

# On Phonetic Aspects of Tonal Register Feature

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## ABSTRACT

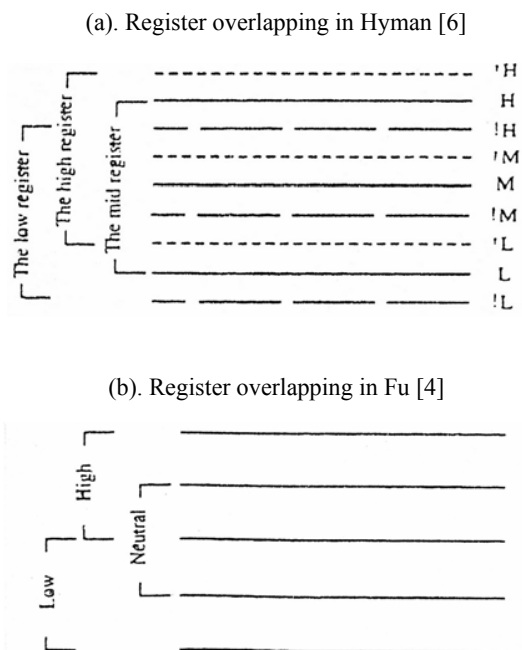
Register, when referring specifically to the subdivision of tone space, has received much attention in phonology. However, questions as to how many registers a tone space should be divided into, and where the boundary between registers should be located, are still debatable. Furthermore, regarding the phonetic implementation of previous phonological claims concerning register feature, it is rarely seen to be addressed in the literature. Data presented in the paper offer a preliminary discussion on phonetic aspects of register feature, primarily in the following aspects: (1) articulatory behavior with respect to register feature; (2) register effect in tonal coarticulation; and (3) register effect in lexical tone perception. These data provide a clear picture of the phonetic behavior of tones with respect to register feature. They further suggest the need for and the possibility of conducting phonological research on a reliable and firm phonetic basis.

## 1. INTRODUCTION

Register has different meanings in tonal phonology. In the present discussion, however, it refers specifically to the subdivision of tone space known as pitch range. When associated with syllable initials, the concept of register corresponds to the traditional Chinese notion of *yin* and *yang* tones. *Yin* tones, occurring in syllables with voiceless initials, often take a high pitch, while *yang* tones, occurring in syllables with voiced initials, often take a low pitch. When the voicing distinction was obliterated through historical change, as evidenced in most Chinese dialects today, the phonetic difference became distinctive in the pitch height under some situations [9]. This indicates a dichotomy of between high and low register. In the literature of phonological research on tone, Yip [11] was the first person to employ register ( $\pm$ upper) as a distinctive feature in her system. Since then, concepts involving tonal features can no longer ignore the historical register split. Bao [1] used a system where the dichotomy of register is represented as  $\pm$ stiff, which is directly relevant to laryngeal features. From these previous tone feature systems, the two-way register split has phonologically received much attention, both in perceptual terms ([upper] and [lower]) and in articulatory terms ([stiff] and [slack]).

There is another proposal of a three-way register split in the phonological literature. The following figure

represents two systems for tripartition of tone space with different manner of overlapping.



**Figure 1:** Tripartition of tone space in different manners of register overlapping, respectively, from Hyman [6] and Fu [4]

The location of the boundary between registers, in either way of split, however, has not been particularly defined or well addressed, either phonologically or phonetically. Moreover, the previous phonological claims about the tonal register feature seem to lack precise and reliable evidence. In contrast to phonological attention to the dichotomy or tripartition of register, investigations, from a phonetic angle, on the phonetic implementation of these features, have been rarely reported. The authors of this paper attempt to provide a preliminary discussion on some phonetic aspects of tonal register features, with the intent to fill this gap.

## 2. ARTICULATORY BEHAVIOR WITH RESPECT TO REGISTER FEATURE

Although the phonetic characteristics of register feature have so far never been well discussed, traces of it can already be seen scattered in several previous phonetic studies on tone [3, 8, 10]. The discussion in this paper is

largely based on the previous phonetic experimentation by one of the authors [7], which is a cross-language examination of tonal behavior of Mandarin, Cantonese and Jinanese. The data from this investigation either provides new findings about articulatory behavior of the register feature, or show the need for further discussion on previous phonological claims regarding register feature.

A register effect on tonal articulation initially appears on the magnitude of tonal variation. When produced in sequences, a tone undergoes variation. Tones at the high register seem to vary frequently in a larger space area than those at the low register, irrespective of tonal contour shape. Tables 1 and 2 show the results of tonal variation of tones in Cantonese and Jinanese, contrasting with the register feature in both anticipatory and carryover coarticulation.

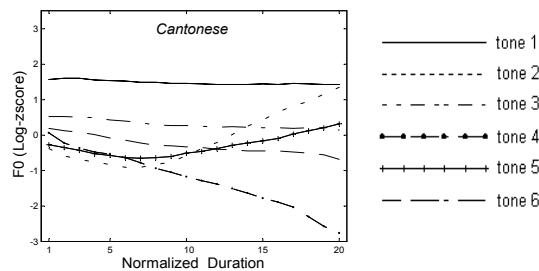
Tone Category	Tone Shape	Anticipatory	Carryover
Tone 1	High-level	0.33	0.28
Tone 3	Mid-level	0.22	0.24
Tone 6	Low-level	0.18	0.24
Tone 2	High-rising	0.36	0.29
Tone 4	Low-rising	0.32	0.22

**Table 1:** Variation range of some Cantonese tones in contexts (unit: Log-zscore)

Tone Category	Tone 2	Tone 4
Tone Shape	High Falling	Low Falling
Anticipatory	0.78	0.23
Carryover	0.48	0.36

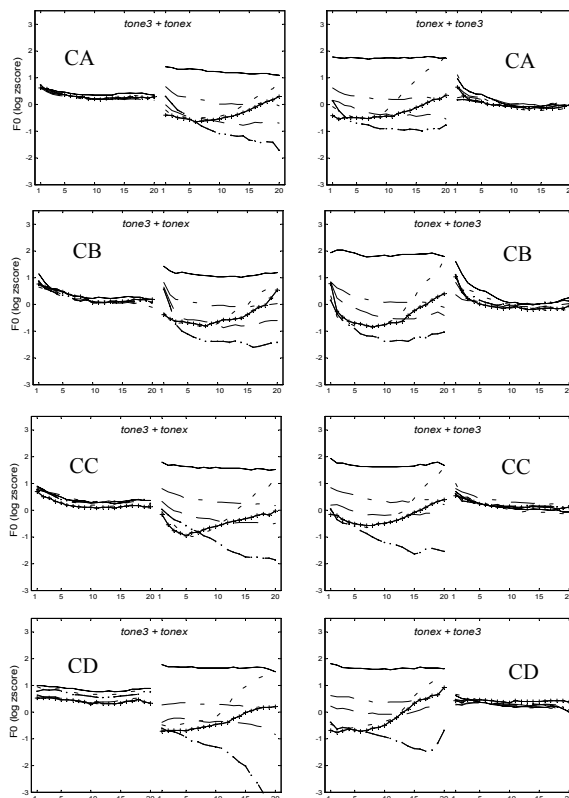
**Table 2:** Variation range of some Jinanese tones in contexts (unit: Log-zscore)

With respect to whether a tone is located at the high or at the low register, it is often hard to determine, except for those confined to the extremely high or the low space level. Articulatorily speaking, however, the boundary between high register and low register can be defined as the most comfortable frequency level for the vocal cords. Empirically speaking, extra effort is needed for producing a tone at either the high or the low pitch level, in contrast at the moderate level. When the mid feature is phonologically exploited, as in the Cantonese tone system, the phonetic moderate frequency level seems to be comparable to the phonological mid feature. This is usually true, though the moderate frequency level seems to vary, depending on different speakers and on various prosodic positions. Moreover, a tone system involving the mid feature seems to take a tripartition of the acoustic tone space. As exemplified by the Cantonese tone system, the high-level tone (tone 1) and the low-falling tone (tone 4) take more space at the high and the low space level, respectively, than the other tones (tones 2, 3, 5 and 6), which are located in the mid space level.



**Figure 2:** Contrasts of six Cantonese tones in the acoustic tonal space (adopted from [7])

In contexts, the tripartition of the tone space seems to agree with the overlapping pattern proposed in Fu [4]. The mid-level tones can take either a high feature or a low feature, depending on the individual physiological constraints and its prosodic positions. As exemplified by the Cantonese mid-level tone (see Figure 3), the phonological mid-level tone is parallel with the phonetic mid range for speakers CA and CD; for speakers CB and CC, however, it shows acoustically a slight falling contour. It can also be observed that the Cantonese mid-level tone is more flattened in pre-position, than in post-position in bitonal sequences.



**Figure 3:** Production of Cantonese mid-level tone (tone 3) under both anticipatory (left graphs) and carry-over (right graphs) effects by four Cantonese speakers.(adopted from [7])

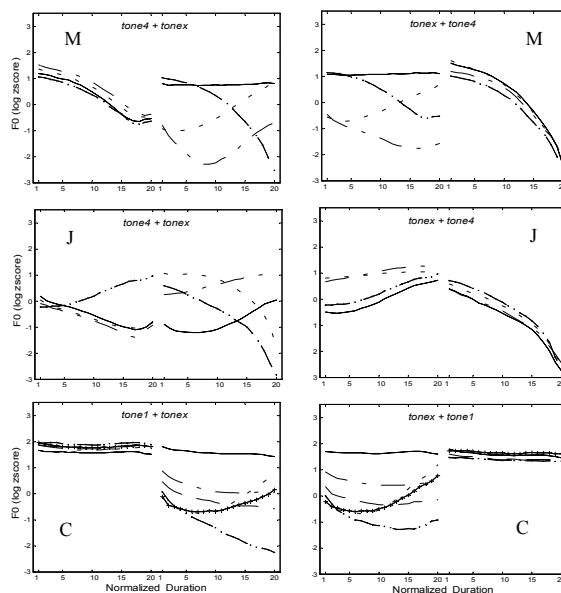
There are other observations, worth noting, concerning the productional behavior on register feature. First, the phonological level tone is implemented often at the high register. Acoustically, it assumes a slight falling contour at the low register. Second, tones with onset at the high register are often produced immediately at a rather high level, while those with onset at the low register often assume a short falling contour at the starting portion. It seems that it is physiologically easier for vocal cords to start vibrating at a high frequency rather than at a low one. By examining the production of low tones in English intonation, Erickson et al. [2] found that extra muscles are used for producing a low fundamental frequency. These observations on production behavior of tones show strong physiological evidence in support of some phonological statements about tone features. For example, it is claimed phonologically, that high feature is more favored than the low one [9]. The present phonetic investigation has provided a physiological basis for this claim.

### 3. REGISTER EFFECT IN TONAL COARTICULATION

In the literature dealing with tonal coarticulation, questions are frequently asked about the nature of tonal coarticulation, and coarticulation effects on tones in different contour shapes. Previous studies reveal that coarticulation would cause both the overall height and the slope change of level and contour tones [5, 10]. As discussed above, if one accepts that there is a register effect in tonal articulation, it seems feasible to offer a new explanation for the coarticulatory effects for level and contour tones. Coarticulatory effects indeed always tend to bring an upward and downward shift on the overall height of particular adjacent tones. The obvious slope change for some contour tones is probably due to the register effect. In other words, tonal targets at the high register vary in a wider space area, whereas those at the low register vary in a narrower space area. This results in the slope change for contour tones.

Moreover, the register feature also can be observed to exert influence on the nature of tonal coarticulation. Xu [10] finds a very neat correspondence between preceding offsets and following onsets in an order of  $F_0$  height in Mandarin bitonal sequences. The highest preceding offset always corresponds to the highest following onset in carryover coarticulation. In anticipatory coarticulation, however, a correspondence in reverse order of  $F_0$  height is found. In other words, the highest preceding offset corresponds to the lowest following onset. These results influenced Xu to conclude that it is the ending and starting pitches, rather than any other part of a tone, that is exerting the carryover or anticipatory influence. However, Xu's conclusion must have been drawn from the use of a voiced nasal as the initial consonant in the testing bisyllabic sequences. The continuity of  $F_0$  movement within a bitonal sequence has limited the onset of the post-tone to start only from where the offset of the pre-tone ends. In the study by one of the authors [7], voiceless

fricatives were used as initial consonants in the bisyllabic sequences. Consequently, instead of a consistent and absolute correspondence between pre-offsets and post-onsets as reported in Xu's study [10], the register feature of a whole tone bearing appears often to play a role in exerting the carryover or anticipatory influence. In the following figureb(4), Mandarin (M) and Jinanese (J) tones 4, and the Cantonese (C) tone 1 illustrate this,

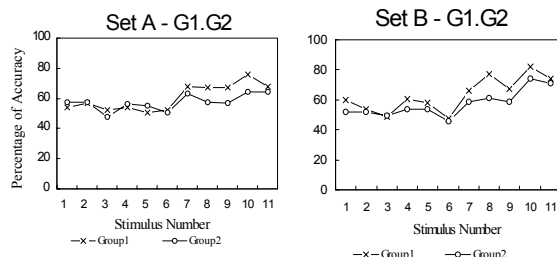


**Figure 4:** Examples showing a register effect in both carryover and anticipatory coarticulation in Mandarin, Cantonese, and Jinanese.

The graphs in Figure 4 show both assimilatory and dissimilatory associations, which exist, respectively, in carryover and anticipatory coarticulation. Under carryover effects (right graphs), a certain tone is often higher in its overall  $F_0$  height when preceded by a tone with a relatively high offset. In contrast, anticipatory effects (left graphs), result in a certain tone that is often higher when followed by a tone with a relatively low onset. These assimilatory or dissimilatory associations between pre-offsets and post-onsets, however, are far from being as well defined as those that were reported by Xu [10]. In Mandarin and Jinanese, the assimilatory or dissimilatory effects often extend throughout the entire duration of particular tones. In Cantonese, however, except for the high-level tone, the assimilatory or dissimilatory effects are only discernible at the starting or the ending points of particular tones. The remaining portion of the contours usually occurs in a random order in terms of  $F_0$  height. This indicates that the register feature of a tone may influence the nature of tonal coarticulation. In many cases, the assimilatory association in carryover coarticulation and the dissimilatory association in anticipatory coarticulation are also sensitive to the register feature of a tone, rather than merely to the absolute onset or offset frequency value of particular tones.

#### 4. REGISTER EFFECT IN LEXICAL TONE PERCEPTION

A register effect is also found in tonal perception behavior during a categorical perception experiment with Mandarin tones 1 and 4 [7]. The following figure shows the perceptual curves based on a discrimination task. In a categorical perception test in the ABX manner, usually, a peak in the discrimination curve is expected to appear at the phonemic boundary. In the two graphs of Figure 5, however, instead of a peak, a sharp rise appears, starting from the identification boundary, i.e. stimulus number 6. This probably occurs in response to a register effect. Due to the abscissae in the two graphs, the larger the number of the stimulus, the higher the fundamental frequency value that it represents. This means that the discrimination accuracy, with stimuli after number 6, is higher than prior ones. This is consistent with stimuli from both Sets A and B, which are different in tonal duration, and with both the subjects of Groups 1 and 2.



**Figure 5** Perceptual results from a discrimination test on Mandarin tone 1 and tone 4 (adopted from [7])

According to the above data, we can observe that when it is articulatorily easier with fundamental frequency values at high register, listeners are also more sensitive with high fundamental frequency values perceptually. Moreover, the perceptual bias across different groups of subjects can only be observed with the stimuli at the high register. The difference in this experiment is that subjects of group 1 had previous linguistic training, while those of group 2 had not. Group 1 subjects performed better only with tones at a high register, compared with those of Group 2.

#### 5. CONCLUSION

Data collected in this paper, either show some new interesting findings with respect to the phonetic behavior about tonal register feature, or show evidence which both counters and supports previous phonological claims. This is, in fact, not only important for phonological theory, but also very helpful for increasing the knowledge on tonal production mechanisms. In addition, the discussion in the study reported here, also shows the need for and the possibility of conducting phonological research on a reliable and firm phonetic basis. Stated differently, it is necessary to study phonological and phonetic research on tone, concurrently. This is obviously significant and helpful for the general linguistic theory.

#### ACKNOWLEDGMENTS

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#### REFERENCE

- [1] Z. M. Bao, *The Structure of Tone*. Oxford University Press, 1999.
- [2] D. M. Erickson, K. Honda, H. Hirai, and M. E. Beckman, "The production of low tones in English intonation", *Journal of Phonetics*, 23, pp. 179-188, 1995.
- [3] C. Y-Y. Fok, *A Perceptual Study of Tones in Cantonese*, Centre of Asian Studies Occasional Papers and Monographs, No.18. Hong Kong: Centre of Asian Studies, University of Hong Kong, 1975.
- [4] B-N. Fu, *A System of Tone Features and Its Implications for the Representation of Tone*, Ph.D dissertation, Simon Fraser University, 1995.
- [5] M. S. Han and K. Kim, "Phonetic variation of Vietnamese tones in disyllabic utterances", *Journal of Phonetics*, 2, pp. 223-232, 1974.
- [6] L. M. Hyman, "Register tones and tonal geometry", In *The Phonology of Tone: the Representation of Tonal Register*, Harry van der Hulst, Keith Snider Ed., Mouton De Gruyter, 1992.
- [7] J. Liu, *Tonal behavior in some tone languages*, Ph.D dissertation, City University of Hong Kong, 2001.
- [8] C-L. Shih, "The phonetics of Chinese tonal system", *Technical memorandum*, AT&T Bell Laboratories, 1986.
- [9] W. S-Y. Wang, "Phonological features of tone", *International Journal of American Linguistics*, 33, pp. 93-105, 1967. Also in *Explorations in Language*. Pyramid Press, Taiwan, 1991.
- [10] Y. Xu, "Contextual tonal variation on Mandarin", *Journal of Phonetics*, 25, pp. 61-83, 1977.
- [11] M. Yip, *The Tonal Phonology of Chinese*, Ph.D. dissertation, MIT, 1980.