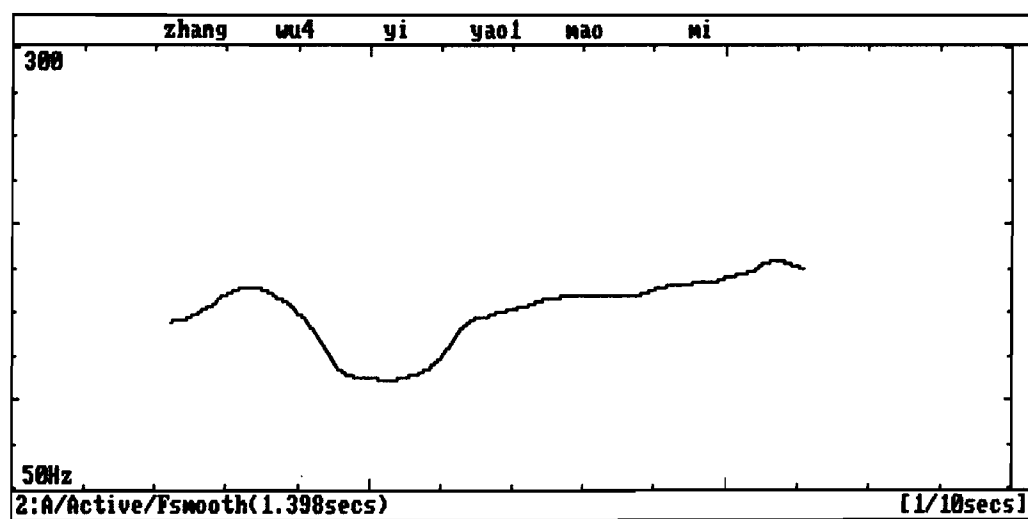
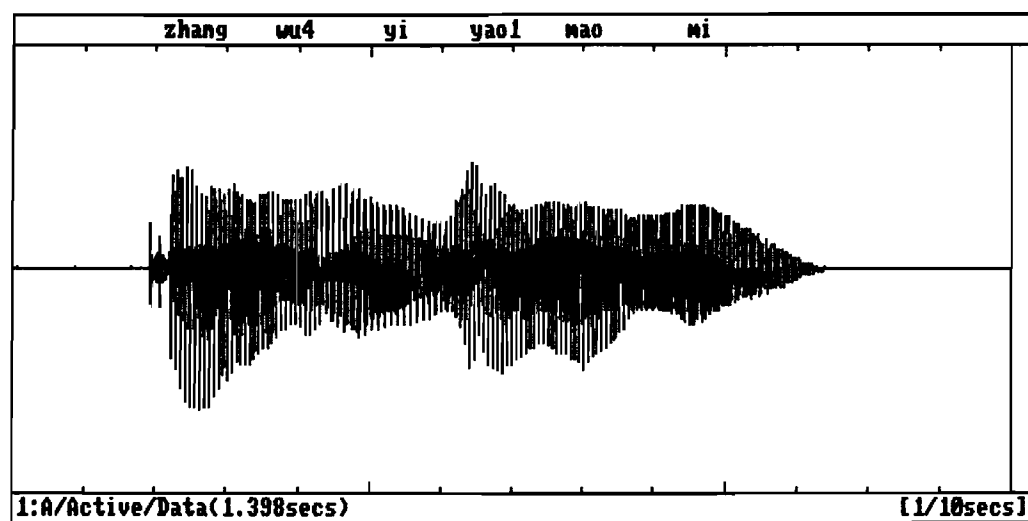


Figure 7.13 Waveform and pitch tracks of sentence RW4Y1 by speaker SH, Zhang Wu-yi yao maomi? 'Does Zhang Wu-yi invite a cat?'

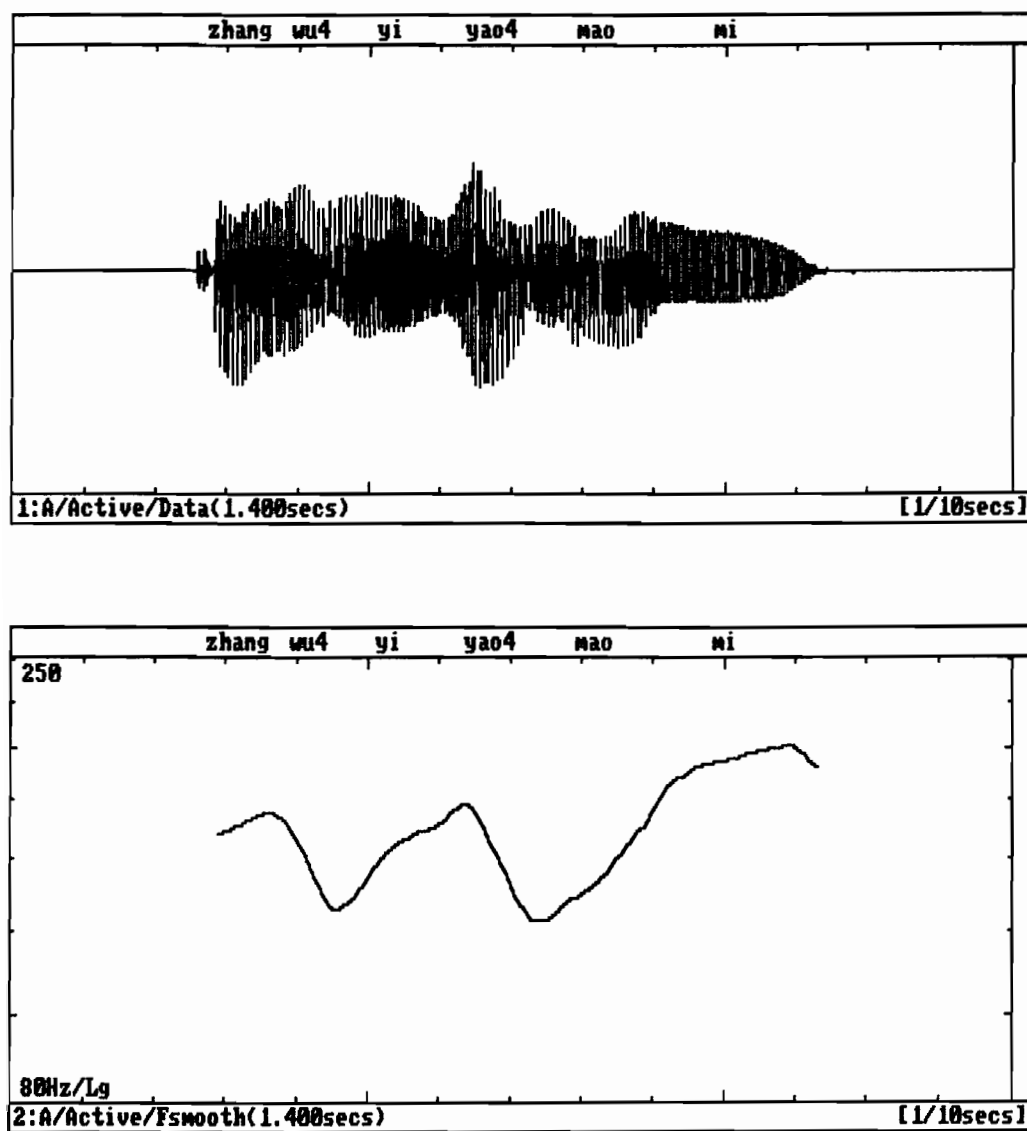


Figure 7.14 Waveform and pitch tracks of sentence RW4Y4 by speaker SH, Zhang Wu-yi yao maomi? 'Does Zhang Wu-yi want a cat?'

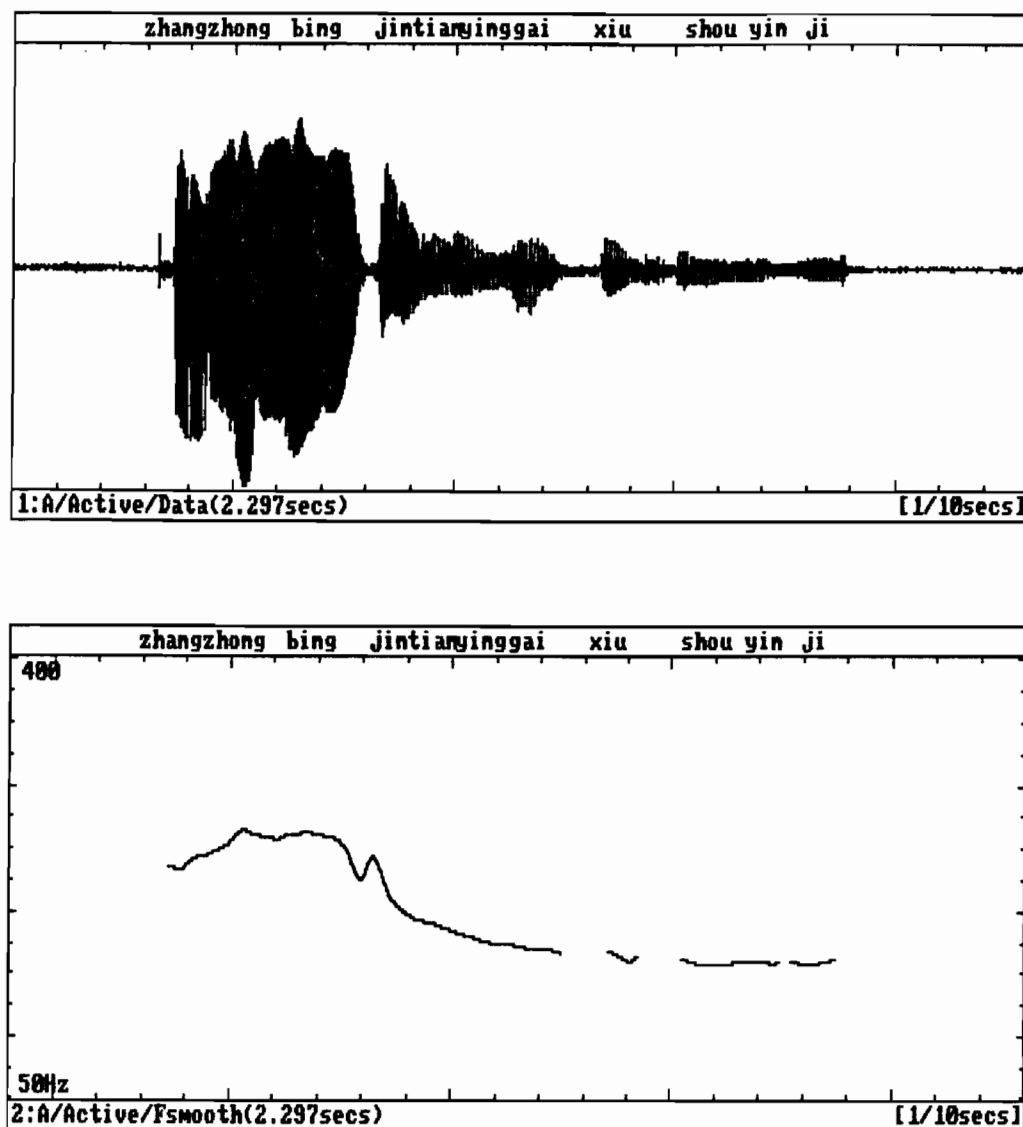


Figure 7.15 Waveform and pitch tracks of sentence HJS1d, Zhang Zhongbing jintian yinggai xiu shouyinji. 'Zhang Zhongbing should repair a radio today.' Zhang Zhongbing is emphasized.



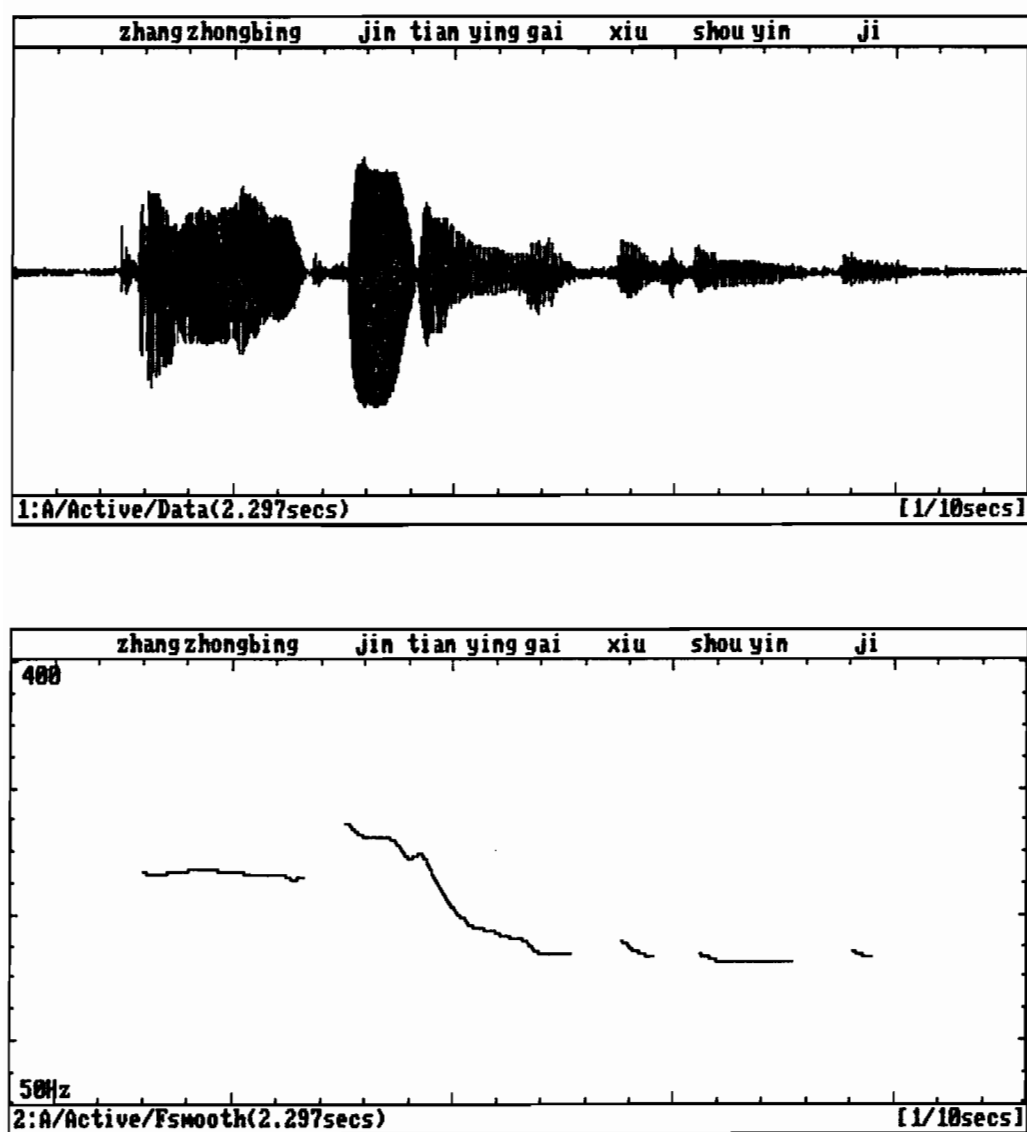


Figure 7.16 Waveform and pitch tracks of sentence HJS1e, Zhang Zhongbing jintian yinggai xiu shouyinji. 'Zhang Zhongbing should repair a radio today.' Jintian is emphasized.

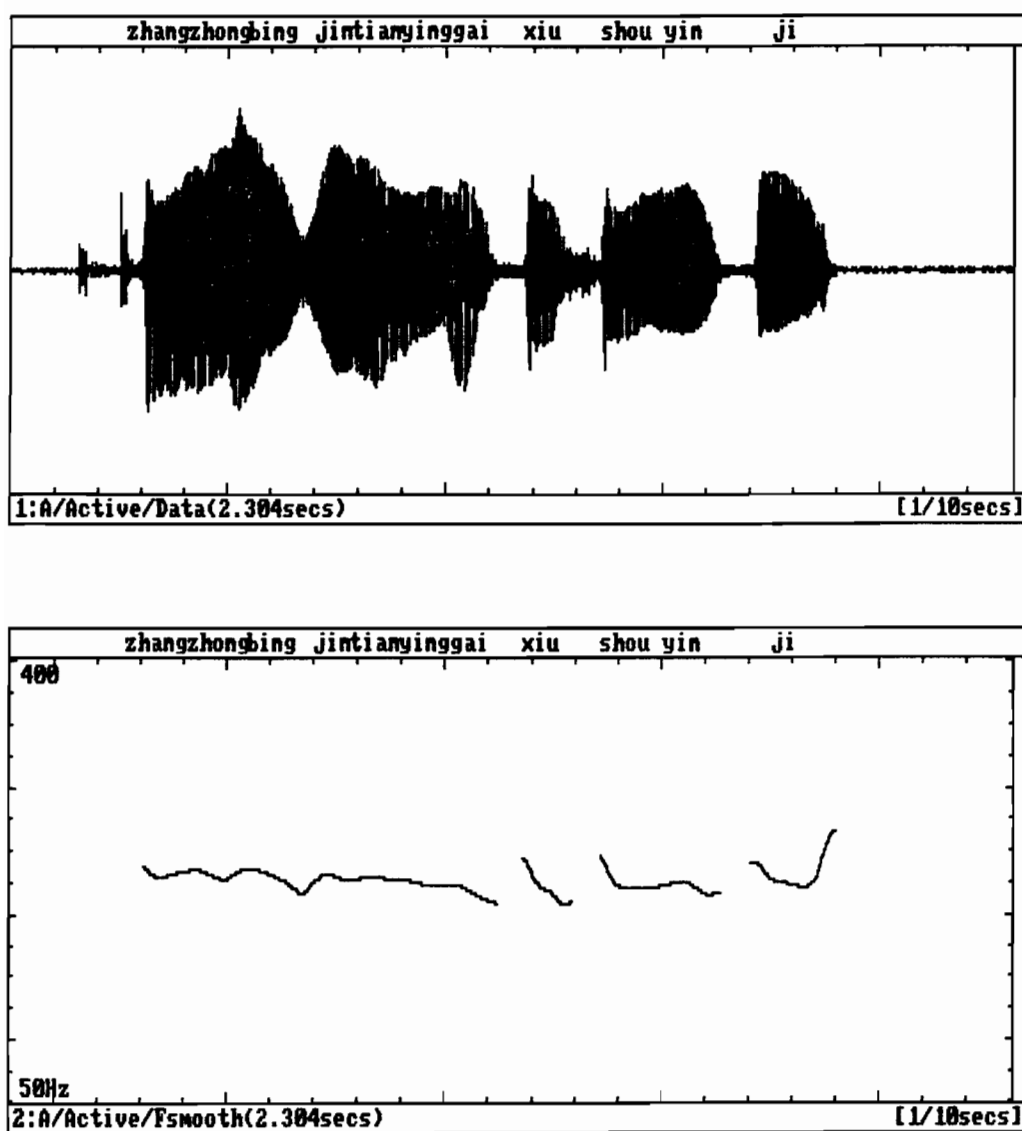


Figure 7.17 Waveform and pitch tracks of sentence HJS1f, Zhang Zhongbing jintian yinggai xiu shouyinji. 'Zhang Zhongbing should repair a radio today.' Shouyinji is emphasized.

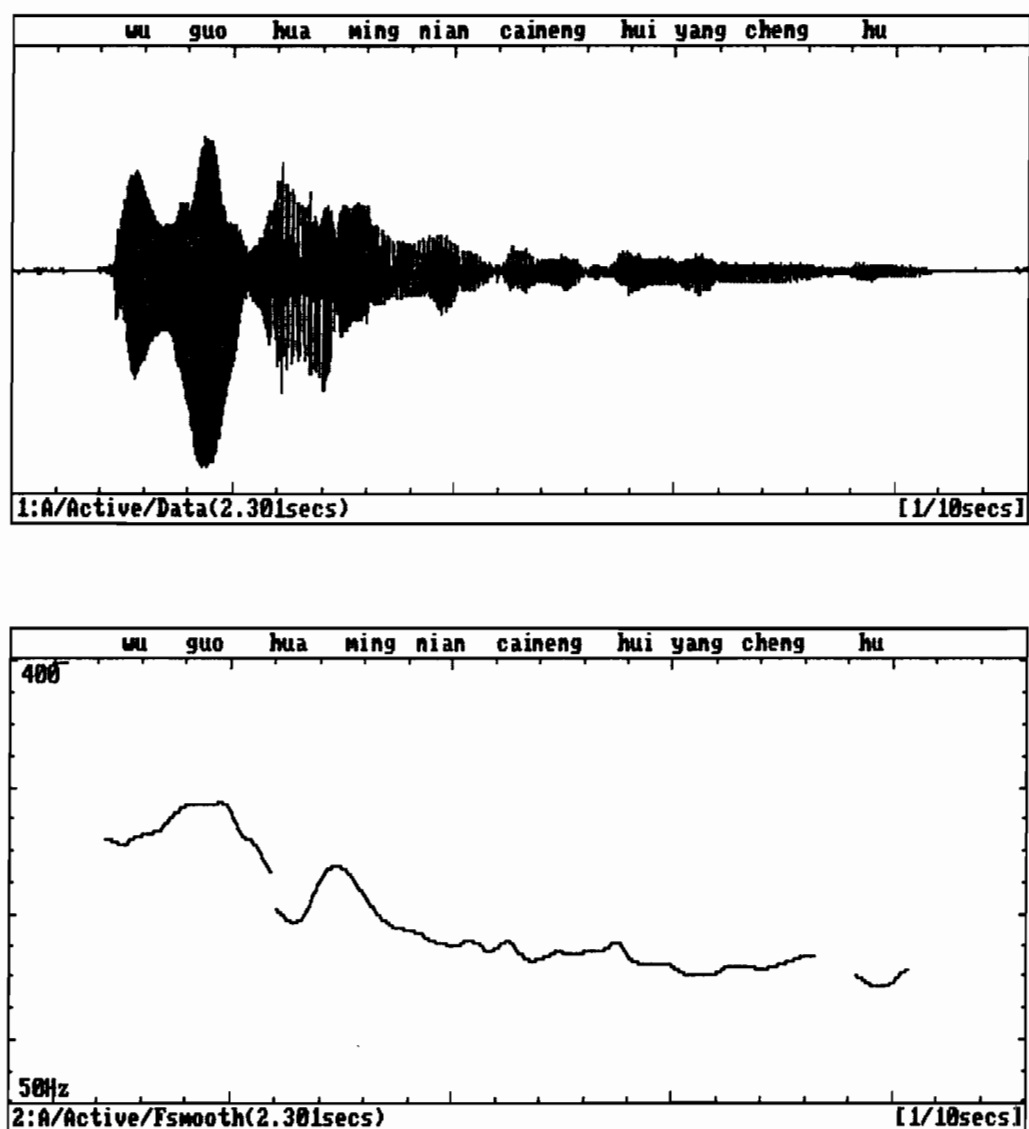


Figure 7.18 Waveform and pitch tracks of sentence HJS2d, Wu Guohua minqnian caineng hui Yangchenghu. 'Wu Guohua cannot go back to Yangcheng Lake until next year.' Wu Guohua is emphasized.

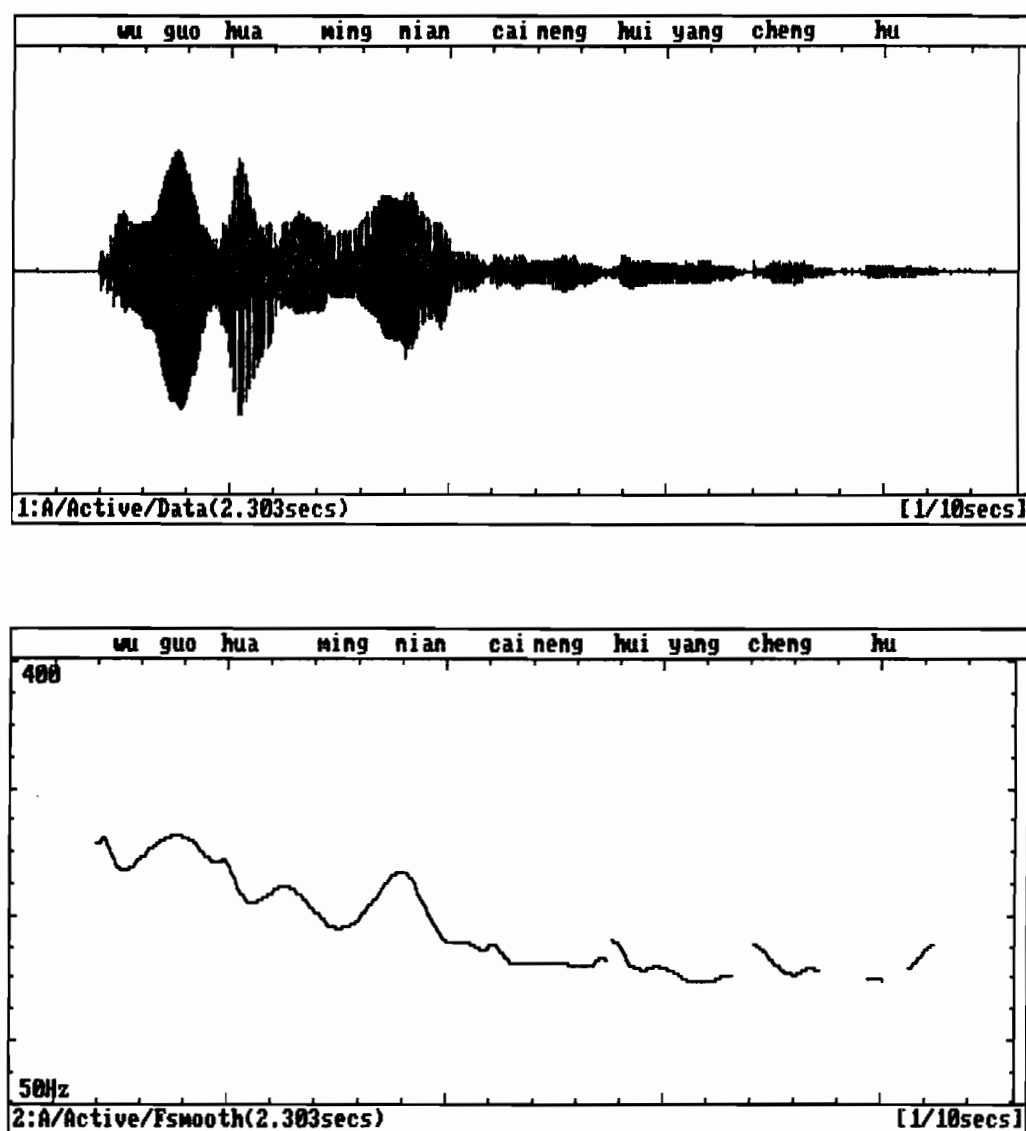


Figure 7.19 Waveform and pitch tracks of sentence HJS2e, Wu Guohua mingnian caineng hui yangchenghu. 'Wu Guohua cannot go back to Yangcheng Lake until next year. Mingnian is emphasized.

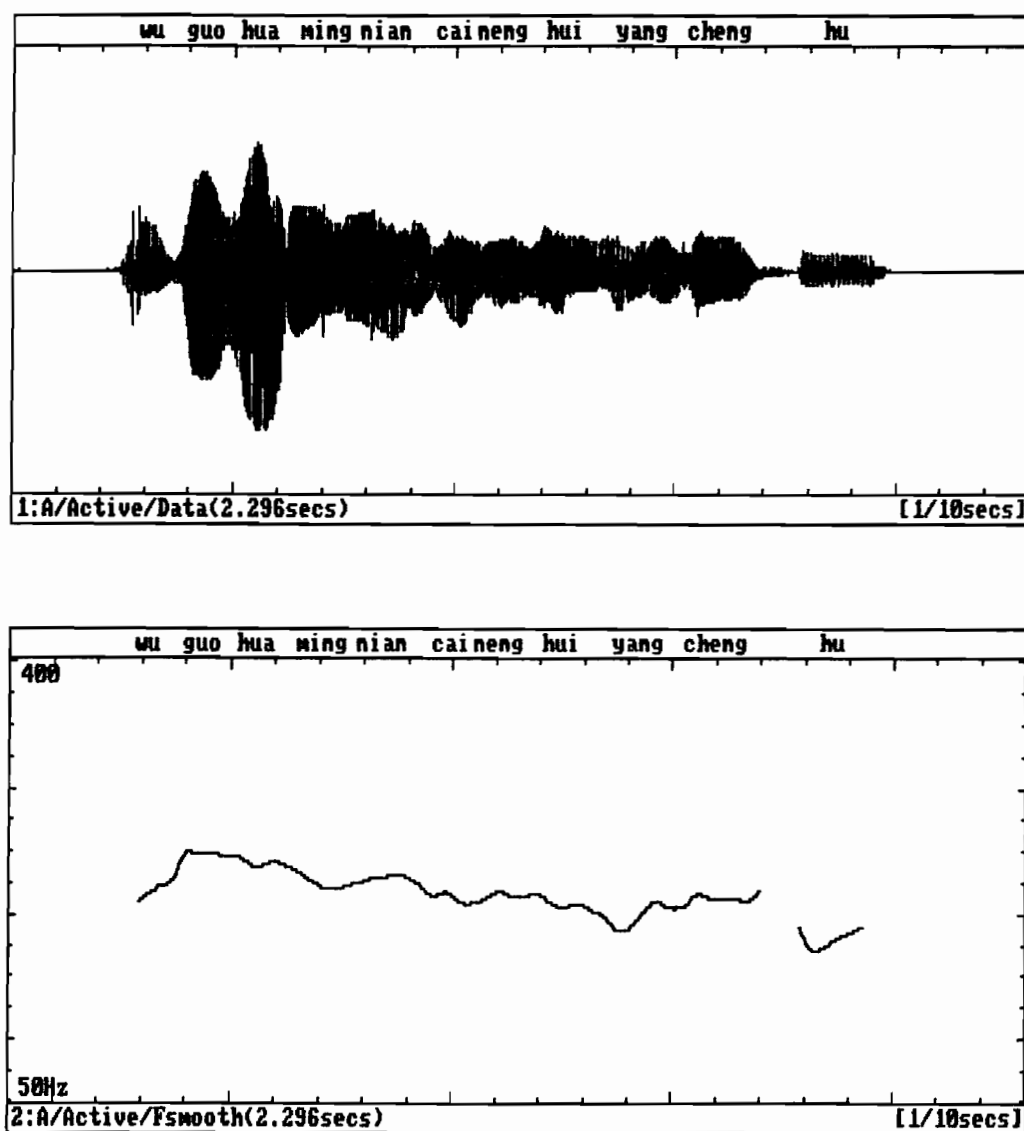


Figure 7.20 Waveform and pitch tracks of sentence HJS2f, Wu Guohua mingnian caineng hui Yangchenghu. 'Wu Guohua cannot go back to Yangcheng Lake until next year.' Yangchenghu is emphasized.

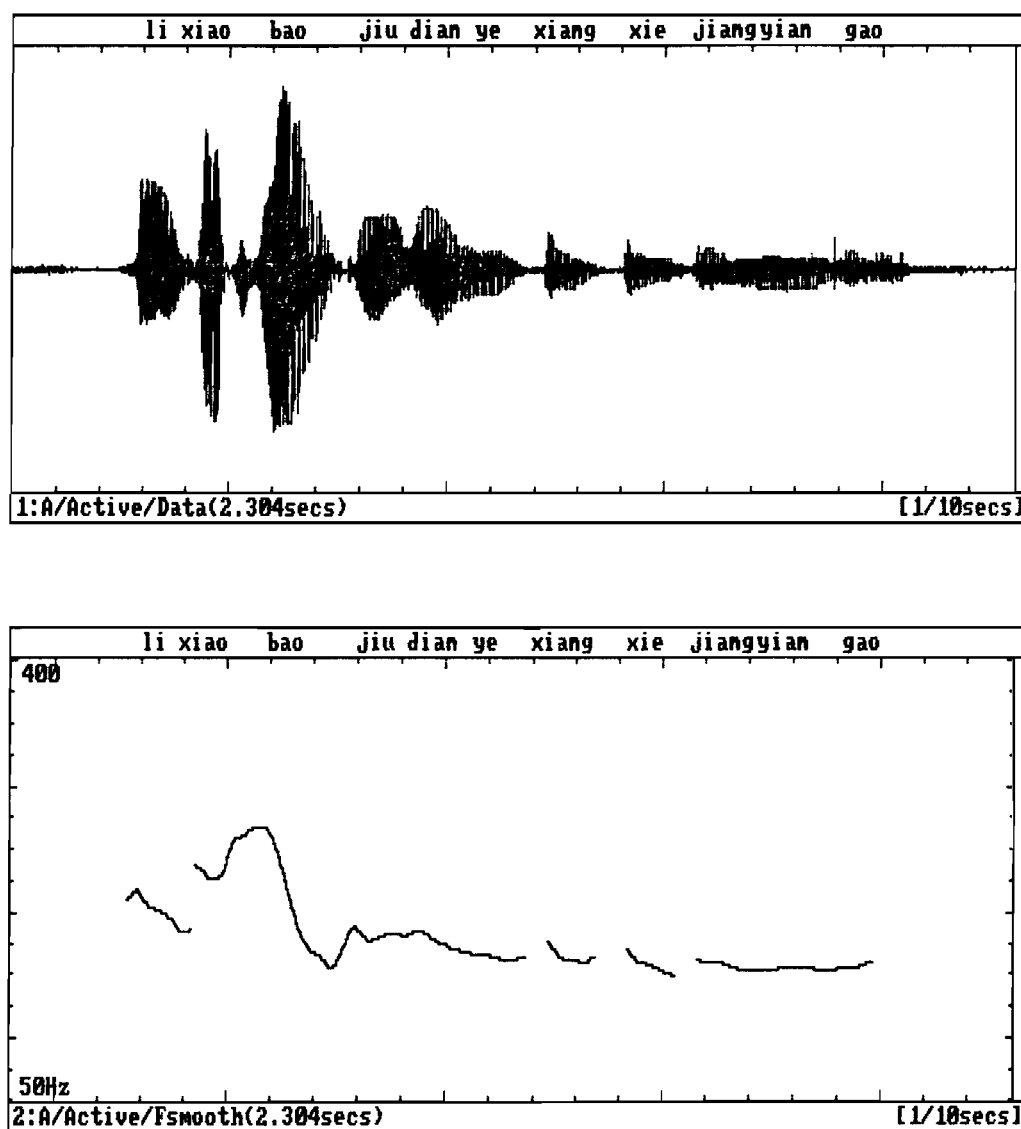


Figure 7.21 Waveform and pitch tracks of sentence HJS3d, Li Xiaobao jiudian ye xiang xie jiangyangao. 'At 9:00, Li Xiaobao wants to write a draft for a lecture too.'  
Li Xiaobao is emphasized.

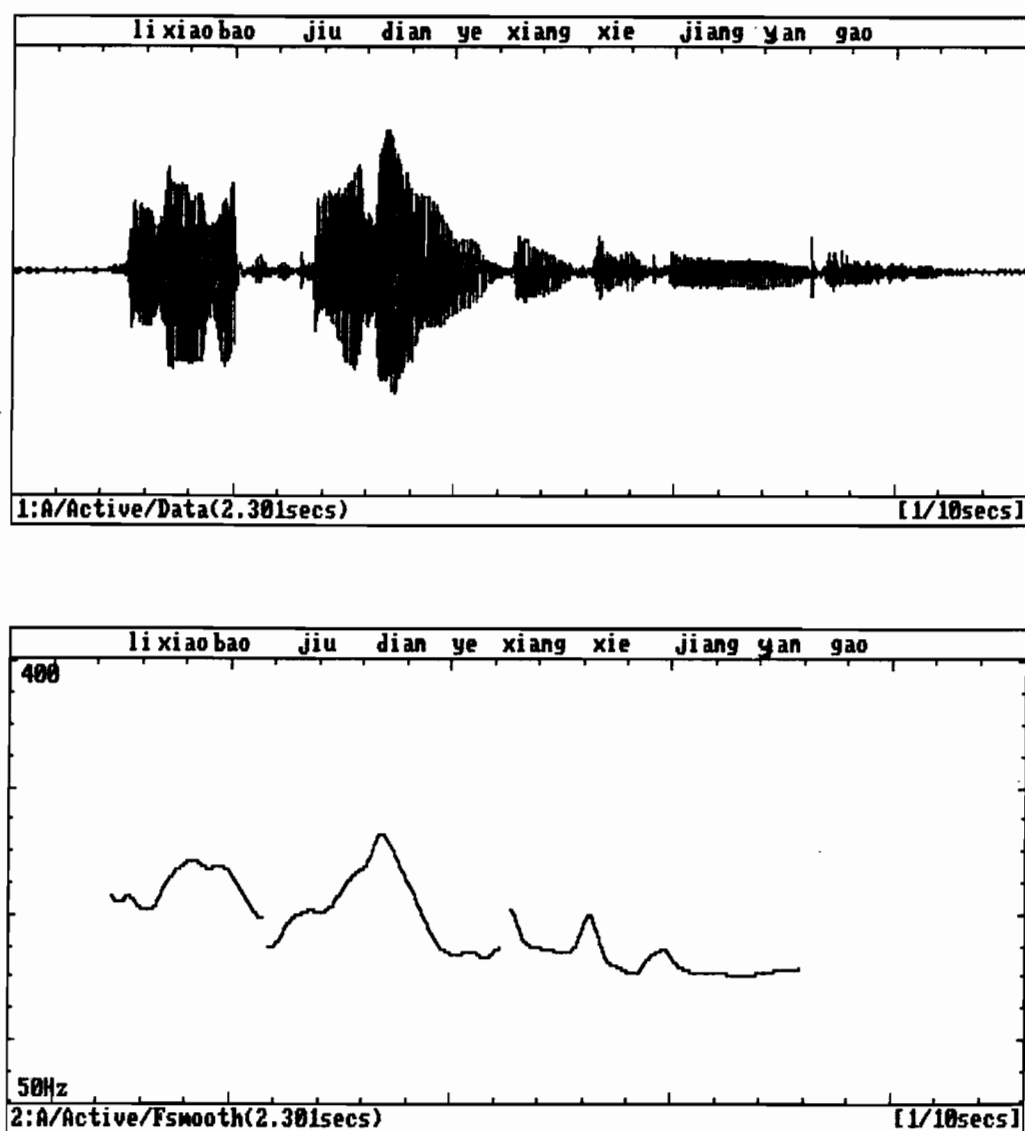


Figure 7.22 Waveform and pitch tracks of sentence HJS3e, Li Xiaobao jiudian ye xiang xie jiangyanqao. 'At 9:00, Li Xiaobao wants to write a draft for a lecture too.' Jiudian is emphasized.

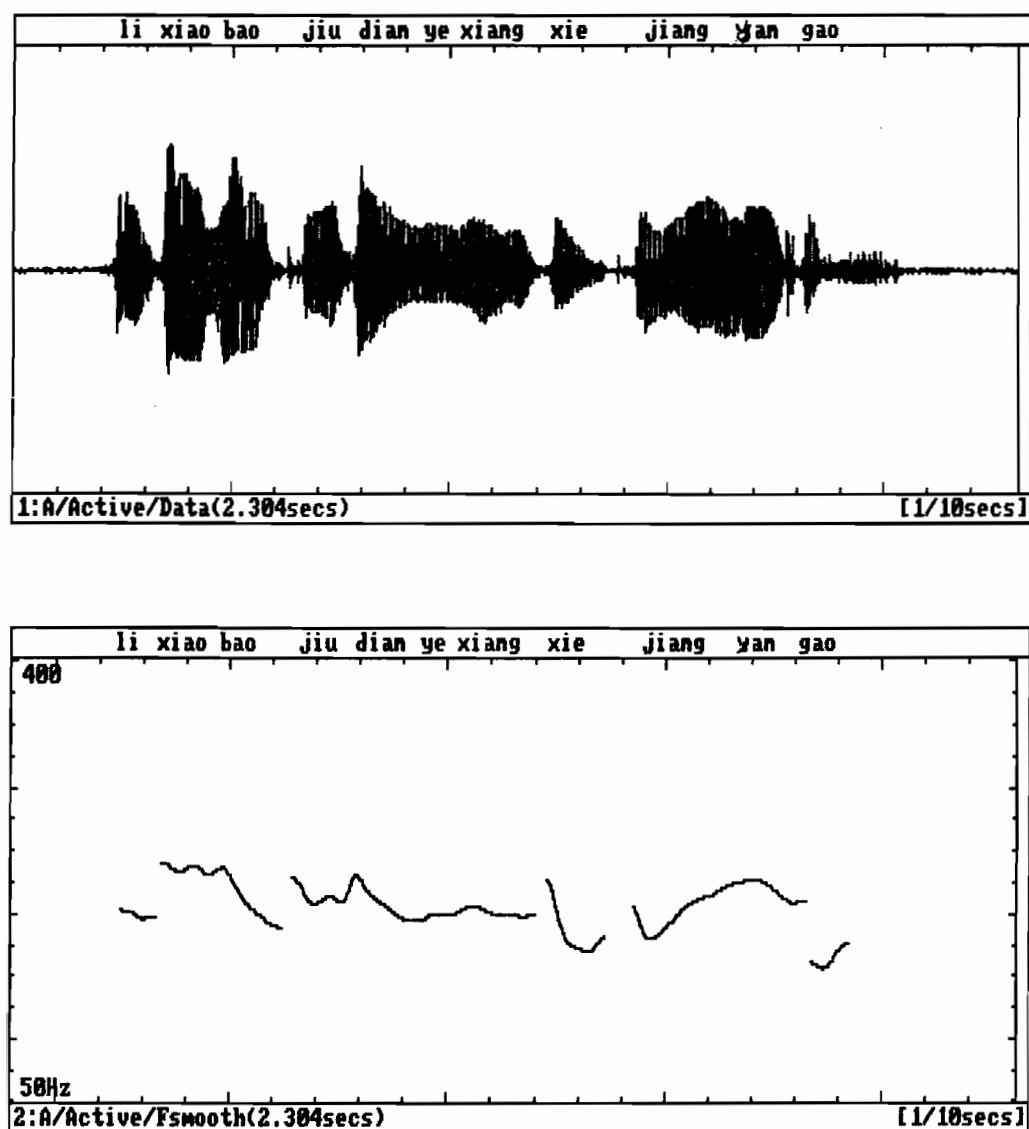


Figure 7.23 Waveform and pitch tracks of sentence HJS3d, Li Xiaobao jiudian ye xiang xie jiangyanqao. 'At 9:00, Li Xiaobao wants to write a draft for a lecture too.' Jiangyanqao is emphasized.



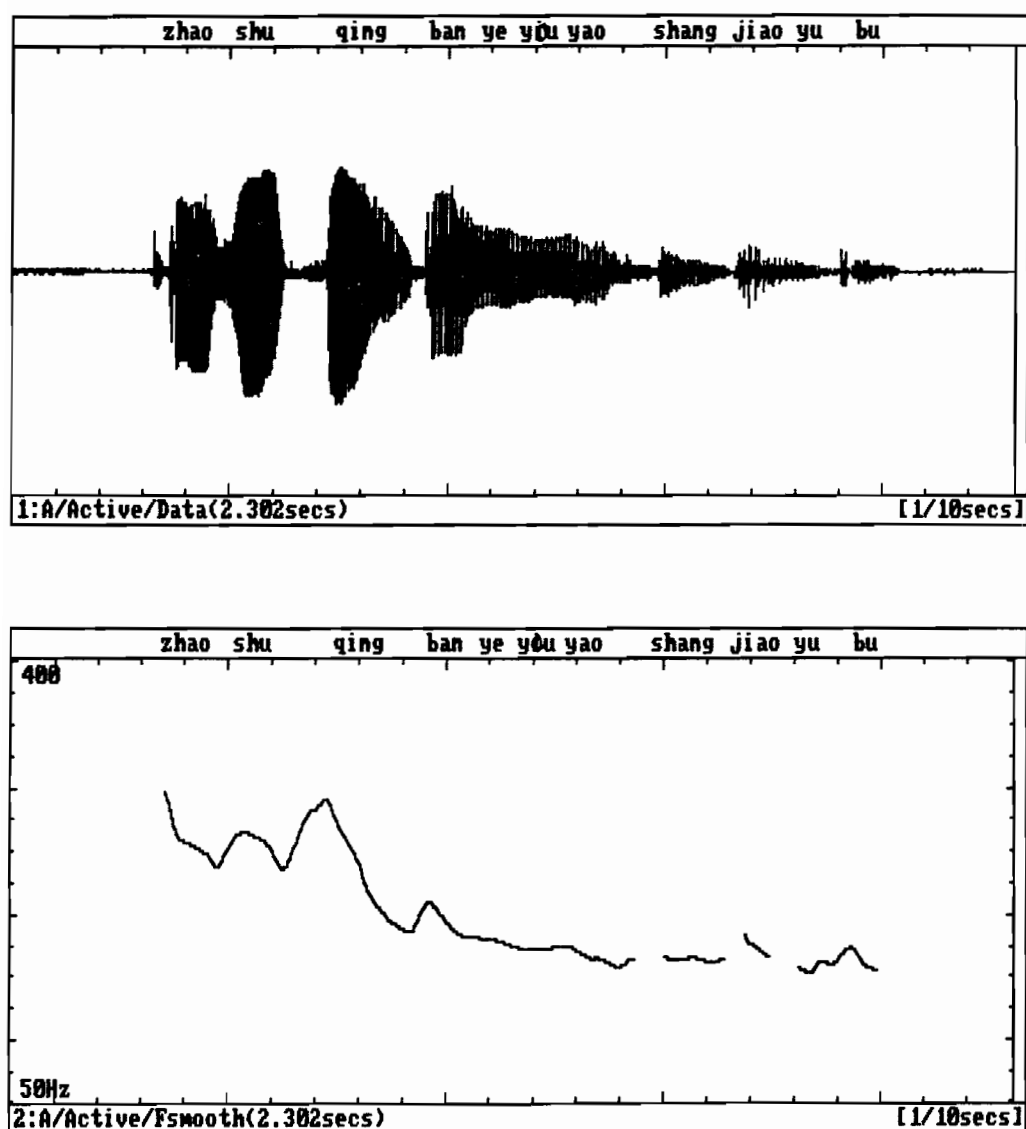


Figure 7.24 Waveform and pitch tracks of sentence HJS4d, Zhao Shuqing banye you yao shang jiaoyubu. 'Zhao Shuqing will go to the Ministry of Education in the middle of the night again.' Zhao Shuqing is emphasized.

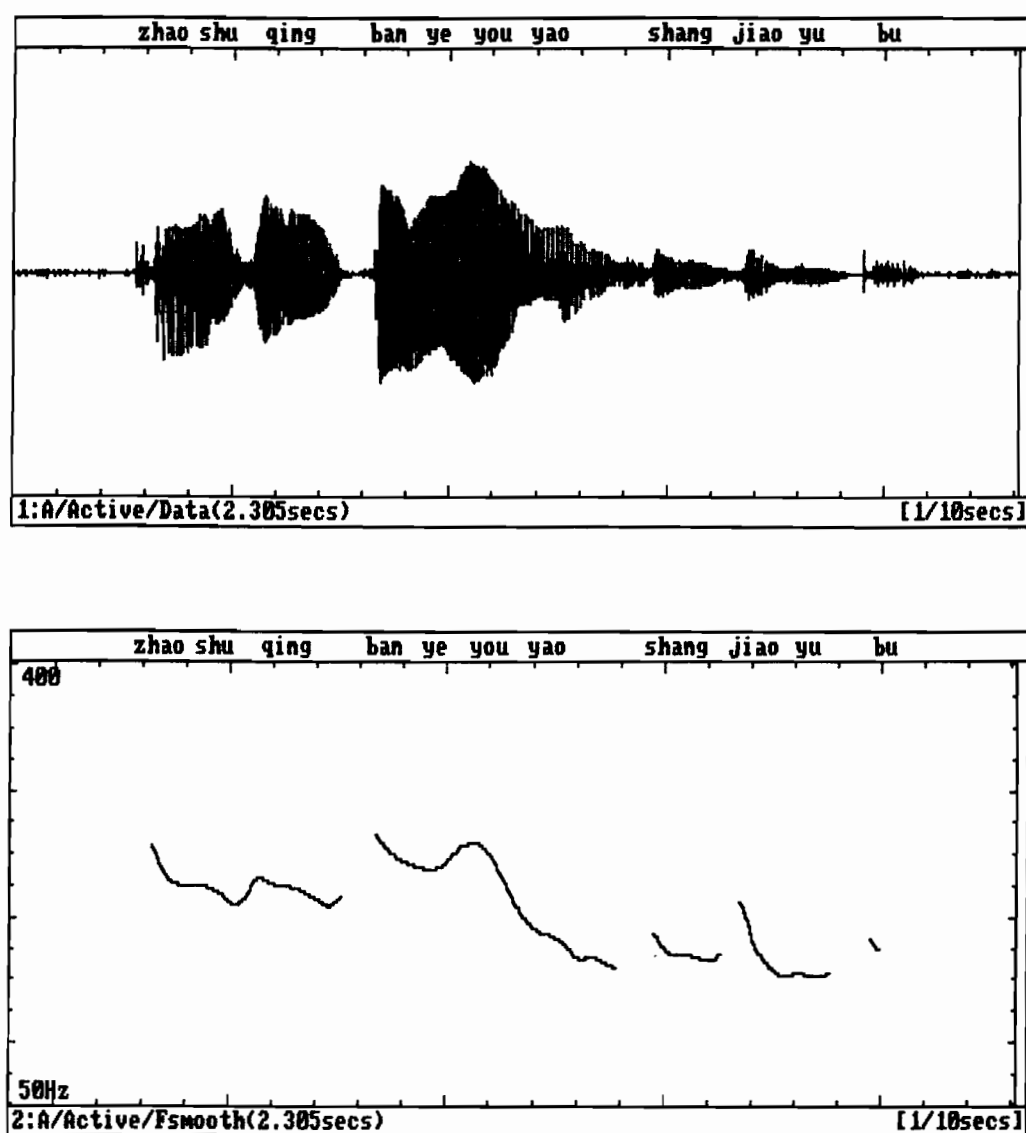


Figure 7.25 Waveform and pitch tracks of sentence HJS4e Zhao Shuqing banye you yao shang jiaoyubu. 'Zhao Shuqing will go to the Ministry of Education in the middle of the night again.' Banye is emphasized.

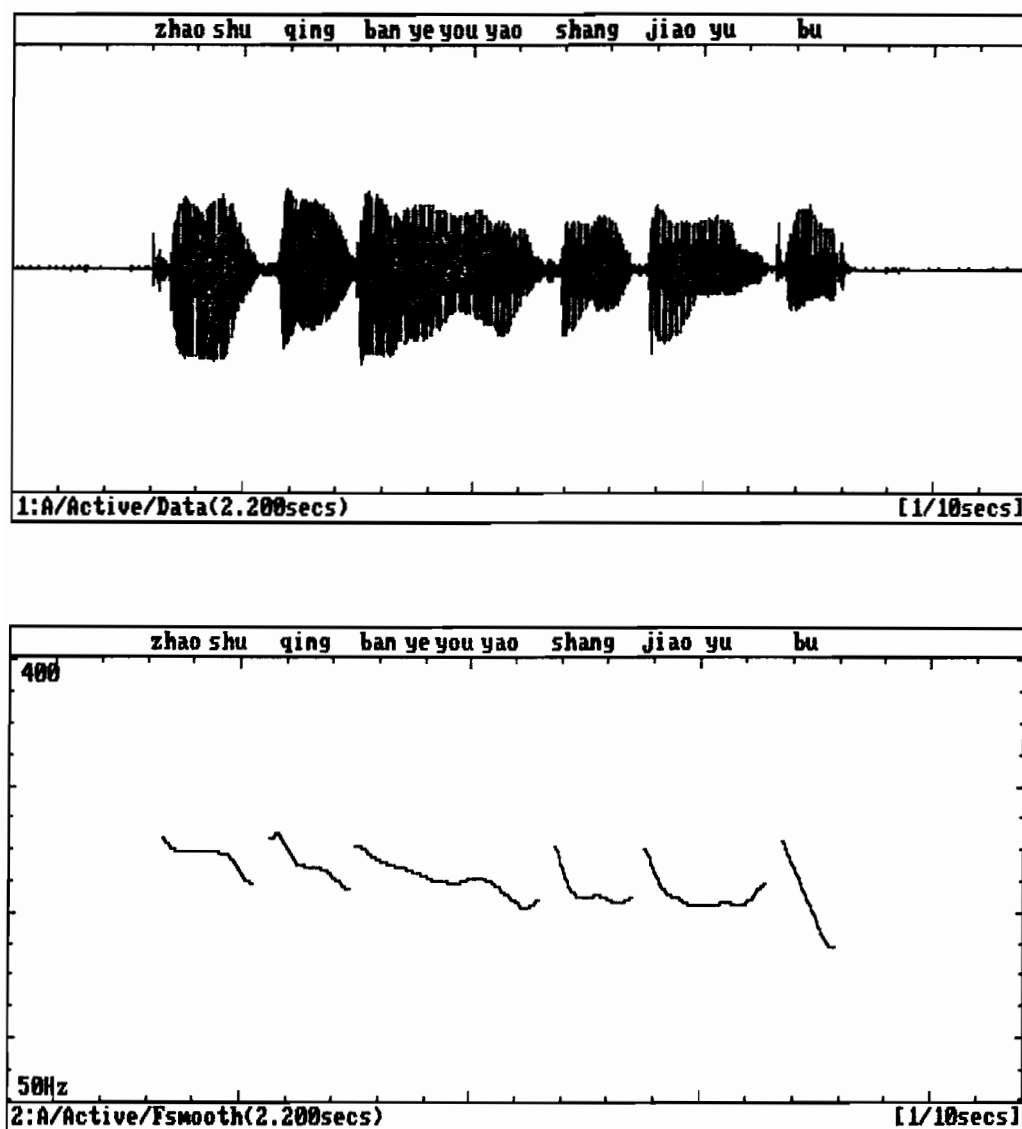


Figure 7.26 Waveform and pitch tracks of sentence HJS4f Zhao Shuqing banyeyouyao shang jiaoyubu. 'Zhao Shuqing will go to the Ministry of Education in the middle of the night again.' Jiaoyubu is emphasized.

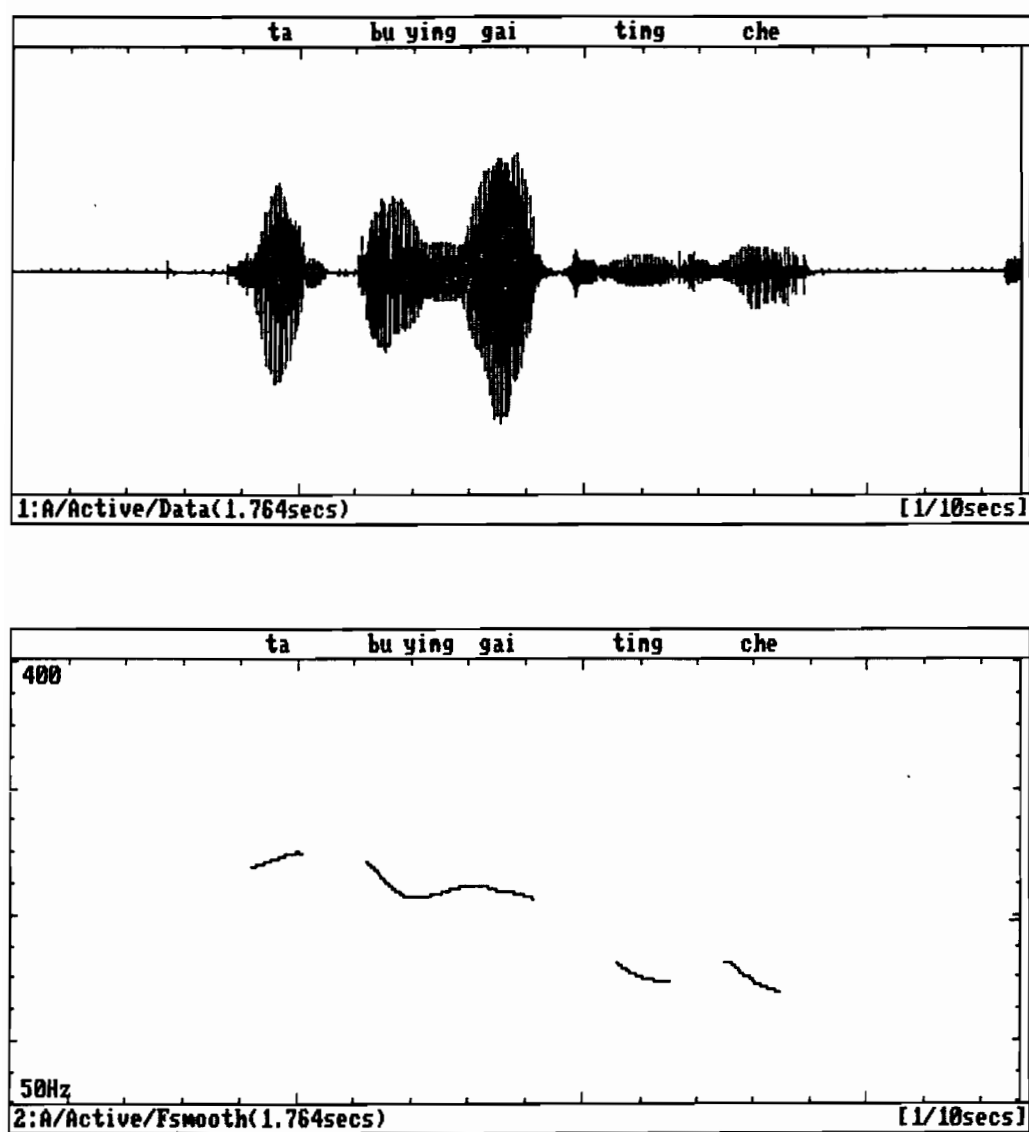


Figure 7.27 Waveform and pitch tracks  
of sentence ZJ32, Ta bu yinggai ting che.  
'She should not stop the car.'

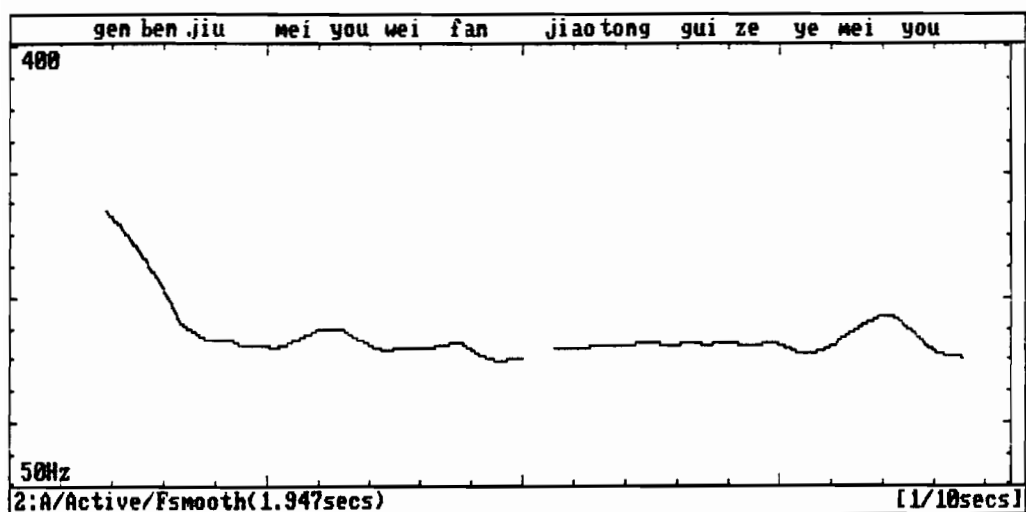
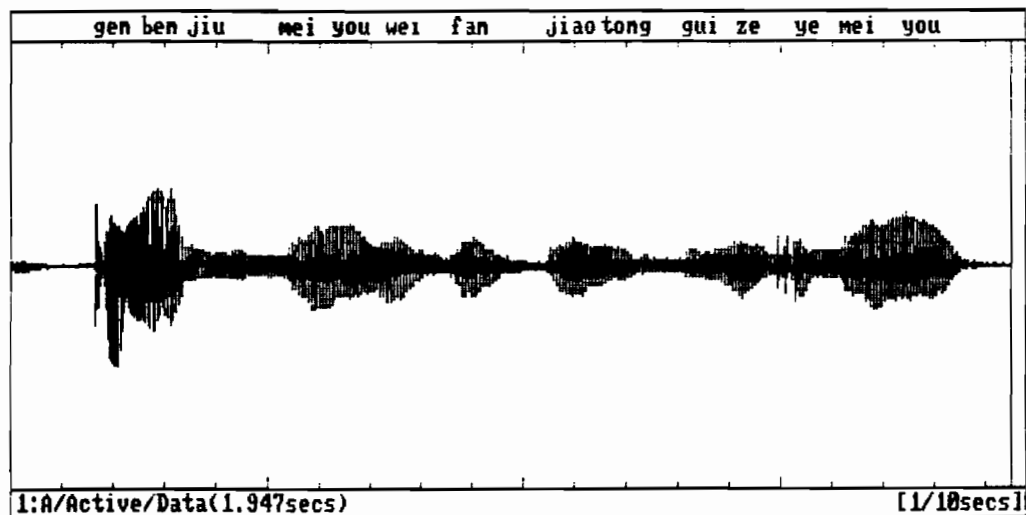


Figure 7.28 Waveform and pitch tracks of sentence HJ45, Genben jiu meiyou weifan jiaotong guize, ye meiyou... '(She) simply did not violate the traffic regulation, also did not...'

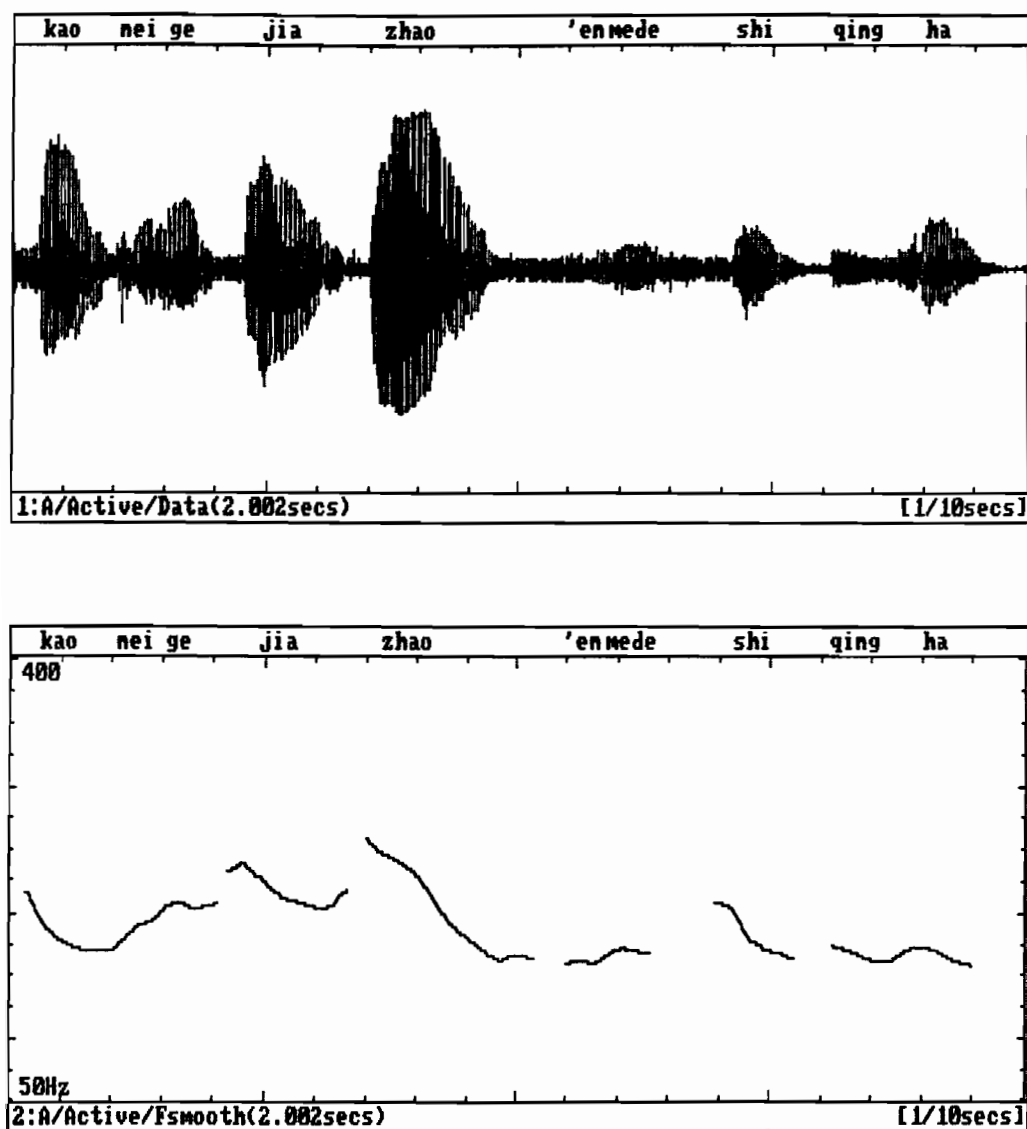


Figure 7.29 Waveform and pitch tracks of sentence HJ8, ...kao neiqe jiazhao shenmede shiqing ha. '...things like taking road test for driver's license.'

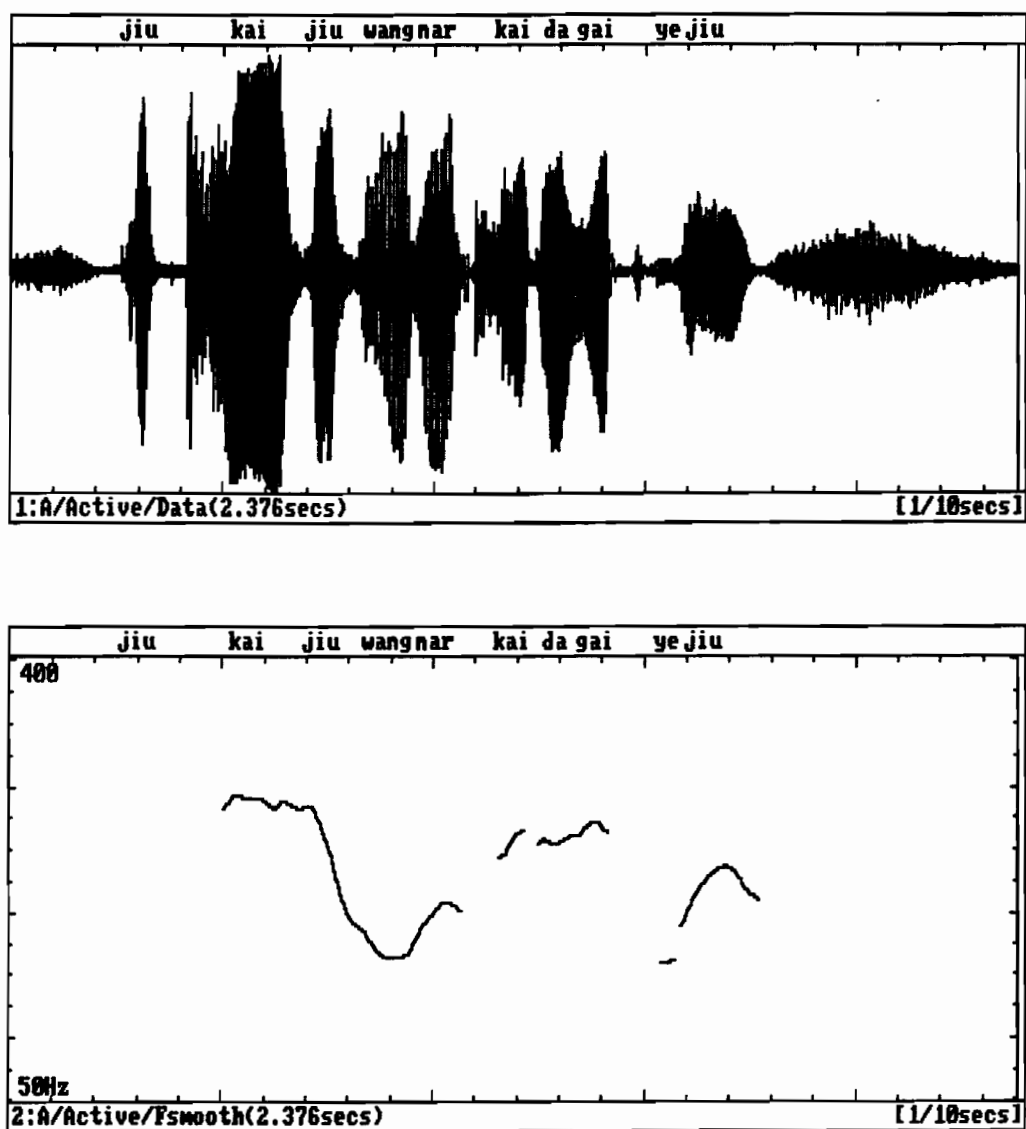


Figure 7.30 Waveform and pitch tracks of sentence ZJ4041, Jiu kai, jiu wang nar kai, dagai ye jiu... '(I) just drove, drove forward, maybe only...'

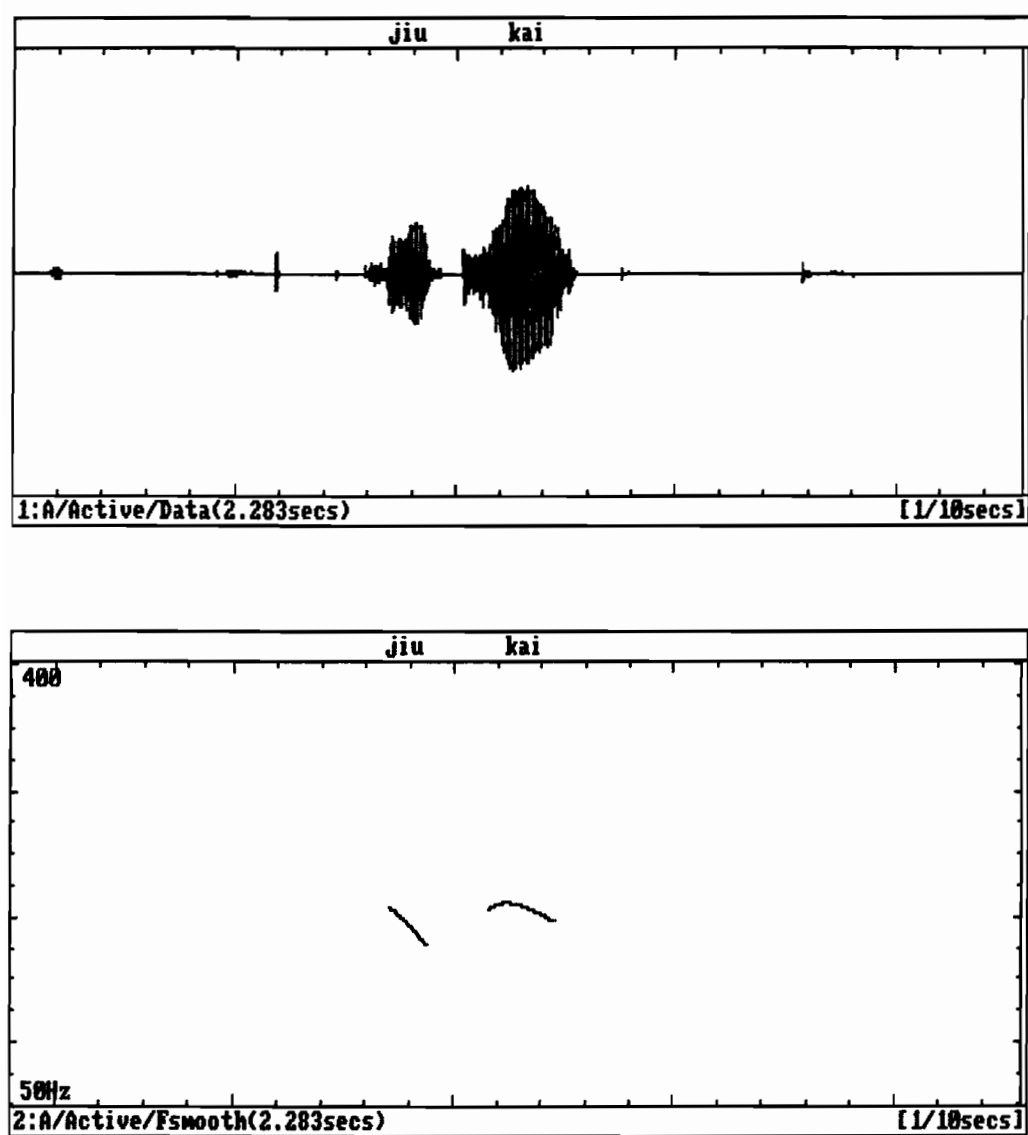


Figure 7.31 Waveform and pitch tracks  
of sentence ZD40, Jiu kai,... '(I) just  
drove, ...'



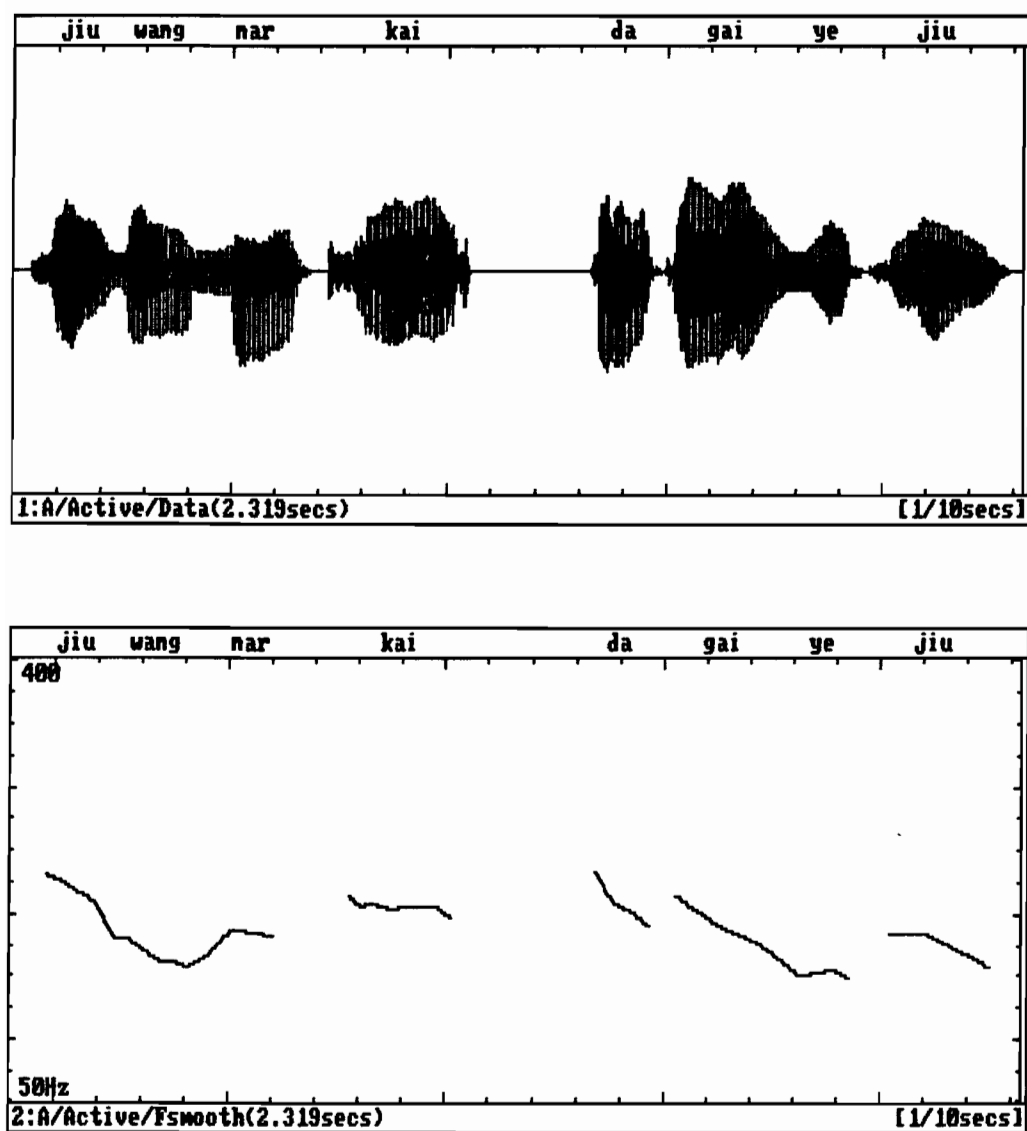
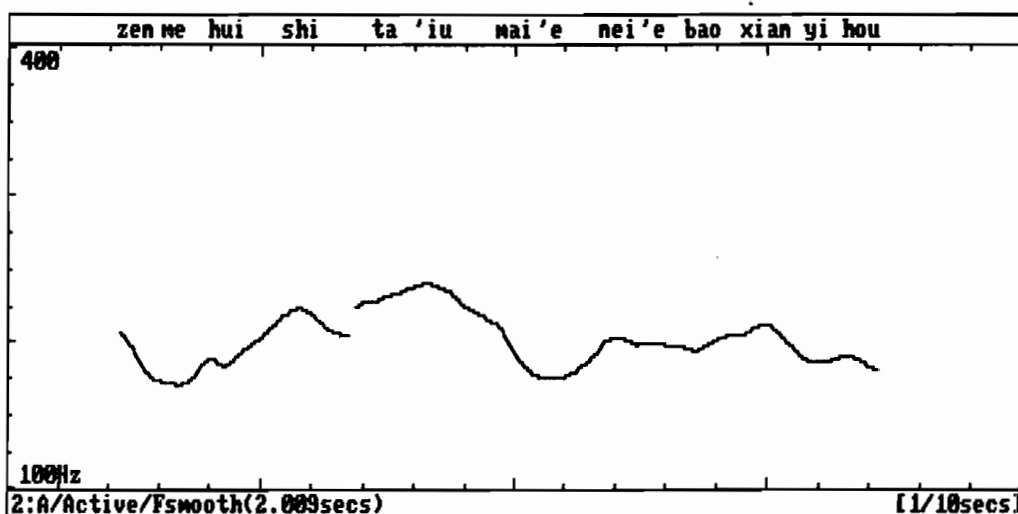
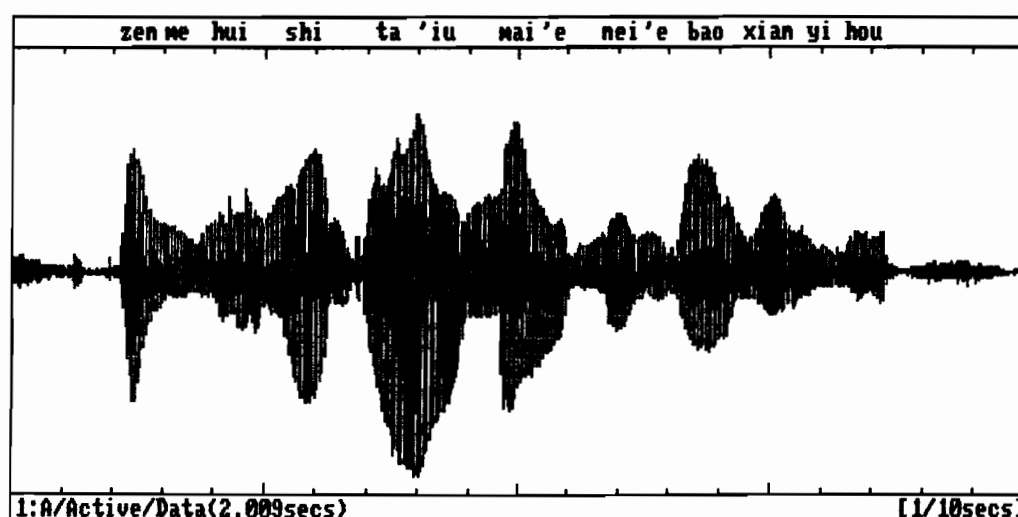
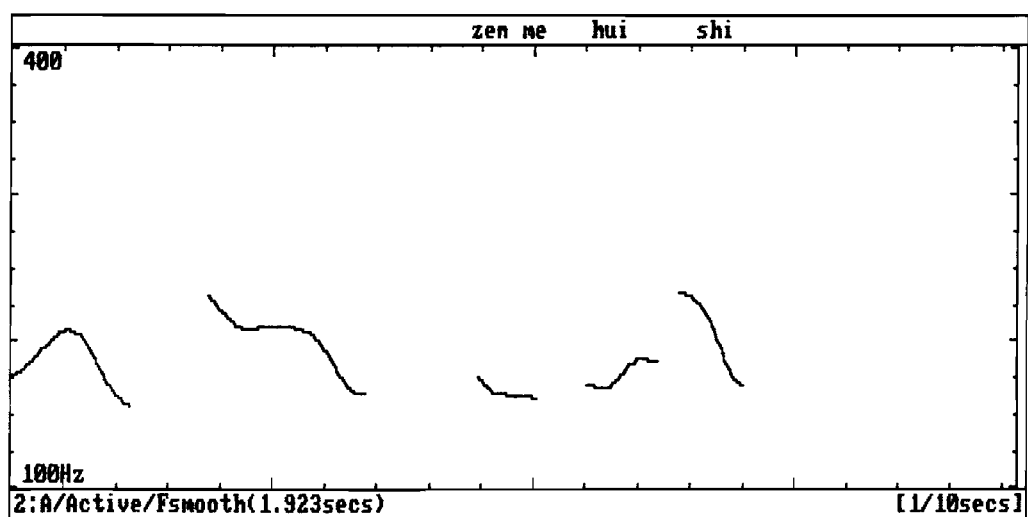
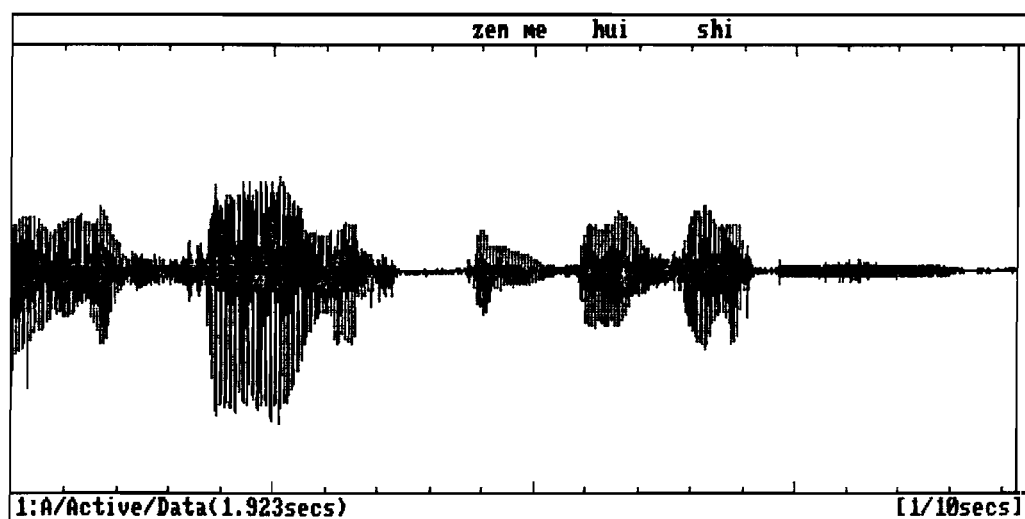


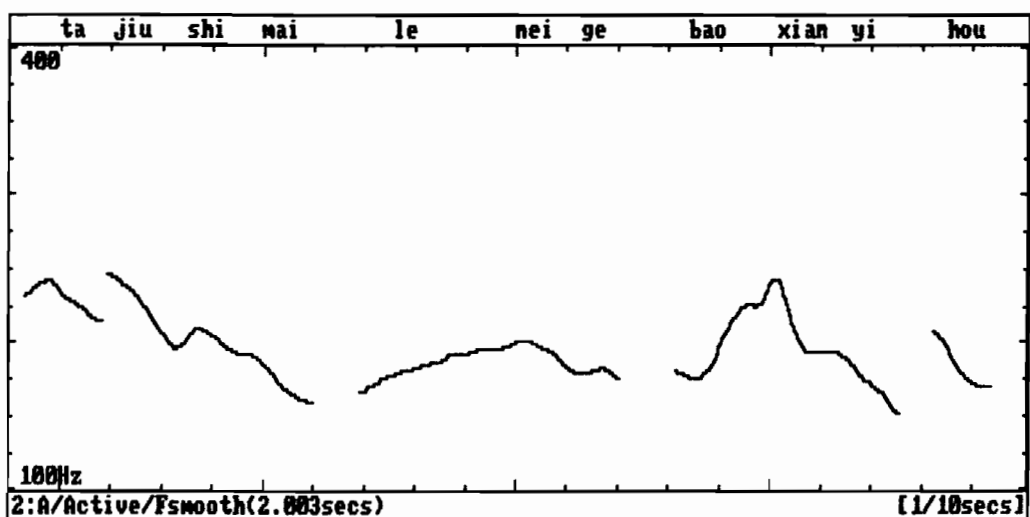
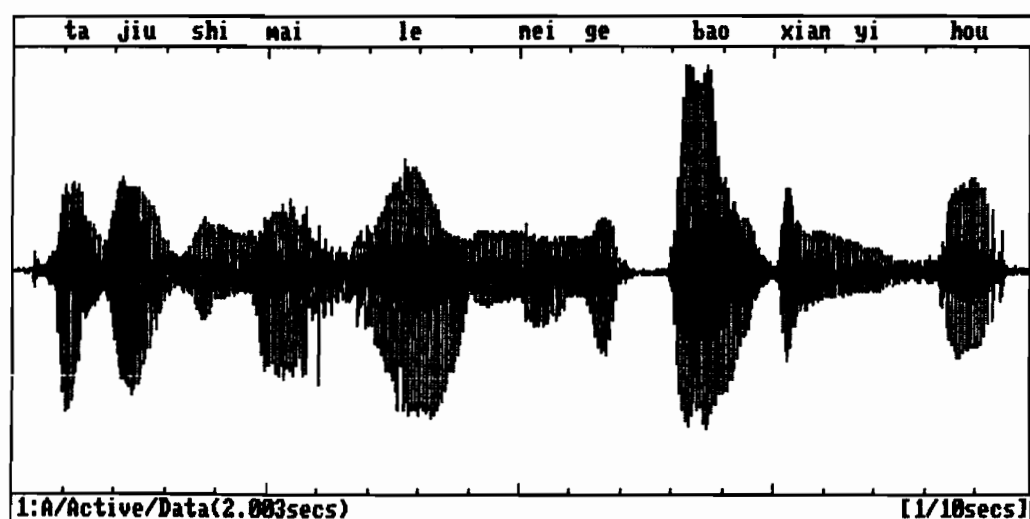
Figure 7.32 Waveform and pitch tracks of sentence ZD41 jiu wang nar kai, dagai ye jiu... '(I) drove forward, maybe only...'



Figures 7.33 Waveform and pitch tracks of sentence HJ4041, Zenme hui shi? ta jiushi mai le neige baoxian yihou,... 'What has happened? It is that after she bought the insurance,...'



Figures 7.34 Waveform and pitch  
tracks of sentence HD40, Zenme hui shi?  
'What has happened?'



Figures 7.35 Waveform and pitch tracks of sentence HD41, Ta jiushi mai le neige baoxian yihou,... 'It is that after she bought the insurance,...'

## CHAPTER VIII

### FORMATION OF PITCH MOVEMENT

I have assumed that there are three levels of pitch units. They are tone, tune, and intonation. The questions of how does a tone realize its surface form in a syllable and how a tune is formed at the level of intermediate phrase have been discussed. The question now I am facing is: what is an intonation and how is it formed? How many prosodic levels are there in Mandarin speech? How are pitch undulations formed at higher levels? In this chapter, the questions are briefly answered and a short discussion about prosodic structure in Mandarin speech is provided.

#### 8.1. Prosodic structure

In order to obtain a comprehensive understanding of tonal phenomena in Mandarin speech, a clear idea of prosodic structure of the language is necessary. As mentioned before, the prosodic structure of a specific utterance is decided by various known and unknown

linguistic and non-linguistic factors. In other words, how people speak is decided by these factors. For a specific utterance, we may not know how all factors function and how they function in determining the prosodic structure, nor why the speaker spoke in this manner. However, it is possible to identify the prosodic structure of this utterance through the surface information that we obtained. The information includes not only the listening impression, but also the output of instrumental analysis. In this study, I identify prosodic structures of real life speech mainly according to listening impression. Data from acoustic analysis are also used to support the identification.

I propose that the prosodic structure in Mandarin speech is as follows.

(1)	Prosodic levels	Tonal constituents
	-----	-----
	(Higher Levels)	(Group of Intonations)
	Intonational Phrase	Intonation
	Intermediate Phrase	Tune
	Prosodic Word	Tone

The three lowest prosodic levels of the structure are those of prosodic word, intermediate phrase, and intonational phrase. The corresponding tonal constituents at the three levels are tone, tune, and intonation. A prosodic word is a

single stressed syllable, which usually has a full tone. However, sometimes a single-syllable exclamation which does not bear a typical tone is also a prosodic word. Usually, a prosodic word is equal to a syntactic word or morpheme. An intermediate phrase contains at least one stressed syllable and serves as a basic tone sandhi domain. It is usually equal to the whole or a portion of a word, phrase, or sentence. An intonational phrase contains at least one intermediate phrase and may be equal to more or longer syntactic constituents.

## 8.2. Intonation

As mentioned in Chapter 2, because there is no commonly held definition of intonation in Mandarin, I have to clearly state my definition of intonation. A Mandarin intonation is the actual movement of the fundamental frequency, or pitch, in an utterance. In fact, this is a definition of the surface form of the intonation.

I assume that the underlying form of intonation includes three types of component information. The first type of component information includes a sequence of underlying tones which occur in the sentence, and the order of their occurrence. This information have been discussed in previous chapters.

The second type of component information is a set of

features about the height of the imagined pitch range. I have already proposed the three lowest prosodic levels: prosodic syllable, intermediate phrase, and intonational phrase. The corresponding tonal constituents are: tone, tune, and intonation. Underlying features of height should be available at each of these three levels. Most studies of tones discuss the height of each underlying tone. As reviewed in Chapter 2, most recent studies of intonation discuss the shape and overall height of the pitch range for a sentence, and define this curved band of pitch range as the intonation of the sentence.

I hypothesize that there is an underlying height not only for each tone, but also for each tune and intonation. The underlying height of each of the four tones is lexically decided, which is already well known. The imagined pitch range of an intermediate phrase is used as reference to determine a feature as "high" or "low". In Chapter 4, we have already used such a local pitch range as reference to evaluate heights of surface tonal contours.

The underlying height of a tune is decided by different linguistic or non-linguistic factors. The reference for the feature "high" or "low" of the tune is the pitch range for the intonation, which contain the tune, the size of the intonational pitch range is decided by the maximum and minimum pitch values occurring on the intonation. Inside an



intonational pitch range, the underlying features "high" or "low" of tunes provide a framework, i.e. the shape and overall height, of the sequence of intermediate pitch ranges. This framework has been considered as intonation itself by many scholars, as reviewed in Chapter 2. Figure 5.13 is a good example showing the relationship between intonational and intermediate pitch ranges, as well as that between pitch undulations and pitch ranges. The corresponding utterance of Figure 5.13 is CJ2829, transcribed in (1). CJ2829 contains three intermediate phrases, and the first two belong to one intonational phrase. Referring to the intonational pitch range, the underlying heights for these two tunes are clearly reflected by the surface pitch contours. The overall feature is "high" for the first tune, but it is "low" for the second tune. However, in most situations, heights of tunes do not vary this much. Figure 5.14 shows a normal example, where each tune has the same feature "low".

The underlying height of a sentence is usually decided due to pragmatic reasons. For example, the intonation of an unimportant explanatory insertion in a discourse often has a low key, and hence the underlying height at the sentence level is "low". We have seen such an example in Figure 4.27, which shows the low intonation of sentence ZJ27. The reference of the overall feature "high" or "low" of an

intonation is the possible pitch range, which is defined in Chapter 6.

The third type of the component information, which is included in the underlying form of an intonation, is about the pattern of strength. As mentioned in Chapter 2, the degree of stress, "stressed" or "unstressed", is used as underlying feature for an isolated syllable according to actual strength. However, the notion of "stress pattern" is built on comparison of strengths among constituents which are at the same level. In Chapter 5, stress patterns have been introduced and marked in example sentences by "s"'s and "w"'s only at intermediate phrase level. In fact, underlying information of stress pattern should also be introduced at intonational phrase level. At the level of intermediate phrase, a specific stress pattern indicates the comparison of strengths among syllables inside an intermediate phrase. At the level of intonational phrase, a stress pattern indicates the contrast of overall strengths among intermediate phrases which are contained.

The following expression shows all of the component information which are included in the underlying form of an utterance.

## (2) CJ2829

Conglai meiyou	kai guo che,	ye conglai meiyou, ...	
35 35 35 21	55 51 55	21 35 35 35 21	UT
H	L	H	IM
H		H	IT
s w w s	w s w	s s w w s	IM
s	w	s	IT

hitherto not drive ASP car also hitherto not  
 "(I) have never driven a car, I have also never..."

In this example, there are three intermediate phrases, which belong to one and a half intonational phrases. In the above expression, "IM" and "IT" indicate the level of intermediate phrase and that of intonational phrase respectively. Stress patterns at both levels are marked. The underlying tones and overall heights of tunes and intonations are also provided. Figure 5.13 shows the surface form of pitch movement in this example.

In the process of surface realization of intonation, all three types of component information in the underlying form, function to create a surface intonation. The key point is that pitch has to undulate. Similar to a tune, an intonation is normally in a shape of pitch undulation, which is exhibited in all figures that we have examined. The tendency of pitch undulation, and the stress patterns at both levels control surface realization of the tones to form a surface intonation.

Under the control, the sequence of underlying tones

and their order of occurrence contribute to the shapes of the tunes at the level of intermediate phrase. These tunes and their order of occurrence, contribute to the shape of the intonation. The features of height at intermediate phrases level adjust the overall heights of the tunes, and those at intonational phrase level adjust the overall height of the intonation. The pitch range of an intermediate phrase is positively proportional to the strength of stress. The stress patterns adjust the amplitude of the tunes, and hence influence the actual shape of the pitch movement. This is reflected clearly in Figure 5.13. Because of the stronger stress, the pitch range is much larger in the first intermediate phrase than in the second one. The amplitude of pitch undulation, which indicates the size of pitch range, is much larger for the first tune than for the second. The shape of each tune, and hence the whole shape of intonation, is obviously affected by the pitch range. Since the whole sentence is produced with rather strong strength, the overall pitch range is rather large throughout the sentence. As noted in Chapter 7, compared with read speech, spontaneous speech exhibits larger variation of pitch ranges.

In an utterance, if the stress is very strong in one intermediate phrase, but weakened in the following ones, then the phenomena caused by strong emphasis, exhibited in

Chapter 7, may occur. The pitch undulations of weak intermediate phrases reduce in proportion to the degree of weakness. The extreme situations are those we have seen in Figures 7.15, 7.18, 7.21, and 7.24. When the stresses of the intermediate phrases are totally weakened, their tunes are totally reduced. These tunes serve as a long tail of the emphasized tune and declined toward the end of the sentence.

Comparing the function of weakening in intermediate phrases to that in intonational phrases, i.e. comparing the functions at the two different levels, we can see the similarity. We have observed many examples of how a tone realizes its surface form in a weakened, or stressless, syllable. The underlying shape disappears, and the pitch contour is realized as a pre- or a post-extension of a strong tone, or a transition between two strong tones. Now we see that at the sentence level, this also happens: the long tail realized in the weak intermediate phrase is in fact a post-extension of the tune of the previous strong intermediate phrase. As noted in Chapter 7, this effect of stress at the intonational phrase level overrides that at the intermediate phrase level.

Considering the realization of the surface form of an intonation, I hypothesize that a principle of pitch contour formation in intonational phrases exist. This principle

governs tonal realization conditioned by stress pattern at both levels of intermediate phrase and intonational phrase. However, a more careful study of pitch movement at the intonational phrase level is necessary for both spontaneous and designed speech. I would rather leave the task of presenting this comprehensive principle for future studies.

### 8.3. Levels at which different effects function

In previous chapters, a principle of pitch contour formation at the level of intermediate phrase has been hypothesized, and a principle at the level of intonational phrase has been discussed. Several effects have also been assumed or observed, which include the effect of physical constraint on the production of T3's and the effects of catathesis, contrastive stress, and speech styles. However, the question, "At which levels do these effects function?" has not yet been considered.

According to the pitch tracks of both spontaneous and controlled speech, it is obvious that the effect of physical constraint on the production of T3's function at the level of intermediate phrase. Tone sandhis of a sequence of T3's never cross the boundary of intermediate phrases. A low falling T3 only influences the pitch contours of preceding T3's, which are in the same intermediate phrase. The low falling T3 never causes tone sandhi of

a T3 immediately preceding it but not belonging to the same intermediate phrase.

The effect of catathesis observed in this study also functions at the level of intermediate phrase. Since all the sentences which are designed to test this effect are short, each of them was produced as one intermediate phrase. Therefore, it is not yet known whether the effect of catathesis can cross a boundary of intermediate phrase in Mandarin. If the effect can cross the boundary, then the level at which it functions might be of intonational phrase, rather than of intermediate phrase, as in some other languages, such as Japanese (Pierrehumbert and Beckman 1988).

Strong emphasis, as noted in Chapter 7, may influence pitch movement not only in the same intermediate phrase, but also the following intermediate phrases. Clearly, the effect of strong emphasis observed in my data functions at the intonational phrase level. However, whether it may extend to following intonational phrase has not been analyzed in this study.

The effect of speech style functions at a higher level. Difference of speech styles, spontaneous versus read speech, has been discussed and observed in pitch tracks. In my data, sentences of a whole uncontrolled speech is produced in both spontaneous and read style. The level at

which different styles affect pitch movement is that of discourse. During vivid story-telling, sentences of background information and unimportant explanations are usually uttered much weaker than sentences with important information spoken in a main episode. For example, in speaker Z's spontaneous story telling, sentence ZJ17 is an unimportant explanation. The whole sentence is weak, so its pitch range is very small, which is seen in Figure 4.24. However, in the main episode, every sentence is much stronger and in a relatively higher pitch. Figure 6.12 provides pitch tracks of two such sentences, ZJ4243. The pitch range is much larger throughout the sentences, and several tones lose their basic features to form the undulation with a large amplitude. In a plain read speech, all the sentences are produced in a similar loudness. Reflected in pitch tracks, the pitch range is in a relatively stable size. As a consequence, tonal realization is not affected much by contrastive or weakened stress at both intermediate and sentence levels; therefore, more basic tonal features are maintained. In short, the overall strength of a sentence, either weak or strong, is "planned" at the discourse level according to speech style.

Each of the above effects, no matter on which level they function, contribute to the final formation of pitch undulation of an intonation.



#### 8.4. Valediction

This study tries to provide a general explanation of the complicated tonal phenomena in Mandarin. Pitch movement in a sentence is assumed to form under the control of the principle which has been hypothesized and under the function of various expressive or productive factors. Many points in this study are compatible with the results of previous phonological studies, given certain conditions, such as specific speech style, stress pattern, or occurrence of tonal combinations. I hope that this study will spark more comprehensive studies of pitch movement in Mandarin as well as all Chinese dialects.

# APPENDIX (Chapter 7)

Table 7.1 Averaged frequency value of each syllable insentences WiYj and RWiYj for each speaker and among speakers (in Hz)

---

W1Y1	zhang	wu	yi	yao	mao	mi
SPK1	292	288	278	298	276	274
SPK2	252	256	234	232	217	215
SPK3	195	195	180	186	180	180
SPK4	128	128	128	127	119	113
Average	217	217	205	211	198	196

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W1Y3	zhang	wu	yi	yaoh	yaol	mao	mi
SPK1	300	296	283	277	189	242	246
SPK2	256	267	263	212	137	205	224
SPK3	201	204	182	174	99	132	161
SPK4	133	134	138	127	63	103	113
Average	223	225	217	198	122	171	186

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W1Y4	zhang	wu	yi	yaoh	yaol	mao	mi
SPK1	290	287	276	304	234	256	250
SPK2	250	250	223	248	173	202	212
SPK3	195	199	179	188	147	145	151
SPK4	131	131	133	132	98	102	108
Average	217	217	103	218	163	176	180

---

Table 7.1 (continued)

W3Y1	zhang	wuh	wul	yi	yao	mao	mi
SPK1	301	295	199	251	287	281	281
SPK2	258	253	155	207	225	215	220
SPK3	210	212	107	145	177	173	173
SPK4	135	132	79	102	121	120	119
Average	226	223	135	176	203	197	198

W3Y3	zhang	wuh	wul	yi	yaoh	yaol	mao	mi
SPK1	301	295	198	257	238	182	243	237
SPK2	258	245	158	243	202	136	199	216
SPK3	206	210	114	169	148	93	125	142
SPK4	135	132	94	124	119	70	103	109
Average	221	220	141	198	177	120	168	176

W4Y1	zhang	wuh	wul	yi	yao	mao	mi
SPK1	293	295	230	258	288	279	279
SPK2	252	254	198	212	224	221	227
SPK3	198	207	131	145	166	168	171
SPK4	133	135	105	110	120	119	120
Average	219	223	166	181	200	197	199

W4Y4	zhang	wuh	wul	yi	yaoh	yaol	mao	mi
SPK1	283	292	232	259	300	235	235	261
SPK2	253	254	184	202	247	174	197	206
SPK3	205	216	130	143	172	109	120	127
SPK4	138	137	107	120	133	94	101	109
Average	220	225	163	181	213	153	163	176

Table 7.1 (continued)

RW1Y1	zhang	wu	yi	yao	mao	mi
SPK1	288	280	278	306	313	328
SPK2	247	252	231	227	231	238
SPK3	195	201	183	193	195	200
SPK4	138	137	140	145	148	161
Average	217	218	208	218	222	232

RW1Y3	zhang	wu	yi	yaoh	yaol	mao	mi
SPK1	298	296	288	275	203	263	299
SPK2	262	266	260	218	151	222	244
SPK3	199	203	185	184	102	138	200
SPK4	139	132	144	134	85	120	168
Average	225	224	219	203	135	186	228

RW1Y4	zhang	wu	yi	yaoh	yaol	mao	mi
SPK1	294	291	286	318	271	295	320
SPK2	252	258	230	256	185	227	239
SPK3	215	227	217	225	175	207	238
SPK4	137	137	141	147	112	127	171
Average	225	228	219	237	186	214	242

RW3Y1	zhang	wuh	wul	yi	yao	mao	mi
SPK1	305	302	200	257	302	307	323
SPK2	256	252	153	213	230	237	246
SPK3	206	217	114	142	191	198	207
SPK4	141	136	75	111	138	150	164
Average	227	227	136	181	215	223	235

Table 7.1 (continue)

RW3Y3	zhang	wuh	wul	yi	yaoh	yaol	mao	mi
SPK1	296	295	204	262	249	191	257	283
SPK2	256	253	164	240	214	144	221	245
SPK3	194	202	119	178	151	102	139	195
SPK4	141	139	88	137	130	79	117	166
Average	222	222	144	204	186	129	184	222

RW4Y1	zhang	wuh	wul	yi	yao	mao	mi
SPK1	308	312	244	275	311	318	332
SPK2	252	257	197	217	230	236	241
SPK3	209	220	135	159	186	189	196
SPK4	144	146	111	118	138	146	161
Average	228	234	172	192	216	222	233

RW4Y4	zhang	wuh	wul	yi	yaoh	yaol	mao	mi
SPK1	310	313	252	283	318	265	294	311
SPK2	260	262	202	210	252	190	232	249
SPK3	220	231	148	172	205	172	199	214
SPK4	148	147	118	132	148	113	135	167
Average	235	238	180	199	238	185	215	235

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