The Effects of Intonation Patterns on Lexical Tone Production in Cantonese

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Abstract

This study investigated the influence of intonation patterns on lexical tone identity. The use of intonation in tonal languages poses an interesting research question since changes in the fundamental frequency (F0) of phonation serve two separate functions at the same time: marking of lexical meaning at the syllabic level and signaling intonation patterns at the sentential level. Speech materials of two intonation patterns (question versus statement) with six tonal contrasts placed at different positions (medial and final) were produced by 10 speakers (five males and five females). Dialogue was used for elicitation. Acoustic analysis was performed by measuring the F0 at nine evenly-spaced point from the beginning to the end of the voiced segment on each of the target word embedded. The F0 patterns of each of the six tones were similar for targets in statements and in medial position of questions. In the final position of questions, all six tones were observed to have rising contours. Final tone lowering effect was also noted in statements. The level of the tone at the final position was lowered in statements.

1. Introduction

The use of intonation in a tone language could be potentially confusing as fundamental frequency (F0) serves two similar but separate functions (Vance, 1976). In tone languages like Cantonese, variation in F0 at the syllabic level marks tone while variation of F0 at the sentential level marks intonation. This poses an interesting research question on how the identity of lexical tone is influenced by intonation in speech production. The identification of lexical tones might be affected when the direction of F0 movement in a tone does not coincide with the pitch changes of the intonation, such as when a low falling tone is placed at the final position of a question, which has a rising F0 contour.

Cantonese is a tonal language in which a contrast in tone marks a difference in lexical meaning. Cantonese tones are characterized by tone level (high, mid and low) and tone contour (rising, falling and level) (Fok-Chan, 1974). The six basic tones in Cantonese are high-level (55), high-rising (35), mid-level (33), low-falling (21), low-rising (23) and low-level (22); numerical values in brackets describe the level of the pitch at the beginning and the endpoint of the tone (Chao, 1947). The intonation patterns of Cantonese are similar to those of other world languages (Bauer & Benedict, 1997; Fok-Chan, 1974), and are used for both linguistic and nonlinguistic purposes, like marking grammatical units and expression of emotions. In this study, the intonation patterns of questions and statements were investigated. In Cantonese, statement is characterized by falling intonation pattern while question has a rising intonation pattern (Bauer and Benedict, 1997; Vance, 1976).

Studies have been conducted to investigate how tone and intonation co-exist in a language. Fry (1968) suggested that though tone is not completely subordinate to intonation, tone is likely to be modified by it. Chao (1932) stated that the actual pitch of speech would be the algebraic sum of tone and intonation values. Chang (1958; cited in Vance, 1976) described the effect of intonation on tone in Chengtu as allophonic tone sandhi, i.e., alteration in F0 patterns of tone by the adjacent linguistic environment, like intonation. Vance (1976) commented that if the tone contour and height were studied in enough detail, the changes observed might actually be characterized as paradigmatic sandhi, i.e., exchange of tones in a specific linguistic environment, rather than due to allophonic changes.

Acoustic analysis has been used to study the impact of intonation on tone in different languages. It is generally agreed that intonation changes the F0 pattern of tone, especially at sentence-final position, see, for example, Rumjancev, 1972 (cited in Lyovin, 1978) and Ho, 1977. However, there is no consensus on how intonation influences tone. In studying Chengtu, Chang (1958) concluded that rising intonation would level falling tones at final position, and that falling intonation would level rising tones at final position. Ho (1977) found that the F0 patterns of tone at sentence-final position did not differ much from its isolation forms in Mandarin, but both tone level and contour towards the end of the tone were modified by intonation. On the other hand, Rumjancev (1972; in Lyovin, 1978) claimed that it is the tone level and the steepness of the rise or fall but not the contour which is significantly affected.

There are two studies concerning the interaction between intonation and tone in Cantonese. Fok-Chan (1974) studied tones produced in neutral, anger, empathetic and interrogatory manners and analysed the data using perceptual judgements. She found that tones produced in interrogatory manners were the most difficult to identify among the four manners, particularly for tones 23 and tone 35. Confusion between level tones was also noted. From the acoustic analysis, She found that all the six tones had a rising F0 contour for interrogatory manner and she suggested that a disruption in both tone contour and level was the reason for difficulty in perception. Unfortunately, the stimuli used in these experiments were produced in isolation form, which might differ from tones produced within sentences. Fok-Chan (1974) used a sentence frame in one of her experiments, with the target word embedded as the second-last syllable of the sentence frame. No major difference was found in the F0 patterns of the tones on acoustic analysis. However, as indicated above, the effect of intonation on tone is likely to be most profound on the last syllable.

Vance (1976) studied the effect of position on production of tone by placing the test words in medial, final and

contrastive positions of a declarative sentence. From acoustic analysis, he noticed a sentence-final tone (F0) lowering effect in Cantonese ("downdrift"), but the relative pitch relationships among the six tones were maintained. In an identification task, it was noted that test words at sentence final positions were less accurately identified compared with those from medial and contrastive contexts.

Previous studies showed that in Cantonese the F0 patterns of tones at sentence-final position were affected by intonation. There have been no systematic studies of the effects of intonation patterns on the acoustic characteristics of lexical tones in Cantonese. As suggested by Vance (1976), changes in F0 patterns of tones due to intonation might be characterized as paradigmatic sandhi, if the F0 patterns of tones are studied in greater detail. Therefore, the purpose of this study is to investigate the effect of question and statement intonation patterns on the F0 patterns of Cantonese lexical tones using acoustic analysis.

2. Methods

2.1. Speakers

Ten native Cantonese speakers were recruited as speakers (five males and five females, age 19 to 25 years). They were all undergraduates or graduates from local universities. Cantonese was reported to be the native language for all speakers, while English was the second language. All speakers had no reported history of speech problems and all passed hearing screening (≤ 20 dBHL at 250, 500, 1000, 2000 and 4000 Hz).

2.2. Materials

The stimuli consisted of 72 sentences. Two contexts were designed with the target word in different positions: (a) medial position (/sɛ$_{35}$ kɔ$_{33}$ X tsi$_{22}$ sin$_{55}$/ 'Write the X word first'), and (b) final position (/lei$_{55}$ kɔ$_{33}$ tsi$_{22}$ hɐi$_{22}$ X/ 'This word is X').

Three sets of target words were embedded in the above contexts. Each set of words consists of six words that differ only in tone. The three sets of words were derived from the syllables /si/, /ji/, /jɐu/. All target sentences could be read in two different intonations – question or statement. With two different contexts, eighteen target words and two intonation patterns, there are a total of 72 different stimuli for each speaker.

2.3. Procedures

Data collection was carried out in a sound-attenuated room (IAC sound-proof booth), with a Sony TCD-D3 DAT recorder and a Bruel & Kjaer (4003) low-noise unidirectional microphone. A 10 cm mouth-to-microphone distance was maintained during recordings.

The speech materials used has the "use-mention" problem, in which the embedded target word is mentioned in the sentence rather than used in a natural context. This has the disadvantage of making the target word receiving some kind of prominence in production as the speakers tend to stress on the embedded word (Vance, 1976). However, this method of elicitation would be necessary to control the segmental and tonal properties of adjacent words.

In order to overcome the above disadvantage and to make the speech sample as natural as possible, subject was engaged in a dialogue during data collection with the first author. She initiated the conversation and the subject then answered by using one of the stimuli. The dialogues were presented visually on the screen of a by G4 Apple Macintosh running the HyperCard (Apple^{TM}) programme. The sequence of presentation was randomized across subjects. In a trial, one of the dialogues was presented on the screen and the subject would be engaged in a guided conversation with the experimenter.

After the recording, each token was low-pass filtered at 22kHz and digitized at sampling rate of 44.1kHz and recorded onto the computer as separate file with, using a DigiDesign Audiomedia II DSP card on a Apple PowerMacintosh 7100 computer

2.4. Data Analysis

The F0 of each target word was measured using Praat software (Version 4.0.46) (Boersma & Weenink, 2003). The F0 was measured at nine evenly-spaced time points from the beginning to the end of the voiced segment of the word. An autocorrelation algorithm was used for the estimates. The voiced segment of each word was identified visually from the wide-band spectrogram and waveform plot display. Manual measurements from the amplitude waveform were used when the software produced F0 estimates that were largely different from preceding and following F0 estimates.

3. Results

Out of the nine time points taken, only first, third, fifth, seventh and ninth time points were used for subsequent analysis. The mean F0 value for each speaker at each time point was calculated. Intonation (questions versus statements), position (medial versus final) and gender (male versus female) were calculated separately. A four-way ANOVA was computed separately for each tone, with gender being the between group factor, and intonation, position and time being the within-group factors.

Mean F0 values for questions and statements for male speakers are displayed in Figure 1(a), while the mean F0 vales for questions and statements for female speakers are shown in Figure 1 (b).

The F0 patterns of the six tones are similar for targes in statements and medial position of questions. The F0 patterns of the six tones are consistent with those reported in previous studies (Fok-Chan, 1974; Bauer and Benedict, 1997). The three level tones (tone 55, tone 33 and tone 22) started with a slight increase to the peak followed by slightly falling contours. The distance between tones 33 and 22 was closer than that between tones 55 and 33. Tones 35 and 23 started with a slight dip in F0 followed by increase in F0 until the end of the syllable. Tone 21 started at about the same height as tone 22, and the F0 fell to a level below that of tone 22. For the final position of questions, all the six tones were noted to have rising tone contours for both males and females. The F0 patterns for tone 35, tone 21, tone 23 and tone 22 were overlapping with each other; tones 55 (highest position) and 33 (slightly lower F0 values) were distinct from the rest.

Tones produced within a question have significantly higher F0 compared to tones produced at the same position in a statement. Two sources of differences were identified: changes in tone level and changes in tone contour. For medial position,

it can be noted from Figure 1 (a) and (b) that the F0 patterns of tones of questions and statements appeared to be parallel. The difference in F0 between questions and statements is due to higher F0 level in question. However, for final position, it can be observed that beside the tone level of questions is higher, tone contour is being modified to a rising contour in questions and the differences between the two intonations grows greater towards the end of the tone. Statistically significant differences were noted for all the six tones between the two intonations at least at time point 7 and 9 (Tukey HSD test, $p < 0.01$). For some of the tones, significant differences were noted also at other time point.

For positions, the differences in F0 between the three positions (initial, medial and final) are also of statistical significance. When comparing the tone level across positions in a statement from Figure 1 (a) and (b), it was found that for the same tone, tones at the medial position had higher F0 compared to that of the final position.

4. Discussion

The findings suggested that both tone level and tone contour would be influenced by intonation. Tone contours were modified by intonation only at the sentence final position of questions, while tone contours at the medial positions were maintained. These were not entirely unexpected as question intonation has a rising pitch pattern from the start to the end of sentence. All the six tones at the final position of questions had rising contours, at least at the last two time points, regardless of the original contour. These findings do not support Rumjancev's (1972; in Lyovin, 1978) claim, according to which only tone height and the steepness of the rise and fall will be affected by intonation, but not the tone contour. Previous studies also suggested that the falling pitch pattern of statements would have a similar effect on tone contour, that is, change the tone contour to falling direction or level off the rising contour (Chang, 1958). However, the results of this study show that the tone contours of words at sentence final position of statements have a similar tone contour patterns compared to words in medial position.

There are different theories accounting for the changes in pitch contour for different intonations. Lieberman (1967; cited in Vance, 1976) suggested that statement-final drop is related to reduced subglottal pressure. Ohala (1978) suggested that, in addition to a purely mechanical reason, downdrift in a sentence is used intentionally by speakers to depict linguistic units. However, it is generally agreed that it is the speaker's intention to raise the pitch towards the end to convey the linguistic meaning of the interrogative utterances (Ohala, 1978). It is still unclear why this intentional effort to raise the pitch changes the tone contour of all the six tones at final position, while the falling pitch in statements does not affect the contour of the tones in final position. This difference could be related to the extent of change in pitch of the sentence as the tone increase of question is more drastic than that of the gradual fall in statement.

Differences in tone level were also noted at different positions of a sentence in different intonations. Although the falling pitch contour of statements did not change the contour of tones, downdrift had an impact on the level of the tones. For statements, tones at the medial position had higher F0 than that of the final position. For example tone 22 of the medial position has the same F0 level as tone 33 of final position. This is likely to cause confusion in perception as well if the context was not made clear to the listeners, as perception of tone is based on relative rather than absolute F0 of tone (Fok-Chan, 1974; Vance, 1976).

5. Conclusions

This study showed that both tone level and tone contour will be modified by intonation in a tone language. The tone contour of the final syllable of question was modified by sentence intonation to rising contour regardless of the original contour, while the F0 level of tone was lowered towards the end of statement. Although the acoustic patterns of the influences of intonation on tones have been revealed in the present study, further studies in perception of these tones will be needed to explore how these changes in tones brought by sentence intonation will be understood.

6. References

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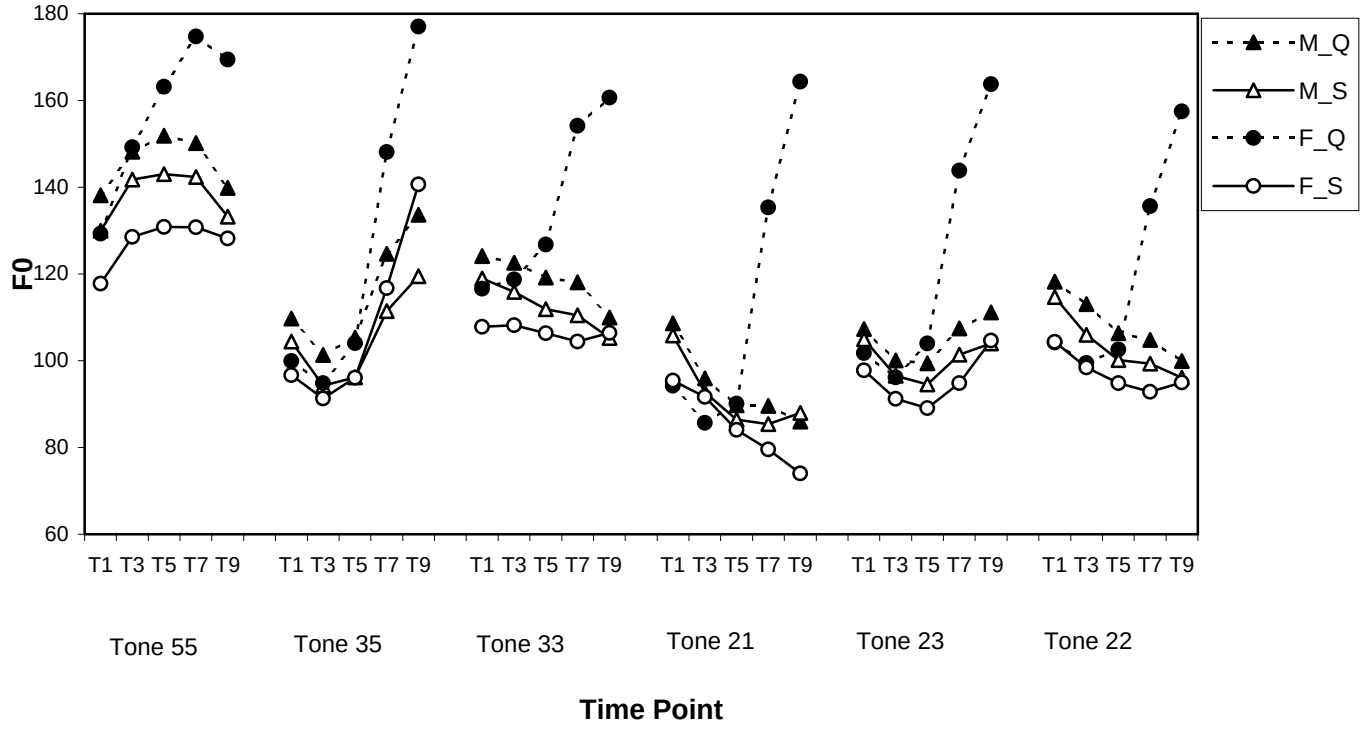
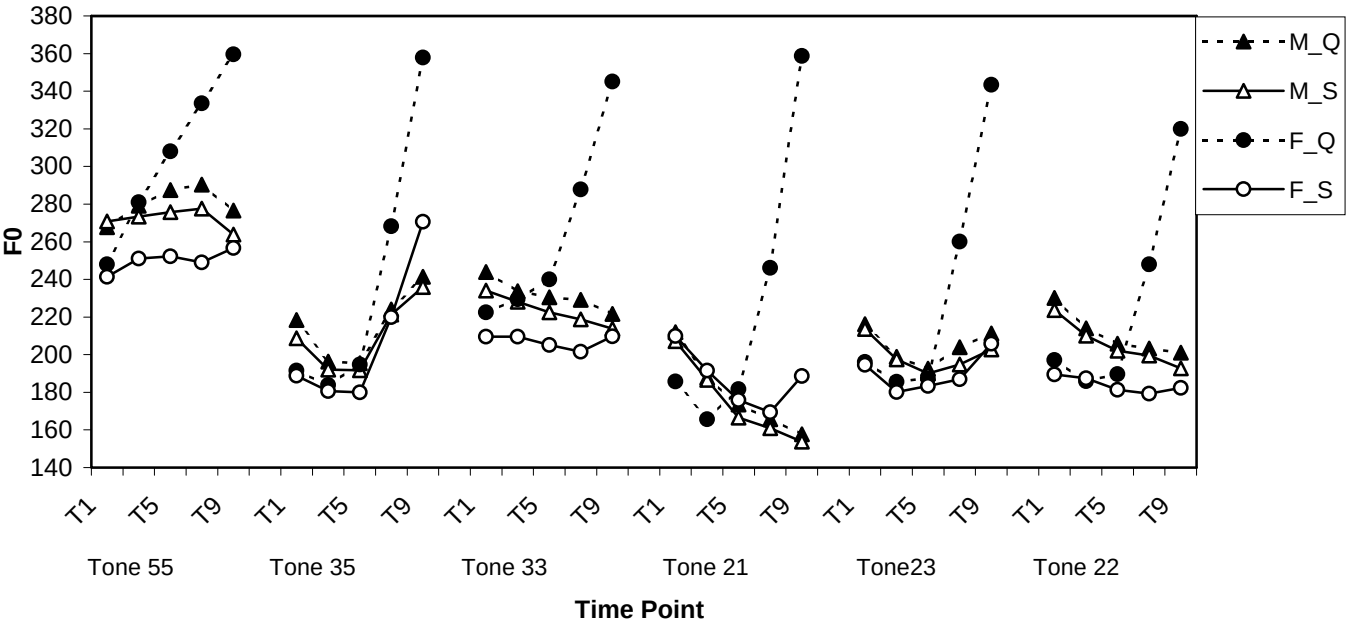


(a)



(b)

Figure 1. Mean F0 values for (a) male speakers and (b) female speakers are displayed horizontally for all the six tones as marked. Open symbols and continuous line represent statement while filled symbols and dotted line represent question. Squares represent mean F0 values for initial position, triangles for medial position and circles for final position.