

## **Representation of Mandarin intonations: boundary tone revisited**

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In order to find where exactly the Mandarin interrogative cues are located and whether Mandarin question intonation could be represented using a boundary high tone (H%), we conducted a perceptual experiment, asking 10 native listeners to identify manipulated Mandarin utterances with question or statement intonations. Listeners judged four types of stimuli, which are full utterance, utterance without the last syllable, utterance without the last prosodic word, utterance remaining the first prosodic word. The results show that the correct question identification percentage drops significantly when the last prosodic word is missing, but the majority of listeners are still able to identify the questions correctly, even when the stimulus only contains the first prosodic word. This result supports the claim that Mandarin interrogative cues distribute over an entire utterance. High pitch in both edges of the intonation phrase should be marked out. \*

### **1. Introduction**

Boundary tone, proposed by Pierrehumbert (1980) as a phonological unit for representing the internal makeup of an intonation phrase, has been disputed in the study of Mandarin intonation. Most scholars argue that the boundary tone described as the element of intonation does not exist in Mandarin as the contrasts of Mandarin sentence moods are not differentiated by the “pitch height of the sentence-final syllable”. Instead, it is the “pitch register contrast over whole utterance domain” that signals Mandarin intonations (Ho 1976, 1977, Shi 1980, Shen 1985, Shen X.N. 1990, Yuan, Chih and Greg 2002, Lee 2005). As early as 1930s, Chao has proposed his “simultaneous addition” hypothesis to describe intonation’s register adjusting effect on tones. He says that there is a general raised or lowered levels of pitch when imposing sentence intonations on connected lexical tones, and the pitch range over whole utterance domain will be widened or narrowed (Chao 1932, 1933, 1968). Therefore, the concept of boundary tone, if it exists

in Chinese, only represents boundaries of prosodic units (something like a break between prosodic units), but does not represent intonations which convey pragmatic functions of sentences (Shi F. 2010). There are, however, exceptions which support that the boundary tone could be used in Mandarin to represent intonations. Lin (2004, 2006) argues that “information about question or statement is carried by an overwhelming majority of the last one or two syllables without neutral tones in the final prosodic word.” He proposes using a boundary high tone to represent question intonation in Mandarin. Lin is not the only one who insists sentence-final syllables’ decisive roles in carrying intonational meanings. Hu (1987), without instrumental help, summarizes the last syllables’ distinctive features in different intonation environments. He thinks the features of sentence-final syllables’ pitch, duration and intensity are the key factors in describing different types of intonations. Following Hu’s claim, He Y. and Jing S. (1992) did acoustic measurements of the sentence-final stressed syllables in statement, question and imperative intonations’ environments, and they reported the acoustic data of the final syllable’s pitch, duration and intensity in different sentence moods. Neither Hu nor He Y. has proved the last syllable’s independent function in distinguishing different sentence types before they proceed to investigate the final syllable’s phonetic features. Lin, Hu and He.Y all adopt some ideas from Chao (1933)’s “successive addition hypothesis” which also describes pitch interactions between lexical tones and sentence intonations. Different from his “simultaneous addition”, this hypothesis proposes that sentence intonation is like a rising or falling pitch tail attached to the original sentence-final lexical tones’ contours, thus the original tones’ shapes are changed. Lin, Hu and He.Y acknowledge that intonation’s major modification domain is in the last syllable, but they do not agree that lexical tone shapes were changed by sentence intonations. In their analysis, intonations only raise or lower the pitch registers of the last syllables. Boundary tone is also adopted in recent ToBI conventions for Mandarin intonation transcription. Peng et al (2005) use a boundary high tone (H%) to transcribe Mandarin echo question and yes-no question with sentence-final particle like “ma”. However, they mark out the overall pitch level rising at the same time, by a tag “%q-raise”, which means the boundary high tone at the right edge of the question utterance is not the only high pitch feature that carries the interrogative information, it combines with the overall pitch raising to signal questions.

As discussed above, it seems that three disputed views still exist regarding boundary tone’s status in Mandarin intonation representation. The first view thinks it is not necessary to include the boundary tone as a unit in the phonological representation of Mandarin intonation. In great contrast, the second view considers boundary tone as an indispensable element, almost all the necessary phonetic cues for signaling sentence moods are included in the last syllable’s domain, or, the weak version of this view thinks

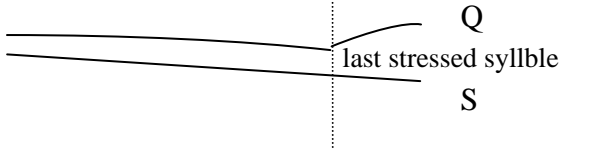
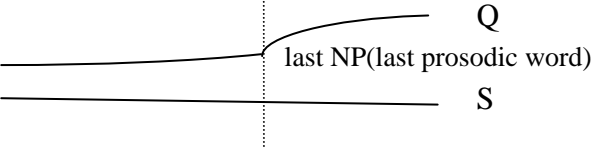
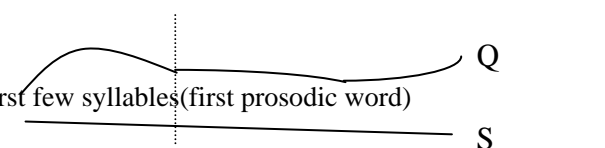
that terminal high pitch combines with the overall high pitch to signal questions. The third view acknowledges boundary tone’s existence. However, boundary tone has nothing to do with sentence moods in this proposal, it only indicates pause or break between prosodic units. In order to make this controversial issue more clear, the current paper is going to discuss whether the “boundary high tone” is a proper phonological component of Mandarin interrogative intonation by looking into some experimental evidences.

## 2. Purpose and methods

### 2.1 The goal and reasoning of the experiment

The goal of conducting the perceptual experiment is to test listeners’ judgments on manipulated incomplete question utterances, so as to find out in which part of the intonational phrase the overwhelming interrogative cues locate. Here, based on previous studies, we assume the major acoustic correlate of intonation is pitch (Howie 1976, Tseng 1981, Shen 1990). High or raising pitch will be interpreted as having interrogative meanings (Ohala 1983, 1984), so the major interrogative cues are located in the part of the question which has most significant higher pitch contrast to its statement counterpart. However, previous production studies reported different results about this most significant pitch rising domain. Schemas listed in figure1 compare those results.

figure1: the domain of the most significant pitch expansion and rising in questions.

different findings from production data	schematized representation of that findings
Lin (2004, 2006):  last stressed syllable	
Lee (2005):  last NP	
Shen X.N.(1990); Shi(1980):  first few syllables	

Lin (2004, 2006) reported that the localized most significant pitch raising occurred in the sentence-final stressed syllable. The F0 values at the starting point and the ending point of sentence-final lexical tones are higher in questions than in statements. The F0 slopes' values of the four lexical tones increase in questions. Lee (2005)'s acoustic study on un-marked yes-no questions found that the most significant pitch rising and expansion occurred in the last noun phrase (last prosodic word) domain. Shen X.N. (1990) and Shi (1980) both mentioned the starting few syllables in questions had gone through notable pitch rising, so the first prosodic unit is also a suspect domain for major interrogative cues location. Based on their findings on production data, we hypothesized three possible locations of the interrogative cues in question utterances: 1) the last stressed syllable, 2) the last prosodic word, 3) the first prosodic word. If we take off the hypothetic portion of the question utterance which may carry most of the interrogative cues, native listeners' correct identification rate will drop significantly. By this way, we could locate the interrogative cues by observing listeners' performances.

## 2.2 Methods

### 2.2.1 What could be improved in previous perceptual experiments

Some perceptual studies on question intonations have been done. Experimenters used synthesized, manipulated and natural tokens for different research purposes. However, there are some insufficiencies in the previous stimuli designs.

First, the semantic meanings of utterances become incomplete after manipulation. For example, Lin (2006)'s cutting manipulation break the meaning of the last disyllable word; Wu, Tao and Lu (2006) cut off question markers in the middle part of the utterance, leaving some of the stimuli like fragments. We may question that the low ratios of questions identifications are because of listeners' confusions about the utterance meanings rather than lack of interrogative cues in the stimuli.

Second, little attention has been paid to the tones of the ending syllables in previous manipulated utterances. However, some perception studies have found the influence of sentence-final tones in intonation identification (Yuan, 2004 2006). If there is no variation of sentence-final tones, the perception results are questionable. In Lin(2006)'s perception study, when the final object is cut off, the utterances for identification are always ended in falling lexical tone of the verb 去 “qu4”. The low correct rates of questions identifications may be influenced by the pitch interactions of ending lexical tones rather than influenced by loss of interrogative cues.

Third, studies using synthesized materials for identification (e.g., Liang and Van, 2007) generated different pitch patterns by adjusting both the boundary point F0 value and the overall F0 level value. The problem with this synthesizing method is that it limits

the localized significant pitch rising effect in the last syllable domain without proving the real localized effect domain in advance.

Although there are some weaknesses in the previous studies, these investigators laid down solid foundations in perception studies looking for interrogative cues. Based on previous studies, the present study tries to design a corpus taking into considerations the above mentioned problems.

### 2.2.2 Our corpus design

A corpus of 64 utterances was built up. The original recording materials are four pairs minimally contrasted simple declaratives and their corresponding unmarked yes-no questions without narrow focus. The recording materials are listed below (with pinyin transcriptions and numbers to indicate four citation tones in Mandarin):

- 1) ma3xiao3ming2chi1han4bao3bao1. “Ma Xiaoming eats hamburger.”
- 2) wang2jiao4shou4jiang3xin1wen2xue2. “Prof. Wang gives lectures on journalism.”
- 3) lin2xiao3jie3lai2yun4dong4chang3. “Miss Lin comes to the playground.”
- 4) zhang1xian1sheng0zai4ban4gong1shi4. “Mr. Zhang is in the Office.”

Four citation tones and the neutral tones were mapped into four specific positions in the utterances, they are: the last syllable of the first prosodic word, the syllable before last prosodic word, the syllable before last syllable and the utterance-final syllable.

### 2.2.3 Recording

All these sentences were recorded from a native female speaker of standard Mandarin Chinese. The sentences were randomized and presented one by one to the speaker in a computer screen. The speaker was asked to say the sentence naturally without any emphasis. She was reminded to pay attention to the punctuations and say the sentences in appropriate intonation. She was required to repeat each utterance for three times. We choose the one which is more natural and clear from the second or third time repetition. The recording was carried out in a quiet room by means of a high quality microphone connected to the computer. The speech was recorded with a sampling rate of 16000 Hz. by a computer software called “Cool Edit Pro 2.0”. The recorded materials were stored in the computer for further manipulation.

### 2.2.4 Manipulation

We manipulated the original sentences using Praat5.1.23. The semantic meaning of each token is kept intact after manipulation and the four lexical tones were mapped onto the

end of the manipulated utterance. Table1 shows the meaning and tone mapping of the tokens after manipulation (with pinyin transcriptions and numbers to indicate tones):

table1: experiment design

Remain the first prosodic word(I)	Cut off the last prosodic word(II)	Cut off the last stressed syllable(III)	Utterance in full-length (IV)	Last syllable tone mapping			
				I	II	III	IV
马小明 ma3xiao3ming2 Ma Xiaoming (name of a boy)	马小明吃 ma3xiao3ming2chi1	马小明吃汉堡 ma3xiao3ming2chihai4bao3	马小明吃汉堡包 ma3xiao3ming2chihai4bao3	R	H	L(R)	H
林小姐 lin2xiao3jie3 Miss Lin	林小姐来 lin2xiao3jie3lai2	林小姐来运动 lin2xiao3jie3lai2yun4dong4	林小姐来运动场 lin2xiao3jie3lai2yun4dong4chang3	L(R)	R	F	L(R)
王教授 wang2jiao4shou4 Prof. Wang	王教授讲 wang2jiao4shou4jiang3	王教授讲新闻 wang2jiao4shou4jiang3xinwen2	王教授讲新闻学 wang2jiao4shou4jiang3xinwen2xue2	F	L(R)	R	R
张先生 zhang1xiansheng0 Mr. Zhang	张先生在 zhang1xiansheng0zai4	张先生在办公 zhang1xiansheng0zai4bangong1	张先生在办公室 zhang1xiansheng0zai4bangong1shu4	N	F	H	F

After manipulation, we got 32 utterances. Each token was repeated one time and stored, we obtained 64 tokens in total (4 utterances \* 2 intonation types \* 4 ways of manipulation \* 2 repetitions = 64 stimuli).

### 2.2.5 Further processing of the stimuli

The 64 tokens were grouped into 4 separated sound files by syllable numbers. In each sound file, the utterance orders were randomized. Each stimulus was repeated once again and put together with 1s intervals. The inter-stimulus interval (pause between offset of the second repetition of the previous stimulus and the beginning of the next stimulus) was fixed at 3s. For example, in the sound file containing three syllable stimuli, listeners will hear:

“wang2jiao4shou4 (1s interval) wang2jiao4shou4 (3s interval) lin2xiao3jie3 (1s interval) lin2xiao3jie3 (3s interval).....”

### 2.2.6 Listening test

The test was carried out in a quiet office in The Chinese University of Hong Kong. 10 native listeners took the perception test one by one. The experimenter played 4 sound files to the listeners through a lap-top and a headphone. The playing order was from 3

syllables file to 4 syllables file, then 6 syllables file and finally 7 syllables file. By this order, listeners could not guess the intonations of short stimuli from longer stimuli which contain more phonetic information. Before the real experimental section, there is a practice section including three stimuli. There are 16 trials in each experimental section. Subjects were required to choose between statement and question by marking their choices in four separated answer sheets provided to them. The test was a forced-choice task. The whole process took about 20 minutes. Only questions identification results were analyzed statistically.

### 3. Results and discussions

#### 3.1 Results

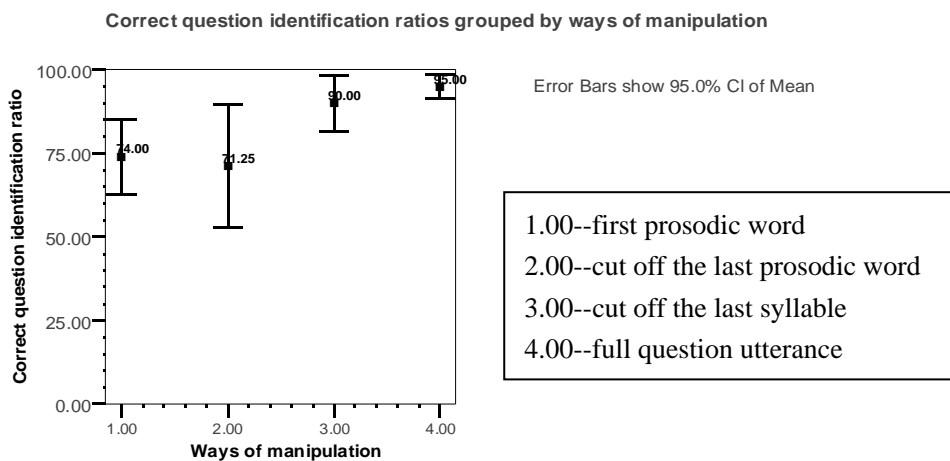
Listeners' questions identification results are listed in table2 and figure2. Table 2 shows the mean correct questions identification results on four kinds of stimuli, while figure2 shows the mean correct identification rates plus one positive and one negative standard deviations. The deviation values let us know the data distribution patterns.

table2: listeners' mean correct questions identification results

<u>Utterance in full length</u>	<u>Cut off the last syllable</u>	<u>Cut off the last prosodic word</u>	<u>Utterance remaining the first prosodic word</u>
马小明吃汉堡包?	马小明吃汉堡?	马小明吃?	马小明?
林小姐来运动场?	林小姐来运动?	林小姐来?	林小姐?
王教授讲新闻学?	王教授讲新闻?	王教授讲?	王教授?
张先生在办公室?	张先生在办公?	张先生在?	张先生?
Mean correct rates: <b>95.00</b>	Mean correct rates: <b>90.00</b>	Mean correct rates: <b>71.25</b>	Mean correct rates: <b>74.00</b>

We found from table2 that mean correct questions identification rates on “utterance in full length” and “utterance without the last stressed syllable” are close to each other, both are around 90%. Even for full utterances, listeners' identifications are not 100% correct. On the other hand, mean correct questions identification rates on “utterance without the last prosodic word” and “utterance remaining only the first prosodic word” are close to each other, both are around 70%. When the last prosodic word is missing, the mean correct identification rate drops about 20%. All the correct identification rates are above chance level (50%).

figure2: mean correct questions identification results, with two standard deviations



The numbers 1~4 represent four ways of manipulation. Figure2 tells us that:

1) 10 listeners' correct questions identification rates for the "full utterance" has little variations, most of the data distribute in the 90~100% interval. It means that most of listeners have no problem in figuring out the question intonation.

2) 10 listeners' correct question identification rates for the "utterance without the last syllable" has the second smallest variations, most of the data distribute in the 80~100% interval. It means that listeners have a little difficulty in figuring out the question intonation when the last syllable is missing. However, most of them could catch the interrogative meaning from the "utterances without the last syllable".

3) 10 listeners' correct question identification rates for the "the utterance without the last prosodic word" has the largest variations. It means that individual differences exist among listeners. Some of them could get the question interpretation; others are confused in judging "the stimuli missing the last prosodic word".

4) 10 listeners' identification rates for the "the first prosodic word" also has relatively large variation. But the variation is smaller than group 2. It means that listeners have individual differences in identifying "utterance remaining only the first prosodic word", but the differences are smaller than group2's.

5) There is few overlap of group2 and group4's error bars. That means data in group2 contrasts statistically significantly to data in group4. Listeners' correct question identification rate drops significantly when the last prosodic word is missing.

6) The bar of group 4 overlaps with the bar of group3. That means data in these two groups have no significant difference, taking off the last syllable did not cause many misjudgments of the question intonation.



## 3.2 Discussions

### 3.2.1 Marking out boundary high tones according to interrogative cues' locations

The results in 3.1 suggest two major findings: first, it is the final prosodic word rather than the sentence-final stressed syllable which carries most of the interrogative information. Second, both the global pitch level rising and the localized significant pitch rising at the final prosodic word contribute to the question detection.

Our result supports Lee (2005)'s acoustic measurement result, i.e., pitch rising begins from the first syllable of the question and goes to the highest place in the sentence ending place. Significant pitch swing occurs in the last prosodic word, thus the localized pitch rising and expansion carry most of the interrogative information. The perceptual data shows that listeners' correct identification rates amount to 74% even when the utterance remains only the first prosodic unit. Therefore, the upward pitch moving in front portion of the sentence also contributes a lot to signaling questions.

The result did not support the opinion that sentence-final syllable is the only carrier of question intonation. Cutting off the last stressed syllable does not influence the correct question identification a lot. Mandarin question intonation is different from intonation language like English which signals questions by boundary syllables' pitch shapes.

In syntactically un-marked yes-no questions, interrogative cues are distributed over the whole sentence rather than limited to the boundary stressed syllable at the end point of the utterance. Therefore, if we equals a "boundary high tone (H%)" to a phonological representation of "high or rising pitch which conveys the question meaning", an adequate representation of Mandarin question intonation should mark out the beginning high tone of question sentence in addition to the ending high tone. A syntactically un-marked question utterance which contains only one intonation phrase should be marked as:

"H% [intonational phrase] H%".

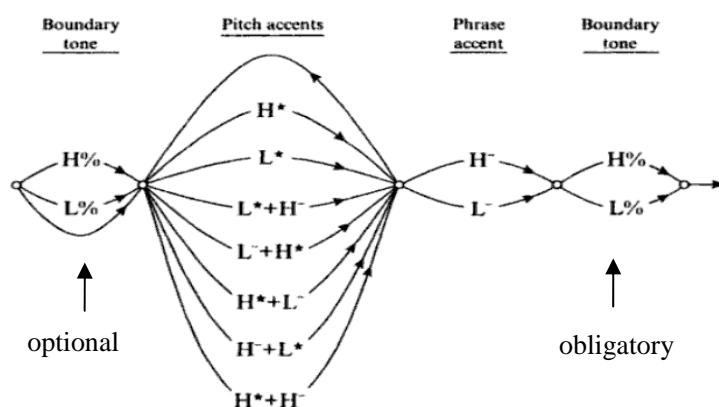
The phonetic realizations of these two boundary high tones lead to the pitch rising in the entire question utterance, and the pitch rising for the prosodic units at the beginning part and the ending part of the questions are more significant because they are near the high tone target.

### 3.2.2 Whether boundary tone is suitable for representing Mandarin intonation

The above analysis may be invalid if the notion of "boundary tone" has nothing to do with the sentence moods. If the boundary tone does not convey sentences' pragmatic meanings, we should not use this notion to categorized question or statement intonations. Since we adopt the term "boundary tone" from Pierrehumbert (1980)'s work on phonological aspects of English intonation, we need to make it clear whether the notion of "boundary tone" should be used to represent intonation's pragmatic meanings at all.

Figure3 shows Pierrehumbert (1980)'s finite state grammar for generating intonational tunes in English.

figure3: finite grammar for generating intonation (Pierrehumbert, 1980: p29)



It displays the internal makeup of the melody for an intonational phrase. In Pierrehumbert's definition, "boundary tone" is a high tone or low tone target associated to either beginning or ending edges of an intonational phrase. In her original work, the boundary tone unit has two functions. Firstly, it signals the pause position or boundary of an intonational phrase. The intonation phrase boundary (marked by "%") occurs "where there is a non hesitation pause", or the last syllable of a phrase is lengthened. In most of cases, [intonational phrases] corresponds to syntactic structures. The high tone or low tone target appeared in this position are marked by H% or L%. Secondly, boundary tone helps discourse interpretation. It "contributes information about the [intonational phrase] as a whole, it conveys information about whether the current phrase is to be interpreted with particular respect to a succeeding phrase or not". A high boundary tone means "forward-looking", "connects to following discourse" or "needs further interpretation with respect to a succeeding phrase". A low boundary tone means "all the relevant information to an utterance is already in the previous discourse" (Pierrehumbert & Hirschberg 1990). All polar questions are ended in a high boundary tone because they need further interpretation with respect to the succeeding answers.

Although the "boundary tone" notion has been adopted in Mandarin intonation discussions, its' definition seems to be different from Pierrehumbert's original descriptions. Boundary tones' functions are changed in Mandarin intonation analysis. In Lin (2006)'s work, "boundary tone" has the exclusive function of distinguishing question from statement, so a boundary high tone is the signal for question intonation. However, original "boundary tone" only signals phrasing positions between intonational phrases.

Polar question is just one kind of intonational phrases ending with high boundary tone whose discourse interpretation requires forward reference to the following context. Shi F. (2010)'s "boundary tone" is more similar to Pierrehumbert's original usage. Following Pierrehumbert's definition, Shi F. thinks it is better to study the phonetic features of the prosodic boundary and the features of the semantic focus in a separate way when describing Mandarin intonation. By his definition, boundary tones do not indicate sentence moods. Boundary tones tell only boundaries between prosodic words. In his example "zhang1zhong1bin1/xing1qi1tian1/xiu1shou1yin1ji1/", boundary tones realized in the final syllables of each prosodic words, which are bin1, tian1 and ji1. However, Shi F.'s usage of boundary tone also has a little difference from Pierrehumbert's. He gave up boundary tone's function in discourse interpretation, viewing it as a pure break without conveying any semantic meanings. Boundary tones are not limited to the high (H%) or low(L%) tone targets in Shi. F.'s system.

Based on our experiment's results and phonological point of view, we suggest retaining boundary tones in Mandarin intonation representation. Our interpretation of the boundary tone unit strictly follows Pierrehumbert (1980)'s definition. Boundary tone is not a purely sentence mood's indicator or a simply break in our interpretations. Therefore, when we transcribe a syntactically un-marked polar question as "H% [intonational phrase] H%", the boundary high tones (H%) represent the structural boundaries of this question phrase. They also indicate that this question phrase needs further information from the following discourse.

#### 4. Conclusions

The experiment shows that in syntactically un-marked polar questions, both global pitch register rising and significant localized pitch rising at both edges of the intonational phrase contribute to cue questions.

Un-marked yes-no questions which contains only one intonational phrase is represented as "H% [intonational phrase] H%". The global pitch rising and localized extra pitch swing are viewed as the phonetic realizations of these two boundary high tones.

Our interpretation of the boundary high tone (H%) follows Pierrehumbert(1980)'s original definition. Structurally, the H% signals intonational phrase boundary. Functionally, the high tone means the question needs further information from the following discourse, which is, the answer.

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