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The Role of Metrical Structure in Signaling Focus: An Acoustic Study of Focus and Prosody in Shanghai Chinese

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Abstract

This paper reports the results of an experiment designed to investigate the relation of focus and prosody in Shanghai Chinese. The experiment examined durational adjustment and f0 modification of the target syllables at different levels of prosodic structure under different types of focus. The results confirm that post-focus pitch register lowering in Shanghai Chinese is a phrasal marker and show that the tone sandhi pattern observed in verb phrases is in fact a tonal reduction process due to the lack of focus-induced prominence. The study also finds that F0 range of the tones carried by post-focus constituents do not always compress as reported in the literature, raising doubts on the view that focus is manipulated directly by prosodic cues.

1. Introduction

The relation between focus and its prosodic realization in languages has been approached from different perspectives. There has been a long tradition in studies of intonational languages such as Dutch and English that focus is marked by pitch accent, that is, the on-focus constituents have pitch accents while post-focal constituents are deaccented [1] [2] [3]. However, the findings of recent experimental studies suggest that the nature of focus-induced F0 modification is more gradient and the effect of focus may not be purely structural [4]. An alternative interpretation of the relation of focus and prosody argue that focus is marked prosodically by means of metrical structure [2][5][6][7]. This 'metrical structure' view is also supported by the findings of studies that investigate the expression of focus in tonal languages such as Standard Chinese [8]. In Standard Chinese the speakers cannot delete tones even the tone-carrying constituents are not under focus, which challenge the 'pitch accent' view. Moreover, the F0 adjustments under focus in Standard Chinese are tone-intrinsic in the sense that the measurements of some acoustic correlate such as the F0 range show different patterns depending on the specific tones even under the same condition of focus, raising doubts about one view that focus is manipulated directly from prosodic cues. Following the same spirit, the present study argues for an account for the relation of focus and prosodic realization in Shanghai Chinese (SH) by means of metrical structure.

This study is also motivated by one acoustic study of tone sandhi patterns in SH [9]. SH has five lexical tones (Tone 1: high falling; Tone 2: high rising; Tone 3: low rising; Tone 4: short high1; Tone 5: short low rising). Impressionistic studies have proposed that SH has two types of tone sandhi [10]. One is called the "Left-Dominant" pattern (LDP): within a compound noun, the tone carried by the first syllable determines the f0 contour of the whole domain while the tonal contours of non-initial syllables never surface. The other is commonly referred to the "Right-Dominant" pattern (RDP) and found mostly in verb-object phrases: the tone carried by the initial verb is realized with a level contour while the tone carried by the object is realized with the f0 contour of the underlying tone. [9] argues that LDP is a phonological process changing from one tone category to another, but RDP is phonetic reduction. Such a difference is made due to different types of morphosyntactic structure (compound vs. phrase). The present study aims at providing a different analysis of RDP and argues that RDP is indeed phonetic tonal reduction, but it is due to the lack of focus-induced prominence.

Finally, the present study is motivated by the controversy in the acoustic realization of tones carried out by post-focus constituents in SC. In Chinese languages it has been believed that focus is encoded via pitch range [11][12]. Post-focus pitch compression (often abbreviated as PFC) is considered a strategy speakers use to express focus in a number of studies done by Xu and his colleagues. However, recent research has shown that PFC is found to be absent in Taiwanese and Cantonese [13][14]. This suggests that the occurrence of PFC may not be due to the effect of focus, but may be attributed to the phonological structure of the target language. The present study argues that the presence or absence of PFC result from the interaction of prosodic structure and the language-specific phonological constraints.

[15] has found that post-focus pitch register in SH is not lowered at the level of Prosodic Word, but only at the level of Major Phrase following the terms used in [16] and thus interpreted as a phrasal marker. But in that study, pitch range under different conditions of focus is not examined. The RDP tone sandhi is reported briefly and calls for more investigation. The present study therefore analyzes the same set of data and presents a more detailed investigation. Following the design in [15], boundary strength is manipulated in this study by adjusting the syntax of the utterances to be produced. The central question addressed here is how focus is marked in SH. This study aims to answer the following two specific questions:

(1) When the target constituent is on focus, can PFC be observed on the post-focus constituent? If yes, at which level of established boundaries is PFC found?
(2) In a verb-object phrase, how is the tone carried by the verb realized under different conditions of focus?

2. Methods

2.1. Design and procedure

Three morphosyntactic boundaries are manipulated: within a compound (Boundary 1: B1), between a verb and its direct object (B2) and between the subject and the transitive verb

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(B3). These constructions are commonly recognized to have fundamental syntactic distinctions that are expected to map onto different prosodic domains. At each level, two target syllables S1 and S2 are separately constructed at the pre-boundary position and the post-boundary position. As illustrated in Table 1, at B1, S1 and S2 constitute a compound, which is expected to map onto the level of Prosodic Word (PW) and also the domain where the LDP tone sandhi takes place [16]. At B2, S1 is the ending syllable of the bi-syllabic verb and S2 is the beginning syllable of the bi-syllabic object. The verb-object phrase is the domain where the RDP tonal reduction pattern is observed. At B3, S1 is the ending syllable of the bi-syllabic subject while S2 is the beginning syllable of the bi-syllabic verb. Different focus locations are elicited: corrective focus on constituents containing S1 (CF1, (1) in Table 1), S2 (CF2, (2) in Table 1) or on the final part of the carrier sentences (No-Focus: NF, (3) in Table 1).

Table 1. *A table of utterances with different morphosyntactic boundaries and focus positions (Square brackets indicate B1~B3 boundaries. Target syllables S1 and S2 are bolded and focused syllables are underlined.)*

Boundary	Sentences
B1: Noun + Noun	**(1)** σ σ σ σ $\underline{\boldsymbol{\sigma}}$]#[**σ** σ σ σ σ σ.
B2: Verb + Object	**(2)** σ σ σ σ **σ**]#[$\underline{\boldsymbol{\sigma}\ \sigma}$ σ σ σ σ.
B3: Subject + Verb	**(3)** σ σ σ σ **σ**]#[**σ** σ σ σ $\underline{\sigma\ \sigma}$.

Three tonal combinations are chosen for S1 and S2 (T1T1, T1T3, T3T1) and four pairs of homophones are constructed for each combination. Tone 1 precedes T1T1 while Tone 3 precedes the other two tones. The experiment is carried out on a laptop using E-prime [17]. The data produced by ten native speakers of SH are chosen for the present study. Participants are college students aging from 19 to 24 and they are asked to read the randomized sentences on the screen after they hear the questions played first. To make sure that focus can be elicited naturally, the experiment uses a within-subject and between-block design in which every speaker produces every target sentence only once.

2.2. Acoustic and statistical analyses

In total 1080 sentences were recorded and were manually labeled in Praat [18]. To test if the manipulated boundaries in the design indeed have varying boundary strength, two important acoustic correlates of prosodic boundaries are examined: final Lengthening (the duration of S1) and domain-initial strengthening (the duration of the consonant onset of S2). These two phenomena are used as a methodological tool for confirming that the experimental design has captured differences of strength across the constructed boundary conditions: the higher the prosodic domain, the stronger the effects of the prosodic boundary on the two correlates [19]. Duration of S1 was measured from the ending of the preceding syllable to the offset of F2 in the vowel of S1. Duration of the S2 onsets was taken from the point of the stop release to the voice onset of F2 in the vowel of S2 (after closure time, ACT, [21]).

F0 contours were obtained by taking 20 points (in Hertz) in the rhyme parts of S1and S2 separately and the raw values in Hz were then transformed into semitones by following formula (1) (*ST*: semitone; *f0*: raw f0 value in Hz; *fref*: the reference frequency with 100 Hz for females and 50 Hz for males) and were averaged across speakers. Maximum and minimum f0 were also taken over S1 and S2 separately. Maximum and minimum f0 were also taken over S1 and S2 separately. An index for f0 range in semitone was derived via Formula (2). To compare f0 contours, each speaker's raw f0 data was converted to speaker-specific z-scores by formula (2) (Meanf0: the grand mean f0 of each subject in Hertz; SD: the standard deviation of the overall f0 of the same speaker) (Rose, 1987).

(1) $ST = 12 \text{ x } {}^{2}\log\,(f0\,/fref)$

(2) $F0\ range = 12 \text{ x } {}^{2}\log\,(\text{Maxf0/Minf0})$

(3) $Z = (\text{Raw } f0 - \text{Mean } f0)/\text{SD}(f0)$

Separate repeated-measures ANOVA analyses were performed on the duration of S1, the duration of S2, the Maxf0 and the Minf0, and the f0 range of S1 and S2 separately using the function *ezANOVA()* and *pairwise.t.test()* in R [20]. Boundary (three levels: B1~B3), Focus (three levels: CF1, CF2, NF), Voicing (two levels: voiced, voiceless), Tone (three levels: T1T1, T1T3, T3T1) are independent variables. When examining duration of S1 and S2 onsets, only Boundary and Focus were entered to the model.

3. Results

3.1. Duration

Figure 1-2 illustrates the patterns of durational adjustment of S1 and S2 onsets under Boundary and Focus (Boundary, Focus and Voicing for S2 onsets). The conditions of Focus are represented in Figure 1-2 are C1 (focus on S1), C2 (focus on S2), N (focus on the end of the sentence). The conditions of Boundary are represented as W (B1), P (B2), S (B3). Results of ANOVAs showed that Boundary and Focus both had a significant main effect on duration of S1 [Boundary: F(2, 18) = 49.15, *p<0.001*; Focus: F(2, 18)=69.6, *p<0.001*]. The interaction of the two factors on duration of S1 was also significant [the GG estimate of sphericity was 0.5, F(2, 18) = 13. 26, *p<0.001*]. Duration of S1 was significantly longer in prosodically stronger positions, i.e., longer in the higher domain than in the lower domain, and longer with focus than without focus. However, the lengthening at B1 was unexpectedly larger than at B2, which seems to suggest that duration of S1 does not correlate with varying boundary strength as hypothesized. Post-hoc pairwise comparisons revealed that the magnitude of lengthening of S1 at B1 under CF1 and CF2 was the same [*p=1*]. This indicates that the effect of focus on a compound in SH operates over the whole word instead of its subcomponents.

The onsets of S2 include both voiced and voiceless consonants depending on the tones used due to tonal split [21]. As shown in Figure 2, Focus did not have a main effect on duration of S2 onsets for either voiceless or voiced stops [Focus: F(2,18)=0.97, *p<0.5*]. Boundary and Voicing had a main effect on it separately [Boundary: F(2,18)=0.13, *p<0.001*; Voicing: F(1,9)=0.12, *p<0.01*]. The interaction of these two factors was also significant [Boundary*Focus: F(2, 18) = 9.1, *p<0.01*]. Post-hoc pairwise comparisons showed that duration of voiced stops was significantly longer in higher domains (B2 and B3) than the lower domain B1 and there was no significant difference between B2 and B3 [*p=1*]. Therefore, unaspirated voiceless stops in SH do not exhibit domain-initial lengthening or shortening in terms of VOT, and voiced onset stops increase only from B1 to B2. Focus does not have an effect on either of them.

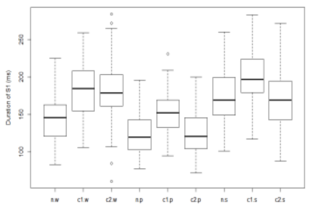

Fig.1. Boxplot of duration of S1 as a function of Boundary and Focus

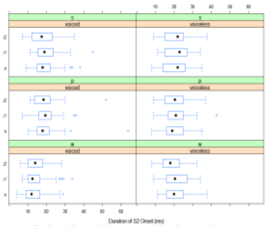

Fig.2. Bwplot of Duration of S2 Onset as a function of Focus, Boundary and Voicing

3.2. Tonal reduction

To study f0 realization of tones carried by S1 at B2 under different focus conditions, three acoustic correlates are examined: Maxf0, Minf0 and F0 range. F0 contours are also plotted for graphic comparisons. Figure 3-4 plots the results of the Maxf0 and the Minf0 of S1 at B2. Figure 5-6 shows the f0 contours of S1 in the three tonal types at B1 and B2. Figure 7 illustrates the f0 range of S1 under different conditions of Focus at B2. Tone is also added into statistical analysis as a factor.

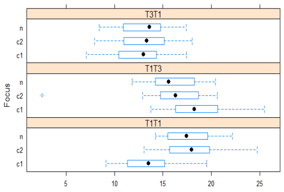

Figure.3. Boxplot of the Minf0 of the tones carried by S1 as a function of Focus

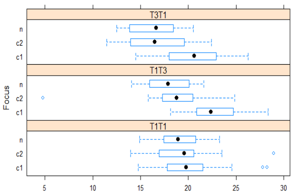

Figure.4. Boxplot of the Maxf0 of the tones carried by S1 as a function of Focus

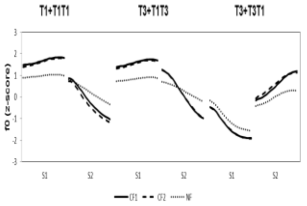

Figure.5 . F0 contours of the three tonal combinations (T1T1 preceded by T1, T1T3 preceded by T3, and T3T1 preceded by T3) uttered in three discourse contexts at B1.

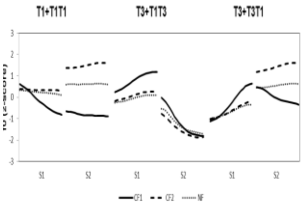

Figure.6. F0 contours of the three tonal combinations (T1T1 preceded by T1, T1T3 preceded by T3, and T3T1 preceded by T3) uttered in three discourse contexts at B2.

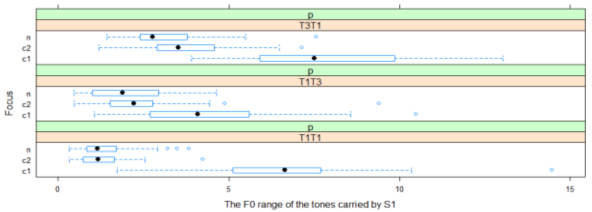

Figure.7. Boxplot of the F0 range of the tones carried by S1 as a function of Focus and Boundary

As shown in Figure 3 and 4, both Focus and Tone had a significant effect on the Minf0 and Maxf0 of S1 and the interaction between the two factors was also significant [Minf0 (Focus: F (2,18) = 4.74, *p<0.001*; Tone: F(2,18) = 85.35, *p<0.05*; Focus*Tone: F(4, 36) = 32.47, *p<0.001*); Maxf0 (Focus: F(2,18) = 43.24, *p<0.001*; Tone: F(2,18) = 26.72, *p<0.001*; Focus*Tone: F(1.8, 16.2) = 12.61, *p<0.001*)]. Pairwise comparisons showed that the Minf0 of Tone 1 in T1T1 was significantly lowered under Focus (CF1) than CF2 and NF [*p<0.001*], but Focus did not have an effect on the Maxf0 of Tone 1[*p=1*]. When Focus was on S2 or at the end of the carrier sentence, neither the Maxf0 nor the Minf0 of S1 changed significantly. This was also confirmed by the results of f0 contours in Figure 5 and f0 range in Figure 6. Figure. 5 illustrated that Tone 1 in T1T1 was realized with a falling contour, which suggests that Tone1 in T1T1 is realized as the underlying Tone 1 under Focus. The f0 range of S1 was the largest under Focus as Focus lowered the Minf0 of S1 and thus resulted in the expanded F0 range. The same pattern was also found in the other two combinations (T1T3 and T3T1). For example, in Tone 1 in T1T3, Focus raised both the Maxf0 and Minf0 of S1 significantly, but the Maxf0 and Minf0 did not differ under the other two Focus conditions. The f0 range of Tone 1 was also the largest under Focus, as shown in Figure. 6.

As mentioned in 2.1, Tone 1, Tone 3 and Tone 3 precede the three tonal types separately. The results showed that acoustic realization of the on-focus carried by S1 is determined by the preceding tones. Compared with the f0 contours at B1 in Figure. 5, all of the tones carried by S1 under Focus at B2 are realized with the f0 contours of the underlying preceding tones: Tone 1 in T1T1 is realized as a falling tone (Tone 1), Tone 1 in T1T3 is realized as a rising tone (Tone 3), and Tone 3 in T3T1 is realized as a rising tone (Tone3), namely the first tone in the bi-syllabic verbs. The interesting finding is that when the tones carried by S1 are not focused (i.e., CF2 or NF), the tones are realized with reduced forms, reminiscent of the description about the level contours in impressionistic studies [10].

3.3. Post-focus f0 range and f0 register

To investigate the distribution of post-focus pitch register lowering and PFC, the three acoustic correlates are also examined for S2: Maxf0, Minf0, and F0 range. Figure.8-10 plots the results. Figure 8-9 illustrates the results of the Maxf0 and the Minf0 of S2 and Figure.10 shows the results of f0 range of S2.

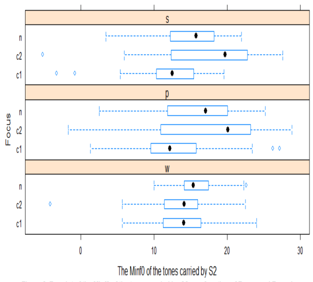

Figure.8. Boxplot of the Minf0 of the tones carried by S2 as a function of Focus and Boundary

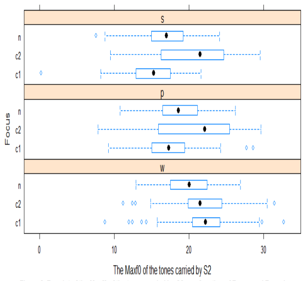

Figure.9. Boxplot of the Maxf0 of the tones carried by S2 as a function of Focus and Boundary

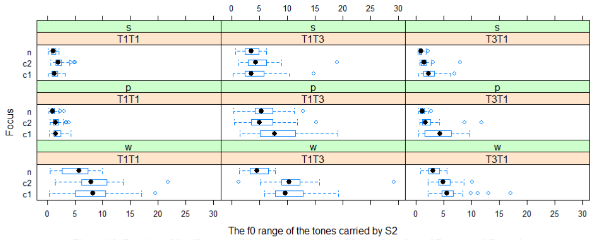

Figure.10. Boxplot of the f0 range of the tones carried by S2 as a function of Focus and Boundary

As illustrated in Figure 8-9, both the main effects of Boundary and Focus on the Maxf0 and Minf0 of S2 and the interaction between two factors were significant [Minf0 (Boundary: F (2, 18) = 16.17, *p<0.001*; Focus: F (2,10) = 40.63, *p<0.001*; Boundary*Focus: F (4,36) = 26.91, *p<0.001*); Maxf0 (Boundary: F(2,18) = 59.67, *p<0.001*; Focus: F(2,18) = 40.51, *p<0.001*; Boundary*Focus: F(4,36) = 33.95, *p<0.001*)]. The f0 realization of the tones carried by S2 when Focus is on S1 is the target condition examined here (CF1), with the baseline condition when Focus is at the end of the carrier sentence (NF). Pairwise comparisons showed that at B1 the f0 register of the tones carried by S2 was not lowered as the Maxf0 was significantly raised [*p<0.001*] while the Minf0 was significantly lowered [*p<0.001*]. More importantly, neither the

Maxf0 nor the Minf0 changed as the position of Focus changed from S1 to S2 [*p=1* for both the Maxf0 and Minf0]. At B2, only the Minf0 of the tones carried by S2 lowered significantly [*p<0.0001*], but the Maxf0 was not raised or lowered [*p=0.13*]. At B3, both the Maxf0 and the Minf0 were lowered significantly [*p<0.0001*]. As illustrated in Figure 6, the Maxf0 of the tones carried by S2 were strongly influenced by the tones carried by S1 at B2, a phenomenon called "peak delay" [22].

To examine post-focus f0 range, one more factor, Tone, was added (three levels: Tone 1 in T1T1, Tone 3 in T1T3, and Tone 1 in T3T1). The results showed that all of the factors, Boundary, Focus and Tone, had a main significant effect separately (Boundary: F(2,18) = 76.54, *p<0.0001*; Focus(2,18) = 42.54, *p<0.0001*; Tone: F(2,18) = 84.15, *p<0.0001*]. The interaction between the three factors was also significant. Further pairwise comparisons showed that the f0 range of all of the tones did not change as Focus shifted from S1 to S2, which confirmed again that the effect of focus on a compound in SH operates over the whole word instead of its subcomponents. At B2 and B3, the interesting finding was that none of the f0 range of the tones under CF1 was compressed compared with that under NF. For example, as shown in Figure 10, at B2, the f0 range of Tone 1 in T3T1 was expanded under CF1 [*p<0.0001*] while the f0 range of Tone 1 in T1T1 and that of Tone 3 in T1T3 did not change even without Focus on either S1 or S2 [*p=0.05* for both of them].

4. Discussion and Conclusion

This study examined durational adjustment of pre-boundary syllables and the consonant onsets of post-boundary syllables as well as the acoustic realization of tones in SH with different types of morphosyntactic structure and focus. The results of duration showed the unexpected lengthening of S1 at B1 that seems to contradict the varying boundary strength. As illustrated in Table 1, S1 and the preceding syllable do not constitute any word, unlike S1 at B2 and B3. Therefore, S1 at B1 becomes the initial syllable of a compound or a PW in [16] and there is a word boundary to the left of S1, which induces unexpected lengthening of S1. At B2 and B3, S1 and the preceding syllable constitute a word and there is no boundary beside S1. However, duration of voiced stops at the post-boundary position shows that the boundary strength increases from B1 to B2. Combining the results from both of the two correlates, the established boundaries in this study indeed have varying boundary strength. One thing to note here is that such statistical significances are not reliable for postulating the existence of different types of domains, but just act as a tool for confirming the experimental design.

In terms of tonal reduction at B2, the results show clearly that the LDP tone sandhi pattern surfaces on the verb with focus and the f0 contours of the verb show reduced patterns when the verb is not on focus or the object is on focus. The f0 contours of the compounds at B1 display the LDP tone sandhi pattern even when focus is not on the compounds. However, it seems not enough to conclude here that such tonal reduction process is not related with morphosyntactic structure, but produced only as a result of the lack of prominence. The f0 contours are averaged across speakers and items and are plotted using the means. It is also possible that reduced tones can be found on the compounds without focus and averaging hides the fact. If such a hypothesis is on the right track, then the first question we need to ask is what factor(s) decide the occurrence of tone sandhi in SH.

Such tonal reduction also raises another question about the function of focus-induced prominence in SH. Focus expands the f0 range of the on-focus tone and lengthens duration of the on-focus syllable, which seems to support the view that focus is manipulated directly from prosodic cues. But the results of the experiment show clearly that PFC is not found on any post-focus tones. More importantly, Figure 6 shows that post-focus tonal realization display different f0 patterns depending on the specific tones. These finding jointly suggest that focus cannot be manipulated simply by some prosodic cue. On the contrary, Focus expands the f0 range of the on-focus tone, resulting in a more clear f0 contour. Without focus, the f0 contour of the tone (such as the tones carried by the verb at B2) is less clear and reduced. Therefore, the function of focus-induced prominence is to increase the contrastiveness of tonal realization, i.e. maximization of the tonal distinction of contrastive tones [23].

The last question is how focus is marked prosodically in SH. Post-focus pitch register is only found at B2 and B3 in SH and becomes a phrasal marker. At B1, the results of the experiment show that the effect of focus on durational adjustment and f0 modification are computed over the whole compound instead of its subcomponents, indicating a PW domain. Therefore, the prosodic structure of SH consists of two prosodic domains: Prosodic Word and Major Phrase in the terms used in [16]. The present study argues that in SH focus induces the highest level of prosodic prominence, which leads to the alignment of the on-focus constituent with the boundary of the highest prosodic domain, that is, Major Phrase, causing the on-focus constituent to have wide pitch range and longer duration and the post-focus constituents to have lowered pitch register or probably compressed pitch range for some tones. But the effect of prominence on the on-focus constituent or the constituent without focus is constrained by the phonological system of the target language. This is why post-focus pitch register lowering is absent in a PW because in SH the minimal focus adjustment domain is a PW and focus does not have an effect on any subcomponent in it.

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