Intonation in Chinese

Yi Xu

Intonation, when used in a narrow sense, refers to fundamental frequency (henceforth F0) patterns in speech that convey information beyond lexical meanings. In a broader sense, intonation also includes other suprasegmental patterns such as duration, intensity and voice quality, etc., that also convey non-lexical meanings. This article will focus mainly on the former, because, as will be seen, F0 is the main carrier of non-lexical meaning, although for boundary marking, duration likely plays a major role.

Function versus form

As the definitions above indicate, there are two sides to intonation, namely, its form and function. The form refers to various observable patterns, while the function refers to the meanings they carry. Like most other aspects of speech, intonation has been studied primarily for its form, i.e., its shape and structure. This is the case with major theories of intonation for European languages, including nuclear tone analysis (O'Connor & Arnold 1961; Wells 2006), the Bolinger (1986, 1989) theory, and the Autosegmental-Metrical (AM) theory (Pierrehumbert 1980; Ladd 2008). For Chinese, the classical work of Chao (1968) lists 13 intonation patterns, all of them primarily defined in terms of form. The recent trend in research, however, is putting increasing emphasis on the functional aspect of intonation (Hirst 2005; Kohler 2005; Xu 2005). This article will reflect this trend, and describe Chinese intonation in terms of how specific communicative functions are encoded with unique intonational properties.

An advantage of studying intonation of Chinese over many other languages is that its tonal nature forces us to discover how it is possible for tone and intonation, which are functionally distinct from each other, to co-exist even though both use F0 as their primary carrier. An idea made popular by Chao (1968) is that tones are like small ripples riding on large waves of intonation. More recent scientific findings support this idea in general, but also point to specific articulatory and encoding mechanisms that enable the co-production of tone and multiple intonational functions (Xu 2005). This knowledge has increasingly been shown to be applicable not only to Chinese, but also to languages in general (Liu et al. 2013; Prom-on et al. 2009; Xu & Prom-on (submitted)).

Intonational functions

Just as lexical tones serve to distinguish words and morphemes, intonational functions serve to mark contrasts that are meaningful though non-lexical. It is therefore critical to understand intonation by identifying individual functions, their specific encoding schemes, and how they interact with each other. This can be achieved by empirical methods that allow strict control of all relevant factors. The intonational functions that have been recognized this way for Chinese languages include focus, modality (statement/question), topic and boundary marking.

Focus

(1) 他今天上學了 [He went to school today]
(2) 誰今天上學了? [Who went to school?]
When the Mandarin Chinese sentence in (1) is said as a response to different questions as in (2-5), there is a natural emphasis on tā ‘he’, jīntiān ‘today’, shàngxué le ‘went to school’, or none of the words, respectively. Such an emphasis on a particular component of an utterance is known as prosodic focus, narrow focus, or simply focus. Focus in Mandarin has been extensively studied, and the emerging picture is that it is marked by multiple cues. In general, a focused component exhibits expanded pitch range, increased duration and magnified intensity (Chen & Gussenhoven 2008; Chen & Xu 2006; Liu & Xu 2005; Jin 1996; Xu 1999). An example is shown in Figure 1b, where focus is on the first disyllabic word, which clearly contrasts with the neutral focus contours in Figure 1a. Furthermore, the pitch range and intensity of the post-focus region are compressed (narrowed and lowered), a pattern known as post-focus compression (PFC), as can be also seen in Figure 1b as compared to Figure 1a. Little, however, is systematically changed in pre-focus words.

Figure 1. Mean time-normalized F₀ contours of Māomī mō māomī 猫咪摸猫咪 [Kitty strokes kitty] (solid line) and Māomī mō mǎdāo 猫米摸馬刀 [Kitty strokes saber] (dotted line) with either no narrow focus (a) or focus on the first word (b). Each contour is an average of 40 tokens said by four male speakers of Beijing Mandarin (5 repetitions by each). Adapted from Xu (1999).

The identification of this asymmetrical pitch range, intensity and duration modification by focus in Mandarin (Jin 1996; Xu 1999) as well as in English (Cooper et al. 1985; Xu & Xu 2005) has led to a significant new development in intonation research. That is, PFC, the most stable feature of focus in these languages, turns out to be non-universal, and unevenly distributed among the world’s languages, including even among the Sino-Tibetan languages (Xu 2011, Xu et al. 2012). For example, while PFC is present in Běijīng Mandarin, Tibetan, Uyghur and Nánchāng 南昌 贛, it is absent in Southern Mǐn 閩, Cantonese, Yi, Deang, Wa, and even Táiwān Mandarin (Mandarin spoken in Táiwān) (Wang et al. 2011; Xu et al. 2012). More globally, PFC distribution seems to correlate with language families, e.g., present in Indo-European, Uralic, Altaic and possibly Arabic languages (Hellmuth 2006), but absent in most other language families (Zerbian et al. 2010). This has raised profound questions about the relation between these languages and their evolutionary history. A new area of research is therefore emerging which may lead to a rethinking of language typology, language change and human evolution (Xu 2011).
Modality and utterance-final particles

Modality, also known as sentence type, refers to whether an utterance makes a statement or asks a question. This function is often marked morphosyntactically, and in Chinese languages often by sentence-final particles. In addition, however, in Mandarin as in many other languages, a question shows a global rising intonation toward the end of the utterance, whether or not a question particle is present. As found by systematic empirical studies, however, at least in Mandarin, modality interacts extensively with focus to determine not only the utterance-final but also the entire F0 contour of a sentence (Liu & Xu 2005; Yuan, 2004). Figure 2 shows mean F0 contours of Mandarin question versus statement in sentences consisting of only syllables in the first (high level) tone. In Figure 2a focus is either on the sentence-initial word, or there is no narrow focus (hence, neutral focus). In Figure 2b, focus is either sentence-medial or sentence-final. It is apparent that the divergence between statement and question starts from the focused word, rather than occurring from the beginning of the sentence or only in the final word of the sentence.

![Normalized time](image)

Figure 2. Mean F0 contours of Mandarin sentence Zhāng Wěi dānxīn Xiāo Yīng kāichē fāyūn 張威担心肖英開車發暈 [Zhang Wei is concerned that Xiao Ying may get dizzy when driving] spoken as either a statement or a question. On the left, either focus is on the sentence-initial word (thick lines), or there is no narrow focus (thin lines). On the right, focus is either sentence medial (thick lines) or sentence final (thin lines). The black solid lines represent statements, and the pink dashed lines represent questions. Data from Liu and Xu (2004).

Figure 2 also demonstrates that the pitch range adjustment by question intonation is a nonlinear function of time, with greater increase toward the end of the question. This nonlinearity is consistent with the general observation that sentence-final rise is typically much more conspicuous than F0 changes in earlier regions. But the interaction of modality with focus shows that the right edge of an utterance is not the only location of modality coding. This has undermined the notion of a H% boundary tone as a standalone intonational entity (Pierrehumbert 1980), because modality involves adjustments to other parts of the sentence, especially at the location of focus. Furthermore, the nonlinear adjustment of pitch range occurs not only in questions, but also in statements, in which the F0 lowering accelerates toward the end of an utterance, resulting in the greatest drop in the final syllable. This final drop is referred to as final lowering or L% boundary tone for English (Liberman & Pierrehumbert 1984). But again, this final drop is likely only part of a continuous F0 decline that encodes the statement modality.
The accelerating F₀ change found in Mandarin reflects the importance of sentence-final location for marking modality-related information. Beside the question/statement contrast, other information can be also encoded at that location. This is reflected in the wide use of sentence-final particles (SFPs) among the Chinese languages. One of the richest repertoires of SFPs is found in Cantonese, where SFPs make use of a combination of lexical-tone-like F₀ contours and modality-relevant modifications (Wu 2009). Also, some of the Cantonese SFPs exhibit an edge-tone-like component, which is sequentially attached to the end of the SFP by lengthening its vocalic component without adding an extra syllable. Similar edge tones have been noted in Mandarin by Chao (1968), who refers to them as particles. Because of the difficulty of eliciting natural edge tones in experimental situations, it is only recently that there has started to be empirical studies of them (Li et al., 2011; Mueller-Liu, 2006). More such research is certainly needed.

**Comparison with English**

The findings about the encoding of modality in Mandarin and the methodology developed in the research makes it possible to have relatively direct comparisons between Mandarin and other languages. For example, Figure 3 shows that in English F₀ contours of question and statement diverge sharply after focus. In particular, post-focus F₀ in a question rises sharply above the pre-focus level, and then continues to rise gradually all the way to the end of the utterance. This is very different from Mandarin as shown in Figure 2, where post-focus F₀ goes below the pre-focus level even if the utterance is a question.

![Figure 3](image-url)

Figure 3. Mean F₀ contours of statements (S) and questions (Q) in American English. The word after “/” is focused. Data from Liu & Xu (2007).

**New topic (topic shift / turn taking)**

When a sentence is the very first in a conversational turn or a read paragraph, its F₀ is higher than in the following sentences (Lehiste 1975; Umeda 1982). This affects the pitch range of the sentence non-linearly, with a large F₀ increase near the beginning and a gradual drop afterwards (Wang & Xu 2011). This gradual drop due to topic is distinct from focus prosody which
immediately lowers post-focus pitch range, as seen in Figure 1b. The communicative function of this topic-related initial F0 increase is not yet fully clear. It has been described as marking a new paragraph (Lehiste 1975; Tseng et al., 2005), introducing a new topic (Nakajima & Allen 1993; Wang & Xu 2011), or initiating a new conversational turn (Swerts 1997). Conceptually, topic seems to overlap with some other prosodic notions, in particular focus and newness. The conceptual overlap with focus is the greatest in the case of contrastive topic, which is described as a topic that contains an alternative and is marked by a rising accent in English (Büring 2003). So far, however, no experimental evidence has been reported for such rising accent associated with contrastive topic in English. For Mandarin, a recent study has found no acoustic cue for contrastiveness in a topic (Wang & Xu 2011). The same study also finds that after controlling for focus and topic, newness does not have intonational correlates except for a small duration lengthening.

**Boundary marking**

The function of boundary marking can be exemplified by an ancient story whose written form is humorously ambiguous in the absence of punctuation:

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下 雨 天 留 客 天 天 留 我 不 留
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xià yǔ tiān liú kè tiān tiān liú wǒ bù liú
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down rain sky/day keep guest sky/day sky/day keep 1sg not keep

Among its possible interpretations are

(a) 下雨天，留客天。天留，我不留。
   ‘A rainy day (is) a day for keeping visitors. The weather keeps the visitor but I don’t.’

(b) 下雨天，留客天。天留我不？留！
   ‘A rainy day (is) a day for keeping visitors. Does the weather keep me? Yes!’

In spoken language, expressing meanings equivalent to the differently-punctuated written forms can be achieved by boundary marking, i.e. through pausing and lengthening the domain-final syllable. For English, it is shown that syllable duration alone can mark as many as seven grades of boundary strength (Wagner 2005). For Mandarin, domain-final lengthening is also consistently found (Tseng et al. 2005; Yuan et al. 2006; Xu & Wang 2009). A further question about boundary marking is whether it also involves other cues. There is some evidence that at the phrasal level, no direct F0 marking is involved in Mandarin (Xu & Wang 2009). At the sentential level, however, the issue is still unclear. Further research on the issue is clearly needed.

**From functional intonation patterns to global trends**

As the discussion so far has shown, intonational information is encoded by modifying various aspects of the tone production process, including, in particular, pitch range and duration. These modifications are associated with various specifically defined communicative functions. Interestingly, once the impacts of these modifications are added together, some of the widely recognized global patterns also start to emerge, including, in particular, declination and rhythm.
Declination

With the exception of final F₀ raising by question modality, most of the pitch range modifications by various functions are in the direction of generating an F₀ downtrend over the course of an utterance. First, from the left edge, a new topic raises sentence-initial F₀, and lets the subsequent F₀ gradually drop. Second, whenever a sentence consists of more than just high-level-tone syllables, any non-high-level tone lowers the F₀ of its following tone relative to its preceding tone. In Figure 1a, for example, compared to the slight downtrend over the course of the all-high-tone sentence marked with the solid line (as has also been found by Kochanski & Shih 2003), the sentence consisting of high and low tones marked with the dotted line (tone 1 and tone 3, respectively) shows a much larger overall downtrend. But we can see clearly that this is due to two downsteps which each renders a post-low high tone lower than the pre-low high tone. Taking a closer look at the first downstep we can also see that it consists of two components: pre-low F₀ raising and post-low F₀ lowering. While the latter is the familiar carryover effect, the former is known as anticipatory raising or anticipatory dissimilation, which has been found not only for Mandarin (Xu 1997), but also for Yoruba (Laniran & Clements 2003), Thai (Gandour & Potsikok 1994) and Cantonese (Gu & Lee 2007). Second, if the sentence happens to have a non-final focus, the global F₀ pattern is further tilted in two ways: on-focus raising (unless the focused tone is Low, e.g., tone 3 in Mandarin) and post-focus lowering. Third, the final word, and especially the final syllable of a statement, is lowered in F₀ to contrast with the rising question intonation.

Putting these pitch range modifications together we can see a global F₀ downtrend similar to the intonational phenomenon known as declination, which refers to an observed gradual decline in F₀ over the course of an utterance (Cohen & 't Hart 1967; Shih 1997). But the different sources of this downtrend shown above suggest that declination is likely a byproduct of different meaningful functions. As such it is unlikely to be due to an independent intonation mechanism. A similar find has been made for English by Liberman and Pierrehumbert (1984).

Rhythm

A widely known hypothesis is that languages of the world can be divided into three rhythm classes: stress-timed, syllable-timed and mora-timed (Abercrombie 1967; Ramu et al. 1999; Trubetzkoy 1958). Like declination, the grossly measured rhythm pattern as a gestalt is decomposable into individual temporal properties, each with a specific articulatory or communicative source. An important source of the isochrony tendency is polysyllabic shortening (Lehiste 1972; Nakatani et al. 1981), which generates a trend toward equal duration for words of different lengths. Interestingly, however, there is recent evidence that polysyllabic shortening is stronger in the supposedly syllable-timed Mandarin (Lin & Wang 2005) than in the stress-timed English (Xu & Wang 2009). Because polysyllabic shortening is directly related to boundary marking, it itself is a likely byproduct of a clearly defined communicative function (Tseng et al. 2005; Wagner 2005; Xu & Wang 2009; Yuan et al., 2006). Furthermore, duration patterns are affected by additional factors whose sources are relatively clear: intrinsic segment duration (articulatory — Klatt 1973), focus (functional) and contrastive vowel length (functional). Overall, the evidence suggests that speech rhythm is likely an epiphenomenon derived from a number of independent articulatory and functional mechanisms, and as such it has little to do with either isochrony or language-specific holistic temporal control.
**Concurrent realization of tonal and intonational functions**

All the intonational functions, however, need to be realized concurrently with lexical tones which encode the lexical function (together with consonants and vowels). One way to characterize this process is the parallel encoding and target approximation (PENTA) model (Xu 2005), as shown in Figure 4. The model assumes that communicative functions in speech are conveyed in parallel, as represented by the first block from the left. These functions are parallel to one another, because the meanings they carry are mutually independent rather than governed by a hierarchy. Each function is associated with a unique *encoding scheme*, represented by the second block, which typically consists of multiple properties. These properties control the articulatory parameters represented by the third block. These parameters in turn control an articulatory mechanism of *target approximation* (TA), represented by the fourth block. The TA mechanism, as elaborated in the lower panel of Figure 4, directly generates surface intonation.

![Parallel Encoding and Target Approximation (PENTA) model](image)

*Figure 4. Parallel Encoding and Target Approximation (PENTA) model (Xu, 2005).*

The TA model assumes that each syllable is assigned a pitch target that is either static (slope \(\approx 0\)) or dynamic (slope \(\neq 0\)), and surface \(F_0\) results from asymptotic approximation of the underlying target, which are articulated in full synchrony with the syllable. At the boundary between adjacent syllables, the final articulatory state of one syllable is transferred to the next syllable, which often lead to a delay of the apparent alignment of an \(F_0\) turning point, as depicted in the lower panel of Figure 4. Thus all the concurrent tonal and intonational functions jointly determine a linear string of “functionally loaded” local pitch targets, which, when articulated through syllable-synchronized target approximation, generate surface \(F_0\) contours that carry all
the encoded meanings. This conceptual process has been quantified into a computational model that has been tested on Mandarin as well as a number of other languages (Liu et al. 2013; Prom-on et al. 2009; Xu & Prom-on submitted).

Summary

To summarize, the concurrent realization of tone and intonation in Chinese languages is likely achieved by controlling different aspects of the target approximation process. While lexical tones are mainly encoded by local pitch targets in terms of height and slope, various intonational functions are likely encoded mainly via modifications of lexical pitch targets and syllable duration. Once the contributions of each of the articulatory mechanisms and functional codes are recognized, it is possible to also better understand global intonational patterns such as declination and rhythm. The patterns of intonation described in this article are predominantly based on Mandarin Chinese for which most of the systematic empirical studies have been conducted. But the function of prosodic focus has been investigated in recent years in a number of other Chinese dialects, and a pattern very different from those of Mandarin has been found in some of these dialects. But overall much more research is needed on intonation of Chinese languages and dialects other than Mandarin. The research on Chinese tone and intonation has also led to a computational model that is applicable to both Chinese and non-Chinese languages. Much more research, however, is needed to both collect systematic empirical data from various Chinese languages and perform computational modeling to further enhance our knowledge about Chinese intonation and intonation of languages in general.

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