

# On Production and Perception of Boundary Tone in Chinese Intonation

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## Abstract

Two variables: pitch accent and boundary tone in Chinese intonation have been found by acoustical analysis and listening test of echo questions in read speech and yes-no questions in spontaneous speech.

Identification test is adopted to verify the acoustic manifestations of boundary tone, and to find out that the register of the ending-point (or the slope) of the  $F_0$  curve in boundary tone plays a more important role than the register of its starting-point in differentiating between question and statement and the identification function about question and statement is not categorical, but continuous.

It is advocated that features of boundary tone is “high” and “low”. Pitch ( $F_0$ ) patterns of boundary tone in Standard Chinese is given. Whether tone-1, tone-2, tone-3, or tone-4, pitch pattern in the boundary tone with question keeps the citation form.

It is single-directionally and hierarchically that intonation acts upon on tones. In the pitch space of five-point values, intonation is represented mainly by register and range of the  $F_0$  curve, but tone is represented by its  $F_0$  contour.

## 1. Introduction

“Movement of pitch in Chinese speech also expresses attitudes, moods and implication, etc., and this part corresponds in part to intonation in English.” [1] Some scholars proposed that the difference between question and statement in Chinese is related to pitch range,  $F_0$  curves or 3 tones of the utterance [2-3, 4-5, 6, 7, 8, 9]), but some other scholars held there is a terminal intonation [10, 11, 12, 13].

Intonation, as I will use the term, refers to the use of  $F_0$  and duration to convey sentence-level pragmatic meaning in a linguistically structured way. Chinese intonation which is represented only by  $F_0$  and duration is yes-no question without “ma0” and the corresponding statement. Chinese intonation has two variables: pitch accents and boundary tone. [14] In this paper, boundary tone will be studied mainly.

This paper is divided into 6 parts. Following part 1 of “introduction”, the acoustic manifestation of boundary tone is presented in part 2. In part 3, an identification test is adopted and its results are presented. In part 4, it is advocated that the way that intonation acts upon tone is single-directionally and hierarchically. In part 5, the pitch ( $F_0$ ) patterns of boundary tone in Standard Chinese is given and features of boundary tone to differentiate between question and statement in Chinese is proposed. Conclusion and future work are in the last part.

## 2. Acoustical manifestations of boundary tone

Boundary tone is found from echo questions in read speech and

yes-no questions in spontaneous speech. For intonation phrase (hereafter IP), information about question or statement is carried by an overwhelming majority of the last one or two syllables without neutral tone in the final prosodic word (hereafter PW) of the IP, but there are some exceptions in which it is carried by the first syllable. Therefore, the tune carrying the information about question or statement is known as a boundary tone. The boundary tone in Chinese is represented by register of starting-point or/and the ending-point of its  $F_0$  curve (or the slope of its curve). The register of the starting-point or/and the ending-point of the  $F_0$  curve of tone-1, tone-2 and tone-4 in boundary tone of a IP with question is higher than that of the last syllable of IP with statement; in the  $F_0$  curve of boundary tone with tone-3 with question, there appears a rising part comparing to that of tone 3 in the last syllable with statement. [14]

## 3. Identification test about boundary tone

Two types of perceptual tests are required to study the speech categorical perception: an identification test and a discrimination test [15]. In this study, Identification test is adopted to verify the results of acoustic analysis and listening test, and to determine which is more important of the register or slope of the  $F_0$  curve in boundary tone. The discrimination test is not done in this study, because it has been found that the interrogative information of either echo question or yes-no question out of context has different degrees in acoustic study: strong question → weak question → either question or statement → non-terminal intonation → statement.[14]

### 3.1 Identification test of boundary tone in the IP “hai2you3fang2jian1” (there still is a room )

Figure 1.1 shows a series of  $F_0$  curves in the IP “hai2you3fang2jian1” in which only the register of  $F_0$  curve in the last syllable “jian1” (bay) is changed. In the series, there are 12  $F_0$  curves. The series of  $F_0$  curves in the IP “hai2you3fang2jian1” is used to synthesize by Praat 39 to obtain a group of stimulus in identification test. Each of stimuli is repeated 8 times and then randomized. The group of stimulus is stored in computer. Listeners and procedure of identification test are the same as in the listening text in [14].

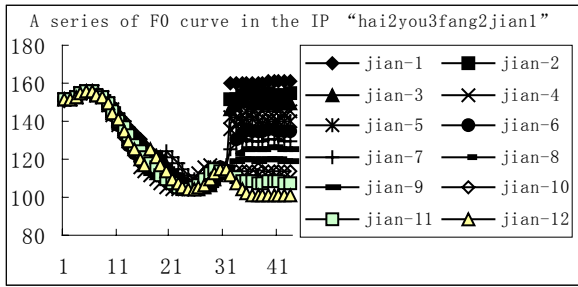


Figure 1.1: a series of  $F_0$  curves in the IP “hai2 you3 fang2 jian1” in which only the register of  $F_0$  curve in the last syllable “jian1” (bay) is changed.

Figure 1.2 shows the identification function that the stimuli in Figure 1.1 are judged by force as questions (—●—) or statements (—■—) by 5 listeners. It can be seen in Figure 1.2 that different moods can be achieved by only changing the register of  $F_0$  curve in the last syllable “jian1” (bay) of “hai2you3fang2jian1” and the different moods are as follows: strong question → weak question → either question or statement → non-terminal intonation → statement. The definitions about the different moods are the same to that in the acoustic analysis [14].

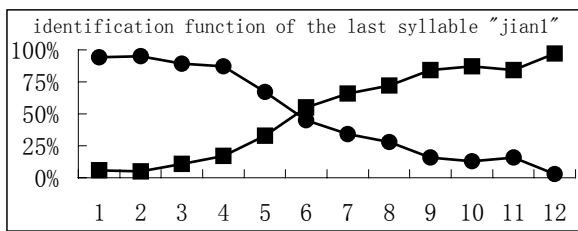


Figure 1.2: the identification function that the stimuli in Figure 1.1 are judged by force as questions and statements by 5 listeners.

### 3.2 Identification function of boundary tone in the IP “te4bie2zhong4yao4”(“particular important”)

When boundary tone is tone-4, difference between question and statement not only relies on the register of its  $F_0$  curve, but also on the slope. Therefore, there are two kinds of identification functions of boundary tone in the IP “te4bie2zhong4yao4”. One is that only the register of its  $F_0$  curve is changed, and the other is that only the slope of its  $F_0$  curve is changed.

#### 3.2.1 Identification function of boundary tone in IP “te4bie2zhong4yao4” in which only the register of the $F_0$ curve in its last syllable is changed.

A series of 7  $F_0$  curves in IP “te4bie2zhong4yao4” obtained by only changing the register of the  $F_0$  curve of its last syllable is showed in Figure 2.1 (Figure 2.1 is omitted). Figure 2.2 shows the identification function that the stimuli in Figure 2.1 are judged by force as questions (—●—) or statements (—■—) by 5 listeners. It can be seen in Figure 2.2 that different moods can be obtained by only changing the register of  $F_0$  curve in the last syllable “yao4” of “te4bie2zhong4yao4”

with the exception of strong question. Since maximum percentage of the series of the  $F_0$  curves that is judged as interrogative mood was only 79% and 74%, they are weak question according to the definition. If the register of the  $F_0$  curve are still raised, sound quality of the stimulus will be destroyed.

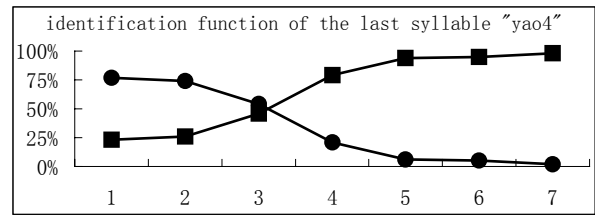


Figure 2.2: the identification function that the stimuli in Figure 2.1 are judged by force as question or statement by 5 listeners.

#### 3.2.2 Identification function of boundary tone in the IP “te4bie2zhong4yao4” in which only the slope of the $F_0$ curve in its last syllable is changed.

Figure 3.1 shows a series of 12  $F_0$  curves in the IP “te4bie2zhong4yao4” in which only the slope of the  $F_0$  curve of its last syllable is changed.

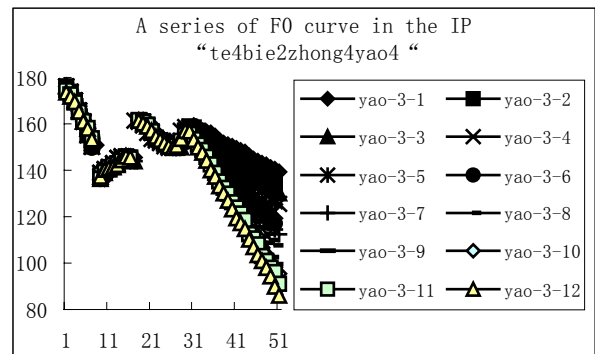


Figure 3.1: a series of 12  $F_0$  curves in IP “te4bie2zhong4yao4” in which only the slope of the  $F_0$  curve of its last syllable is changed.

Figure 3.2 shows the identification function that the stimuli in Figure 3.1 are judged by force as questions (—●—) or statements (—■—) by 5 listeners. It can be seen in Figure 3.2 that different moods can be obtained by only changing the slope of  $F_0$  curve in the last syllable “yao4”(important) of “te4bie2zhong4yao4”, and the different moods are strong question → weak question → either question or statement → non-terminal intonation → statement.

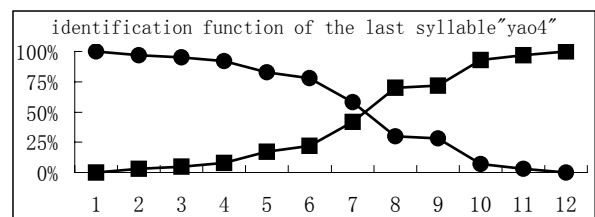


Figure 3.2: the identification function that the stimuli in Figure

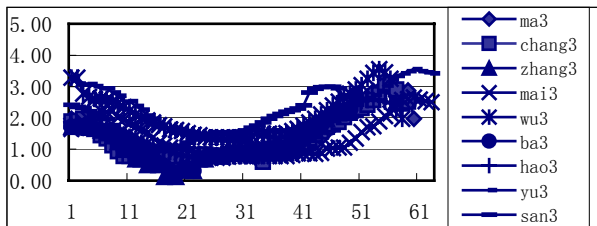
3.1 are judged by force as question or statement by 5 listeners.

### 3.3 The results in identification test

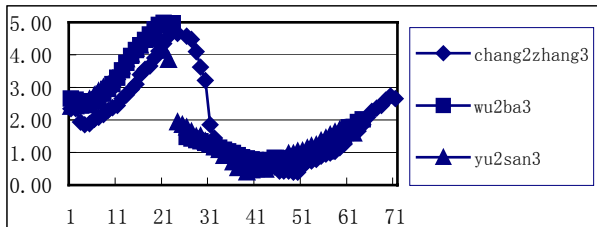
It is found in the identification function that different moods can be acquired by only changing the register or slope of the  $F_0$  curve in a boundary tone; the slope of the  $F_0$  curve in a boundary tone takes more important role than the register of its  $F_0$  curve, this result is obtained by comparing the difference between figures 3.2 and 2.2. The identification function between question and statement is not categorical, but continuous.

## 4. The relation between tone and intonation

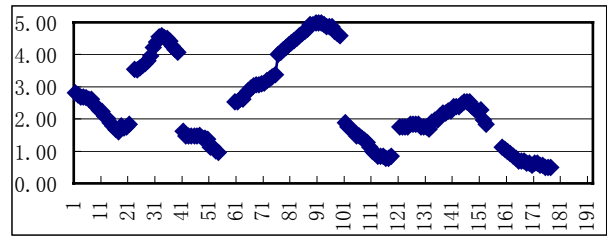
It is advocate [16] that there are two variables in Chinese intonation: pitch accent and boundary tone. Boundary tone conveys the information of mood in an IP including the declarative mood, the interrogative mood, the imperative mood, or the exclamatory mood. Pitch accent conveys the information of focus that is represented by prominence in an IP indicating which part is more important in linguistic content than others. Pitch accent is hierarchical: pitch accent in a PW, pitch accent in a PH and pitch accent in a IP. PW is a time-varying  $F_0$  group and one (or two syllables) in it is more prominence than others. The syllable (s) with more prominence is (are) referred to as a pitch accent in a PW. Pitch accent in a PH refers to the syllable (s) that is (are) most prominence in the PWs. Pitch accent in a IP refers to the syllable (s) that is most prominence in PHs. In the pitch accent of a PW, the register and/or range of its  $F_0$  curve is higher and/or wider than them that follow and/or precede it. When the register and/or range of the  $F_0$  curve in some syllable of a IP approximates more to the  $F_0$  contour of the syllable in citation form, the syllable is perceived as having a normal pitch accent; When the register and/or range of it is higher and/or wider than the  $F_0$  contour of syllable in citation form, the syllable is perceived as having a emphatic pitch accent. [14,16] It was found by Xu [17, 18] that there are three distinct focus-related pitch ranges: expanded in non-final focused words, suppressed (lowered and compressed) in post-focus words, and neutral in all other words.



↓ tone sandhi in lexical word



↓ prosodic process (prosodic organization, pitch accent)



↓ mood transform (boundary tone)

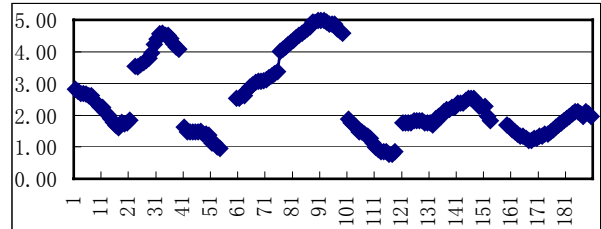


Figure 4: the process from  $F_0$  contours in each isolated syllables to  $F_0$  curves in the IP.

Boundary tone in Chinese, as it is pointed out above, is represented by register of the starting-point of or/and ending-point of its  $F_0$  curve (or the slope of its curve).

The relation between tone and intonation will be expounded by boundary tone and pitch accent. The process from the  $F_0$  contours in each isolated syllables to the  $F_0$  curves in a IP is illustrated in Figure 4. In Figure 4, 5-point values is represented by vertical axe, duration by horizontal axe. 4 charts in Figure 4 are examples about the pitch space of 5-point values.

The upper part of Figure 4 shows the  $F_0$  contour of the isolated syllables: “ma3” (a surname), “chang3” (works), “zhang3” (head), “mai3” (buy), “wu3” (five), “ba3” (classifier), “hao3” (good), “yu3” (rain) and “san3” (umbrella). These 9 syllables make 3 lexical words: “chang2zhang3” (head of a work), “wu2ba3” (five units) and “yu3san3” (umbrella). Because tones in “chang3zhang3”, “wu3ba3” and “yu3san3” consist of form “tone-3+tone-3”, the first tone-3 becomes tone-2.  $F_0$  curves in these three words are showed in the upper-middle of Figure 4. In the lower middle of figure 4,  $F_0$  curves in the IP with statement “ma3chang3zhang3 mai3wu3ba3 hao3yu3san3” is shown. “ma3chang3zhang3”, “mai3wu3san3” and “hao3yu3san3” are three PWs, because the  $F_0$  reset and pause with silent occur between them. The  $F_0$  reset and pause with silent following “ma3chang3zhang3” is bigger than that preceding “hao3yu3san3”, “ma3chang3zhang3” was a PH. And “mai3wu3ba3 hao3yu3san3” is a PH too. “mai3wu3ba3” and “hao3yu3san3” are two PWs. “mai” in “mai3wu3ba3” is changed so into tone-2, “mai” and “wuba” uttered tightly, these two lexical words make a complex PW, but “ma3wu3ba3” and “hao3yu3san3” are two compound PWs.

In the complex PW of “mai3wu3ba3”, the register of  $F_0$  curve in “wu3” is higher than that of its following syllables “ba3” and its preceding one “mai”, so the syllable “wu3” is perceived as having the most prominent, and the syllable “wu” is a pitch accent in the complex PW. And the  $F_0$  range of “mai3wu3ba3” is wider than that of “ma3chang3zhang3” and “hao3yu3san3”, so “wu3” is perceived as having the most prominent, and “wu” is a pitch accent in the IP with statement. “chang3” is a pitch accent in PH “ma3chang3zhang3”, “yu3”

is a pitch accent in compound PW “hao3yu3san3”.

When both moving up the register of the starting-point in  $F_0$  curve in the last syllable of “san3” of the IP with statement and rising up the register of the ending point in its  $F_0$  curve, a interrogative mood can be realized. The  $F_0$  curve of the IP with question is shown in the lower part of Figure 4.

It is advocated that the  $F_0$  curve and duration of each syllable in an IP is conditioned by pitch accent and boundary tone, and that the  $F_0$  contour in any isolated syllable cannot resist the action of intonation. It is pitch accent and boundary tone that lead to the time-varying  $F_0$  curve and duration in the related syllables in an IP. It is single-directionally and hierarchically that intonation acts upon tones that likes in figure 5.

In Figure 5, “+” indicates that intonation acts upon tone. In the pitch space of five-point values, intonation is represented

mainly by register and range of  $F_0$  curve, but tones are represented by its  $F_0$  contour, so the acoustic manifestations of intonation and tone are different.

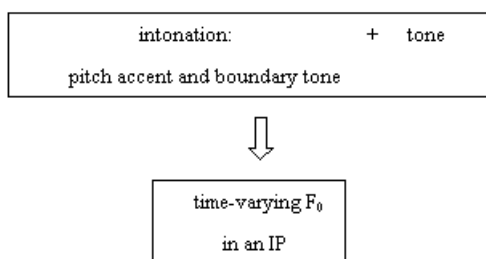


Figure 5: *schema that intonation acts upon tones.*

### 5. Pitch ( $F_0$ ) pattern of boundary tone

Figure 6 shows the pitch ( $F_0$ ) pattern of boundary tone in Standard Chinese. The  $F_0$  pattern is derived based on that boundary tone is represented by register of the starting-point or/and the ending-point of its  $F_0$  curve (or the slope of its curve).

In Figure 6, there are four rows of chart. The first row shows the  $F_0$  pattern of boundary tone with tone-1, the second row is the  $F_0$  pattern of boundary tone with tone-2, the third row is the  $F_0$  pattern of boundary tone with tone-3, and the last row is the  $F_0$  pattern of boundary tone with tone-4. In each small chart, the solid lines indicate the boundary tone with statement, the lines with triangle is the boundary tone with question. When the boundary tone is with tone-1, tone-2 or tone-4, there are three ways to change statement into question and vice versa. The first way is that  $F_0$  curve of the boundary tone moves up or down with certain semi-tone. The second way is that the starting point of its  $F_0$  curve keeps stable, but to rises up or down the ending point of its  $F_0$  curve. The third way is not only to moves up or down the starting point, but also to raise up or down the ending point of its  $F_0$  curve. When the boundary tone is with tone-3, there are only two ways to change statement into question and vice versa.  $F_0$  curve of the boundary tone with tone-3 is always falling in the IP with statement, but it is always falling-rising in the IP with question. In the first way of realizing the boundary tone of tone-3 with question, the first falling part keeps stable and the second part of  $F_0$  curve raises up or down. But in second way, the register of the first falling part moves up and the ending point in

second rising part raises up or down. In any one of the three ways of boundary tone with tone-1, tone-2 or tone-4, the  $F_0$  curve that moves up or/and raises up can give having an impression with a interrogative mood, but the  $F_0$  curve that moves down or falls down can give having an impression with a declarative mood.

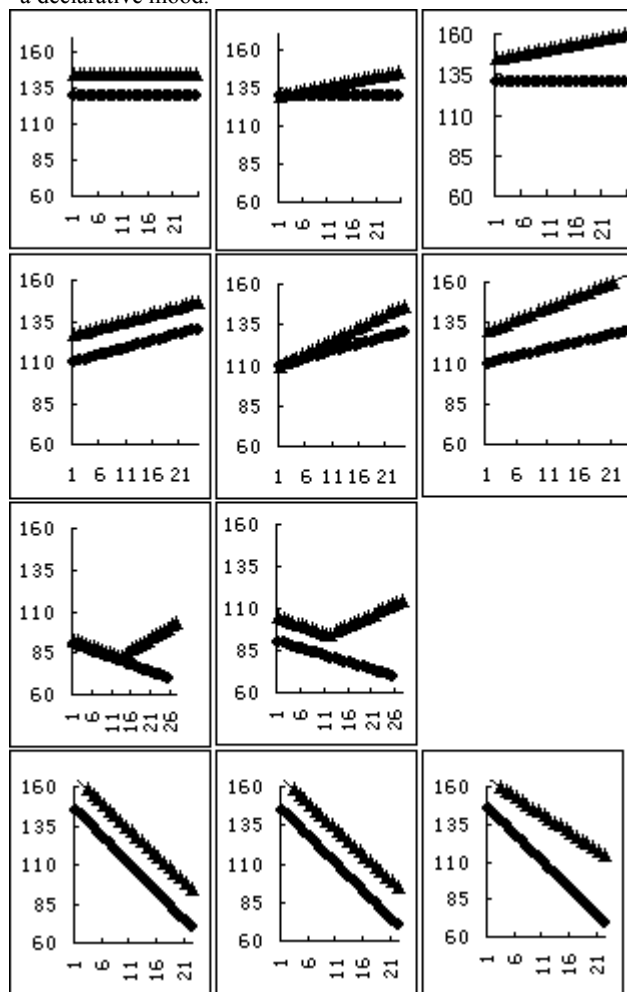


Figure 6: *F0 pattern of boundary tone in Standard Chinese.*

In short, the feature of boundary tone with question is “high” relative to that with statement, but the feature boundary tone with statement is “low” relative to that with question, and whether tone-1, tone-2, tone-3 or tone-4,  $F_0$  curve of boundary tone with question keeps its citation form.

Feature of boundary tone to differentiate between question and statement in Chinese is “high ” and “low”, just as the feature of that in English [19].

## 6. Conclusion and next works

### 6.1 Conclusion

Results of acoustical analysis and listening test indicates that Boundary tone conveys the information of mood in a IP. Boundary tone is represented by register of starting-point or/and ending-point of its  $F_0$  curve (or the slope of its  $F_0$  curve).

Identification test is adopted to verify the acoustic

manifestations of boundary tone, and to find out that the register of the ending-point (or the slope) of the  $F_0$  curve in boundary tone plays a more important role than the register of its starting-point in differentiating between question and statement, and the identification function about question and statement is not categorical, but continuous.

Result of this study doesn't support the view that the difference between question and statement in Chinese is related to pitch range,  $F_0$  curves, or 3 tones of the utterance.

Pitch ( $F_0$ ) pattern in Standard Chinese is given, and whether tone-1, tone-2, tone-3 or tone-4,  $F_0$  curve of boundary tone with question keeps its citation form. This result support the idea that in the utterance “wo3xing4lu4, ni3xing4wang2”

(my surname is lu4, your surname is wang2 ) ,the register of “lu4” with question is raised, but the  $F_0$  curve keeps its tone-4 [1]; when the last syllable of a utterance with question is tone-4, its  $F_0$  contour doesn't be changed[3]; in the utterances of “ta1xie3shi1” (he writes a poem) , “san1xiao3shi2” (three hours), “gang1kai1shi3” (just begin) and “ni3you3shi4” (you have some personal business) with question, the last syllables “shi1” , “shi2” , “shi3” and “shi4” keep the  $F_0$  contour in citation form respectively[20]. The ideas proposed by Chao and Lin and Wang with impressionistic approach and by Wu with spectrographic analysis.

It is single-directionally and hierarchically that intonation acts upon tones.

Features of boundary tone to differentiate between question and statement in Chinese is “high” and “low”, just as the features of that in English. In English, the acoustic manifestation of boundary tone with question or statement is rising or falling [19], but in Chinese, the acoustic manifestation of boundary tone with question or statement is the register of the starting-point and/or ending-point of its  $F_0$  curve (or its slope).

## 6.2 Future works

That the identification function about question and statement is continuous will be researched further.

## 7. References

- [1] Chao, Yuanren, 1933. Tone and Intonation in Chinese. *Bulletin of Institute of History and Philology, Academia Sinica*. 3, 121-134;
- [2] Wu, Zongji, 1982. Tonal variation in utterance of Standard Chinese. *Zhongguoyuwen*, 6, 439-450, (in Chinese).
- [3] Wu, Zongji, 1990. The basic, tone-sandhi patterns in standard Chinese intonation. In YANG Naisi (chief editor), *Essays Linguistics, Festschrift of WANG Li*, 54-73, Beijing: Commerce Press.
- [4] Garding, E., 1985. Constancy and variation in Standard Chinese tonal patterns. *Lund University Working Papers 28, Linguistics-phonetics*, 19-51.
- [5] Garding, E.,1987. Speech act and tonal patterns in Standard Chinese: Constancy and variation. *Phonetics*, 44, 13-29.
- [6] Shen, Jiong, 1985. Beijinghua Shendiao de yinyu he yudiao [pitch range of tone and intonation in Beijing dialect]. In LIN Tao and WANG Lijia (eds.), *Beijing Yuyin Shiyuanlu*, 78-130, Beijing: Beijing University Press (in Chinese).
- [7] Shen, Jiong, 1994. Hanyu yudiao gouzao he Yudiao leixing [Intonation structure and intonation types of Chinese]. *Fanyang*, 3, pp. 221-228 (in Chinese).
- [8] Shen, Xiaonan, 1989. *The Prosody of Mandarin Chinese*. UCP: University of California Press.
- [9] Chao, Jianfen, 2002. The relation between tone and intonation in Chinese. *Zhongguo Yuwen*, 3, 195-202.(in Chinese)
- [10] Chang, Nien-chuang T., 1958. Tone and intonation in the Chengdu dialect (Szechuan, China). *Phonetica*, 1-2, 59-85.
- [11] Hu, Mingyang, 1987, On intonation of Beijing dialect. *Preliminary study of Beijing dialect*, 146-163, Beijing: Commercial Press.
- [12] Jin, Song, 1992. Mood and intonation in Beijing dialect. *Zhongguo Yuwen*, 2, 113-123 (in Chinese).
- [13] Yuan, Jiahong, Chilin Shih and Grep P. Kochanki, 2002. Comparison of Declarative and Interrogative Intonation in Chinese. *Speech Prosody 2002, Aix-en-provence, 11-13 April, 2002*.
- [14] Lin, Maocan, 2004, Boundary tone and its pitch pattern in Chinese intonation. In Gunnar Fant, Hiroya Fujisaki, Jianfen Chai and Yi Xu (eds), *Festschrift for Professor WU Jongji 95 year<sup>th</sup> birthday*, Beijing: Foreign Language Teaching and Research Press.
- [15] Strange, Winifred and Janes J. Jenkins, 1978. The role of language experience in speech perception. In R. D. Walk and H. L. Pick Jr. (chief editors), *Perception and Experience*, chapter 5, New York: Plenum Press.
- [16] Lin, Maocan, 2002. Prosodic structure and top and bottom lines of  $F_0$  in the utterances of Standard Chinese. *Contemporary Linguistics*, 4, 154-265 (in Chinese).
- [17] Xu, Yi and Wang, Q. Emily, 2001. Pitch targets and their realization: Evidence from Mandarin Chinese. *Speech Communication*, 33, 319-337.
- [18] Xu, Yi, 2002. Sources of tonal variation in connection speech. *Journal of Chinese Linguistics*, monograph series # 17, 1-31.
- [19] Ladd, D. Robert, 1996. *Intonational Phonology*, Cambridge: Cambridge University Press.
- [20] Lin Tao and Wang Lijia, 1991, *The Course of Phonetics*, Beijing: Commercial Press (in Chinese).