

# An Acoustic Study of the Five Thai Tones Produced by ASD and TD Children

*Therdpong Thongseiratch<sup>1</sup>, Jariya Chuthapisith<sup>1</sup>, Rungpat Roengpitya<sup>2</sup>*

<sup>1</sup> Department of Pediatric, Faculty of Medicine Ramathibodi Hospital, <sup>2</sup> Department of English, Faculty of Liberal Arts, Mahidol University, Bangkok, Thailand

ttherd@gmail.com, kositprapa@hotmail.com, rungpat@gmail.com

## Abstract

This paper explores how autism spectrum disorder (ASD) children would acoustically produce the five Standard-Thai tones, as compared to the Thai tones uttered by typically developing (TD) children. In the literature, ASD children had the unusual prosody, i.e. abnormal stress and intonation. 30 ASD and 33 TD children participated in this study. All utterances were recorded in the Praat program, were measured for related acoustic cues, and were statistically analyzed. The acoustic results showed that ASD children produced Thai tones with the higher f<sub>0</sub> values, shorter tonal duration, and less f<sub>0</sub> range than those uttered by TD children.

**Index Terms:** acoustics, autism spectrum disorder, Thai tones.

## 1. Introduction

Autism spectrum disorder (ASD) is a group of neuro-developmental disorders characterized by persistent deficits in social communication and the presence of stereotyped behaviors and restricted interests [1, 2, 6, 16]. One of the fundamental diagnostic domains in ASD is the qualitative impairment in communication. Children with ASD show the delays and deficits in both the expressive and receptive language, with the range from the almost complete absence of the functional communication to the adequate linguistic knowledge, and with a possible lack of the pragmatic skills [7, 10, 11].

Some of the major characteristics of ASD children are abnormal speech patterns. The speech of many ASD children appears abnormal and is described as a monotonic or machine-like speech. This abnormal speech pattern was first described in [15]. In the literature, observational reports presented the differences between the ASD and TD speech, including the monotonic or machine-like intonation, the deficits of using the pitch and of controlling the volume, the deficiencies in the vocal quality, and the use of aberrant stress patterns.

In general, speech is composed of segments and suprasegments or prosody. The latter involves stress, intonation, rhythm, and tones. However, previous studies investigating the prosody of ASD [12, 13, 14] were conducted in non-tonal languages such as English and French [3, 4, 5, 8, 25, 26]. Unlike non-tonal languages in which the pitch of each syllable does not make a semantic difference, tonal languages such as Thai [19, 24] and Chinese [17, 18, 23] have the distinctive phonological pitch on each syllable, which can differentiate the meaning of one word from another.

Thai is a monolexic tonal language with the five lexical tones: mid, low, rising-falling, high, and falling-rising. Mid, low, and high tones are considered as level tones; and rising-falling and falling-rising are contour tones. An example is the minimal pair of two Thai monosyllabic words with the same CVV structure: the word /maa/ with a mid tone meaning 'to come' and the word /ma<sup>v</sup>a/ with a falling-rising tone meaning 'a dog.'

As prosody plays a role in the speech of a language, especially in tonal languages, a question arose of how pitch would be produced if speakers are ASD children, when compared to the tonal production of TD children. Both groups speak Thai, a tonal language, as their first or native language. Would the production of both groups be the same or different? Moreover, what would be the acoustic cues involved in producing the five Thai tones for both ASD and TD groups?

Previous literature [20, 21, 22] revealed the major acoustic and perceptual cues for distinguishing the five Thai tones both in citation form and in connected speech. The acoustic cues include F<sub>0</sub> height, F<sub>0</sub> range, F<sub>0</sub> shapes, and tone-bearing unit (TBU) duration.

In this study, the aim is to explore how ASD children would produce the five lexical Thai tones, as compared to the same tones uttered by TD children with the same age range.

This study is a pioneer study of the acoustic Thai tones produced by ASD children, and the comparative and contrastive results of the ASD and TD children would help gain a better understanding of the ASD speech for further speech and language therapy.

An acoustic study was conducted.

## 2. Methodology

### 2.1. Participants

In this research, two groups of speakers participated in the acoustic study. The two groups were the ASD group and the TD group, respectively. Both groups were in the same age range. The details are, as follows.

In the first group, there were 30 ASD participants, with the age ranging from 6 to 12 years and with the mean age of 8.5 years (SD 1.8). In this group, 28 children (93%) were males, and 2 were females (7%). All were children who attended the developmental and behavioral clinic at a state hospital in Bangkok, Thailand. All of the participants had a clinical diagnosis of ASD based on DSM-IV-TR criteria made by the developmental and behavioral pediatrician.

The second group consisted of 33 TD participants, with the age ranging from 6 to 12 years and with the mean age of 8.5 years (SD 1.3). In this group, 31 children (94%) were males, and 2 were females (6%). All the TD children studied in a normal educational program in primary schools in Bangkok, Thailand. None had any deficits in speaking, nor hearing.

In this study, there were a total of 63 participants (30 ASD children and 33 TD children).

### 2.2. Tokens

In this study, there were a total 12 sets of the stimuli: Sets No.1-11 with 2 meaningful Thai words (each set) and Set No.12 with 3 meaningful Thai words. There were 25 tokens for each speaker to utter in this study.

Each token was uttered once by each speaker. Thus, there were a total of 1,575 utterances (25 tokens x 63 participants).

It can be noted that all the words were familiar to children at a primary level such as animals, relatives, plants, and common objects.

### 2.3. Procedures

In this acoustic study, all participants were asked to see 25 pictures and to utter the word related to each picture once. All 1,575 utterances were recorded with a low-pass-filter at 22 kHz and were digitized at sampling rate of 44.1 kHz in the Praat program in a sound-treated room at a state hospital in Bangkok, Thailand.

The acoustic cues for all utterances such as the F0 values and tonal duration were extracted, measured, and analyzed in the Praat program.

In this study, the tonal duration was measured from the tonal onset at the onset of the tone-bearing unit (TBU) or the beginning of the vowel to the tonal offset at the end of the TBU or where the vowel ends for an open syllable without any final or at the end of the final sonorant for a closed syllable with a final sonorant.

The f0 of each syllable was measured at 11 consecutive sampling points at the 10-Hz steps at the TBU onset (0%), 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and the TBU offset (100%) of the total tonal duration.

The f0 was plotted in an autocorrelation algorithm in the Praat program, with the range of the f0 set optimally based on the manual f0 estimates for each word. The acoustic results of the ASD children and TD children were compared and contrasted.

### 2.4. Statistical analysis

The results were analyzed in the SPSS program. In the statistical analysis, the T-test statistical method was used to compare the mean of the f0 values of the tonal production between the ASD and TD groups. In addition, the Chi-square tests of significance were used for bivariate variables.

## 3. Results

The results are presented in terms of the f0 values and tonal duration (Section 3.1); tonal duration (Section 3.2); and f0 range (Section 3.3), as follows.

### 3.1. F0 values and tonal duration

In this section, the mean f0 values of 11 temporal points of the total tonal duration are presented in Figures 1-5 for the mid, low, rising-falling, high, and falling-rising tones in Thai, respectively.

Each figure illustrates the mean f0 at the tonal onset (0%), 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and the tonal offset (100%) of the total tonal duration of each tone.

In each figure, a solid line presents the mean f0 values for the tone produced by the TD speakers, and the dashed line is for the tone uttered by the ASD speakers.

Figures 1-5 are illustrated below.

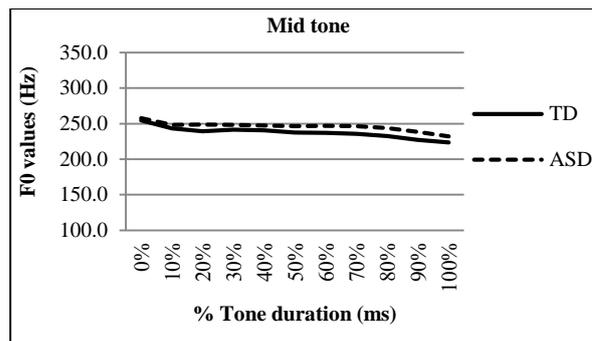


Figure 1: The mean f0 values and tone duration of the mid tone in Thai produced by TD and ASD children.

The results in Figure 1 show that the overall f0 line for the mid tone in Thai produced by the TD children is a bit lower (5-10 Hz) than that of the ASD children.

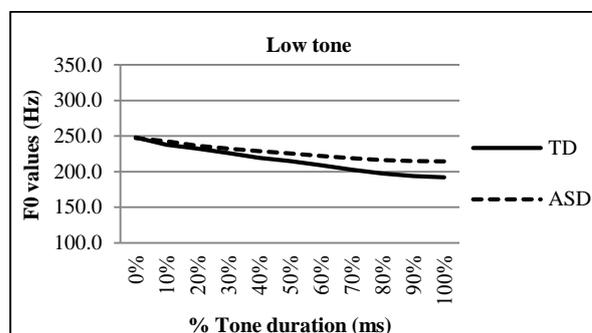


Figure 2: The mean f0 values and tone duration of the low tone in Thai produced by TD (solid) and ASD (dashed) children.

Figure 2 reveals the shared tonal onset of the low tone produced by the TD and ASD children, but the mean f0 line for the low tone gets diverged, starting at about the 30% temporal point of the total tonal duration to the tonal offset. Moreover, the tonal divergence becomes greater for the second half of the low tone of both groups. Overall, the low tone of the TD group is lower than that of the ASD group.

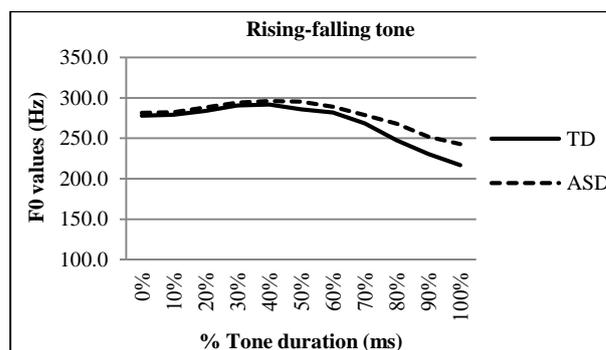


Figure 3: The mean f0 values and tone duration of the rising-falling tone in Thai produced by TD (solid) and ASD (dashed) children.

Figure 3 presents the f0 curve of the Thai rising-falling contour produced by the TD and ASD children. In the figure, the rising-falling tone uttered by the TD children is lower than the one of the ASD children and has a greater f0 range and slope.

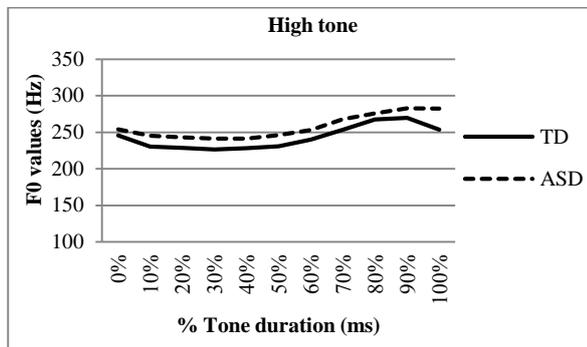


Figure 4: The mean f0 values and tone duration of the high tone in Thai produced by TD (solid) and ASD (dashed) children.

Figure 4 presents that the high tone produced by the TD children is lower than that of the ASD children from the tonal onset to the tonal offset. Furthermore, the TD children produced a high tone with a little drop of the f0 values at the last 10% of the tonal duration, while the ASD children maintained the high f0 level at the end of the high tone.

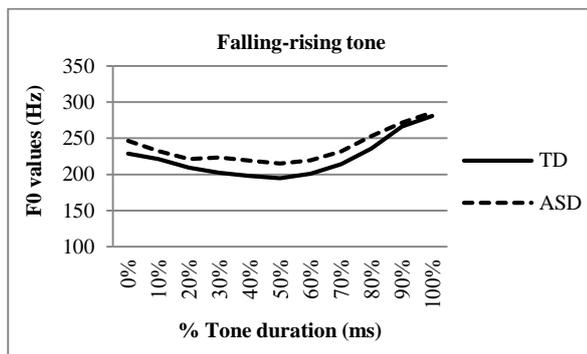


Figure 5: The mean f0 values and tone duration of the falling-rising tone in Thai produced by TD (solid) and ASD (dashed) children.

In Figure 5, the overall f0 values for the falling-rising tone of the TD children are lower than those of the ASD children. It is interesting to see the merged f0 values of the last 15% of the falling-rising tone produced by the TD and ASD children.

From Figures 1-5, it can be seen that, generally, the average F0 values of the five Thai tones were lower (by 10-20 Hz.) when the tones were produced by the TD speakers, when compared to the higher f0 values of the ASD speakers.

### 3.2. Tonal duration

In this section, Figure 6 illustrates the mean tonal duration produced by the TD speakers (a black bar) and the ASD speakers (a gray bar) for all five tones in Thai.

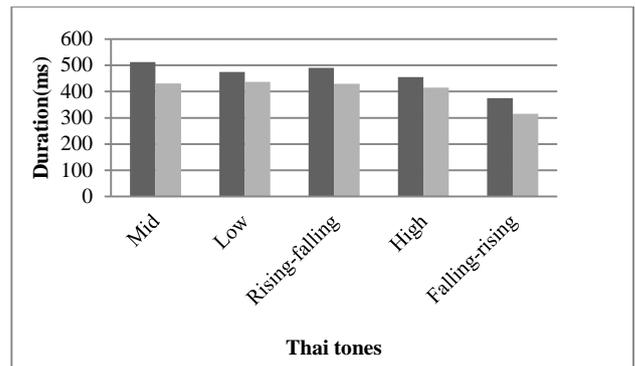


Figure 6: The mean tonal duration of the five Thai tones uttered by TD and ASD children.

In Figure 6, the TD group produced longer tonal duration than did the ASD group. Moreover, a paired-sample two-tailed t-test for the tonal duration difference among the tone pairs of TD and ASD speakers presents the statistical significant differences amongst two groups for the mid, rising-falling, and falling-rising tones.

### 3.3. F0 range

Figure 7 illustrates the mean f0 range produced by the TD speakers (black) and the ASD speakers (gray) of all five Thai tones.

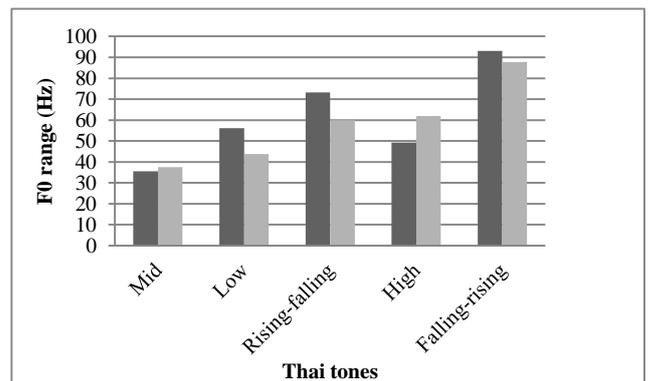


Figure 7: The mean F0 range of the five Thai tones produced by the TD and ASD children.

In Figure 7, the f0 range of the ASD group was about 10-Hz. less than the one of the TD group for the low, rising-falling, and falling-rising tones; but was greater (5-12 Hz.) for the mid and high tones.

## 4. Discussion

In this study, the results can be discussed in terms of the f0 values and shapes, the tonal duration, and the f0 range.

As for the f0 values and shapes, the ones produced by the TD group were lower than those of the ASD group, and the differences in f0 levels of the two groups occurred more on the second portions of the Thai tones. Previous research [25] did not demonstrate whether the f0 values of the ASD group were higher or lower than the ones of the TD group. However, in

terms of the importance of the tonal segments [the first and second halves], in [22], it reported that, when Thai tones were on shorter TBUs, the first portions were kept and the second portions would be truncated or have a higher F0 rate of change. Thus, it has yet to find out whether such differences in the f0 levels would affect the perception of the five Thai tones to both native-Thai ASD and TD listeners, based on [27]. Furthermore, in the literature [26], the f0 difference of approximately 20-30 Hz was likely to affect the noticeable difference in the pitch perception.

In terms of the tonal duration, the results showed that the tonal duration of all five Thai tones of the ASD children was shorter than the one of the TD children, especially the mid, rising-falling, and falling-rising tones. This may be due to the fact that the ASD children who participated in this study still had the symptoms of the hyperactivity and impulsivity, and produced a faster rate of speech, even when uttering a word in citation form.

In terms of the f0 range, it was found that the f0 range of the ASD group was significantly lower than that the TD group for the low, rising-falling, and falling-rising tones; but higher than that of the TD group for the mid and high tones. This was consistent with the previous studies that ASD speakers had a monotonous speaking style. In this study, the monotonous style of the ASD speakers was found to affect the production of the lexical tones, particularly in the contour tone (the rising-falling tone). In producing the rising-falling contour, it requires certain f0 values, shape, and range to be acoustically and perceptually differentiable. Moreover, the results of the study showed that the f0 range of the high tone produced by the ASD group was statistically greater than the one of the TD group. This may be due to the fact that the high tone was a level tone with a slight f0 rise during the second half of the tone. In sum, the Thai tones produced by the ASD group were acoustically different from the TD group.

## 5. Conclusion

This research revealed the different acoustic characteristics of the five Thai tones produced by the TD and ASD children. It is hoped that this research will shed light on other future research in ASD, speech perception, and communication for specific speech therapy.

## 6. References

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