Constancy and variation in Standard Chinese tonal patterns

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INTRODUCTION

For some time now we have been studying Chinese intonation in Lund. This work is part of a project sponsored by the Swedish Research Council which aims at giving phonetic descriptions of some non-European languages, Chinese, Arabic, and Hausa.[2]

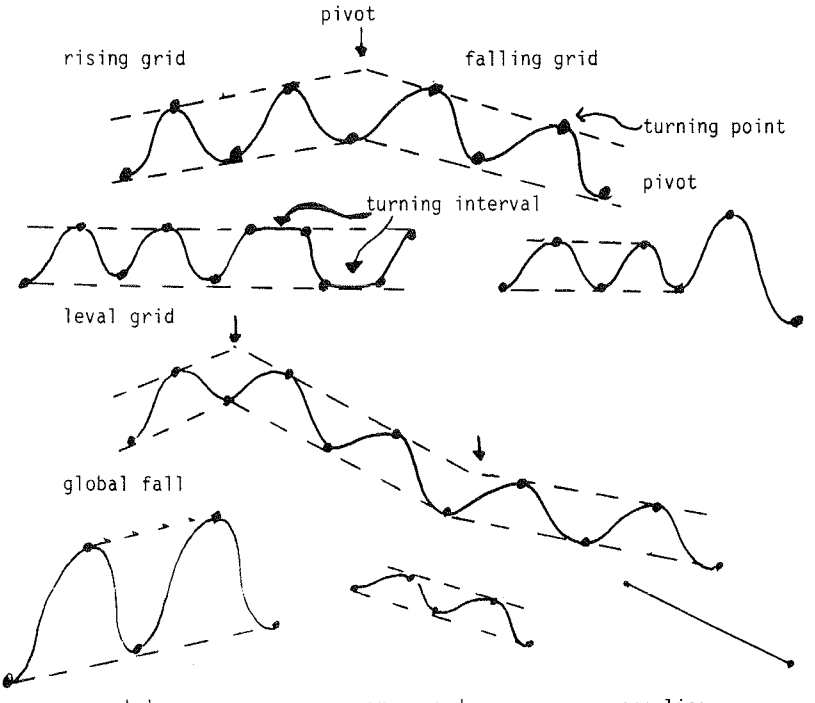
My personal interest in the project is primarily to test if the intonation model developed for Swedish dialects could be used for diverse prosodic systems (Bruce & Gårding, 1978, Gårding, 1981).

Our first study of Chinese tone and intonation was based on data from one Standard Chinese speaker (Gårding et al., 1983, Gårding, 1983). In this paper I shall present data from three more speakers of the same dialect.

Descriptive frame

Figure 1 illustrates the main features of the descriptive frame we have used, in particular the turning points, the grid and the pivot.

With good accuracy, an intonation curve can be reconstructed by smooth interpolation over the voiced segments between its turning points, i.e. the local maxima and minima and the beginning and end points. Turning points may also be end points of flat intervals called turning intervals. All these points are part of a global pattern, the grid, which is most easily seen if the main maxima are connected by a topline and the main minima by a baseline. In ideal cases, as in the figure, the grid appears



INTONATION PARAMETERS	FUNCTION	
	semantic	syntactic
turning points	words, morphemes	d:o
pivots	constituents (theme/rheme)	d:o (subject/predicate)
grid: direction	speech act type	sentence type
grid: width, position	information weight (focus)	clause type

Fig. 1 Concepts of the model and their communicative functions, illustrated by schematic FO curves connecting turning points over sonorant segments. Grids are marked by broken lines, pivots by vertical arrows.

as a sequence of units which are clearly rising, falling or level. A grid can be normal, expanded or compressed, even to the extent of being best represented by one line only. Grids of careful speech may have four lines, an upper and a lower topline and an upper and a lower baseline.

The part of the grid where the direction or width is changed or where the grid takes a jump is called a pivot. The lower part of the figure shows the communicative function of these features. The local turning points signal words or morphemes. The pivots serve as semantic and syntactic boundaries. The general direction of the grid of a sentence, often in combination with the direction of its final part, is associated with speech act type and sentence type. The levels (lines) of the grid vary according to style of speech, and the use of the levels differs across idiolects, dialects and languages. The width and position of the grid signal its information weight relative to other intonation units (Gårding, 1983c).

When the model is used for generative purposes, the global features, the grid, are generated first. Then the local maxima and minima pertaining to lexical accents or tones are inserted as points into the grid according to specific rules which state how the points are aligned relative to the segments. The fact that this alignment is relatively constant makes this arrangement of the rules convenient. In the last step the fundamental frequency curve is obtained by smooth interpolation. The generative part of the model is not the topic of this paper, but there will be some comments on its feasability in the light of the new data.

Material

Our material, presented in Figure 2, has been selected to investigate the interaction of tone and intonation.

A Chinese morpheme of the standard dialect can have one of four tones: Tone 1 called 'high' or 'level', Tone 2 'rising', Tone 3 'low' or 'dipping' and Tone 4 'falling'. There is, in addition, phonemic stress and the nuclear stress falls on the last stressable item if nothing else is indicated (Kratochvil, 1968).

MATERIAL

1. Wāng Yī chōu xiāngyān
   Wang Yi smokes cigarettes
2. Sòng Yán mài niúròu
   Song Yan sells beef
3. Chěn Lǐ mǎi yǔsǎn
   Chen Li buys an umbrella
4. Wāng Lǐ chuān yǔyī
   Wang Li wears a raincoat

PROSODIC CONTOURS

1. Focus free statement
2. Focus free yes-no question

   Statements:

3. after focus
4. focus left
5. focus right

There are 3 utterances of each sentence called a, b, c.

Code:

Li: 1.2.a means Li's production of tonal pattern 1 in prosodic contour 2, utterance a.

Fig. 2

Four tonal patterns have been chosen, three consisting of so-called contour tones, i.e. rises and falls, and one composed of level tones only.

The tonal patterns occur in a syntactic subject/predicate frame and have been pronounced as statements and questions. The statements have four different focus arrangements. Test sentence 1 represents a statement without any focussed part, an intonation used for example when the sentence introduces a short story. Test sentence 3 is a statement intonation occurring after a strongly focussed shì 'yes'. It expresses confirmation of known circumstances. Numbers 4 and 5 have been elicited by questions calling for focus to the left and right respectively. Number 2 is a yes-no question. The questions have not been asked in different focus arrangements.

Four speakers have been analysed. Each sentence has been pronounced three times as an answer to a question or elicited by a well defined and well described situation. The order of the test items has been randomized.

Informants

All of our informants represent Standard Chinese (Putonghua). Chen was born in Suzhou, Southern China, in 1948, and moved to Beijing at the age of six. He was an elementary school teacher until 1980, when he came to Sweden.

Li was born in Beijing in 1947 and studied languages and literature at a university there. He works as a translator.

Shi was born in Beijing in 1965. He grew up in Beijing where he completed his high school education. At the time of the recording he was a student at the Royal Institute of Technology in Stockholm.

Zhang was born in 1931 in the Liaoning province north-east of Beijing. At the age of 15 he came to Beijing where he pursued his university studies. He is professor of speech acoustics at the Academia Sinica, Beijing.

An impressionistic ranking of the speech style of the speakers from formal to informal would be: Zhang, Chen, Li, Shi.

Outline

The first part of the paper describes the material produced by Chen, who has been chosen as the prototype.[3] In the second part of the paper I shall summarize the most important similarities shared by all of our four speakers and also comment on some differences between them.

CONSTANCY AND VARIATION: ONE SPEAKER

Figure 3 shows one of the tonal patterns, Sòng Yán mài niúròu, 'S.Y. sells beef', produced by Chen, our prototype speaker. The tonal pattern is falling, rising, falling, rising, falling, in five different prosodic contours uttered three times in each. The three utterances have been lined up with the end of each utterance as a common time reference.

The uppermost statement shows a slightly falling general trend all through the sentence. The interrogative contour, that of a

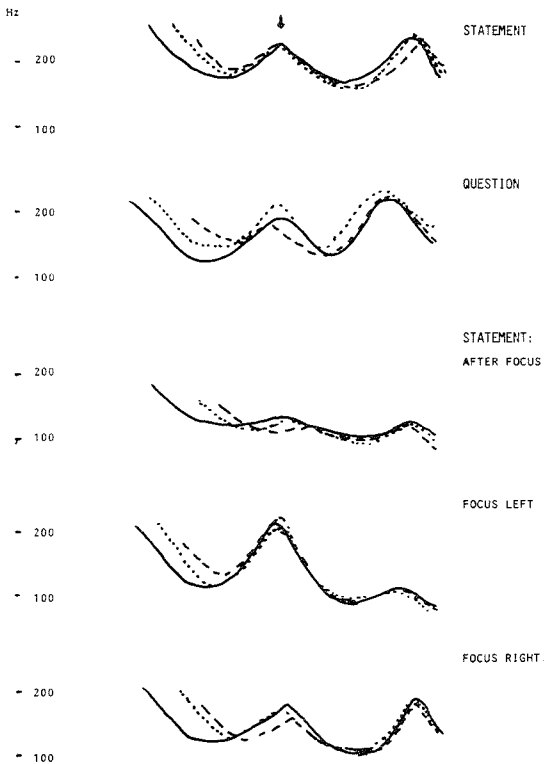


Fig.3 Chen: Sòng Yán mài niúròu. 3 utterances in 5 prosodic patterns. Arrow marks C/V boundary of mài.

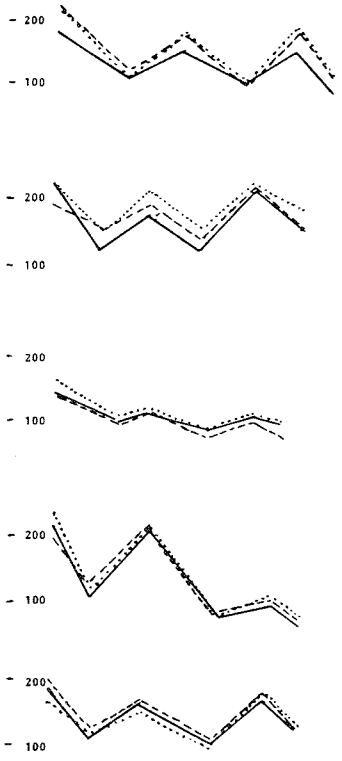


Fig.4 Chen: Sòng Yán mài niúròu, normalized for duration (see text).

yes-no-question, is level over the subject and rising over the predicate.

The third contour, a statement referring to previously known circumstances, occurred after a strongly focussed shi 'yes' meaning 'yes of course'. The contour is falling as in the first statement but the level of the upper turning points has dropped half an octave and the range of the rising and falling intervals is compressed by half. The fourth contour, also a statement, is level or rising over the focussed subject and strongly falling over the predicate. The last one is falling over the subject, and the focussed predicate reaches a slightly higher level. This contour is similar to the first one, which reminds us of the rule giving nuclear stress to the last stressable item (see Introduction). We notice in passing that there is the same asymmetry in the pitch movements before and after focus as in other languages in that before focus there is much more fundamental frequency movement than after focus.

We can picture the prosodic contours of Figure 3 as global deformations of a basic tonal pattern. This illustrates in a neat way the aim of this part of the analysis: to describe the basic patterns and the deformations imposed by sentence intonation.

Temporal features

Let us now look at the durations. With the ending as a common time reference we notice that the temporal variation is largest at the beginning of an utterance. Some of the temporal variation is contour bound. The first statement contour, the one expressing new information, is the longest one. The question is somewhat shorter and the patterns with the whole sentence or part of the sentence unfocussed are the shortest ones.

Even within each group the durations vary quite a bit. In general the first utterance of the speaker is longer than the other ones. The temporal variation is somewhat irregular but it is clear, even if it is less conspicuous in this speaker than in the others, that the variation is not due to a uniform stretching and shrinking. What may happen when a speaker goes from a faster to a slower tempo is that the rate of fall and rise is kept rather constant and a turning point is exchanged for a turning interval. The presence and width of such turning inter-

vals seems to be connected with consonants and syntactic boundaries. (Similar observations were made for Swedish by Gårding, 1975.) Variation of fundamental frequency patterns due to tempo changes are being studied separately.

Fundamental frequency features

To describe the variation of intonation contours we need to measure similarities and differences in some way. Among all possible alternatives, I have chosen to study the variation of fundamental frequency values of turning points (max and min), including beginning points and end points. This is particularly appropriate for sequences consisting of contour tones. In Figure 4, I have normalized the patterns for overall duration and durations between consecutive turning points. From what we can see here the curves are roughly parallel. This means that there is covariation of the FO values of these points and hence a certain stability in the configuration of the contour. A natural interpretation of this covariation is that it is the direction (or directions) of the configuration that is important for the speech act type and that it is possible to move it up and down on the frequency scale without changing its speech-act information.

Turning points related to segments

In Figure 5, I have marked the position of the turning points relative to the segments which have been normalized to a certain duration for the vowels and another for the consonants and consonant clusters.

It is quite obvious that the position of the turning points is remarkably constant all through the productions of all the prosodic contours. The falling tone starts at the beginning of the vocalic segment. There is one utterance in which the turning point has crept forward a bit into the vocalic segment. We may be able to correlate this displacement to increased speech effort.[4] The fall of the falling tone is completed before the beginning of the following vowel which carries a rising tone. Also the rising tone is connected with the beginning of the vowel. We draw the natural conclusion that it is the vocalic segment that carries the pertinent tone movement whether it is falling or rising. This is in agreement with certain statements

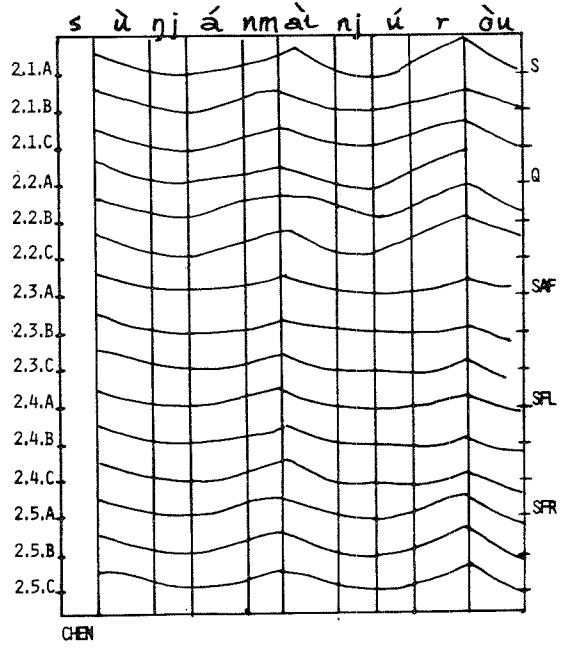


Fig.5 Location of turning points related to segments
Duration of segments normalized (see text).

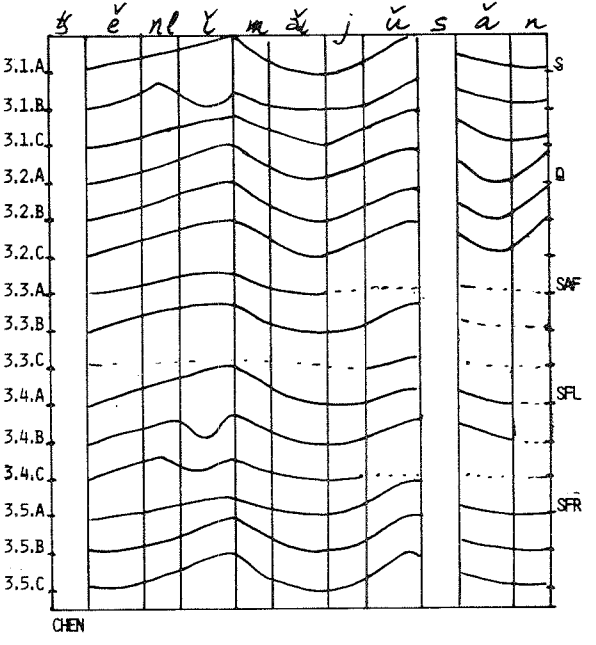


Fig.6 Location of turning points related to segments
Durations of segments normalized (see text).

in the literature (e.g. Howie, 1974, and Kratochvil, 1968) and in disagreement with others (Chao, 1968).

Figure 6 shows the location of turning points in another tonal sequence, uttered by the same speaker. In this sentence, mǎi meaning buy with a low (dipping) tone, appears in a similar position and context as mài with a falling tone meaning sell, which occurred in Figure 5.

We notice that the speaker has fixed the turning point all through the contours and utterances to the beginning of the consonant m. The relevant tone pattern, which we have labelled low, is reached in the middle or latter half of the vocalic segment.

There is also a variation of tone movements over the subject phrase. These are varying results of a sandhi rule, which will be commented on presently.

Considering the alleged importance of turning points, it is interesting to see what a tonal pattern consisting of only level tones looks like and how it behaves in the different contours. Figure 7 shows an all high (level) tonal pattern. Wāng Yī chōu xiāngyān, 'Wang Yi smokes cigarettes'. The curves of the utterances of the same prosodic pattern are rather parallel. As before, the tonal pattern has a constant shape and this shape has a certain leeway on the time scale as well as the frequency scale.

One can ask about the size of this leeway. How far down can a speaker place this all-level pattern without running the risk of being misunderstood?

It turns out that the problem of keeping an all-level pattern distinct from e.g. an all-low one never becomes critical. The reason is that the all-low one has a sandhi rule attached to it which changes any low-low sequence into a rising-falling one. (In this way the low tone really appears 'dipping' as one of its names indicates.) This is the reason why the all-low pattern rises and falls the way it does in Figure 6. The sandhi rule says T3 → T2/ - T3, but this rule does not apply over deep syntactic boundaries, at least not in the style of speech used here (cf. Cheng, 1973). We notice that speaker Chen adheres to this rule (as do the other speakers). After the boundary between

noun-phrase and verb-phrase, mǎi never becomes rising. The noun-phrase, on the other hand, has a variety of manifestations, rising or level all through or rising-falling-level (Fig. 6).

Pivots

Figure 7 also shows that there are bends in the all-high pattern. Some of them are caused by disturbances of the laryngeal tone in connection with the consonants, but others are pivots, associated with the syntactic/semantic structure of the sentence (see Introduction). In the figure pivots occur in connection with the boundary between the noun-phrase and the verb-phrase.

Interaction of tonal patterns and intonation contours

Figure 8 completes the story of Chen. It shows four tonal patterns on top of each other for the five different prosodic contours. Each curve has been chosen as the most representative one out of the speaker's three productions of each sentence (see Appendix).

The tonal patterns are represented as follows.

Unbroken line ——— level tones
Dotted line ..... falling-rising tones
Dashed line --- low tones, by sandhi rule converted to rises and falls
Dashed and dotted line -·-·-·-· level and low tones, phonetically rising and falling with a lingering on high frequencies and the low frequencies often accompanied by creak, which is marked by vertical pieces of line.

From this figure it is possible to grasp the different impositions of the speech acts on the tonal patterns.

In most contours the level tone pattern seems to represent an intonational mean around which the other curves move. The overall tendency for statement intonation is falling. It seems that a corresponding grid should have four levels for the contour tones but the material does not permit precision at this point.

The interrogative intonation is rising except for the low-tone sequence, in which the question is signalled by a local terminal rise, lengthening the pattern of a contour which otherwise

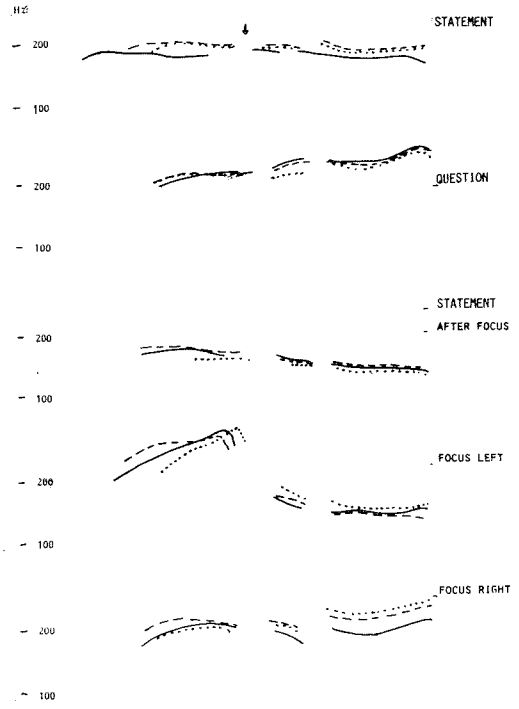


Fig.7 Chen: Wāng Yī chōu xiāngyān. 3 utterances in 5 prosodic patterns. Arrow marks boundary between subject and predicate.

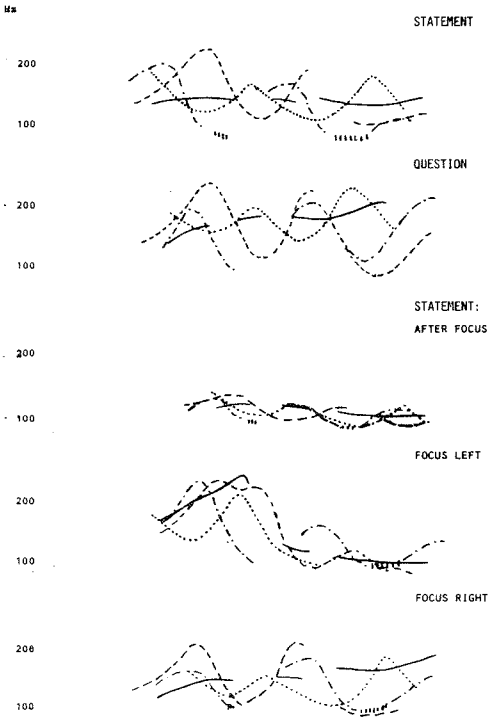


Fig.8 Chen: 4 tonal patterns in 5 prosodic contours. For code, see text.

looks like a statement. In our material, this is the only exception to the general rule that tonal patterns adjust to an intonation contour.

The statement after focus has characteristics similar to the first statement but here all the tonal events occur in a compressed grid. Even in this compressed state there are traces of the four levels, however.

The last two patterns will be treated together. One striking feature is the asymmetry between the effect of focus on the first phrase as compared to the focus effect on the last one. In both cases focus is manifested by an expanded grid, but the compression is considerably greater after focus than before. This feature seems to be general across languages (Gårding, 1983. For Swedish, see Bruce, 1977 and 1978). With focus to the left, the level tone pattern leaves its mean position and reaches the same high level as the other tonal patterns. This may be the optimal way of bringing out focus in a sequence of level tones where the speaker cannot expand a local up and down tonal movement.

CONSTANCY AND VARIATION: SEVERAL SPEAKERS

Tonal patterns and intonation contours

The figures in the appendix (A1-A12) show the test sentences produced by Li, Shi and Zhang and the remaining ones by Chen. The voices of the speakers have different ranges from Zhang's close to two octaves to Shi's less than one.[5] The tonal patterns are the same for all speakers in all situations except for Shi's after-focus statement. Here the last part of the utterance is creaky.

The intonation contours of the speakers have the same overall trends as before with falling statements and rising questions. The focus patterns are also similar with different degrees of compression depending on the position of focus.

As earlier the end of the utterances has been used as a common time reference, because, as was remarked already, the variability is much larger in the beginning of an utterance than in the end. There is for these speakers the same covariation of FO values of consecutive turning points as found for Chen. This gives stability to the configuration of the contour.

Interaction

Figures 9-11 show four tonal patterns on top of each other for the five different prosodic contours.

The following comments made in connection with Chen's intonation patterns remain valid:

The level-tone sequences represent some mean around which the contour-tone patterns move up and down.

The statements are in general falling and the questions rising.

The manifestation of focus is a combination of expansion and compression.

Li's high-level tone in the first part of the statement seems to be an isolated occurrence. Shi's statements are falling according to the general rule but his questions are level rather than rising. On the other hand they are much shorter than his statements. (According to Kratochvil it should be possible to produce a question just by quickening the tempo.)

The interaction between tone and intonation is clarified by the introduction of the descriptive terms of our model, especially grids and pivots.

Li and Zhang follow the focus rule for grids in all cases. Shi replaces a compressed grid in the latter part of the sentence by creaky voice just as he did in the after-focus statement.

The normal variability of repeated renderings of the same prosodic pattern makes it necessary to replace the idealized lines of a theoretical grid by preferably non-overlapping zones, which are nevertheless approximately parallel. The greater variability in fundamental frequency values of the high-frequency turning points of our material compared to the low ones (cf. figures in the Appendix) makes it natural to let the high zones be broader than the low ones.

Figure 12 shows grids for the questions of all our speakers. The scale is logarithmic for speaker Zhang to facilitate comparison between his two-octave voice and the one-octave voices of the other speakers. When looking at the lines of the grid, one has to bear in mind that they are supported by the most representative utterance and that in real life they correspond to

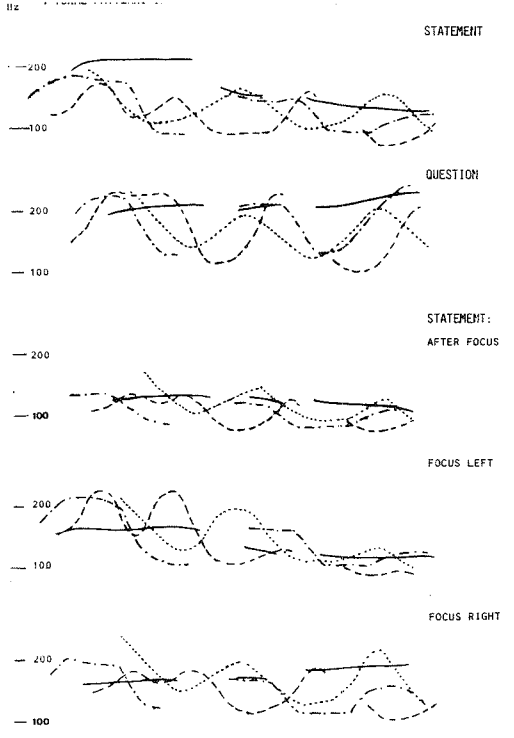


Fig.9 Li: 4 tonal patterns in 5 prosodic contours. For code, see text.

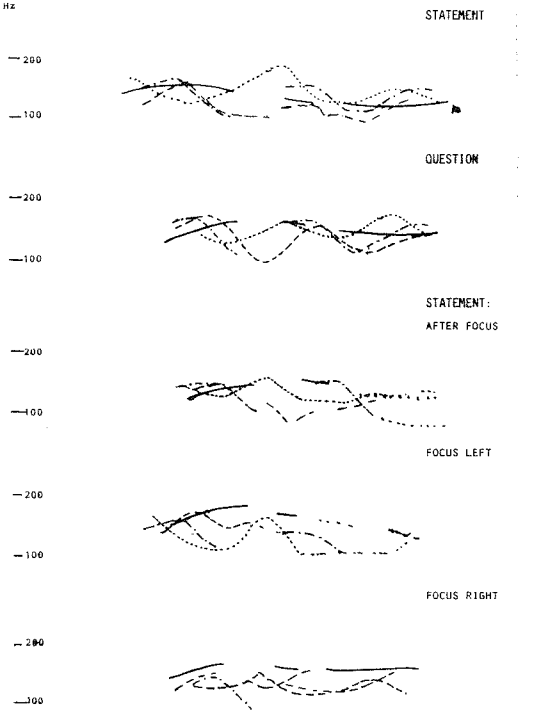


Fig.10 Shi: 4 tonal patterns in 5 prosodic patterns For code, see text.

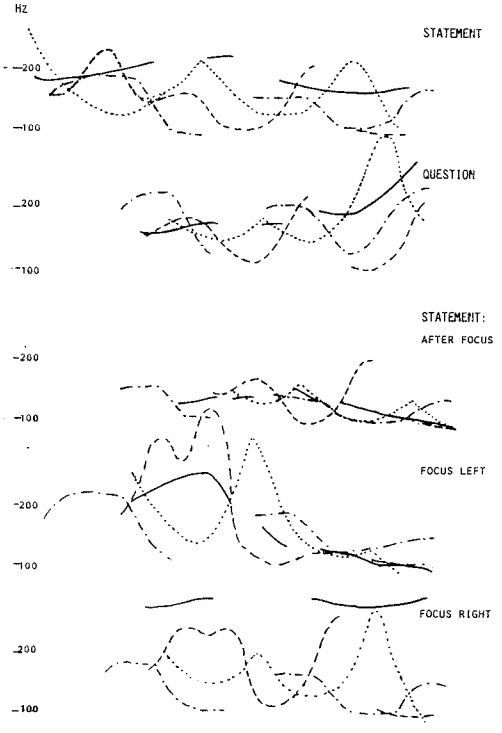


Fig.11 Zhang: 4 tonal patterns in 5 prosodic contours. For code, see text.

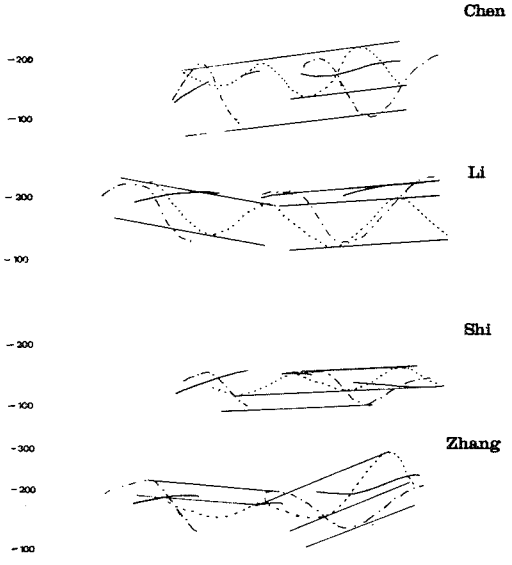


Fig.12. 4 tonal patterns in the question of 4 speakers.

zones due to the variability of the position on the frequency scale of the contours.

When constructing these grids I have not included the all-high (level) patterns, which, as I have mentioned earlier, seem to represent an average of a speaker's voice register. I have also left the all-low pattern aside because for this tonal pattern, all speakers, except Zhang, have used a statement contour combined with a local terminal rise to signal question. In our material this is the only case where a tonal pattern seems to influence the choice of an intonation contour. As a result the grids drawn in Figure 12 are only derived from the falling-rising and high-low tonal patterns. The grids have been obtained in the following way: I have connected the maxima and minima of the rising-falling pattern (dotted line) with the purpose of obtaining two parallel lines. This produces an 'interior grid' which seems to give a good indication of the general direction of the contour. We can see how Chen and Shi use rising grids, whereas Li and Zhang have falling-rising ones with a change of direction, i.e. a pivot, in connection with the subject/predicate boundary. It is obvious that the bidirectional grid is connected with a slower rate of speech. Hence the pivot is not obligatory.

With the parallel grid lines we also notice that the falling-rising subject phrase of Chen and Zhang has a compressed grid as compared to a more expanded grid enclosing the predicate phrase. This indicates that these speakers have given more weight to the predicate phrase in accordance with the nuclear stress rule of their dialect.

The credibility of these grids is perhaps so far a matter of judgement. In any case there are two tonal patters in this contour with three clear turning-point zones, as demonstrated in Figure 12.

Turning points and turning intervals

Figures AT2, AT3 and AT4 at the end of the appendix present the positions of turning points in relation to segments across speakers for the three sequences in which this feature is relevant. (The level tonal pattern has been left out for natural reasons.)

In the sequence Sòng Yán mài niúròu (Fig. AT2) the turning points for the rising and falling tones occur near the C/V boundary. The relevant tone movement, then, seems to start with the vocalic segment. A junction between a falling and a rising tone tends to produce turning intervals whereas a junction between a rising and a falling one seems to produce pointed peaks.

In the sequence Shěn Lǐ mǎi yǔsǎn, the sandhi rule invariably produces a rise for the first syllable of the compound yǔsǎn, starting from a low turning point at the beginning of the vocalic segment (Fig. AT3). The morpheme mǎi introducing the predicate phrase always has a fall from a high turning point in the beginning of the consonant [m] which continues to a low turning point in the first half of the following vocalic segment. In many cases this low point is followed by a turning interval. In the subject phrase, on the other hand, the sandhi rule has different results depending on both speaker and intonation. One result is a rising intonation over the whole phrase regardless of the individual word tones.

In the sequence Wāng Lǐ chūan yǔyī (Fig. AT4) the turning points have clear locations in most cases. The high and low tones seem to be well represented by high and low frequency levels in the vocalic segments. The exceptions, namely the slight rise over the first vowel, the incomplete tonal segments before the voiceless affricate and the end of the utterance are clear coarticulation effects. In many cases a low is accompanied by a creaky segment. The characteristic feature of the low tone, then, is an interval of low frequencies in the vowel after a sharp fall.

The observations above agree well with those made earlier for the prototype speaker. The constancy of the turning-point feature permits an easy specification of the alignment rules of accents and tones onto the grids and a convenient arrangement of the rules of the pitch algorithm with the global features first and the local ones later (see Introduction).

Perceptual testing, work in progress

The two sentences containing the sequence mai have been the object of a special study.

Figure 13 illustrates fundamental frequency curves from our speakers' productions of the sequence mai with a low or a

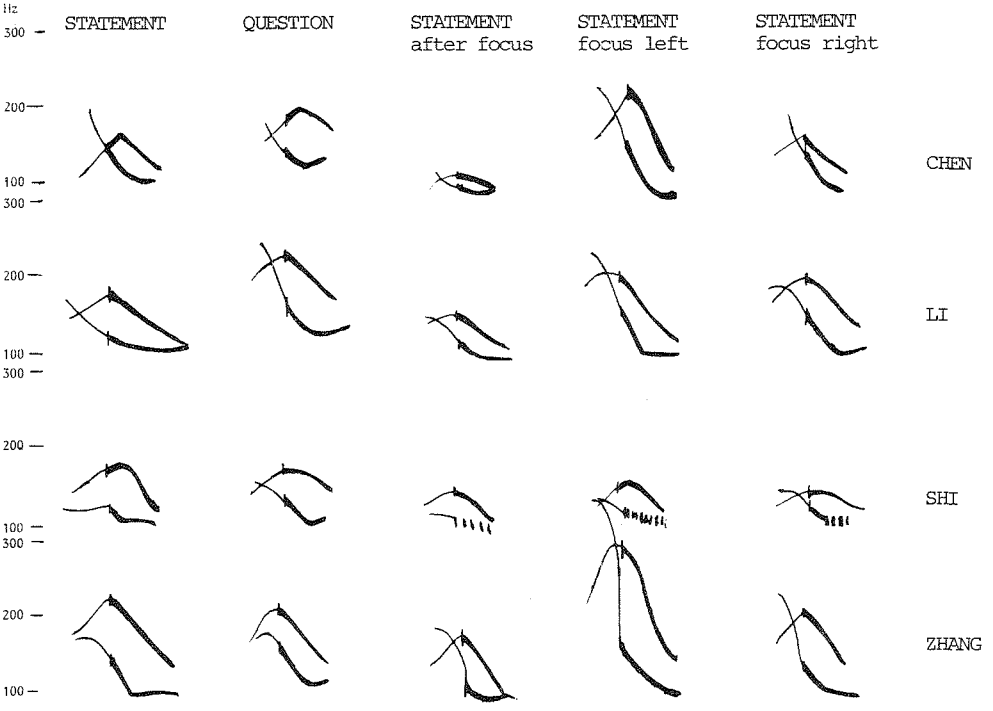


Fig. 13 Superimposed sequences of mai derived from 4 speakers' productions of five prosodic patterns. The falling tone 4 is above and the low tone 3 below. The C/V boundary is the time reference for each pair. The thick line marks the vocalic segment.

falling tone in all five prosodic patterns. The productions have been taken from a comparable context and are superimposed with the beginning of the vocalic segment as a common time reference.

The two tones have distinct manifestations regardless of speaker and prosodic pattern. The common feature of Tone 4 can be described as a fall from a rather high level at the beginning or near the beginning of the vowel. This fall is preceded by a rise including the syllable-initial consonant.

The common characteristic of Tone 3 is a fall reaching low level and sometimes accompanied by creak in the latter half of the vocalic segment. This fall is in most cases a continuation of a fall which started in the preceding consonant. In the last three prosodic patterns, Zhang's low-tone fall shows a discontinuity at the beginning of the vocalic segment as if the vocal cords went into another mode of vibration.

At this point we might perhaps venture the hypothesis that the perceptual characteristic of Tone 4 is a fall prepared by high frequencies in the beginning of the syllable (mainly in the consonant) and that of Tone 3 is low frequencies in the latter half of the syllable prepared by a fall.

Using the ILS program we have tried to change a falling tone into a low one by various maneuvers, e.g. by translating the falling movement of Tone 4 backwards in time or by introducing a simulated creak into the falling tone. It has been claimed that the creak or glottal stop is THE distinctive feature of the low tone. The reactions of my two Chinese-speaking collaborators do not support this claim (Kratochvil, Svantesson). A test tape has been evaluated by a group of listeners in Beijing who respond in a similar way. The results are presented in a separate paper (1985, Gårding, Kratochvil, Svantesson, Zhang).

This experiment marks a new direction in our research. We would like to give our intonation model, which is production oriented, a perceptual complement. And with all the experience we will gain from our analyses of Chinese, Arabic and Hausa we will return to Swedish for reconsidered analysis.

SUMMARY OF RESULTS AND CONCLUSIONS

Finally I would like to sum up our main findings.

1. The four speakers use the same tonal patterns with turning points very much fixed relative to the segments. As a consequence the main falls and rises are also fixed.

2. The tonal patterns have overall shapes characteristic of the five situations which have been used to elicit the utterances. In terms of the model we can say that the grids are similar except that the use of pivots may differ from speaker to speaker, obviously depending on tempo and style. However, when pivots do occur,they are in the same location.

3. In contrast to this constancy there is individual variation in voice range. One speaker has a two-octave voice in a declamatory speech style and the others use about one octave. There is also some individual variation in stress patterns. When focus has not been explicitly provoked to fall on a particular part of the utterance as in the first statement and the question, stresses are either equally distributed over the sentence or the last phrase has been given stronger stress in accordance with the nuclear stress rule.

4. There is also variability in the manifestation of the sandhi rule for Tone 3 but all four speakers agree in letting the rule be blocked by a deep constituent boundary.

5. The model we proposed for Chinese tone and intonation based on one speaker has been validated in at least the following sense: It serves as a convenient frame for further explorations of the interaction of tone and intonation in Chinese. At the same time we have strengthened our claim that the model gives a general frame for any prosodic system and that it sheds light on the structure of intonation in general.

NOTES

1) Modified version of talk given to the Prosody Club of the Department of Linguistics, Stockholm University, 15.11.1984.

2) My collaborators are for the Chinese part, Jan-Olof Svantesson and for Arabic and Hausa, Mona Lindau Webb and Kjell Norlin. I should also like to thank Jiālù Zhāng, Acoustics Institute, Academia Sinica, Beijing, and Paul Kratochvil, Faculty of Oriental Studies, Cambridge University, for help and advice. Jan-Olof Svantesson and Jīālu Zhāng composed the material and made the recordings.

3) The material was recorded in speech laboratories in Lund, Stockholm and Beijing and analysed by Spectrograph Kay Digital Sona-Graph 7800 and by the ILS-program implemented on VAX 730.

4) The effect of speech effort is being studied in a special material.

5) Zhāng has used a declamatory speech style which is common in recitals.

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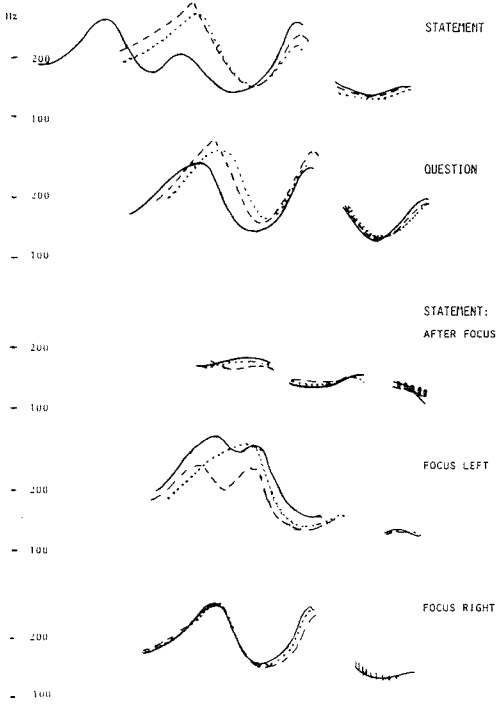
APPENDIX

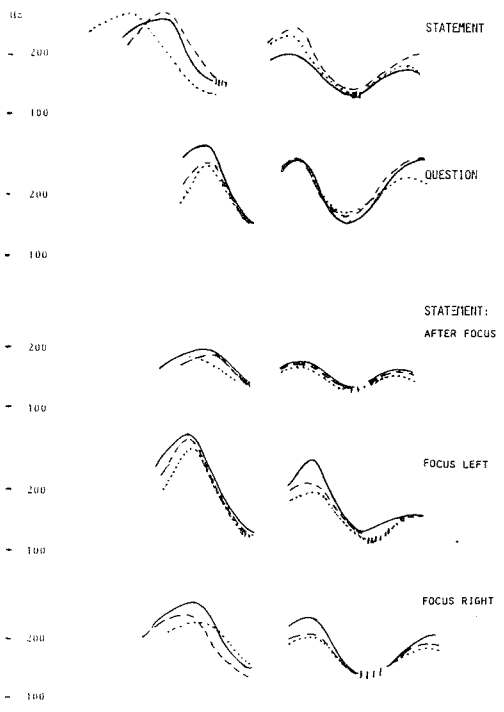
Here the complete material is collected as drawings of FO and diagrams of turning-point locations from spectrograms except parts given in the text (Chen 1 and Chen 2).

CODE

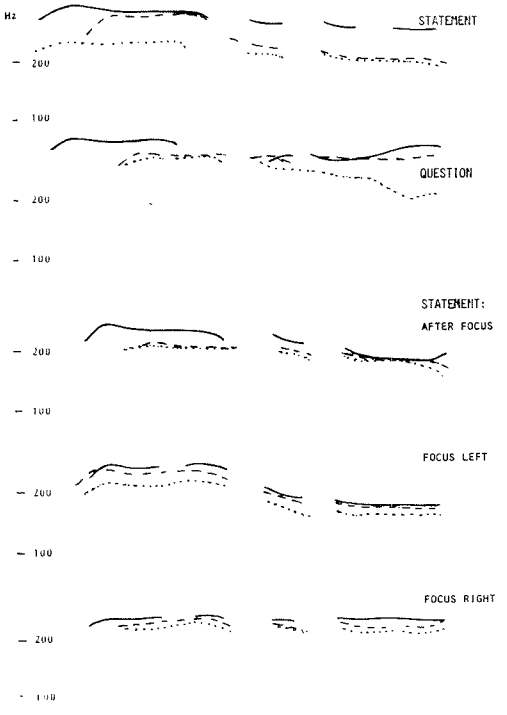
A = Appendix
1 = Wāng Yī chōu xiāngyān
2 = Sòng Yán mǎi niúròu
3 = Chěn Lǐ mǎi yǔsǎn
4 = Wāng Lǐ chuān yǔyī
T = Turning-point diagram
S = Statement
Q = Question
SAF = Statement after focus
SFL = Statement focus left
SFR = Statement focus right



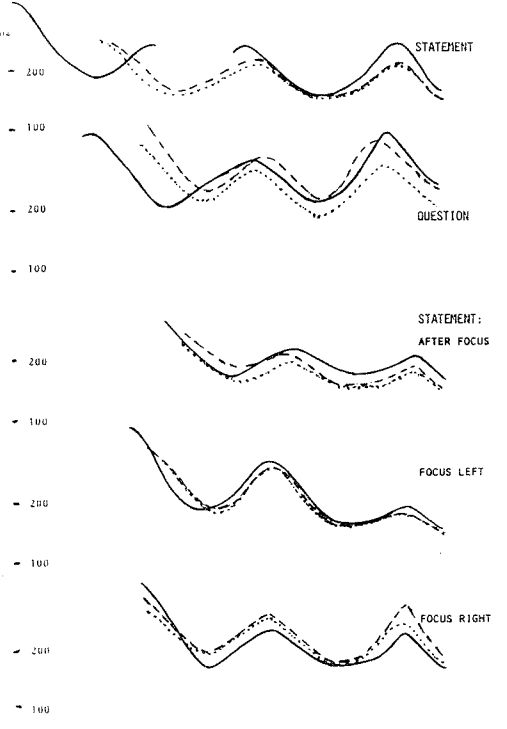
Chen A3: Chěn Lǐ mǎi yǔsǎn. 3 utterances in 5 prosodic patterns



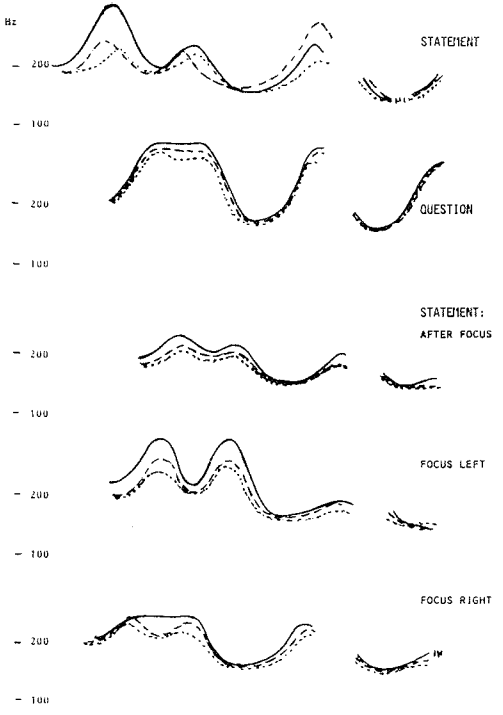
Chen A4: Wāng Lǐ chuān yǔyī. 3 utterances in 5 prosodic patterns



Li A1: Wāng Yī chōu xiāngyān. 3 utterances in 5 prosodic patterns



Li A2: Sòng Yán mài niúròu. 3 utterances in 5 prosodic patterns



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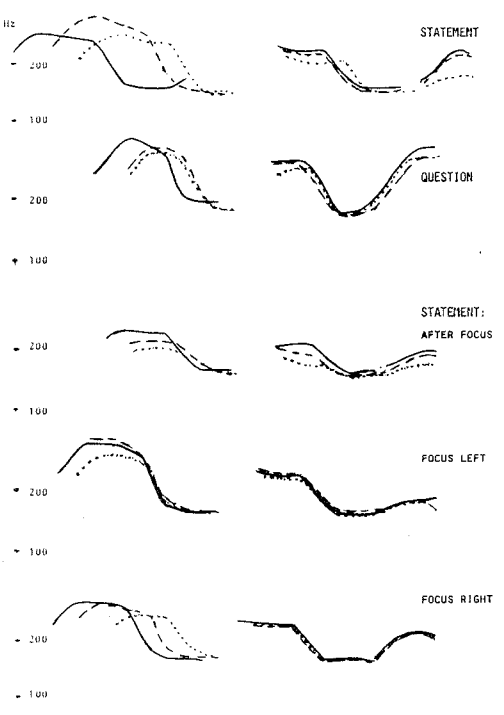

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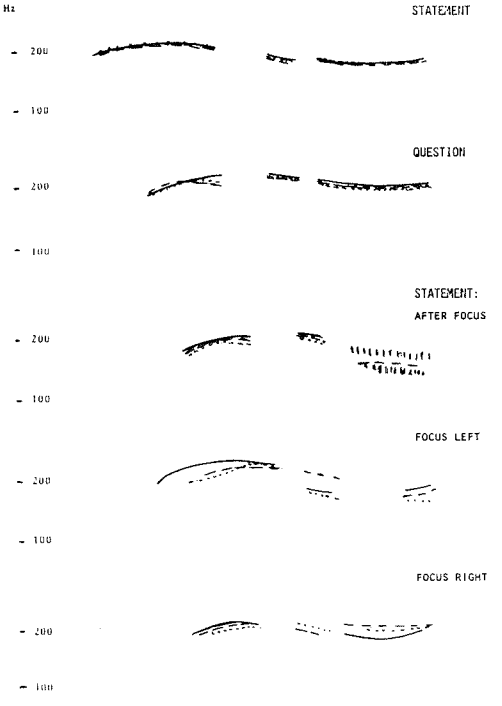
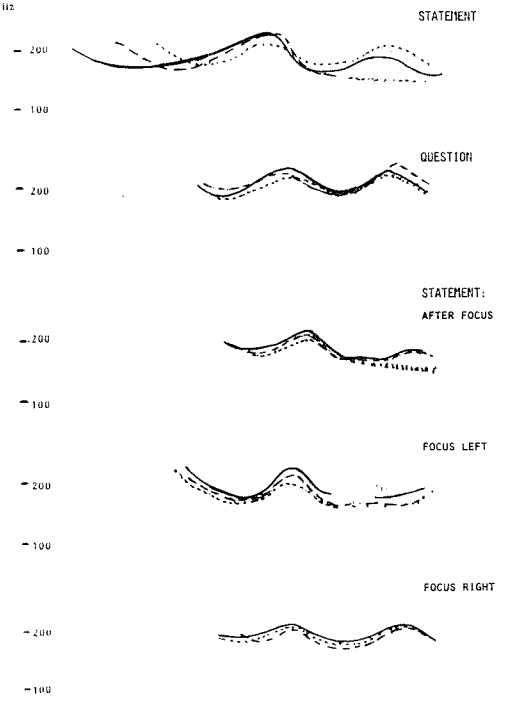


Shi A1: Wāng Yī chōu xiāngyān. 3 utterances in 5 prosodic patterns



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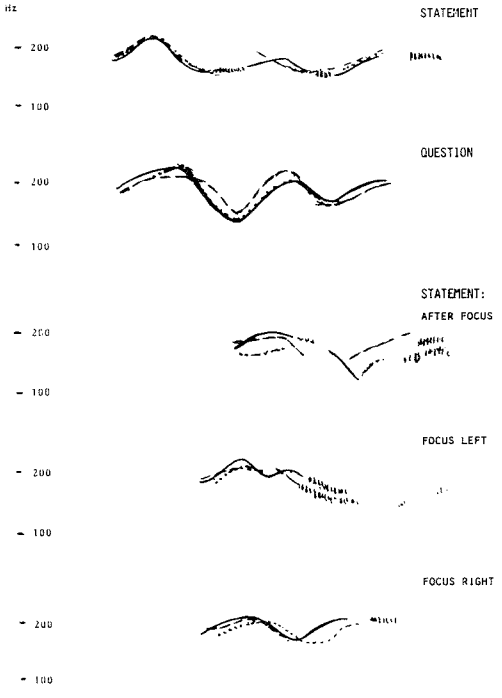

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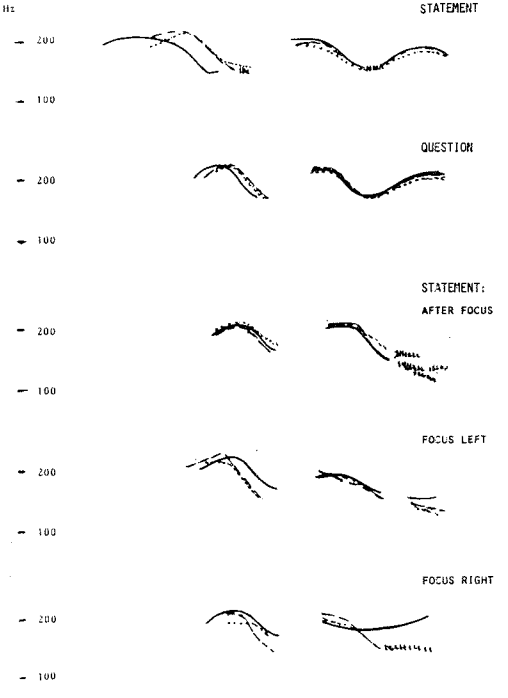
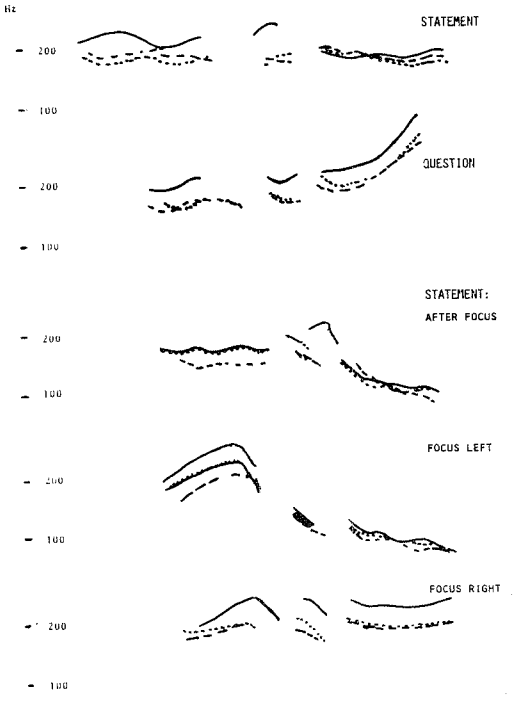


Shi A4: Wāng Lǐ chuān yǔyī. 3 utterances in 5 prosodic patterns



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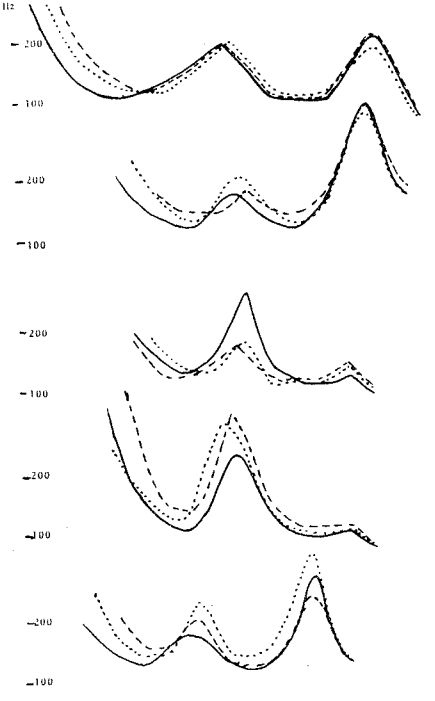
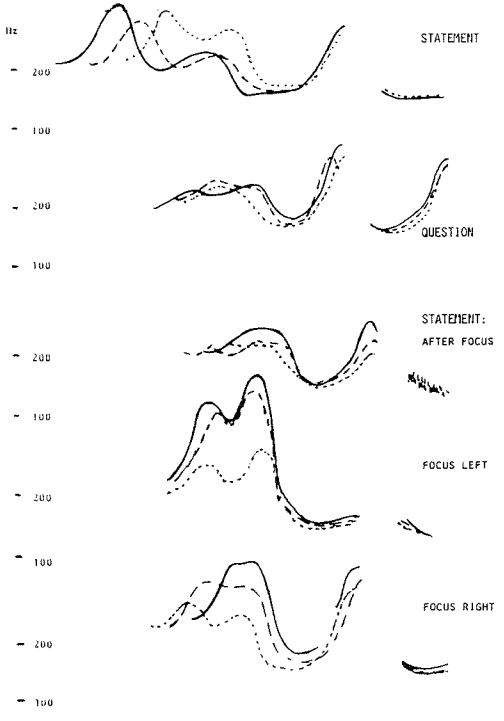


Zhang A2: Sòng Yán mài niúròn. 3 utterances in 5 prosodic patterns



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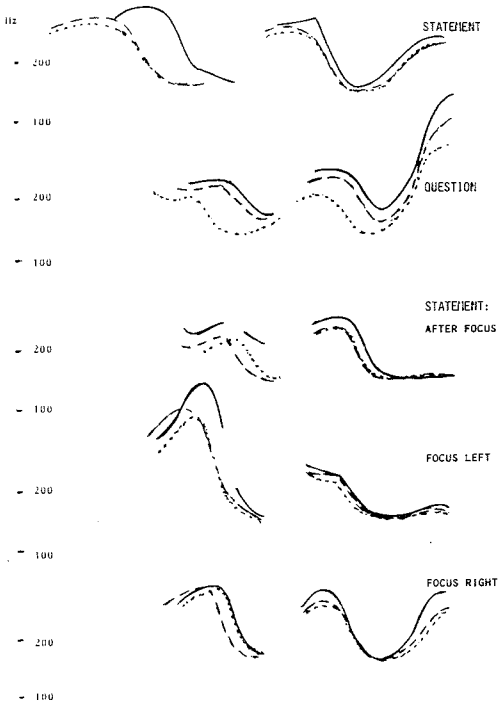
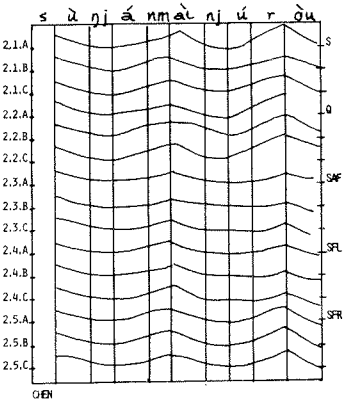
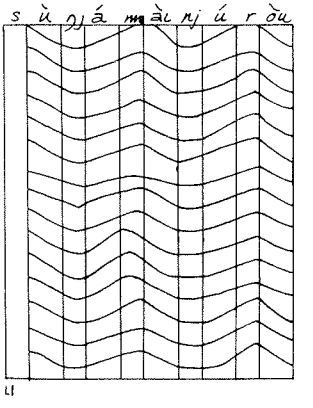
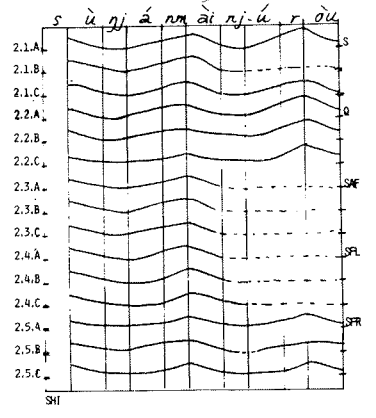
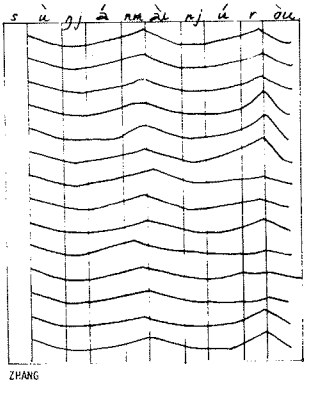


Zhang A4: Wāng Lǐ chuān yǔyī. 3 utterances in 5 prosodic patterns

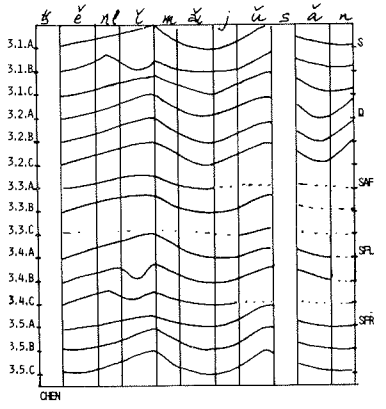


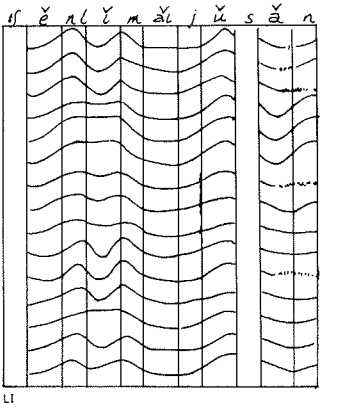


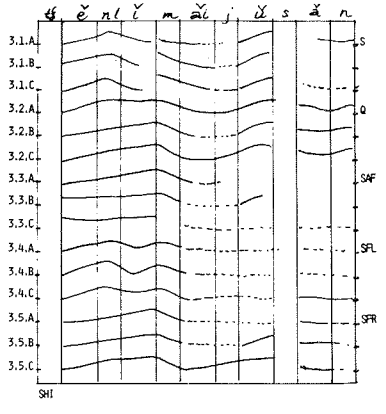


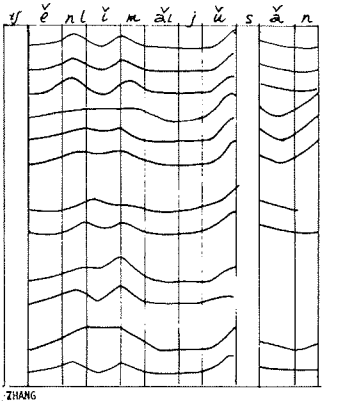


AT2: Sòng Yán mài niúròu. Turning points related to segments. 4 speakers

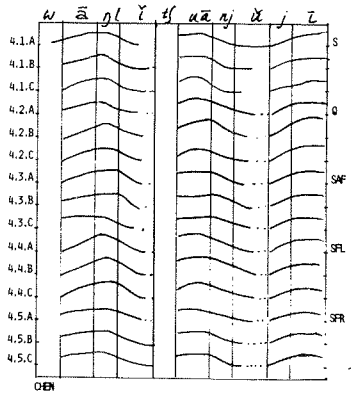


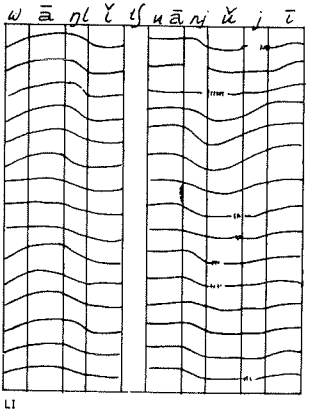


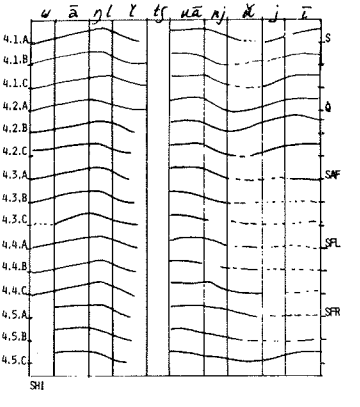


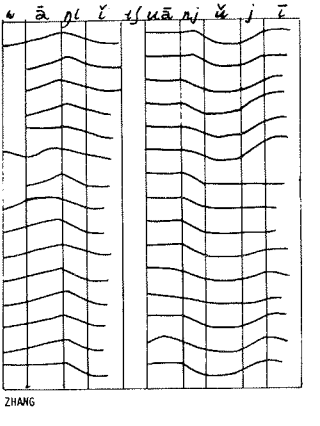


AT3: Chěn Lǐ măi yǔsǎn. Turning points related to segments. 4 speakers









AT4: Wāng Lǐ chuān yǔyī. Turning points related to segments. 4 speakers