Prosodic Hierarchy and Nasalization in Taiwanese

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ABSTRACT

This study investigated nasalization process from final nasal to initial voiced stops across intermediate phrase boundary, word boundary, tone group boundary, and syllabic boundary in Taiwanese. The degree of nasalization was investigated with nasal airflow data collected from four native Taiwanese speakers producing sentences with final nasal at the end of second syllable and initial voiced stops at the third syllable. Results showed that the peak nasal airflow across intermediate phrase boundary was the earliest in time for all four subjects, and the highest in amplitude for subject HFY and HYH. The amplitude of peak nasal airflow across tone group boundary was stronger than that across syllabic boundary. In fact the nasal peak across tone group boundary was the highest for CYS and LYK. The location of peak nasal airflow across word boundary showed a speaker depend pattern. The influence of tone group boundary to the occurrence of peak nasal airflow is more consistent than word boundary.

1. INTRODUCTION

The influence of phonological structure extends into low-level articulatory activities. The signature of prosodic hierarchy on segmental articulation can be found in lingual gesture [5, 6, 7], labial movement [8,9], glottalization [14], glottal opening [11], and jaw movement [13, 16]. Among these studies on different articulators, the movement of velum was not as well investigated. Nasalization that involves the downward movement of velum within the domain of a word can be found in languages such as English, French, Hindi, Bengali, Sundanese, and Italian [1, 12, 17, 18]. However, the spreading of nasality from nasal to oral segment across word boundary was reported in few languages such as Taiwanese [10].

This study investigate the extent of nasalization from final nasal to initial voiced stops across prosodic boundaries of different strength, e.g. intermediate phrase, word, tone group, and syllabic boundaries, in Taiwanese. Taiwanese is a tone language with seven lexical tones. There are two different surface tonal values for each syllable, i.e. juncture and context tonal values. According to tone sandhi rules, a syllable surfaces with juncture tone at the end of tone group, and with context tone value in initial or medial position of a tone group. The tonal value is determined by tone sandhi rule that has a recursive nature, that is [55]and [51] -> [33] -> [31] -> [53] -> [55]. For example the syllable /kun 55/ 'king' which carries tone [55] at juncture position would carries tone [33] at context position, while the syllable /kun 33/ 'near' that carries tone [33] in juncture position turns to tone [31] in context position. Due to the recursive nature of tone sandhi rule, the surface form [kun 33] means 'near' if it is at the juncture position, but surface form [kun 33] means 'king' in context position. To determine the context and juncture tonal values, tone sandhi group boundary must be determined first. Therefore the location of tone group boundary is a very important cue during lexical processing in Taiwanese. Tone sandhi group boundary is an important and unique prosodic boundary in Taiwanese. This study investigated the ranking of tone group boundary in prosodic hierarchy by studying the degree of nasalization across boundaries of different strengths.

2. METHODS

Four male native Taiwanese speakers, i.e. CYS, HFY, HYH, and LYK, participated in the experiments. They were students at the National Chiao Tung University at the time of data collection.

Corpus discussed here was part of the larger database consisted of sentences with vowel and final nasal positioned at the end of second syllable followed by initial voiced stops, and voiceless stops at the beginning of third syllable across prosodic boundaries. Example of corpus was shown in Table 1. According to Ting [2], alveolar lateral, /l/, has a stop-like quality, therefore it is included as one of voiced stops. Data discussed here included final vowels and final nasals, /m, n, ŋ/, in the second syllable and initial voiced stops, /b, l, ɡ/, at the third syllable across intermediate phrase, tone group, word, and syllabic boundaries. The intermediate phrase boundary was placed at the end of a vocative phrase, while tone group boundary was placed within a compound word.

Recording of nasal airflow was conducted with MS100-A2 airflow system manufactured by Glottal Enterprise, and a nasal airflow mask, model P0789, by Hans Rudolph Inc. A TEV microphone was placed 30 cm in front of the subject's mouth. Both nasal airflow and acoustical data were picked up simultaneously and recorded onto a PC.

Recording was conducted at a sound treated room in the phonetic lab at Naitonal Chiao Tung University. To control the speed at which subject produce each sentence, A metronome was used to provide reference speed. Subject wore headphone to hear the beat, and were instructed to produce the first two syllables following the beats. Two speeds were used, i.e. 144 and 200 beats per minute.

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During the recording subjects produced randomized sentences from a list. After production of one sentence subject paused for a few seconds to allow an experimenter to save the acoustical and airflow data with CspeechSP software. Both acoustical and airflow data were then transformed into .wav format and then analyzed with multi-speech by Kay Elemetrics.

Spectrographs were generated from the acoustical data and then aligned with the trace of nasal airflow in time. By using spectrographic cues, the time at the offset of second vowel and the onset of third vowel were determined. The amplitude of nasal airflow at the offset of the second vowel, and onset of the third vowel was then taken, along with the peak and valley of nasal airflow in between the two vowels. 144 sentences (4final segments * 3 initial segments * 4 prosodic boundaries * 3 repetitions) were analyzed for each subject.

3. RESULTS

As shown in the upper panel of figure 1, there were two nasal peaks and a valley between the offset of the second vowel and onset of third vowel, that is during final nasal and initial voiced stop across intermediate phrase boundary. The first nasal peak was reached during the production of final nasal, then the subject inhaled resulting in the valley observed in the trace of nasal airflow. After the valley, the nasal airflow peaked again during the production of initial voiced stop following intermediate phrase boundary. In the lower panel of figure 1, the nasal airflow peaked once and remained exhaling through the final nasal and initial voiced stop. No inhaling of nasal airflow was observed during final nasal and initial voiced stop.

Figure 2 showed the duration of final nasal and initial voiced stop across intermediate phrase, word, tone group, and syllabic boundary. For all subjects, the duration of final nasal and initial voiced stop was the longest across intermediate phrase boundary, and the shortest across syllabic boundary. The duration of final nasal and initial voiced stop across word and tone group boundary was indistinctive, and was shorter than the duration across intermediate phrase boundary, while longer than the duration across syllabic.

To further distinguish between the effect of word and tone group boundaries on the production of nasal airflow, the location and amplitude of first nasal peak during the production of final nasal and initial voiced stop was analyzed, as shown in figure3. The pattern of distribution of nasal peak can be divided into two categories. For CYS and LYK, the distinction between nasal peaks across intermediate, word and syllabic boundaries was mainly in the time domain. However, for subject HFY and HYH, the distinction between nasal peak of tone group, word and syllabic boundary was mainly in the amplitude domain.

Generally speaking, for CYS, LYK, HYH and HFY, the latency of peak nasal airflow across intermediate phrase boundary is the earliest compared with the nasal peak across tone group, word, and syllabic boundaries. Although for HYH and HFY, the amplitude of nasal peak across intermediate phrase boundary was also the highest, however, the amplitude of nasal airflow across intermediate phrase boundary was not the highest for CYS and LYK. Another similarity observed across four speakers was the distribution of peak nasal airflow across tone group and syllabic boundary. For all four subjects, the amplitude of nasal airflow across tone group was higher than that across syllabic boundary. Furthermore, the amplitude of peak nasal airflow was the highest for subject CYS and LYK.

The distribution of peak nasal airflow across word boundary with respect to tone group and syllabic boundary showed speaker dependent patterns. For CYS and LYK, the nasal peak across word boundary was not distinctive from that across syllabic boundary in terms of amplitude domain. However as far as the time domain was concerned, the location of averaged nasal peak across word boundary was around the averaged nasal peak across syllabic boundary. On the other hand, for HFY and HYH, the location of averaged nasal peak across word boundary was not distinctive from those across syllabic and word boundaries, in terms of time domain. Furthermore, in terms of amplitude domain, the location of nasal peak across word boundary was either the lowest in amplitude, as in HFY's data, or higher than those across tone group and syllabic boundaries, as in HYH's data. No clear pattern could be drawn on the location of nasal peak across word boundary with respect to peak latency across tone group and syllabic boundaries.

4. DISCUSSIONS

The influence of hierarchical boundaries extended into low level articulatory activities, such as the lowering of velum, which is involved in the production of nasal and nasalization of oral segments. Through the investigation of amplitude and temporal factors of nasal trace across intermediate phrase, word, syllabic and tone group boundaries in Taiwanese, the study demonstrated how prosodic factor, i.e. edge effect, influences articulation.

Results of this study showed that the duration of nasal trace was the longest across intermediate phrase boundary, shortest across syllabic boundary, with the duration across word and tone group boundary was in between and indistinctive.

The nasal peak across intermediate phrase boundary was the earliest across all subjects. The amplitude of nasal peak across tone group boundary was higher than that across syllabic boundary. No conclusion can be drawn on the location of nasal peak across word boundary, for it shifted in time and amplitude domains and showed speaker dependent pattern.

As far as time and amplitude of nasal peak were concerned, tone group boundary was a more robust prosodic boundary than word boundary in Taiwanese. Unlike the traditional claims that classified tone sandhi group not as a prosodic unit [4, 3, 15], data here strongly suggested tone sadhi group boundary as a prosodic unit in Taiwanese. Due to the vital role that tone sandhi group boundary plays in determination of context and juncture tonal values of each syllable, which in turns influence semantic and lexical processing in Taiwanese, nasality demonstrates tone group boundary as a robust prosodic cue. Further studies on the duration of negative nasality are necessary to explore the status of word boundary in prosodic hierarchy.

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Table 1. Example of Corpus.

Boundary	Example
Intermediate Phrase	/a la**m** **l**ai k^{h}i tŋ la/ ‘A-lam, let’ go home.’
Word	/ si ki**n** **l**ai a siuŋ tse / ‘Four pounds of pear are too much.’
Tone Group But NOT word	/tai la**m** **b**a so mi diam/ /Tainan ground pork noodle store/
Syllable	/be **a** **b**a mi lai a / ‘(I) bought duck meat noodle soup.’

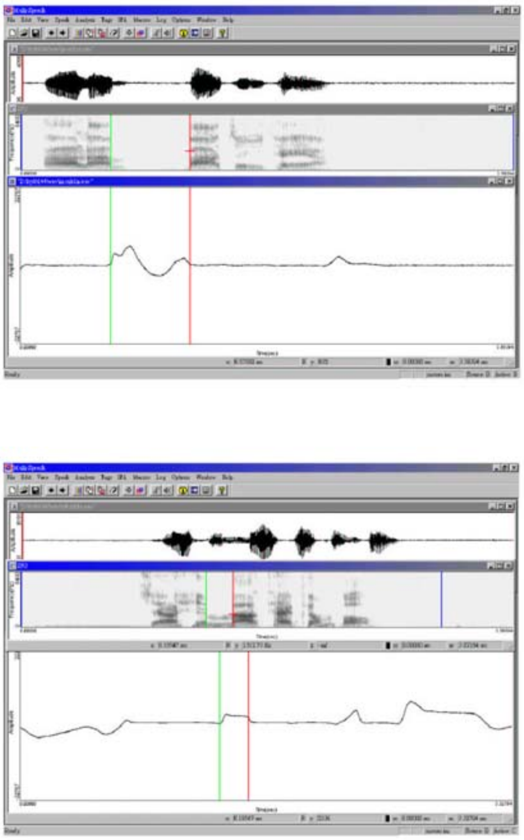

Figure 1. Waveform, spectrogram and trace of nasal airflow across intermediate phrase boundary (upper panel) and word boundary (lower panel).

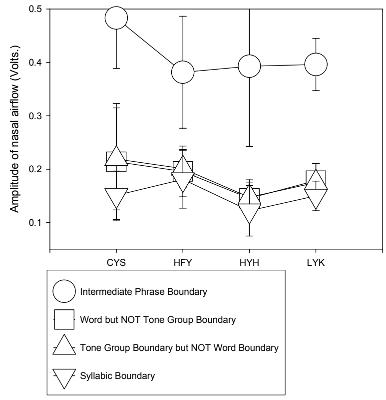

Figure 2. Duration of final nasal and initial voiced stops across prosodic boundaries of various strength produced by subjects CYS, HFY, HYH and LYK.

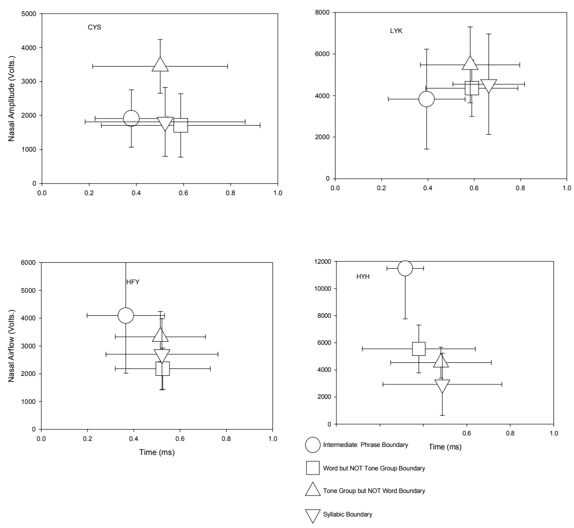

Figure 3. Time and amplitude of peak nasal airflow between onset of final nasal and offset of initial voiced stop across prosodic boundaries of different strength.