(End) Truncation of the Thai Contour Tones on Different Durations of TBUs.

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ABSTRACT

Tones may have different shapes when they sit on different durations of tone-bearing units (TBUs). When a tone sits on a shorter TBU, 'end truncation', may occur, where the terminal portions are lost or shifted to the next syllable. This paper focuses on 'end truncation' in the two Thai contour tones: rising-falling (RF) and falling-rising (FR). Shorter and longer contours with end truncation were studied and the locations of the truncated portions were quantified based on the three main landmarks (maxima and minima in the first and second derivatives of a 7th order polynomial fit to the raw pitch track). It was found that each contour tone keeps its prominent information on its particular portion in order to be distinguished from other tones.

1. INTRODUCTION

When tones appear on different tone-bearing units (TBUs), the tone shapes may vary. Roengpitya [6] reported different phonetic tone changes in Thai on various durations of TBUs. One phenomena which occurs with Thai tones is 'end truncation,' also found in Swedish pitch accent [2] and in English pitch accent [4]. In 'end truncation,' the end portions of tones superimposed on shorter TBUs are truncated (lost or shifted to the following syllable), compared to the shapes of these tones on longer TBUs. In this paper, we attempt to quantify the truncated portions of two Thai contours, i.e., the answer the question, 'where, in the time course of the tone, does the truncation occur?'

Thai has short and long vowels and five phonological tones: mid, low, rising-falling (RF), high, and falling-rising (FR) [1]. The syllable structure of Thai can be open (only for long vowels), or closed (with a final voiceless unaspirated stop including glottal stop or a final sonorant). Previous research [6] indicated that 'end truncation' of Thai contours is found when a tone occurs in a syllable with a short vowel followed by a coda stop, compared to the case when the tone appears on a long vowel with the same type of final or in an open syllable. It was further reported that the truncated portions can be found at the beginning of the following tone, if the targeted tone was in connected speech. In this paper, we attempt to quantify how much a contour gets truncated when short, compared to a longer contour, and we will see whether the two contour tones, RF and FR, will have the same or different behavior for this end truncation phenomenon.

Figure 1 shows an example of a rising-falling tone on short and long vowels with a final stop /p/. It was assumed, based on previous evidence, that the tone onset is at the vowel onset and the tone offset is at the vowel offset (if the token has a final stop or is in an open syllable) [6]. This example shows a rising-falling tone on a shorter TBU, with a truncated end (falling) portion, compared to the rising-falling tone on a longer TBU, with the falling end portion.

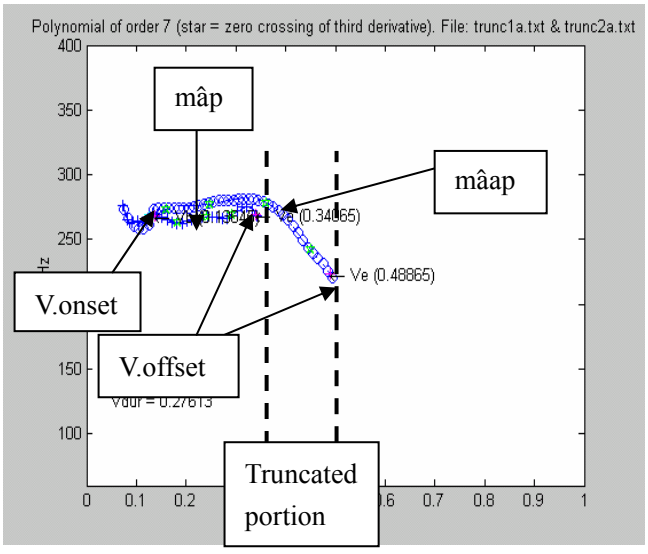

Figure 1. Example showing end truncation of rising-falling tone when placed on a short TBU. The syllables [mâp] 'no meaning' and [mâap] 'in a name mâap-taa-phút' were uttered in isolation by an adult female native-Thai speaker.

2. AN ACOUSTIC STUDY OF TONE END TRUNCATION

2.1. Aim

The aim of this study is to use 'landmarks' in Thai contour tones, as used in a previous study of 'phase realignment' of

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the Thai contour tones [5] to see where (with respect to the landmarks) the end portion of a tone gets truncated, and to find out which information is still preserved for both contour tones.

2.2. Tokens

Twelve meaningful and nonsense words in Thai were chosen for this study. The structure of the targeted tokens had the structure of C1V(:)C2T, where C1 was a nasal /m/, /n/, or /ŋ/; V was a low central vowel /a/; V(:) was a short or a long vowel; C2 was a voiceless unaspirated stop /p/; and T was a rising-falling (RF) or a falling-rising (FR) tone. Each word was read in isolation and in connected speech (in a sentence /phûut kham ____ naan naan/ 'say word ____ long') ten times by a female native-Thai speaker and was digitally recorded at a sample rate of 16 kHz. with 16 bits per sample. There were a total of 240 tokens in this study.

2.3. Processing

The F0 of all the tokens was extracted using the Praat speech analysis program, and then further processed by Matlab routines which gave a 7th order polynomial curve fitted to the F0 contours by the least squares method. A 7th polynomial was chosen as it seemed to give the best fit to the most complex F0 contours.

The contour tones have F0 slopes towards their beginning and end, and a point where there is an inflection (a local maximum or local minimum) in between. The three landmarks for the two contours are defined below.

The rising-falling tone had three main landmarks:

RF1: the point of maximum rate of increase of F0 during the rising part (=negative-going zero crossing of 2nd derivative of F0 (d2)).

RF2: the point where F0 changes direction (=negative-going zero-crossing of 1st derivative of F0 (d1)).

RF3: the point of maximum rate of decrease of F0 during the falling part (=positive-going zero crossing of F0 (d2)).

The falling-rising tone had three main landmarks.

FR1: the point of maximum rate of decrease of F0 during the falling part (=positive-going zero crossing of 2nd derivative of F0 (d2)).

FR2: the point where F0 changes direction (positive-going zero crossing of 1st derivative of F0 (d1)).

FR3: the point of maximum rate of increase of F0 during the rising part (=negative-going zero crossing of F0 (d2)).

An example of these measurements is shown in Figure 2.

All the tokens were measured for the time points of these landmarks from the tone onset to the tone offset, and for the truncated- portion duration.

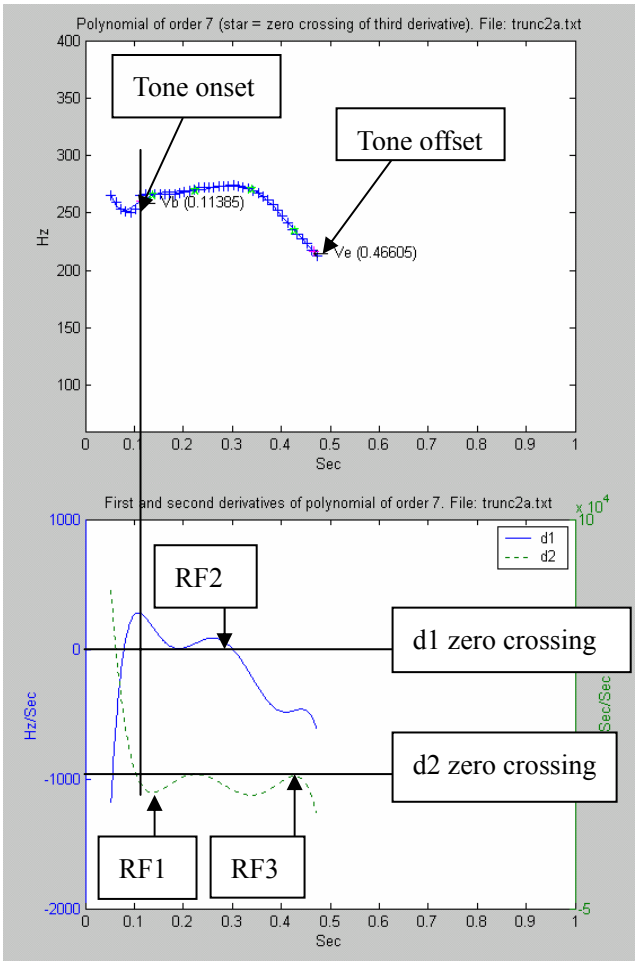

Figure 2. The measurement of the RF tone /mâap/ 'a part of a name mâap-taa-phút.' Top: the raw F0 curve with a 7th order polynomial function fitted to it (not easily visible in this figure). Bottom: the first (d1) and second derivatives (d2) of that fitted curve. See text for details.

3. RESULTS

The results are presented in Figures 3-6. below

Figs. 3-4 were plotted to show the actual durations of the tonal interval between landmarks (in msec.) of tones on shorter TBUs with truncated end portions, compared to the actual tone duration between landmarks of tones on longer TBUs. The four bars in each figure represent the four tonal intervals.

(1) tones on long vowels in isolation [long (alone)],

(2) of tones on short vowels in isolation [short (alone)],

(3) of tones on long vowels in sentence [long (sent.)], and

(4) of tones on short vowels in sentence [short (sent.)].

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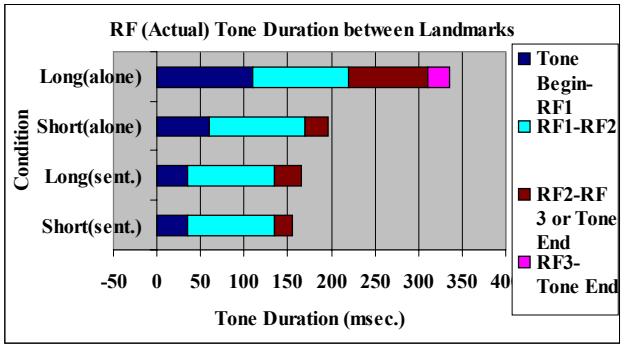

Figure 3. Actual tone duration between landmarks of **rising-falling** tone on long and short vowels in word in isolation (word alone: see the top two bars) and on long and short vowels in connected speech (in a sentence: see the bottom two bars).

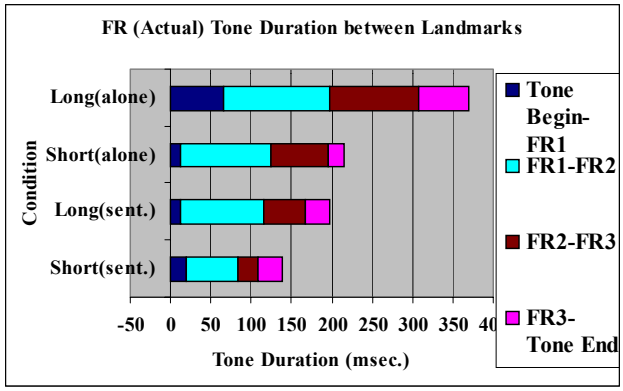

Figure 4. Actual tone duration between landmarks of **falling-rising** tone on long and short vowels in word in isolation (word alone: see the top two bars) and on long and short vowels in connected speech (in a sentence: see the bottom two bars).

Figures. 5-6 below show the tone duration (in %) between landmarks of the two contour tones to see which tone portion is the most prominent for each contour tone.

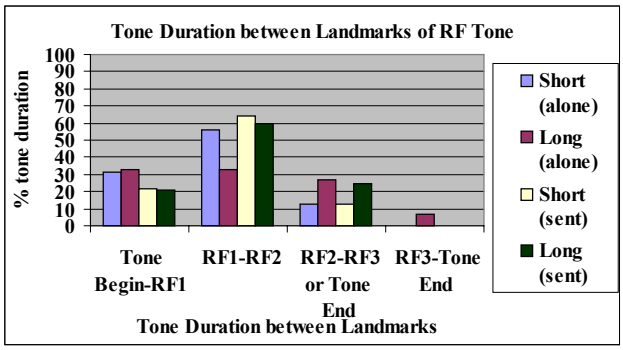

Figure 5. Tone duration (%) between landmarks of **rising-falling** tone.

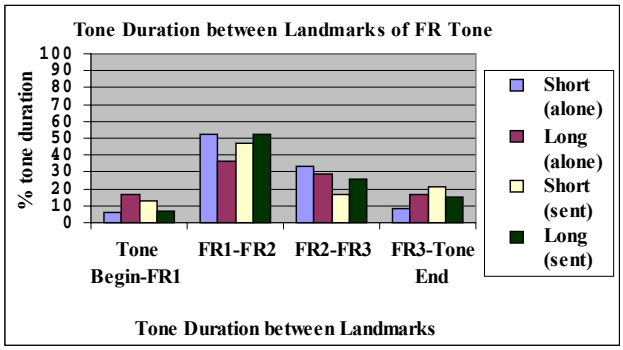

Figure 6. Tone duration (%) between landmarks of **falling-rising** tone.

4. DISCUSSION AND CONCLUSION

Figures 3-4 show the actual tone duration (msec.) between landmarks of the two contour tones: rising-falling and falling-rising. From the two figures, shorter tones (on short vowels or in connected speech) have end truncation, when compared to longer tones. The truncated end portions are from the tone offsets of shorter tones to the tone offsets of longer tones.

Though both rising-falling and falling-rising tones, in Figures.3-4, respectively, show that tones on shorter TBUs have truncated end portions, the two contour tones behave differently. The main differences are that falling-rising tone is longer than rising-falling tone (by 9% in isolation and by 3-8% in sentence), and that falling-rising tone still has all three landmarks; while the third landmark of rising-falling tone is truncated.

Figures. 5-6 present the durations of the four main tonal intervals as delimited by the defined landmarks. The first tonal interval is from tone onset to the first landmark (RF1 or FR1). It can be seen that rising-falling tone has this tonal interval longer than the first interval in the falling-rising tone.

The second tonal interval is from the first landmark (RF1 or FR1) to the second landmark (RF2 or FR2). The result shows that the duration of this interval in the rising-falling is longer than the one in the falling-rising tone.

The third tonal interval is from the second landmark (RF2 or FR2) to the third landmark (RF3 or FR3; if it is not a rising-falling tone on a shorter TBU), or to the tone end (if it is a shorter rising-falling tone). In this case, the tone interval in the falling-rising tone is longer than that of the rising-falling tone. It can be noted that the third landmark (RF3) of rising-falling tone on a shorter TBU is truncated; but the falling-rising tone on a comparably short TBU still preserves the third landmark (FR3).

The fourth tonal interval is from the third landmark (RF3 or FR 3) to the tone end, if it is not a rising-falling tone on a shorter TBU. In this case, the tonal interval in the falling-rising tone is longer than that of the rising-falling tone. Again, the difference is that only falling-rising tone still preserves FR3 in all cases

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It can be concluded that the rising-falling tone gives more importance to the second tonal interval (RF1-RF2), while the falling-rising tone favors the third tonal interval (FR2-FR3) and the fourth tonal interval (FR3-tone end). Moreover, the falling-rising tone still keeps the third landmark (FR3) in all cases, but the third landmark (RF3) of the rising-falling tone on a shorter TBU gets truncated. Why is the third landmark so important to the falling-rising tone, not to the rising-falling tone? One plausible answer can be provided from the previous perceptual study of the phonetic origins of tone sandhi [7] that a long tone when (digitally) truncated (at the end portion) can be perceived as its original tone or as another phonological tone. From the perceptual results, Thai listeners perceived shortened mid tone as mid tone, shortened low tone as low tone, *shortened rising-falling tone as high tone(50-60%),* shortened high tone as mid tone, and *shortened falling-rising tone as low tone (90-100%).*

The results in the perceptual study [7] can be applied to our finding in this paper. In our study for this paper, we found that the rising-falling tone on a shorter TBU has the third landmark truncated; while the falling-rising tone still preserves the third landmark. That means that the falling-rising tone needs to preserve enough information during the rising end portion to be able to differentiate itself from the low tone. It is yet to discover why the rising-falling tone on a shorter TBU perceived as a high tone, though the falling portion and also the third landmark are cut off.

Figure 7 below shows that shorter rising-falling tone lacks the falling portion, and Figure 8 presents shorter falling-rising tone with a part of rising portion (to be different from low tone).

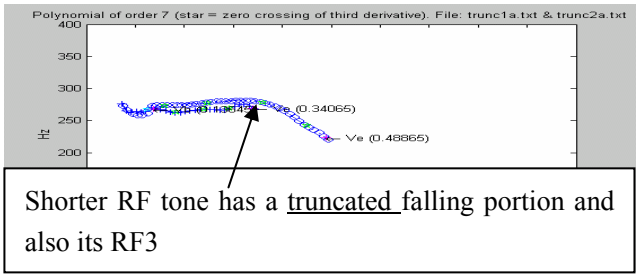

Figure 7. Shorter and longer RF tone [mâp] 'no meaning' and [mâap] 'in a name mâap-taa-phút.'

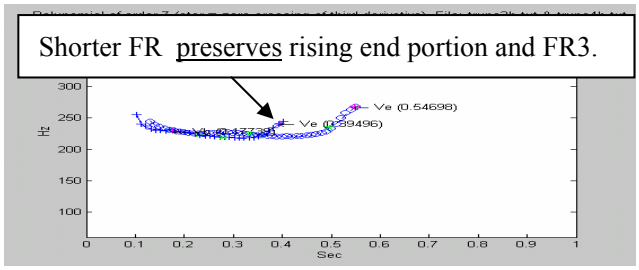

Figure 8. Shorter and long FR tone [măp] 'no meaning' and [măap] 'no meaning.'

In conclusion, it is found in this study that the two contour tones in Thai are different from each other in end truncation phenomena, not only in its combination (rising before falling or falling before rising) but also in how they choose where to keep their prominent part when they are shortened and get end tone portion truncated.

This quantification of tonal truncation of the two contour tones in Thai provides us a better understanding of the behavior of the two contour tones, especially how each contour has its own preferred portion to preserve its crucial information, and makes itself distinctive from another phonological tone. What is found here is also important for speech synthesis and technology, and for the study of contour tones in other languages.

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