Effect of Boundary Strength on Post-focus-compression (PFC) in Mandarin: Comparing Single with Dual Focus

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ABSTRACT

Post-focus-compression (PFC) was found to be quite stable in single focus sentences but not clear in dual focus sentences. We studied how boundary strength interfered with PFC. Background questions was constructed to elicit focus either on word X (a sentence-medial word), word Y (a sentence-final word), both, or neutral. The boundary after word X was constructed as word, phrase, clause or sentence boundary. The results showed that: (1) All focus words had F0 raising in both single and dual focus conditions; (2) PFC of the single focus was reduced to a great extend when the boundary after the focused word was a sentence boundary. (3) PFC of the first focus in a dual focus sentence was reduced when the boundary was a phrase boundary and above. In general, a strong boundary weakened PFC to a greater degree in the dual focus sentences than that in the single focus sentences.

Keywords: dual focus; post-focus compression; boundary strength

1. INTRODUCTION

Focus is to highlight certain part of a sentence due to semantic and pragmatic reasons [1, 3, 14, 16]. In Mandarin, focus is realized in a tri-zone pattern in intonation, that is, focused words have F0 raising and post-focus words have F0 lowering and compressing (PFC), while pre-focus parts are largely intact [2, 12-14]. PFC of a single focus can still apply across a strong boundary with long silent pauses, which is between two clauses [13].

However, in sentences with two foci, several studies have found that no PFC applied after the first focus [4, 5, 11] in both short and long sentences [9]. Thus, it is not the syllable number or time limit, but some other reasons interfering the F0 lowering of the middle part between the two foci. We suspected that, in those studies, a certain boundary after the first focus probably blocked PFC. Thus the middle part between the two foci was the pre-focus words of the second focus. Because pre-focus F0 was largely intact [2, 12-14], then no lowering or compression of the middle part was found.

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Yuan et al. [17] provided an empirical evidence to our assumption. They studied a complex sentence with the structure of "Subject + Verb + Modifier1 + Object1 + Modifier2 + Object2". The first focus was always the sentence-initial word. The first focus showed PFC when the second focus was in M2 and O2, but no PFC was applied when the second focus was in M1 and O1. Visual observation of their figure revealed that PFC of the first focus hold either within a word, a phrase or even two phrases.

A study on dual focus in German [10] showed that in some cases, speakers inserted a high boundary tone to divide the two foci in two intonational phrases. However, there were more often the cases that two foci co-existed in one intonational phrase, both realizing in falling tones and the F0 between two foci decreased to the lowest level. The length of the subject NP and the VP were factors influencing how two foci were realized. When the NP and VP were both very short, the first focus was realized as a rising tone and forms a hat-pattern.

In this experiment, we studied whether different degree of boundary strength would affect PFC in single and dual focus sentences. Here boundary strength was manipulated by syntax, which could avoid some unnecessary confound or controversial problems, such as the circulation on defining boundaries by acoustics or pitch accent. We considered the most common boundaries, i.e., word (B1), phrase (B2), clause (B3) and sentence (B4) boundaries, which were found to be realized with different prosodic strength [13]. However, we were aware that syntactic boundaries do not always map onto prosodic boundaries. Also, it does not imply that prosodic boundaries are categorical or just with these four levels.

Two research questions and the hypothesis are as below.

(1) How does boundary strength interfere with PFC in single focus sentences?
Based on the findings in [13], we predicted that PFC of a single focus remains stable in B1-B3 boundary conditions, but not in the B4 boundary condition.

(2) How does boundary strength interfere with PFC of the first focus in dual focus sentences (hereof, we will just say first focus)?

It has been found that PFC does not exist after a word boundary [9, 17] or a phrase boundary [17]. It seemed that a strong boundary will block PFC of the first focus.

2. METHODS

2.1. Material

Boundary and focus were controlled as two independent variables in a within-subject experiment. Four boundaries after the critical word X were manipulated by syntactic structure, i.e., word, phrase, clause and sentence boundary (B1-B4), See (1) for an example. Critically, the phonemes of word X and X+1 were the same or similar across the four boundary sentences, and the rest of the words were identical so that the boundary effect was not interfered with tones or segments.

(1) One set of the sentences in the four boundary conditions:

B1 LI3LAN2ZHU3 de0[TIAN1MA2]$_X$[HAI3XING4]$_{X+1}$ gei3[MAO2 ma1ma0]$_Y$le0。
LILANZHU's TIANHAIXING was-given-to Mao Mum ASP.

B2 LI3LAN2ZHU3 de[TIAN1MA2]$_X$ [HAO3XING4]$_{X+1}$gei3[MAO2 ma1ma0]$_Y$le0。
LILANZHU's TIANHAIXING seem-to be-given-to Mao Mum ASP.

B3 LI3LAN2 zhu3 le0[TIAN1MA2]$_X$, [HAO3XING4]$_{X+1}$gei3[MAO2 ma1ma0]$_Y$le0。
LILAN boil ASP TIANMA, seem-to be-given-to Mao Mum ASP.

B4 LI3LAN2 zhu3 le0[TIAN1MA2]$_X$. [HAO3XING4]$_{X+1}$kao3[MAO2 ma1ma0]$_Y$le0。
LILAN boil ASP TIANMA. HAOXIANG ask Mao Mama ASP.

Four focus conditions were elicited by preceding background *wh*-questions, i.e., neutral focus (NF), X focus (XF), Y focus (YF) and dual focus (XYF). Taken the B1 sentence in (1) as an example, the English translation of the four questions are presented in (2).

(2) The background questions of the four focus conditions:

NF: What did you just hear about?
XF: What kind of *HAIXING* of LILANZHU was given to Mao Mum?
YF: Whom was LILANZHU's *Tianma Haixing* given to?
XYF: What kind of *HAIXING* of LILANZHU was given to whom?

In total, there were 64 target sentences for each speaker (4sets ×4boundary×4focus).

2.2. Speakers

Nine speakers (2 male, 7 female) aged 20-25 participated in the experiment. They were all from Minzu University of China and spoke standard Mandarin without any noticeable accent or any hearing or speaking disorders.

2.3. Procedure

The recording was carried out at the Phonetic Laboratory at Minzu University of China. Speakers were asked to read aloud both the questions and target sentences in a natural way. During the recording, the sentences were presented on the computer screen in a random order to each speaker by a customer-developed AudioRec software with a HP computer, and a Rode NT1A microphone connected to a Steinberg external sound card (CL1). To make the reading a little easier, the focus words were highlighted. The speech signals were digitized at 44.1 kHz and saved as separate WAV files. Before the formal experiment, speakers had a short practice to get familiar with the experiment. Each speaker repeated the 64 experimental sentences twice in a different random order. Altogether, 1152 sentences were analysed.

2.4. Acoustic measurement

For all the target sentences, syllable boundaries were labelled and the vocal pulses were checked by author LL with ProsodyPro [15] in Praat. Then, the maximum F0, minimum F0 and duration of each syllable were extracted and saved as separate files automatically by ProsodyPro. The F0 values of Hz were converted to semitone (st), using 1 Hz as the reference for all the speakers according to the formula:

$$F0_{st} = 12 \times log_2(F0_{Hz})$$

3. RESULTS

Due to the space limit, only the results of maximum F0 are reported. The results of word duration are quite consistent that all focused words have duration lengthening in both single and dual focus conditions. Minimum F0 does not show much difference across the focus conditions.

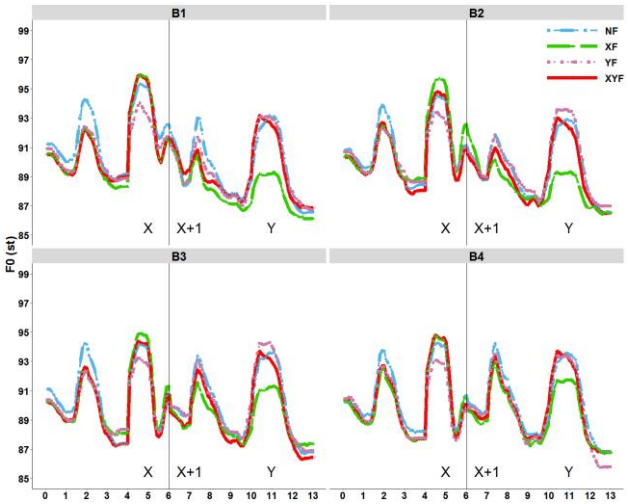
Of the most interest to the current study is whether PFC remains after certain boundaries.

3.1. Intonation contours

Firstly, the intonation contours of the sentences in (1) with four boundary conditions (B1-B4) are presented in Figure1, with four focus conditions overlaid in one figure. Ten time-normalized F0 of each syllable were extracted by ProsodyPro, which averaged the two repetitions of nine speakers. The following statistic tests include all the four sentences.

Firstly, looking at the X focus condition in Fig. 1, we can see that word X shows F0 raising and pitch range expansion as compared to the neutral and Y focus conditions. The F0 in the post-focus words seems to be lowered and compressed. These hold for B1-B4 sentences. As for Y focus condition, the F0 raising in word Y is quite limited in all the sentences.

Figure 1: Intonation contours of sentence 1 under the four focus conditions divided by the four boundary conditions.



Secondly, we look at the dual focus conditions (XYF). We can see that F0 raising in word X is to relatively the same degree as the X focus counterpart, whereas F0 is not raised much in word Y. Looking at word X+1, F0 seems to be lowered in the B1 and B2 sentences, but not in the B3 and B4 sentences. The other three sets of the sentences show a similar trend of the on-focus F0 raising, but varied in the post-focus parts.

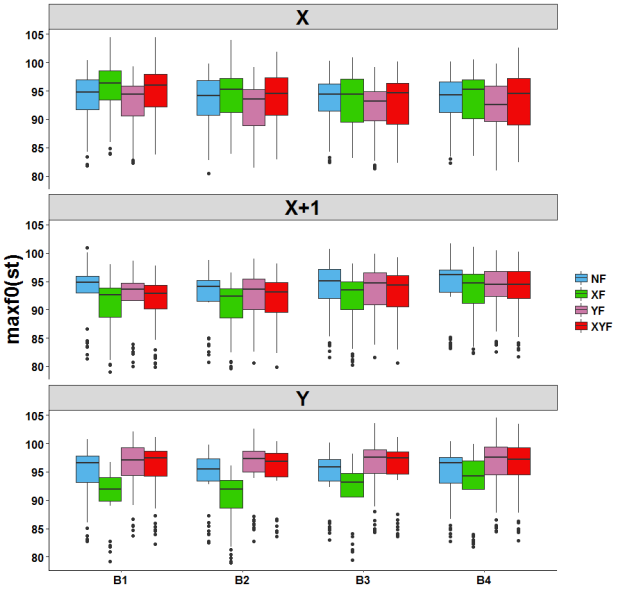
3.2. Maximum F0

The statistic tests aim to answer two questions: (Question 1) Do focus and boundary condition have effects on the maximum F0 in the three target words? (Question 2) In the four boundary conditions, is maximum F0 raised in the on-focus words and lowered in the post-focus words?

The box-plot of the maximum F0 of three target words (X, X+1 and Y) are presented in Figure 2, divided by boundary and focus conditions. In word X, both XF and XYF condition shows higher maximum F0 than the NF and YF condition. In word X+1, maximum F0 is lowered in XF condition than the other three focus conditions in the B1-B3 sentences, but not clear in the B4 sentence. In word Y, maximum F0 is higher in the YF and XYF condition than the NF and XF condition. Word Y also shows the lowest maximum F0 in the XF condition in B1-B3 condition. We can also see that the variation of maximum F0 in word X+1 is greater than in word X and Y. Whether PFC applies in different boundary conditions need to be tested statistically.

Linear mixed models (LMMs) are applied, by using the lmerTest packages [6] in the R environment [7]. Only the *t*-values are reported here due to the space limit. Before modelling the data, for each word, the outliers in maximum F0 beyond two standard deviations are deleted (3% in total).

Figure 2: The boxplot of the maximum F0 (st) of three target words in the four boundary conditions, grouped by focus conditions.



To answer Question 1, for each target word, we apply the LMMs on the maximum F0 with focus and boundary as the fixed factors and with the interaction presumed, while subject and sentence set are two random factors. The results (See Table I) show that both factors have effects in all the three target words, but no interaction is found.

Table I: T values of the LMM analysis in the three target words with focus and boundary as the fixed factors

	X	X+1	Y
Focus	**-5.63**	**-2.47**	**8.35**
Boundary	**-3.83**	**7.40**	**3.17**
Interaction	-0.18	0.32	-0.70

(Note: when t>2, it is considered that the effect holds.)

To answer Question 2, LMMs are applied in each boundary condition separately, with focus as a fixed factor, while speaker and sentence set are random factors. Here, NF is taken as the baseline. The *t*-values of the comparison between the other three focus conditions and NF are reported in Table II. It can be seen *in word X* of all the boundary sentences, that the maximum F0 is significantly higher in the XF and XYF conditions than in the NF condition,

while maximum F0 in the YF condition is lower than in the NF condition. In *word X+1*, both the XF and XYF show lowered maximum F0 than the NF condition, with greater lowering in the XF than the XYF condition. The F0 lowering in the XYF condition is greater in the B1 condition than that in the B2-B4 conditions. Maximum F0 in the YF condition is also lower than in the NF condition. In *word Y*, maximum F0 in the XF condition is lower than NF, while the YF and XYF conditions are with higher maximum F0. Moreover, in the B4 boundary condition, PFC is much smaller in the XF condition than in the other three boundary conditions.

Table II: T values of the LMM analysis in each boundary condition, with focus as a fixed factor and NF as the baseline

B1	**X**	**X+1**	**Y**
XF-NF	5.41	-11.40	-12.94
YF-NF	-4.54	-5.71	3.72
XYF-NF	3.96	-8.94	2.78
B2			
XF-NF	7.29	-7.78	-13.92
YF-NF	-4.41	-1.02	4.99
XYF-NF	3.65	-3.31	3.45
B3			
XF-NF	4.58	-9.47	-9.02
YF-NF	-4.76	-2.40	4.22
XYF-NF	2.12	-4.16	3.18
B4			
XF-NF	2.91	-4.76	-5.37
YF-NF	-4.92	-2.78	4.62
XYF-NF	2.75	-3.15	3.86

In general, the statistic analysis show that focus words are raised and post-focus words are lowered in maximum F0 in both single and dual focus conditions, and in all the boundary conditions. PFC seems to be weakened to a greater degree when the boundary after the focus is stronger. PFC in the single focus sentences is to a larger degree and goes across stronger boundaries than PFC in the dual focus sentences.

4. DISCUSSION AND CONCLUSIONS

In this study, we investigated how prosodic boundary strength interfere with PFC in both single and dual focus sentences of Mandarin Chinese.

The results showed that all focused words had stable F0 raising in both single and dual focus conditions. The F0 raising was greater in non-final focus than that in the final focus.

Unexpectedly, PFC applied in all the boundary sentences both in the single and dual focus condition. Although the first LMM analysis did not find any interaction between focus and boundary in both the focused and post-focus words, the detailed analysis divided by boundary condition revealed that boundary strength affected PFC to a greater degree in the dual focus sentences than in the single focus sentences.

Firstly, we will discuss about the single focus case. In consistent with [13], we also found that PFC in single focus condition can go across a strong boundary with long pauses. The new finding was that PFC still remained even between two separate sentences. However, PFC was greater in the B1-B3 boundary conditions than in the B4 condition. Here, B4 was a boundary between two sentences involving topic change, while B3 was between two clauses. It is possible that the new topic effect in the B4 condition [12] counter balanced PFC.

Then, we will discuss about the dual focus case. When there were two foci in a sentence, the situation was much more complicated, especially in the post-focus part. We found that PFC of the first focus was much greater in the B1 condition than the other three boundary conditions. It implied that PFC hold within a phrase, which was also found in [17]. If the boundary after the first focus is greater than a word boundary, PFC became much weaker. In the previous dual-focus studies in Mandarin [4,5,9], F0 between the two foci were in-between of the neutral and initial focus conditions. Although, F0 lowering in the dual focus condition did not reach statistic significance, such a trend implied that PFC was applied by at least some speakers in some sentences.

Another thing needs to be mentioned is that tone may also interfere with PFC. In this study, word X and X+1 in one set of sentences were all falling tones, and the PFC was greater and more stable than the other sets of sentences.

The following conclusions can be drawn here: (1) All focus words had F0 raising in both single and dual focus conditions; (2) PFC of the single focus was reduced to a great extend when the boundary after the focused word was a sentence boundary. (3) PFC of the first focus in a dual focus sentence was reduced when the boundary was a phrase boundary and above.

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