Boundary Tone of Chinese Intonation and its Pitch (F0) Pattern

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Abstract*

Chinese intonation has two variables: pitch accent and boundary. In this paper, boundary tone will be studied mainly.

The results of acoustical analysis and listening test of echo questions in read speech and yes-no questions in spontaneous speech indicate that for intonation phrase, 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 of the prosodic phrase, 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. Boundary tone in Chinese is represented by register of the starting-point or / and the ending-point (or the slope) of its F0 curve.

Identification test is adopted to verify the results above, and to find out that the register of the ending-point (or the slope) of the F0 curve plays a more important role than the register of its starting-point and the identification function about question and statement is not categorical, but continuous: strong question → weak question → either question or statement → non-terminal intonation → statement.

It is confirmed by synthesize that boundary tone is indispensable to differentiate between question and statement.

The result of this study does not support the view that the difference between question and statement in Chinese is related to pitch range, F0 curves, "3 tunes" of an intonation phrase, and Chinese intonation exists in tones.

It is advocated that features of boundary tone to differentiate between question and statement in Chinese is "high" and "low". Pitch (F0) patterns of boundary tone in Standard Chinese are given. Whether tone-1, tone-2, tone-3, or tone-4, pitch pattern in 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 F0 curve, but tone is represented by its F0 contour.

It is discussed that Chinese intonation or English intonation has its individual character, but they have their general character as intonation.

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." (Chao, 1932) Some scholars proposed that the difference between question and statement in Chinese is related to pitch range, F0 curve or 3 tunes of a IP (Wu, 1980, 1990; Garding, 1985, 1987; Shen J. 1985, 1994; Shen X-N., 1989; Chao, 2002), but some other scholars held there is a terminal intonation in Chinese (Chang, 1958; Hu, 1987; Jing, 1992).

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As the role of boundary tone, Yuan, Shih and Kochanki (2002) had argued that "they do not need the different boundary tone to account for the difference between interrogative and declarative intonation in Chinese.

Intonation，as I will use the term，refers to the use of F0 and duration to convey sentence-level pragmatic meaning in a linguistically structured way. Chinese intonation that is represented only by F0 and duration is yes-no question without "ma0" and the corresponding statement.

Chinese intonation has two variables: pitch accent and boundary. In this paper, boundary tone will be studied mainly.

This paper is divided into 8 parts. Following part 1 "introduction", two variables in Chinese intonation: pitch accent and boundary tone is proposed in part 2. In part 3, the results of acoustical analysis are introduced. In part 4, identification test is adopted to verify the results of acoustical analysis and listening test, and to determine which is a more important of the register or slope of the F0 curve in boundary tone. It is confirmed by synthesis that boundary tone is indispensable to differentiate between question and statement in part 5. In part 6, it is advocated that the way that intonation acts upon tone is single-directionally and nonlinearly. In part 7, it is advocated that feature of boundary tone to differentiate between question and statement in Chinese is "high" and "low", and the pitch (F0) pattern of boundary in Standard Chinese is given. Conclusion and future work are in the last part.

2. Pitch accent and boundary tone in Chinese intonation

It was advocated (Lin, 2001) that there are two variables in Chinese intonation: pitch accent and boundary tone. Boundary tone conveys the information of mood in an intonation phrase (hereafter IP): 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 in linguistic content is more important than others.

2.1 Pitch accent is hierarchical

Pitch accent is hierarchical: pitch accent in a prosodic word (hereafter PW), pitch accent in a prosodic phrase (PH), and pitch accent in an IP. PW is a time-varying F0 group and one or two syllables in it are more prominent than others. In this study, F0 and pitch is a synonym. The syllable (s) with more prominence is (are) referred to as pitch accent in PW. Pitch accent in PH refers to the syllable (s) that is (are) most prominent in PWs. Pitch accent in IP refers to the syllable (s) that is most prominent in PHs. In the pitch accent of PW, the register and/or range of its F0 curve is higher and/or wider than those that follow and/or precede it. When the shape and register of the F0 curve in some syllable of an IP approximates more to the F0 contour of syllable in citation form, the syllable is perceived as having normal pitch accent in the IP; When the register and/or the range of F0 curve in some syllable of an IP is higher and/or wider than the F0 contour of syllable in citation form, the syllable is perceived as having emphatic pitch accent in the IP. (Lin, 2001) It was found by Xu (2001, 2002) 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.

2.2 Boundary tone in Chinese

As for boundary tone in Chinese, it will be studied in the following related parts using different experimental methods and different speech materials (read speech and spontaneous speech).

3. Acoustical analysis of boundary tone

3.1 Echo question in read speech

3.1.1 Question information and boundary tone

3. 1.1.1 Speech data

Boundary tone is found by using the following dialogue that has been put in a context:

A: “mou3 xian1 sheng1 yao4 qu4 mou3 XX（cheng2 shi4）.”

(Mr. X will go to XX (city).)

B: “mou3 xian1 sheng1 yao4 qu4 mou3 XX（cheng2 shi4）？”

(Will Mr. X go to XX (city)?)

A: “shi4 de0，mou3 xian1 sheng1 yao4 qu4 mou3 XX（cheng2 shi4）.”

(Yes. Mr. X will go to XX (city).)

The question asked by B is an echo question. In this dialogue, Mr. X contains one syllable and is replaced with Mr. Jin1, Mr. Hu2, Mr. Ma3 and Mr. Wei4. Each name of the 15 cities has two syllables and one of 15 disyllabic combinations of 4 tones in Standard Chinese. It is replaced with Xi1an1, Cheng2du1, Guang3zhou1, Zhan4jiang1; Bao1tou2, He2fei2, Shen3yang2, Da4tong2; Qing1dao3, Hai3kou3, Shang4hai3; and Shen1zhen4, Chong2qing4, Wu3han4, Da4qing4. Two speakers, C and S, play one part of A and B respectively so that both of them read the echo questions and its answers (statements).

3. 1.1.2 Speech sample

Speech sounds of “Mr. X”, “Mr. X will go to”, and “Mr. X Will go to X (the first syllable of XX)” are sliced from the original sound with echo question using Praat 3.9. The sliced sounds, together with the original sound, are used as speech sample for listening test.

3.1.1.3 Listening test and its result

The sliced sounds, together with the original echo question produced by speakers C and S, are repeated 3 times randomly. The randomized speech sample is judged by force as question or statement by 5 listeners. They also participate the following tests. The result of the listening test is given in table 1.

It can be seen in Table 1 that when the sliced sounds contain only the subject in the IPs with echo question, they are judged as question by about 20%; when the sliced sounds contain the subject and predicate, they are judged as question by about 10%; when the sliced sounds contain the subject, the predicate and the first syllable of the object, they are judged as question by about 30%; only when the sliced sounds contain not only the subject, the predicate and the first syllable of the object, but also the last syllable of it, the percentage judged as question is very high: 99.2% for speaker C and 88.5% for speaker S. It can be concluded that for an IP with question, the question information is carried by an overwhelming majority of the last one or two syllables without neutral tone in the final PW of the IP, but there are some exceptions in which it is carried by the first syllable of the IP. Therefore, the tune carrying the question information is known as boundary tone.

Table 1: mean percentage of each component of the IPs with echo question judged as interrogative mood by 5 listeners.

<table>
<tr><td rowspan="2">Subject</td><td rowspan="2">Predicate</td><td colspan="2">Object (some city)</td></tr>
<tr><td>First syllable</td><td>Second Syllable</td></tr>
<tr><td>21%</td><td></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td colspan="2">8%</td></tr>
<tr><td colspan="3">25%</td></tr>
<tr><td colspan="4">99%</td></tr>
<tr><td>20%</td><td></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td colspan="2">11%</td></tr>
<tr><td colspan="3">30%</td></tr>
<tr><td colspan="4">88%</td></tr>
</table>

3.1.2 Different interrogative mood for echo question out of context

In order to study whether or not there is any difference between echo question out of context and that in context, each of 30 (15×2) echo questions produced by speakers C and S are isolated from their context. Each of the echo questions out of context is repeated 8 times and then randomized. Each of the randomized speech samples is judged by force as question or statement by 10 listeners, among whom 5 listeners have participated the preceding test. They are young females and males who speak Standard Chinese fluently, have good hearing and listen carefully. In this listening test, each of the samples is judged 80 times. Listeners themselves decide how many times each sample is listened, but at least 3 times are asked for by the investigator. The result from this listening test is shown as follows: out of context, for speaker C, 14 echo questions are judged as interrogative mood by 100%, 1 echo question is judged as interrogative mood by 88%, and for speaker S, 7 echo questions are judged by 100%, 4 echo questions are judged respectively by 97%, 94%, 93% and 82%, 3 echo questions are judged respectively by 70%, 68% and 65%, 1 echo question is judged as interrogative mood by 59%.

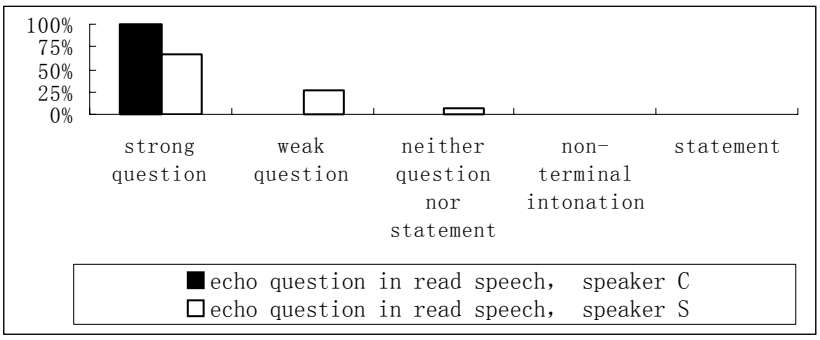


Figure 1: percentage of isolated echo question judged as different moods by 10 listeners.

For convenience of discussion, those that the interrogative mood is judged by 85-100% are defined as strong interrogative mood; those by 60-84% are weak interrogative mood; those by 0-10% are statement; those by 11-40% are non-terminal intonation; and those by 41-59% are “either statement or question”. Figure 1

shows the percentage of echo question out of context judged as different mood by 10 listeners. Out of context, utterances with echo question produced by speaker C are all strong interrogative mood, but those by speaker S are 67% strong interrogative mood, 27% weak interrogative mood, 6% "either question or statement". For echo question out of context, its interrogative information has different degrees: some strong, some weak, some "either question or statement". Strong echo questions （and strong yes-no question, below）are used to calculate the acoustical manifestation of boundary tone. As for why the echo-question out of context has different mood, it will be studied in another paper.

3.1.3 The acoustical manifestation of boundary tone in echo question

The acoustical manifestation of boundary tone was studied by strong echo question. The difference of boundary tone between question and statement is classified roughly into three types: 1) The F0 curve with question move up relative to that with statement；2) The starting point of the F0 curve keeps stable, but to rises up the ending point of the F0 curve，so that the F0 curve with question relative to statement has certain slope with rising；3) Not only to moves up the starting point of the F0 curve and to rises up the ending point of its F0 curve，but also that the register of the ending point of the F0 curve is higher than that of its starting-point. Therefore，two parameters, the register of the starting-point and the register of the ending-point of the F0 curve (or its slope), are used to demonstrate the acoustical manifestation of boundary tone. The starting point of the F0 curve is used to represent the F0 curve moving up or down; the ending-point of the F0 curve (or its slope) is used to represent the F0 curve rising up or down. The registers of the starting-point and ending-point (or the slope) of the F0 curve refer to those of the F0 curve in tone-section (Lin, 1965, 1988). Because echo-question has its corresponding answer part in an IP, whereas yes-no question has no such corresponding answer part, not only the register of the ending-point of the F0 curve, but also its slope of the F0 curve are calculated so that the acoustical manifestation of the boundary in yes-no question can be reliably obtained. The register of the starting-point and ending-point in F0 curve is expressed as semitone (music scale) calculated using logarithm of F0 relative 64Hz with 2 as its base number. The slope of a F0 curve is obtained using linear-regression, if its correlation-coefficient was greater than ±0.8.

F0 curve and the duration of "Mr. X will go to some city?" and "Mr. X will go to some city." produced by speakers C and S are analyzed using Praat 3.9. F0 curve is checked and corrected based on narrow band spectrogram (with suitable parameters).

Table 2 shows that the value of semitone about the register of the F0 curve in boundary tone of IP with echo question is higher than that of F0 curve in the last syllable of IP with statement. It can be seen that the register of the F0 curve in boundary tone of IP with echo question was higher about 5.4 semitone for speakers C and 3.0 semitone for speakers S in average than that of the F0 curve in the last syllable of IP with statement.

Table 2: value of semitone about the register of the starting-point of the F0 curve in boundary tone of the IP with question is higher than that of F0 curve in the last syllable of IP with statement.

	Tone-1		Tone-2		Tone-3		Tone-4	
	av.	dev.	av.	dev.	av.	dev.	av.	dev.
C	4.6	1.6	5.7	1.9	6.8	1.3	4.1	0.9
S	3.2	0.9	0.8	0.9	3.3	1.0	4.6	0.5

Table 3 shows the slope of the F0 curve in boundary tone of IP with question and that of the F0 curve in the last syllable of IP with statement. The slope of 4 tones is calculated using tone-section. It's can be seen that the slope of tone-4 in boundary tone with echo question for speakers C and S is smaller than that in the last syllable with statement, namely, the F0 curve of tone-4 in boundary tone with question is raised with certain angle relative to that in the last syllable with statement; the slope of tone-1 and tone-2 in boundary tone with echo question for speakers C and S is larger than that in the last syllable with statement, namely, the F0 curve of tone-1 and tone-2 in boundary tone with question is raised with certain angle relative to that in the last syllable with statement; the F0 curve of tone-3 in boundary tone with echo question is falling-rising, but the F0 curve of tone-3 in the last syllable with statement is only falling, namely, there appears a rising part in the F0 curve of tone-3 in boundary tone with echo question compared to that of tone-3 in the last syllable with statement. Because the F0 curves of tone-1, tone-2 and tone-4 in boundary tone with echo question are raised with certain angle relative to that in the last syllable with statement, and there appears a rising part in the F0 curve of tone-3 in boundary tone with echo question compared to that of tone-3 in the last syllable with statement, we calculated the value of semitone of the register of the ending-point of the F0 curve in boundary tone with echo question relative to that in the last syllable with statement. Table 4 shows the value of semitone of the register of the ending-point of F0 curve in boundary tone with echo question is higher than that in the last syllable with statement. It can be seen in Table 4 that whether tone-1, tone-2, tone-3, or tone-4 for speakers C and S is considered, values of semitone about register of the ending-point of F0 curve in boundary tone with echo question are positive, which means that F0 curve in boundary tone with echo question rises relative to that in the last syllable with statement. In 4 tones, the F0 curve of tone-3 in boundary tone with echo question rises with much more greater extent than that of tone-1, tone-2 and tone-4. This is because the later part in F0 curve of tone-3 in boundary tone with echo question is rising.

Table 3: the slope of the F0 curve in boundary tone of IP with question and that of F0 curve in the last syllable of IP with statement. (Hz/sec.) ("＋"rising，"－"falling)

		Tone-1		Tone-2		Tone-3		Tone-4	
		av.	dev.	av.	dev.	av.	dev.	av.	dev
C	Q	89	126	130	135	(-399) ＋ (235)	(95) ＋ (68)	-270	54
	S	38	59	72	86	-263	63	-445	109
S	Q	457	147	458	70	(-382) ＋ (525)	(78) ＋ (24)	-377	364
	S	-152	134	-95	256	-44	136	-477	192

Table 4: value of semitone about the register of the ending-point of F0 contour in the boundary tone with echo question is higher than that in the last syllable with statement

	Tone-1		Tone-2		Tone-3		Tone-4	
	av.	dev.	av.	dev.	av.	dev.	av.	dev.
C	6.64	1.52	8.28	1.99	13.6	2.20	5.97	0.97
S	11.23	3.03	5.03	3.52	8.35	2.42	7.47	2.04

Figure 2 shows the F0 curves of the last two syllables in echo question "mou3 xian1sheng1 yao4 qu4 mou3 cheng2shi4?" and its answer "mou3 xian1sheng1 yao4 qu4 mou3 cheng2shi4." for speaker C. In Figure 2, the vertical axis represents F0 in Hz, and the horizontal axis represents duration in sample. There are four charts in Figure 2: the upper-left is the F0 curves of Xi'1an1; the upper-right is that of shen3yang2; the lower-left is that of qing1dao3; the lower-right is that of chong2qing4. In each chart of Figure 2, the line with solid circle indicates the statement, while the line with triangle indicates the question. It can be seen in Figure 2 that the register of the starting point and ending point

of the F0 curves (or its slope) in the last syllable takes the role in differentiating between question and statement.

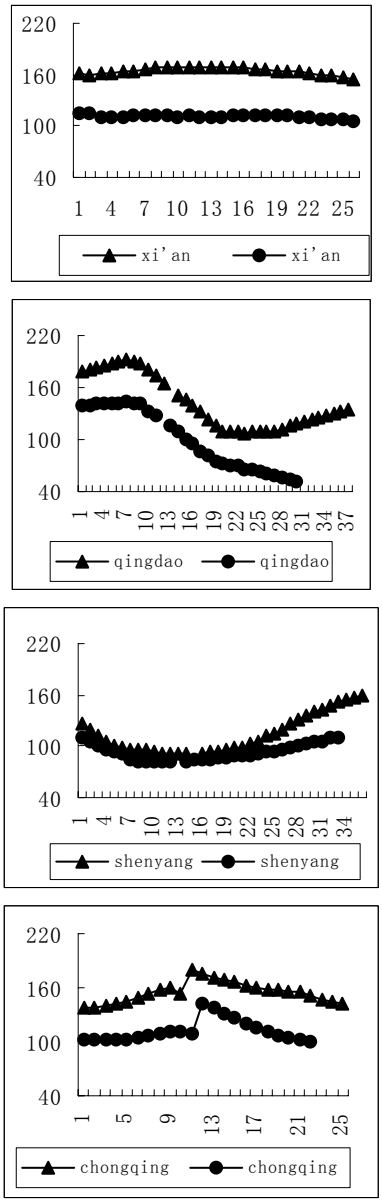


Figure 2: F0 curves of the last two syllables "xi'1an1", "shen3yang2", "qing1dao3" and "chong2qing4" in echo question "Mr. X will go to some city?" and its answer "Mr. X will go to some city." for speaker C.

It was concluded from the acoustical analysis of echo question that boundary tone of echo question in Chinese is represented by register of the starting-point or/and the ending-point (or the slope) of its F0 curve.

3.2 Yes-no question in spontaneous speech

3.2.1 Speech material and listening test

Speech material used to study yes-no question comes from a speech data bank of telephone-dialogue in which there is more than an hour dialogue (Yuan, 1999). In the speech data bank, there are only 133 IPs with yes-no question in which the F0 curve in each IP is correctly displayed or can be checked by following its narrow band spectrum. 133 IPs with yes-no question are sliced by Prrat 3.9. The 133 IPs with yes-no question plus 10 IPs with statement to obtain a group of 144 IPs used in a listening text. Each of 144 IPs was repeated two times and randomized get a group-1 of listening sample. Each of 144 IPs is repeated two times and randomized once again to obtain a group-2 of listening sample. According to the same procedure, a group-3 and group-4 of listening sample are obtained. The 4 groups of listening sample are stored in computer. The randomized speech sample is judged by force as question or statement by 5 listeners. They have participated the preceding tests. In this listening text, each of 144 IPs is judged 40 times. In order to avoid incorrect judgment caused by tiredness, the 4 groups of listening sample are arranged in 4 working sections (2 in the morning and 2 in the afternoon). Listeners themselves decide how many times each sample is listened, but at least 3 times are required by the investigator.

3.2.2 Different mood of yes-no question in out of context

The result of the listening test about different mood of yes-no question out of context is given in Figure 3. It can be seen in Figure 3 that in 133 IPs in context are judged as question, out of context, 39% is judged again as question (19% of strong question and weak question), 17%, 33% and 11% are judged respectively as statement, non-terminal intonation and "either question or statement". For yes-no question out of context, its interrogative information has different degrees: strong question→weak question→"either question or statement" →non-terminal intonation→statement. This paper only uses the IPs with strong question and statement to analysis their acoustical manifestation, but doesn't discuss the IPs with weak question and non-terminal intonation.

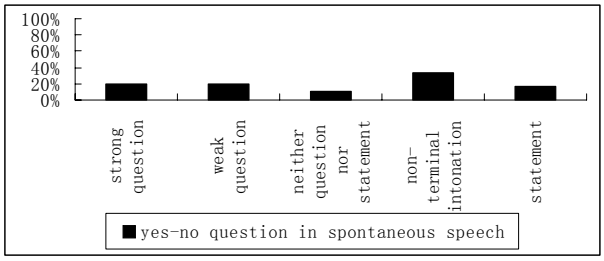


Figure 3: percentage of 144 IPs with yes-no question out of context judged as different moods by 10 listeners.

3.2.3 Acoustical manifestation of boundary tone in yes-no question

Table 5 shows the slope of F0 curves in boundary tone with yes-no question when they are out of context and in the last syllable of the IP with statement. It can be seen that in yes-no question of spontaneous speech as in echo question of read speech, the F0 curves of tone 1, tone 2 and tone 4 in boundary tone with yes-no question are raised by certain angle relative to that in the last syllable with statement. In yes-no question, there is no data about tone-3 with strong question.

Table 5: the slope of F0 curves in boundary tone with question when they are out context and in the last syllable of IP with statement. （Hz/sec.）（"＋"rising，"－"falling）

		Question	Statement
Tone-1	av.	93	49
	dev.	100	158
Tone-2	av.	490	208
	dev.	126	133
Tone-3	av.		-398
	dev.		290
Tone-4	av.	-126	-536
	dev.	188	316
"的"	av.	61	-226
	dev.	73	89
"了"	av.		-202
	dev.		67

Because in yes-no question of IP, there is no corresponding answer part, it can be calculated by their average value of

males or females that whether the register of the start-point and ending-point of the F0 curve in boundary tone with yes-no question is higher or lower than that of the last syllable with statement. Tables 6 and table 7 show the value of semitone about the register of the starting-point and ending-point of the F0 curve in boundary tone of IP with yes-no question is higher than that of F0 curve in the last syllable of IP with statement. It can be seen in tables 6 and 7 that for both male and female, the average register of the starting-point and ending-point of the F0 curve in boundary tone of IP with yes-no question is higher than that of F0 curve in the last syllable of IP with statement, and the register of ending-point of the F0 curve in boundary tone of IP with yes-no question is higher than that of its starting-point, indicating that for both male and female, the register of F0 curve in boundary tone of IP with yes-no question is higher than that of F0 curve in the last syllable of IP with statement, and the F0 curve in boundary tone of IP with yes-no question is rising. It is consistent with the result in table 5 that the F0 curve in boundary tone of IP with yes-no question is rising. Although there are no data about tone-3 in tables 5, 6 and 7, it could be derived from the data in echo question and others that the F0 curve of tone-3 in boundary tone of IP with yes-no question is low-rise and the ending-point of its F0 curve with yes-no question is higher than that with statement.

Table 6: value of semitone about the register of the starting-point of the F0 curve in boundary tone of the IP with yes-no question is higher than that of F0 curve in the last syllable of the IP with statement.

	Tone-1		Tone-2		Tone-3		Tone-4	
	av.	dev.	av.	dev.	av.	dev.	av.	dev.
Male	3.4	2.5	4.3	2.9	lack		2.9	1.9
Female	5.3	3.3	4.1	2.5	lack		3.4	1.0

Table 7: value of semitone about the register of the ending-point of F0 contour in boundary tone with strong yes-no question is higher than that in the last syllable with statement.

	Tone-1		Tone-2		Tone-3		Tone-4	
	av.	dev.	av.	dev.	av.	dev.	av.	dev.
M	5.44	3.52	6.28	2.99	lack		4.97	2.97
F	7.33	4.03	5.03	3.52	lack		5.47	2.04

3.3 Acoustical manifestation of boundary tone

Acoustical manifestation of boundary tone is derived from echo question in read speech and yes-no question in spontaneous speech. In short, for intonation phrase, information about question and statement is carried by an overwhelming majority of the last one or two syllables without neutral tone in the final prosodic word of the prosodic phrase, but there are some exceptions in which it is carried by its first syllable. Therefore, the tune carrying the information about question or statement is known as boundary tone. Boundary tone in Chinese is represented by register of the starting-point or/and its ending-point of its F0 curve (or its slope).

The F0 register of the starting-point or/and the ending-point of the F0 curve of tone-1, tone-2 and tone-4 in boundary tone of IP with question is higher than that of the last syllable of IP with statement，and the register of the ending-point of its F0 curve with question is higher than that with statement; In the F0 curve of tone-3 in boundary tone with strong question, there appears a rising part compared to that of tone-3 in the last syllable with statement, and its ending-point is higher than that with statement.

4. Identification test about boundary tone

Two types of perceptual tests are required to study speech categorical perception: an identification test and a discrimination test (Strange and Jenkins, 1978). In this study, Identification test is adopted to verify the results of acoustical analysis and listening test, and to determine which is more important of the register or slope of the F0 curve in boundary tone. The discrimination test is not done in this study because it have 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,.

4.1 Identification test of boundary tone in IP "hai2 you3 fang2 jian1" (there still is a room)

Figure 4.1 shows a series of F0 curve in IP "hai2 you3 fang2 jian1" in which only the register of F0 curve in the last syllable "jian1" (bay) is changed. In the series, there were 12 F0 curves. The series of F0 curve in IP "hai2 you3 fang2 jian1" is used to synthesize by Praat 3.9 to get a group of stimulus in identification test. Each of stimuli is repeated 8 times and than randomized. The group of stimulus is stored in computer. The listeners and procedure of identification test are the same as in the listening text.

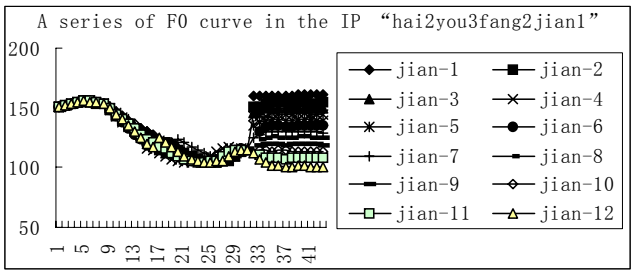


Figure 4.1a: series of F0 curve in IP "hai2 you3 fang2 jian1" (there still is a room) in which only the register of F0 curve in the last syllable "jian1" (bay) is changed.

Figure 4.2 shows the identification function that the stimuli in Figure 4.1 are judged by force as question or statement by 5 listeners. It can be seen in Figure 4.2 that different mood can be got by only changing the register of F0 curve in the last syllable "jian1" (bay) of "hai2 you3 fang2 jian1" and the different mood is as follows: strong question → weak question → "either question or statement" → non-terminal intonation → statement. The definition about the different mood is the same as that above.

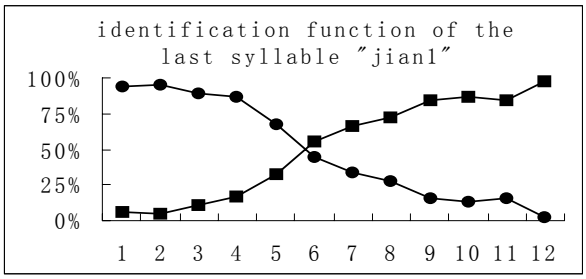


Figure 4.2: the identification function that the stimuli in Figure 4.1 are judged by force as question or statement by 5 listeners.

4.2 Identification function of boundary tone in IP "te4 bie2 zhong4 yao4" (particular important)

When boundary tone is tone-4, difference between question and statement not only relies on the register of its F0 curve, but also on the slope of it. Therefore, there are two kinds of identification function of boundary tone in the IP "te4 bie2 zhong4 yao4". One is that only register of its F0 curve is changed, and the other is that only slope of its F0 curve is changed.

4.2.1 Identification function of boundary tone in IP "te4 bie2 zhong4 yao4" in which only the register of the F0 curve in its last syllable is changed.

A series of 7 F0 curves in IP “te4 bie2 zhong4 yao4” are gotten by only changing the register of the F0 curve of its last syllable (Figure 5.1 was omitted). Figure 5.2 shows the identification function that the stimuli in Figure 5.1 are judged by force as question or statement by 5 listeners. It can be seen in Figure 5.2 that different mood can be got by only changing register of F0 curve in the last syllable “yao4” (important) of “te4 bie2 zhong4 yao4” with the exception of strong question. Since maximum percentage of the series of the F0 curves judged as interrogative mood is only 79% and 74%, they are weak question according to the definition in 3.1.2. If the register of the F0 curve is still raised, sound quality of the stimulus will be bad.

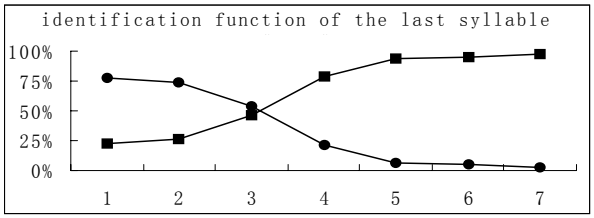


Figure 5.2: the identification function that the stimuli in Figure 5.1 are judged by force as question or statement by 5 listeners.

4.2.2 Identification function of boundary tone in IP “te4bie2zhong4yao4” in which only the slope of the F0 curve in its last syllable is changed.

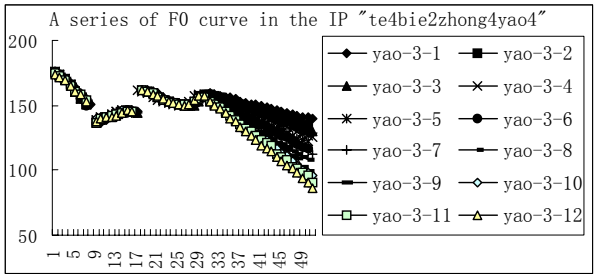


Figure 6.1a: series of 7 F0 curves in IP “te4bie2zhong4yao4” in which only the slope of the F0 curve of its last syllable is changed

Figure 6.1a shows a series of 12 F0 curves in IP “te4 bie2 zhong4 yao4” in which only slope of the F0 curve of its last syllable is changed. Figure 6.2 shows the identification function that the stimuli in Figure 6.1 are judged by force as question or statement by 5 listeners. It can be seen in Figure 6.2 that different mood can be got by only changing register of F0 curve in the last syllable “yao4” (important) of “te4 bie2 zhong4 yao4” and the different mood is: strong question→weak question→“either question or statement”→non-terminal intonation→statement.

It is found in the identification function that different mood could be acquired by only changing the register or slope of the F0 curve in boundary tone; the slope of the F0 curve in boundary tone is more important than the register of its F0 curve, which is got by comparing the difference between figures 6.2 and 5.2. The identification function between question and statement is not categorical, but continuous: strong question → weak question → either question or statement→non-terminal intonation → statement;

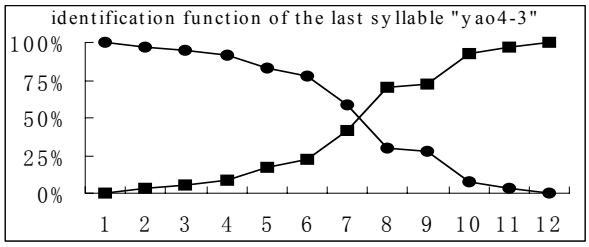


Figure 6.2: the identification function that the stimuli in Figure 6.1 are judged by force as question or statement by 5 listeners

5. Boundary tone is indispensable to differentiate between question and statement

The acoustic analysis, listening test and identification test above have indicated that boundary tone is more important role in differentiating between question and statement in Chinese. In the experiment by synthesize, it was confirmed that boundary tone is indispensable to differentiate between question and statement. In the following, two examples are given to demonstrate the result.

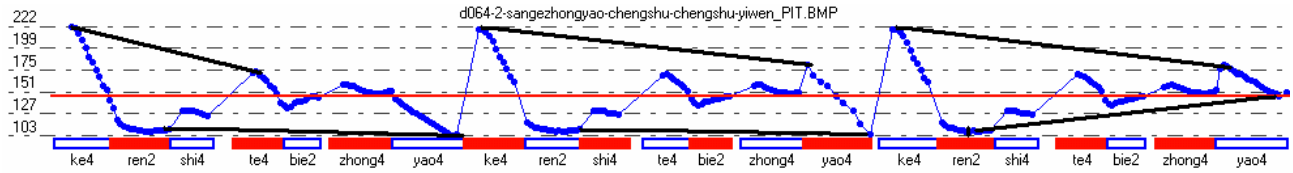
In Figure 7, there are three IPs: IP-1, IP-2 and IP-3. IP-1 and IP-2 are judged as statement and IP-3 as question by all 10 listeners. IP-1 is selected from a database of telephone dialogue, but IP-2 and IP-3 are synthesized by using Praat 3.9 to change F0 of the beginning point, F0 of the beginning and the ending points and slope of F0 curve in the last syllable “yao4” respectively.

Based on pitch accent-principle (Lin, 2002), F0 top and bottom lines of three IPs are constructed as displayed with straight line in figure 7 and 8.

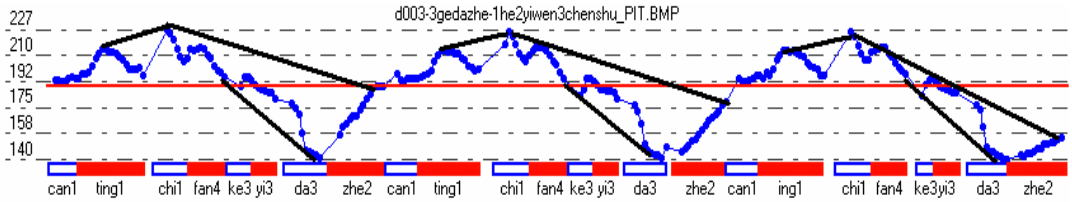
It can be seen in Figure 7 that although F0 of the beginning point of F0 curve of the last syllable “yao4” in IP-2 is raised compared to that of t IP-1, “yao4” in IP-2 is only sounded with more pitch accent than that in IP-1, and it is still judged as statement. IP-3 is judged as question, just because F0 of the beginning and ending points of F0 curve of the last syllable “yao4” are raised simultaneously so that the slope of its F0 curve is decreased relative to horizontal line.

4.3 The results in identification test

Example 1: Figure 7: F0 curve, duration and F0 top and bottom lines of three Ips “ke4 ren2 shi4 te4 bie2 zhong4 yao4”



Example 2: Figure 8: F0 curve, duration and F0 top and bottom lines of three IPs “can1 ting1 chi1 fan4 ke3 yi3 da3 zhe2”



In figure 8, there are three IPs: IP-1, IP-2 and IP-3. IP-1 and IP-3 are judged with question or statement by all 10 listeners respectively, but IP-2 is judged with question by 70% of 10 listeners. IP-1 is selected from a database of telephone dialogue, but in IP-2 and IP-3, F0 curve of the last syllable "zhe2" is derived by changing the F0 curve of the last syllable "zhe2" to get the different mood. In IP-2, although the starting and ending points of F0 curve of the last syllable "zhe2" are lowered by 10Hz, its mood is still question. In IP-3, the ending point of F0 curve of the last syllable is further lowered by 15Hz so that the slope of F0 curve is sufficiently decreased, making its mood judged as statement.

It should be pointed out that in the three IPs, F0 top and bottom lines are the same: F0 top lines are first rising and then falling, bottom lines are declined. These two examples demonstrate that difference between question and statement depends not only on the F0 register, but also on the slope of F0 curve of boundary tone. Boundary tone is indispensable in differentiating between question and statement in Chinese.

6. The relation between tone and intonation

The relation between tone and intonation in Chinese will be expounded by boundary tone and pitch accent. It is pitch accent and boundary tone that lead to the time-varying of F0 curve and duration in related syllables in an utterance. The process from the F0 contour in each isolated syllable in an IP to the F0 curves in an IP is illustrated in Figure 9.

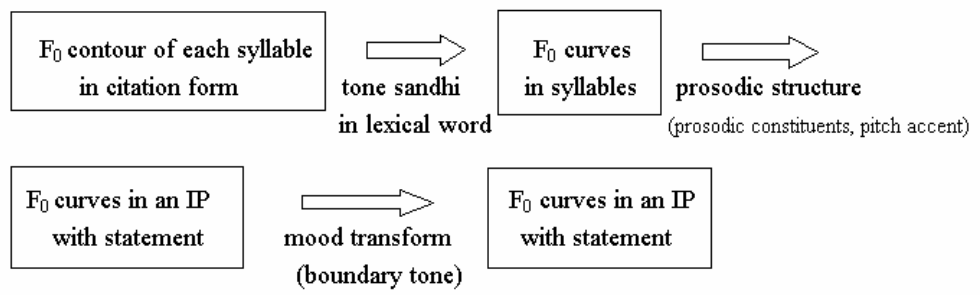


Figure 9: the process from the F0 contour in each isolated syllable to the F0 curves in an IP.

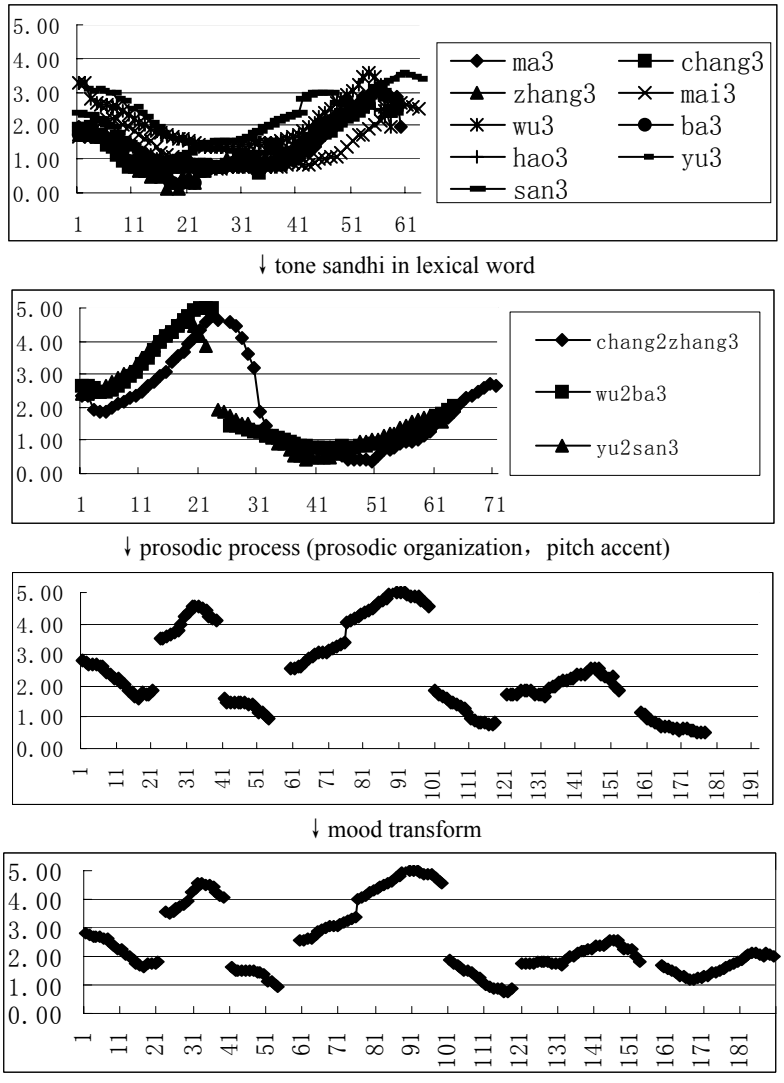


Figure 10: An example of the process

An example of the process is given in figure 10. The upper part of Figure 10 shows the F0 contours 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 works), “wu2ba3” （five units ）, and “wu2san3” (umbrella). Because tones in “chang3zhang3”， “wu3ba3” and “yu3san3” are organized in form of “tone-3+tone-3”, the first tone-3 becomes tone-2. F0 curves in these three words are showed in the upper-middle of Figure 10. In the lower middle of figure 10, F0 curves in the IP with statement “ma3chang3zhang3 mai3wu3ba3 hao3yu3san3” is shown. “ma3chang3zhang3”, “mai3wu3san3” and “hao3yu3san3” are three PWs，because the F0 reset and pause with silent occur between them. The F0 reset and pause with silent following “ma3chang3zhang3” is bigger than that preceding “hao3yu3san3”， “ma3chang3zhang3” is a PH. And “mai3wu3ba3 hao3yu3san3” is a PH too. “mai3wu3ba3” and “hao3yu3san3” are two PWs. “mai” in “mai3wu3ba3” is changed also into tone-2, “mai3”and “wu3ba3” were uttered tightly; these two lexical words made a complex PW, but “ma3wu3ba3” and “hao3yu3san3” are two compound PWs.

In the complex PW of “mai3wu3ba3”，the register of F0 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 so a pitch accent in the complex PW. And the F0 range of “mai3wu3ba3” is wider than that of “ma3chang3zhang3” and “hao3yu3san3”, so “wu3” is perceived as having the most prominent, and a pitch accent in the IP with statement. “chang3” is a pitch accent in PH “mai3chang3zhang3”，“yu3” is a pitch accent in compound PW “hao3yu3san3”.

When both moving up the register of F0 curve in the last syllable of “san3” in the IP with statement “ma3chang3zhang3 mai3wu3ba3 hao3yu3san3” and rising up the register of the ending point in its F0 curve, a interrogative mood can be realized. The F0 curve of the IP with question “ma3chang3zhang3 mai3wu3ba3 hao3yu3san3?” is shown in the lower part of Figure 10. In Figure 10, five-point value is represented by the vertical axis, and the duration in samples is represented by the horizontal axis.

It was advocated that the F0 curve and duration of each syllable in an IP is conditioned by pitch accent and boundary tone, and that the F0 contour in any isolated syllable couldn’t resist the action of intonation. It is single-directionally and hierarchically that intonation acts upon tones that likes in figure 11:

In Figure 11, “＋”means that intonation acts upon tone. In the pitch space of five-point values, intonation is represented mainly by register and range of F0 curve, but tones are represented by its F0 contour, so the acoustic manifestations of intonation and tone are different.

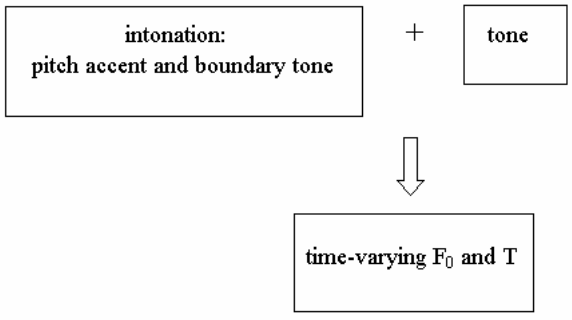


Figure 11: schema that intonation acts upon tones

7. Pitch (F0) pattern of boundary tone

Figure 12 shows the F0 pattern of boundary tone in Standard Chinese. In Figure 12, the vertical axis represents F0 in Hz, and the horizontal axis represents duration in sample. The F0 pattern is derived based on that boundary tone in Chinese is represented by the register of the starting-point or/and ending-point of its F0 curve (or its slope). In Figure 12, there are four rows of chart. The first row shows the F0 pattern of boundary tone with tone-1, the second row is the F0 pattern of boundary tone with tone-2, the third row is the F0 pattern of boundary tone with tone-3, and the last row is the F0 pattern of boundary tone with tone-4. In each small chart, the lines with solid circle indicate the boundary tone with statement, and the lines with solid triangle are 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 F0 curve of its boundary tone moves up or down with certain semi-tone (the value of semi-tone equals roughly to that the register of the staring-point of its F0 curve with question is higher or lower than that with statement). The second way is that the starting point of its F0 curve keeps stable, but to rises up or down the ending point of its F0 curve (the value of semi-tone equals roughly to that the register of the staring-point of its F0 curve with question is higher or lower than that with statement)). The third way is to not only to moves up or down the starting point of its F0 curve, but also rises up or down the ending point of its F0 curve. When the boundary tone is with tone-3, there are only two ways to change statement into question and vice versa. F0 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 F0 curve rises up or down. But in second way, the register of the first falling part moves up and the ending point in second rising part rises up or down. In any one of the three ways of boundary tone with tone-1, tone-2 or tone-4, the F0 curve that moves up or rises up could give an impression with an interrogative mood, but the F0 curve that moves down or falls down could give an impression with a declarative mood. In any one of the two ways of boundary tone with tone-3, the F0 curve with falling-rising can give an impression with a interrogative mood, but the F0 curve with falling can give an impression with a declarative mood.

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, F0 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 （Ladd，1996）.

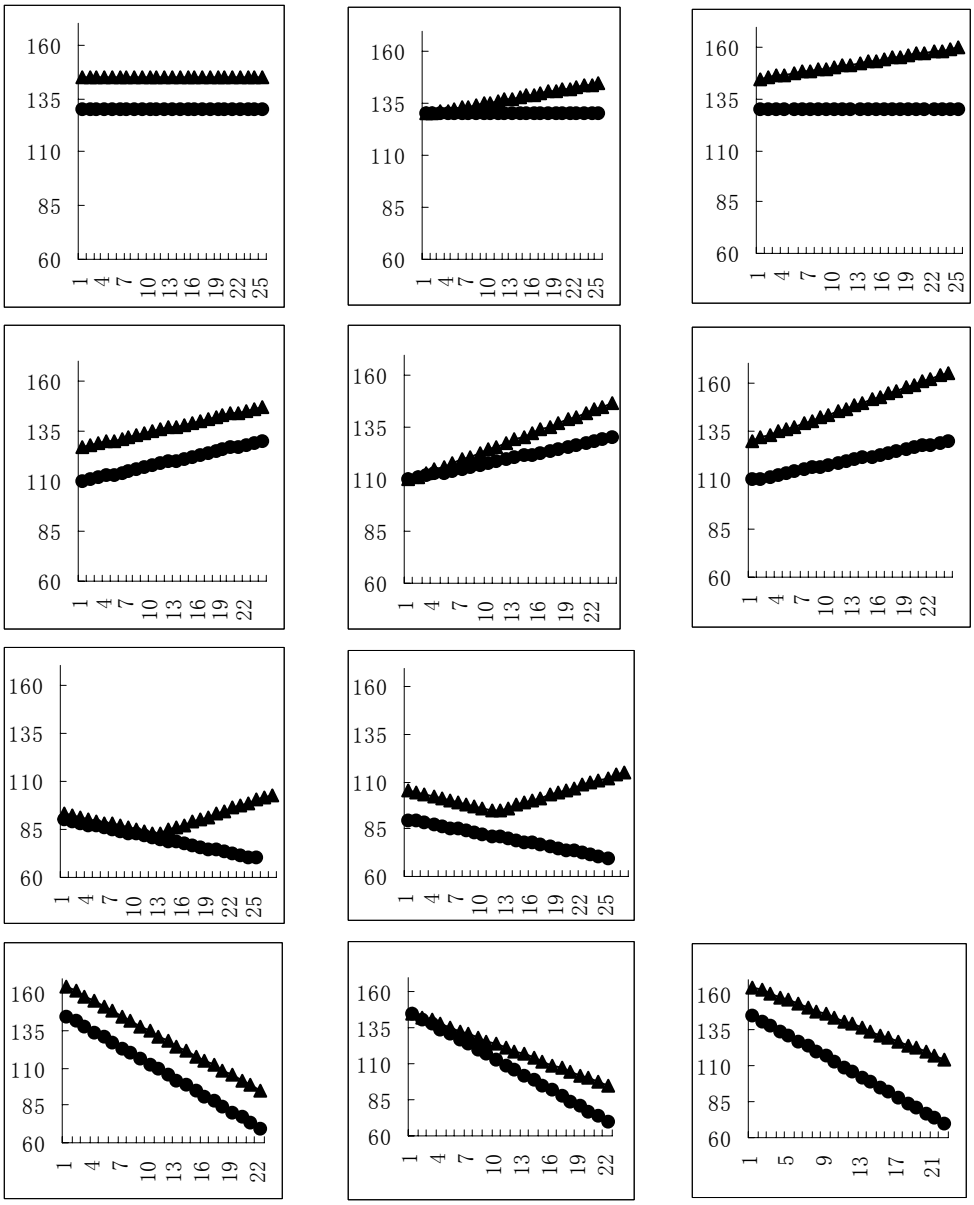


Figure 12: pitch (F0) pattern of boundary tone in Standard Chinese

8. Conclusion and next works

8.1 Conclusion

8.1.1 The results of acoustical analysis and listening test of echo questions in read speech and yes-no questions in spontaneous speech indicates that for intonation phrase, 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 of the prosodic phrase, 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. Boundary tone in Chinese is represented by register of the starting-point or/and the ending-point (or the slope) of its F0 curve.

8.1.2 The identification test is adopted to verify the results of acoustical analysis and listening test, and to find out that the slope of its F0 curve is more important than that of the register in differentiating between question and statement, and the identification function about question and statement is not categorical, but continuous: strong question→weak question→either question or statement non-terminal intonation→statement.

8.1.3 It was confirmed by synthesize that boundary tone is indispensable to differentiate between question and statement.

8.1.4 The result of this study doesn't support the view that the difference between question and statement in Chinese is related to pitch range, F0 curves, or 3 tunes of the utterance.

8.1.5 Pitch (F0) pattern in Standard Chinese is given, and whether tone-1, tone-2, tone-3 or tone-4, F0 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 F0 curve keep its tone-4 (Chao, 1932); when the last syllable of a utterance with question is tone-4, its F0 contour doesn't change (Wu, 1982); 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 its F0 contour in citation form (Lin and Wang, 1991). The ideas proposed by Chao and Lin and Wang with impressionistic approach and by Wu with spectrographic analysis.

8.1.6 It is single-directionally and hierarchically that intonation acts upon tones. In the pitch space

of five-point values, intonation is represented mainly by register and range of F0 curve, but tones are represented by its F0 contour, so the acoustic manifestations of intonation and tone are different.

8.1.7 Features of boundary tone to differentiate between question and statement in Chinese are “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 (Ladd, 1996), 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 F0 curve (or its slope).

8.2 Future works

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

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