Prosodic Hierarchy and Nasalization in Taiwanese

Ho-hsien Pan

Department of Foreign Languages and Literatures
National Chiao Tung University
hhpan@cc.nctu.edu.tw

Abstract

In Taiwanese initial stop was nasalized when preceded by final nasal. This study investigated how this nasalization process was influenced by prosodic boundaries of various strength, such as syllable, word, tone group, and intonation. Nasal airflow data and acoustical signals were collected from four male native Taiwanese speakers reading sentence and phrase that were five syllables long. Final nasal was located at the end of the second syllable, while initial nasal was at the beginning of the third syllable. The trace of nasal airflow between the offset of the second vowel and the onset of the third vowel was analyzed by taking both time and amplitude at the peaks and valley on the trace of nasal airflow. Results showed that the difference between the amplitude of the first peak and the valley of the nasal airflow was the greatest when the nasalization took place across intonation boundary. The difference in nasal airflow between first peak and valley across word boundary was lower than that across intonation boundary but higher than that across word boundary. The nasal airflow difference was the smallest when nasalization took place across syllabic boundary.

1. Introduction

The influence of phonological structure can be found to extend into low level articulatory activities. The signature of prosodic hierarchy on segmental articulation was observed in lingual gesture (Fougeron & Keating, 1996; 1997; Byrd, 1996), labial movement (Byrd & Saltzman, 1998; Byrd et. al., 2000), glottalization (Dilley, Shattuck-Hufnagel, & Ostendorf, 1996), glottal opening (Pierrehumbert & Talkin, 1992), and jaw movement (Beckman, Edwards & Fletcher, 1992; de Jong, 1995). Among these studies on different articulators, the effect of prosodic hierarchy on velum movement was not as well documented compared with lingual, labial, glottal, and jaw movements. Nasalization which involved the downward movement of velum within the domain of a word was found in languages such as English, French, Hindi, Bengali, Sundanese, Italian and Taiwanese (Cohn, 1990; Ladefoged & Maddieson, 1996; Ohala & Ohala, 2000; Maturi, 1991; Pan, 1994). Pan (1994) discovered that Taiwanese initial voiced stop was nasalized when preceded by nasals across syllabic boundary. However, it was unclear whether this process was robust across prosodic boundaries of different strength.

The purpose of this study was to investigate the signature of prosodic hierarchy on nasalization process from final nasal to initial voiced stops across prosodic boundaries such as syllable, word, tone group and intonational boundaries.

Taiwanese is a tone language of which the surface f0 realization of lexical tone has received some attention. There are seven lexical tones in Taiwanese, including five unchecked tones i.e. high level tone (HH), mid level tone (MM), high falling tone (HL), mid falling tone (ML), low rising tone (LH) and two checked tones, high falling checked tone (<u>HL</u>) and mid falling checked tone (<u>ML</u>). Taiwanese lexical tones has a recursive sandhi rule as shown in the following:

$$LH \rightarrow MM \rightarrow ML \rightarrow HL \rightarrow HH \rightarrow MM.$$

Each syllable has two tonal values, juncture tone and context tone. Depending on a syllable position in a tone group, different tonal value surfaces. Final syllable of a tone group carries juncture tone, whiles all other syllable carries context tone. For example, following the recursive sandhi rule stated above a syllable [gun ˥] '軍 army' with a high level juncture tone would carry a mid level context tone, i.e. [gun ˧] '軍 army', in non-juncture position of a tonal group. Similarly a syllable [gun ˧] ' 近 near' carrying mid level juncture tone in final position of a tone group would carry a mid-falling context tone, i.e. [gun ˧˩] '近 near', in non-final position of a tone group. Due to the recursive nature of the tone sandhi rule, unless listener is aware of a syllable's position in a tone group, s/he would have difficulty in lexical and semantic processing when presented with a surface form [gun ˧].

It was shown in a perceptual study that listeners randomly assigned the meaning 'army' or 'men' when presented with [gun ˧] surface form (Peng, 1997). In other words, subject can not distinguish whether a surface form [gun ˧] was truncated from a juncture or context position, since the two forms are completely neutralized on the surface.

2. Method

2.1. Subjects

Four male native Taiwanese speakers participated in the experiments, cys, hyh, lws and lyk. They were students at National Chiao Tung University in Taiwan at time of recording.

2.2. Corpus

The final segment of the second syllable in each utterance was either oral vowel, or nasal, e.g. [m, n, ŋ]. The initial segment of the third syllable was stops, e.g. [p, t, k, p^h, t^h, k^h, b, l, g]. The prosodic boundaries of which the nasalization applied across were intonation boundary, tone group but not word boundary, word but not tone group boundary, both word and tone group boundary, and syllable boundary. Table 1 showed the example of the corpus. There were all together (4 final segments × 9 initial segments × 5 prosodic boundaries × 3 repetitions) 540 utterances produced by each speaker. Utterances with nasalization across the same prosodic boundary were randomized and then written on a list with Chinese characters and IPA symbols.

Table 1: Examples of Corpus

Prosodic Boundary	Example
Intonation boundary	[a-laŋ lai k^hi təŋ la] 'A-lang, let's go home.'
Word but not tone group boundary	[si t^yam p^hau mi lai dʒa] 'Order instant noodle first.'
Tone group but not word boundary (compound word)	[tai lam ba so mi diam] 'Tainan minced-pork noodle store'
Tone group and word boundary	[a-lam la gun dau dua] 'a-lam lived in my house'
Syllable boundary	[tai-lam kuan dʒin dua] 'Tainan county is big.'

2.3. Instrumentation

Recording was done in a sound treated booth with a TEV TM-728II unidirectional dynamic microphone placed 40 cm in front of the subject and a P0769 nasal airflow mask by Hans Rudolph was placed on top of speaker's nose. Acoustic signals were bypassed through a TEAC 860R cassette deck, while nasal airflow signals were low-pass filtered with Glottal Enterprise MS 100-A2 system. Acoustical and nasal airflow signals were digitized with CspeechSP software at 16 kHz into two separate files. Both nasal airflow and acoustical files were converted into .wav format with CspeechSP.

2.4 Recording

Subjects' utterances were produced in two different speed. A metronome with blinking light was used to control the speed to 144 (normal) and 200 (fast) beat per minute. Subject was not required to produce each syllable according to the equal time interval between each beat. In stead they were encouraged to use the metronome as a reference to control the speed at which they produced the first two syllables of an utterance.

Subject paused after each sentence to allow the experimenter to save nasal and acoustical airflow into files.

Each recording session lasted for two hours. There were as many sessions as subject needed to finish the entire corpus. Recordings started from utterance with nasalization across intonation boundary, then word but not tone group boundary, tone group but not word boundary, tone group and word boundary, and finally syllablic boundary.

2.4 Data analysis

Both acoustical and nasal airflow files in .wav format was analyzed with multi-speech software to mark the offset time of the second vowel, the onset time of the third vowel, the time at which the first peak, first valley, and second peak of nasal airflow trace between the second and third vowels (figure 1). Spectrogram was generated to measure the time at the offset of F2 of the second vowel, and the time at the onset of F2 at the third vowel. The first peak of the nasal airflow was the point at which the amplitude of nasal airflow first reached peak value after the offset of the second vowel. The valley was the point at which the nasal airflow reached the lowest value after the first peak and before the onset of the third vowel. If nasal airflow kept on decreasing after the first peak to the point where it reached the onset of the third vowel, then the utterance was judged to posses only one peak, with no valley or second peak between second and third vowels. The second peak was the point after the valley and before the onset of the third vowel at which the nasal airflow reached another peak. Not every utterance has a valley or second peak between the second and third vowels. In some utterances, especially those with prosodic boundary of lower rank, the nasal airflow kept on decreasing after the first peak to the onset of the third vowel. In these cases, only the time and amplitude of nasal airflow at the first peak were taken.

3. Results

Figure 2 showed the preliminary results of the trace of nasal airflow between the second and third vowel. The second vowel was followed by final [n] and [ŋ], while the third vowel was preceded by initial [ɡ]. The prosodic boundaries between the two segments were intonation, word, and syllabic boundaries. It was observed that nasal airflow peaked during final nasals, [n, ŋ] regardless of the following prosodic boundaries. The amplitude of nasal airflow fell to negative values when there was intonation boundary between final nasals in the second syllable and initial stops in the third syllable produced in both normal (144 beat /minute) and fast (200 beat / minute) speeds. In other words, the speakers inhaled when there was an intonation boundary across which the nasalization took place. However, speakers did not inhale and the amplitude of nasal airflow remained to be positive across word and syllabic boundaries produced in both normal and fast speech rates. Following the decrease, the nasal airflow peaked up again during the initial stops of the third syllable. In other words, nasalization took place regardless of the prosodic boundaries in between the final nasal of the second syllable and the initial stop of the third syllable.

Comparing the amplitudes of nasal airflow of the first peaks extracted from [ŋ ɡ] segments across intonation, word and syllabic boundaries, it was found that the first peak was the highest for nasalization across intonation boundary, then across syllabic boundary, and the lowest across syllabic boundary. However, for nasalization from [n] to [ɡ] across intonation, word, and syllabic boundaries, the amplitudes of first peak was the highest across word boundary, followed by that across intonation boundary and finally across syllabic boundary. Not only was there no systematic relationship in which the amplitude of airflow for the first peak was ordered according to strength of boundaries, nor was there a systematic relationship at which the amplitude of valley and the second peak was ordered.

As shown in Figure 3, a further analysis of the amplitude difference for nasal airflow between the first peak and the valley revealed that the amplitude difference was the greatest when there was intonation boundary between the final nasal and the initial stops. The amplitude differences derived by deducting the amplitude of the valley from the amplitude of the first peak was the smallest when the nasalization took place across syllabic boundary from both [ŋ ɡ] and [n ɡ] segment sequences. When there was a word boundary between the final nasal and the initial stop, the extent of nasal airflow difference was lower than that of intonation boundary but higher than that of word boundary for both [ŋ g] and [n g] segmental sequences.

An effect of speech rate was observed by comparing the nasal trace of both [ŋ g] and [n g] segmental sequences produced in normal and fast speeds. The amplitude of nasal airflow during the second peak is higher than the amplitude of nasal airflow of the first peak for utterances produced across word and syllabic boundaries in fast speed.

3. Discussion

Preliminary results indicated that difference in nasal airflow between the first peak and the valley extracted from [ŋ g] and [n g] across various prosodic boundaries was largest across intonation boundary, then word boundary, and smallest across syllabic boundary.

It was proposed that beside [ŋ g] produced in fast speed, speakers was inhaling during the production of final nasal and initial stops across intonation boundary. Intonation boundary which was the strongest prosodic boundary observed in this study, interfered most with the nasalization process as speaker was allowed time to pause in between the final nasal and initial stop and breathed in at the same time. As the strength of prosodic boundary in between the [ŋ g] and [n g] sequence decreased, the congruity of the final nasal and initial stops were stronger, speaker was forced to proceed from final nasal to initial stops in a shorter span of time thus only decreased the amount of nasal airflow slightly, in stead of inhaling around the boundary, and then increased nasal airflow again during the nasalized initial stop as indicated by the second peak.

Beside prosodic boundaries of various strengths, speech rate was another factor that influenced the extent of nasality on the initial stops. The amplitude of nasal airflow for stops produced after word and syllabic boundaries produced in fast speed was higher than those in normal speed. As the speech rate increased, [ŋ g] and [n g] was jammed closer in terms of high level motor planning, thus less time was distributed on each segment which in turn lead to the lesser extent of nasal airflow decrease during the valley (prosodic boundary) and higher degree of nasalization during the second peak (initial stops).

Provide the velum moves in a steady speed, as the strength of prosodic boundary decreased, nasalization from final nasal to initial stop was less interfered, the congruity between final nasal and initial stops increased, thus the amplitude of nasality increased during the valley and the second peak as a result of nasalization.

4. Conclusions

The signature of prosodic hierarchy could be observed in terms of amplitude of nasal airflow that was indirectly correlated with velar movement. Intonation boundary that is accompanied by a pause between the final nasal and initial stops blocked the nasalization process from preceding final nasal to following initial stops by changing the direction of nasal airflow from egressive to ingressive. Compared with nasalization across intonation boundary, the difference between the first peak and the valley of nasal airflow across word boundary was less different, while there was least difference on the nasal airflow across syllabic boundary.

The standing of tone group boundary in the prosodic hierarchy is still under investigation. With further analysis on the data recorded, its status will be revealed.

5. References

[1] Byrd, D., 1996. Influences on articulatory timing in consonant sequences, Journal of Phonetics, 24 (2) 209 – 244.

[2] Byrd, D. & E. Saltzman, 1998. Intragestural dynamics of multiple phrasal boundaries. Journal of Phonetics 26: 173 – 199.

[3] Byrd, D., Kaun, A., Narayanan, S., and Saltzman, E., 2000 Phrasal signatures in articulation. In M. Broe & J. B. Pierrehumbert (eds.) *Papers in Laboratory Phonology V: Acquisition and the lexicon.* Cambridge: Cambridge University Press, 70 –87.

[4] Cohn A. 1990. Phonetic and phonological rules of nasalizaiton. UCLA Working Papers in Phonetics 76.

[5] Dilley, L., S. Shattuck-Hufnagel, & M. Ostendorf (1996) Glottalization of word-initial vowels as a function of prosodic strucutre. Journal of Phonetics 24: 423-444.

[6] Fougeron, C. & P. Keating. 1996 Variations in velic and lingual articulation depending on prosodic position: Results for 2 French speakers. UCLA Working Papers in Phonetics 92:88 –96. lingual

[7] Ladeforged P. & I. Maddieson, 1996. The sound of the world's language. Blackwell Publisher.

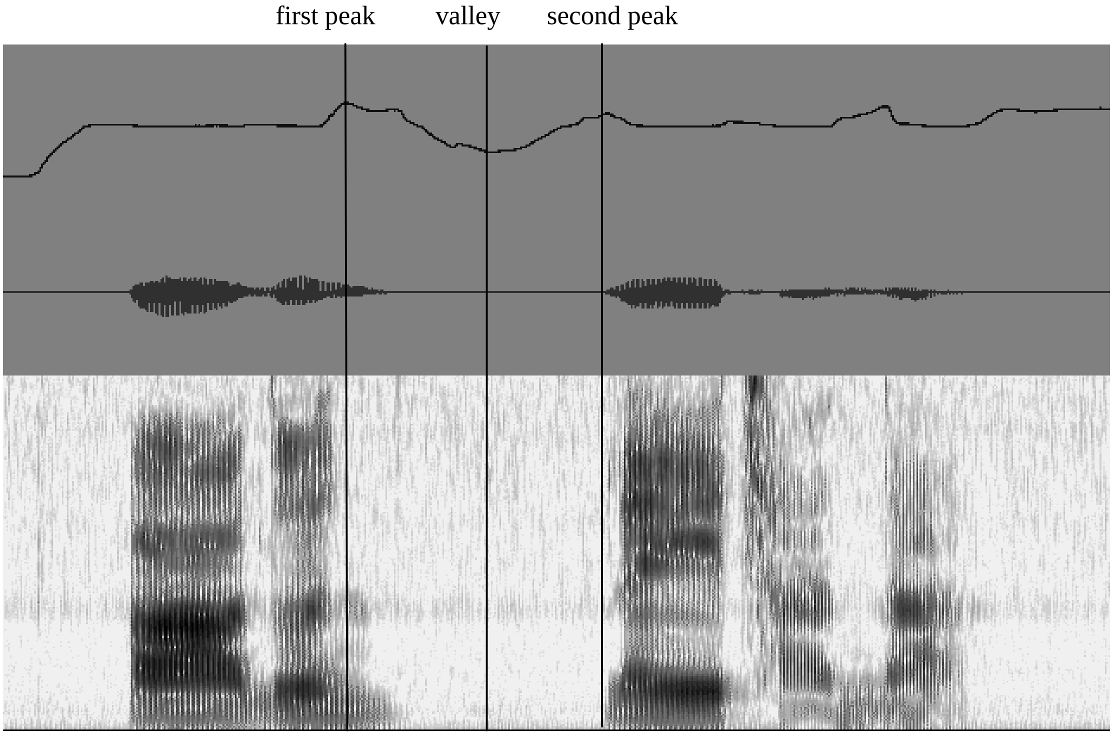
[8] Maturi, P. 1991. The perception of consonantal nasality in Italian: conditioning factors. Proceedings of the XIIth International Congress of Phonetic Sciences, Aix-en-Provence, 5:50-53.

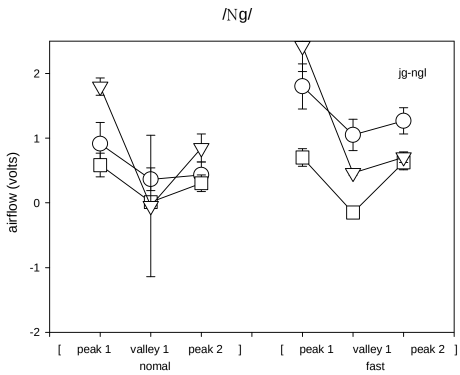
[9] Ohala M. & J. Ohala. 1995. Speech perception and lexical representation: the role of vowel nasalization in Hindi and English. In B. Connell & A. Arvaniti (eds.) Papers in Laboratory Phonology IV : Phonology and Phonetic Evidence. Cambridge: Cambridge University Press. 41 –60.

[10] Pan, H.-H. 1994. The voicing contrast of Taiwanese (Amoy) initial stops: Data form adults and Children. PhD dissertation. The Ohio State University.

[11] Peng, Production and perception of Taiwanese tones in different tonal and prosodic contexts. Journal of Phonetics, 25 (3), 371-400.

[12] Pierrehumbert, J. & D. Talkin. 1992. Lenition of /h/ and glottal stop. In G. J. Docherty & D.R. Ladd (eds.) *Papers in Laboratory Phonology II: Gesture, segment, prosody.* Cambridge: Cambridge University Press, 90 – 117.





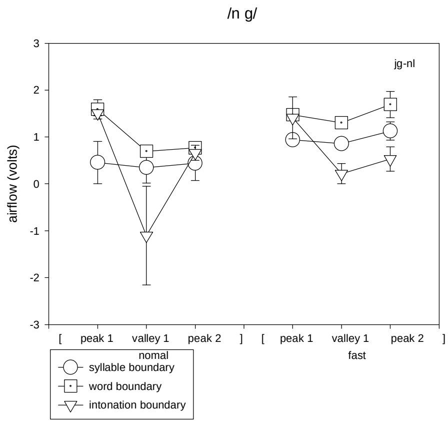


Figure 3. Airflow differences between first peak and valley on the airflow trace

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