Ambisyllabicity in English: How real is it?

Hong Gao & Yi Xu

Sichuan University, University College London

gaohong23@21cn.com; yi.xu@ucl.ac.uk

Abstract

In an English phrase like "an ice cream", does the /n/ remain the coda of the first syllable, or is it resyllabified into the second syllable so that the phrase is no different from "a nice cream"? Or is it ambisyllabic: belonging simultaneously to both syllables? This is an issue that still remains a mystery today. In this study, we revisit this issue with the help of a recently developed technique of using F_0 turning point as reference for segmental alignment. In two experiments, we investigated syllable affiliation of the intervocalic consonant at word boundaries in Southern British English by comparing cases where the intervocalic nasal is word initial, word final or final plus initial (geminate). Results show that initial and final nasals differ little in their F_0 alignment, indicating that final nasals are virtually resyllabified. Nasal geminates, in contrast, seem to be still dividable into coda and onset. Despite the shift in alignment, the underlying affiliation of the coda nasal is nevertheless still reflected by shortened duration of both the nasal murmur and the preceding vowel. We interpret the finding as evidence in support of the time-structure model of the syllable (Xu & Liu, 2006).

Key words: F_0 minimum; F_0 maximum; ambisyllabicity; time structure model of the syllable; Southern British English

1. Introduction

In an English phrase like "an ice cream", does the /n/ remain the coda of the first syllable, or is it resyllabified into the second syllable so that the phrase is no different from "a nice cream"? Or is it ambisyllabic: belonging simultaneously to both syllables? This issue has long interested phoneticians and phonologists and still remains a mystery today. Daniel Jones (1931) assembled an imposing list of such words, saying that "phonetic value of word-division varies considerably. Sometimes, it has relation merely to the incidence of the stress; sometimes differences of sound are involved; very often word-division determines the length of sounds, and probably in some cases it is a determining factor in intonation" (Jones, 60-61). But he did not systemize his findings. Trager & Bloch (1941:225) also referred to such differences and regarded them as juncture phenomena. To them, "open juncture is the totality of phonetic features which characterize the segmental and suprasegmental phonemes at the beginning and at the end of an isolated utterance." The phonetic feature differs between close and open junctures either internally or externally. Lehiste & Anbor (1960) further made a listening test and found that syllable initial consonants are longer than syllable final consonants. However, although the phonetic differences in such minimal pairs have been observed, the syllable affinity of these sounds has never been questioned. According to Turk (1994:107) "it is widely assumed that word-initial and word-final consonants are syllable-initial and syllable-final respectively". Yet a series of studies which investigated the articulatory properties of ambiguously syllabified allophones (Krakow 1999, Sproat & Fujimura 1993, Turk 1994, Gick 2003) shows that word-final consonants across word boundaries gradually approach the word initial allophones. They are partially or completed resyllabified, and the change is not categorical. However, those studies are never very clear about the time division between the vocalic and consonantal gestures.

In recent years, a number of studies reveal that certain F_0 turning points are consistently aligned with the segmental landmarks (Mandarin: Xu 1997, 1998, 1999, 2001; English, Dutch: Ladd et al., 1998, 1999, 2000, 2003; Xu & Xu, 2005, Dilley & Brown, 2007). According to these studies, F_0 minimum always occurs very close to the onset of an accented syllable while F_0 maximum alignment also consistently present certain pattern when focus, word position, lexical stress and vowel length are controlled. What these studies have shown is how F_0 turning point is consistently aligned to segments. In the present study we use this knowledge to determine how segments are aligned to F_0 turning point, following (Xu & Liu, 2007), i.e., using F_0 turning point as reference for determining temporal organization of segments.

In this study, we investigated syllable affiliation of the intervocalic consonant at word boundaries in Southern British English by comparing cases where the intervocalic nasal is word initial, word final or final plus initial (geminate). Two experiments were designed, one by employing the F_0 minimum as reference, the other by employing the F_0 maximum.

2. Method

2.1. Subjects and procedures

To make things comparable, the subjects for both experiments are the same. Four male and four female native British English speakers served as subjects. They were born in Britain and aged from 19 to 50. All of them claimed to be standard British English speakers. None of them reported any history of speech or hearing disorders.

Recordings for both experiments were made in an Anechoic chamber at UCL. The speech signals were digitized at 44.1kHz.with 16 bit quantization. To guarantee the accuracy of F_0 extraction, we also recorded the Lx output from a Laryngograph processor. The subject was seated comfortably in front of a computer monitor. Before recording began a few example sentences were used to allow setting of the peak level at approximately -8dB below overload.

The target sentences were repeated 7 times, and were presented in random order. The speakers were instructed to read aloud the sentences naturally as if talking to a friend. They were also instructed to make sure to put enough emphasis and to not pause anywhere except at the comma.

2.2. Experiment 1

By taking F_0 minimum as a reference, we investigated syllable affiliation of the intervocalic consonant at word boundaries in Southern British English by comparing cases where the intervocalic nasal is word initial, word final or final plus initial (geminate). We predict that for a word initial nasal, F_0 minimum occurs around the onset of the nasal murmur, and for a nasal geminate (word-final + word-initial nasal), F_0 minimum occurs in the middle of the nasal murmur. For a word-final nasal, we assume that if the F_0 minimum occurs around the nasal murmur offset, then it remains to be coda, if the F_0 minimum occurs in the middle of nasal murmur, then it is ambisyllabic, and if the F_0 minimum occurs around nasal murmur onset, then it virtually serves as the onset of the following word and can be taken as syllabified.

In the meantime, duration of word initial and word final consonant is also measured as it is often assumed to be one of the most important characteristics for syllable initial and syllable final consonant. (Lehiste 1960)

2.2.1. Stimuli

To use F_0 minimum as a reference for syllable division, the material used were based on the following considerations:

1. The segments around the pitch valley should be sonorant consonants so that there would be a continuation of pitch contour. For ease of segmentation, nasal consonants were preferred in this experiment.
2. The test phrases should be ones in which both of the target words would bear pitch accents so that speakers would read them with two successive peaks. To meet this criterion, personal names are good candidates, especially when they were placed in contrast with another name (cf. Ladd & Schepman, 2003). In addition, to make the inter-peak F_0 minimum more reliable, disyllabic given names with initial stress were chosen.

Besides the pitch contour, the segmental environment was also carefully manipulated. Seven sets of sentences were used as shown below. In each set there were three target names placed in the carrier sentence “It wasn’t …, but …who has just left”, referred to as a, b and c respectively. In a the given name ended with a vowel while the surname began with a nasal consonant. In b the given name always ended with a nasal consonant while the surname always began with a vowel. In c the given name ended with a nasal and the surname stated with a nasal, and the two nasals thus formed a geminate. To make the three conditions comparable, names sharing the same vowel on either side of the nasal(s) at word boundary were chosen.

1a. It wasn’t Ella Neeson, but Anna Madison who just left.
1b. It wasn’t Ellen Eason, but Ann Addison who just left.
1c. It wasn’t Ellen Neeson, but Ann Madison who just left.

2a. It wasn’t Cara Nelson, but Charles Melson who just left.
2b. It wasn’t Karen Elson, but Helen Eadon who just left.
2c. It wasn’t Karen Nelson, but Helen Melson who just left.

3a. It wasn’t Carrie Nellis, but Fanny Collis who just left.
3b. It wasn’t Karin Ellis, but Dan Williams who just left.
3c. It wasn’t Karin Nellis, but James Colins who just left.

4a. It wasn’t Marley Normand, but Annie Morton who just left.
4b. It wasn’t Marlin Ormond, but Andy Watson who just left.
4c. It wasn’t Marlin Normand, but Andy Morton who just left.

5a. It wasn’t Norma Nevin, but Laura Martin who just left.
5b. It wasn’t Norman Evens, but Lauren Ayling who just left.
5c. It wasn’t Norman Nevin, but Lauren Martin who just left.
6a. It wasn’t Nola Niles, but Rhona Miles who just left.
6b. It wasn’t Nolan Iles, but Robin Ireton who just left.
6c. It wasn’t Nolan Niles, but Ronan Miles who just left.

7a. It wasn’t Merly Nelder, but Ralph Mather who just left.
7b. It wasn’t Merlin Elder, but Alan Alder who just left.
7c. It wasn’t Merlin Nelder, but Robert Mather who just left.

2.2.2. Measurements

The measurements were made with a script (Xu, 2005-2009) written for Praat (Boersma, 2001). The script displays the spectrogram, the waveform and laryngogram waveform of each utterance together with a one-field TextGrid for manually adding event labels. The event labels are shown in Figure 1:

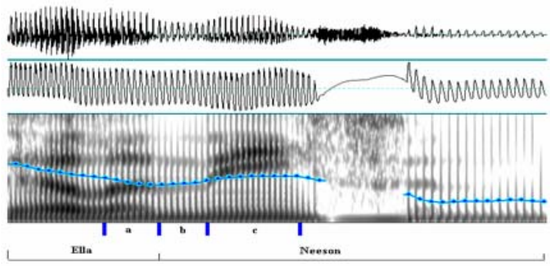


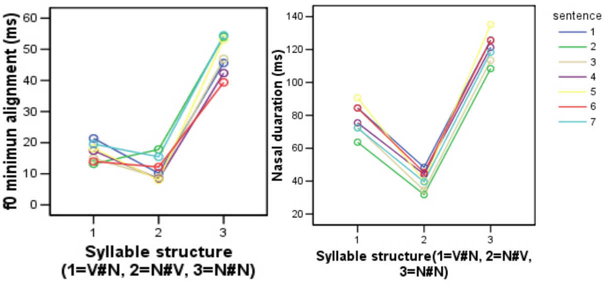
Fig.1. Illustration of event label placement in Experiment 1

In Fig. 1, the interval b corresponds to the nasal murmur while a and c correspond to the vowels on either side of the intervocalic nasal. They were manually placed, using the spectrogram and the waveform as references. To obtain the F_0 contour, the script opens another window to display the laryngogram waveform together vocal cycle marks generated by Praat. Any errors in the vocal cycle markings were rectified manually. The script then generates smoothed F_0 curves based on a trimming algorithm and save the F_0 curve together with a number of other measurements.

2.2.3. Analysis and results

Figure 2a is the summary plot of main effect on the F_0 minimum alignment based on a two-way repeated measures ANOVA, with sentence set (1-7) and syllable structure (V#N, N#V, N#N) as independent variables. The effect of syllable structures was highly significant ($F(2,14) = 46.32$, $p < 0.001$), indicating that the pitch valley alignment differed significantly in the three different syllable structures. The effect of sentence set was not significant, and neither was the interaction between sentence set and syllable structures, indicating that the pitch valley alignment difference was mainly due to the difference in syllable structure.

Bonferroni pairwise comparisons of the means of pitch valley alignment in different syllable structures showed the mean difference between V#N vs N#V, V#N vs N#N, N#V vs N#N conditions was 5.43 ($p=0.23$), -31.04 ($p=0.001$) and -36.46 ($p<0.001$) respectively, indicating a significant difference between V+N vs N#N and N#V vs N#N, but no difference between V#N vs N#V. Bonferroni pairwise comparisons of the pitch valley alignment in different sentence sets showed no significant differences.



(a) (b)

Fig.2. (a) summary plot of main effects on F_0 minimum alignment of a two-way repeated measure ANOVA; (b) summary plot of main effect upon nasal duration of a two-way repeated measure ANOVA

Figure 2b is the summary plot of the main effects on nasal duration based on a two-way repeated measures ANOVA, with sentence set (1-7) and syllable structure as independent variables (V#N, N#V, N#N). The effect of syllable structure was highly significant (F(2, 14)= 66.38, p < 0.001), indicating that the nasal duration differed significantly across the three syllable structures. The effect of sentence set was also significant (F(3,23) = 15.30, p < 0.001). The interaction between sentence set and syllable structure was significant be rather small (F(5,31) = 2.83, p = 0.036), indicating that the difference in nasal duration is mainly syllable structure.

Bonferroni pairwise comparisons of the means of nasal duration in different syllable structures showed the mean differences between V#N vs N#V, V#N vs N#N, N#V vs N#N condition were 37.13 (p = 0.001), -43.48 (p = 0.001) and -80.61 (p < 0.001) respectively, indicating a clear differences in nasal duration between the three syllable structures. Bonferroni pairwise comparisons of mean nasal duration for different sentences with the same syllable structure showed that in most cases, there was no significant difference in nasal duration due to sentences which differed in words but the same in syllable structure.

The results can be more clearly seen if the mean F_0 contours for all tokens across all speakers are plotted on actual time scale, as illustrated in Figure 3. The thick pink section in each curve corresponds to the intervocalic nasal murmur. We can see that the F_0 valley appears roughly at the beginning of the nasal murmur in case of both V#N cluster N#V. But for N#N, i.e., nasal geminate, the F_0 valley occurs roughly in the middle of the nasal murmur. Thus initial and final nasals differ little in their F_0 alignment, indicating that final nasals are virtually resyllabified into the initial consonant of the following syllable. Nasal geminates, in contrast, seem to be still dividable into coda and onset. On the other hand, despite the shift in alignment, the underlying affiliation of the coda nasal is nevertheless still reflected by the shortened duration of both the nasal murmur and the preceding vowel.

2.2.4. Discussion

Using the alignment of F_0 minimum as reference, experiment 1 revealed that first, in Southern British English, the F_0 minimum alignment for both word final nasals and word initial nasals are virtually identical, indicating that the word final nasals are resyllabified into the following syllable. Second, the underlying affiliation of the coda nasal is nevertheless still reflected by the shortened duration of the nasal murmur (as reported previously by Lehiste, 1960).

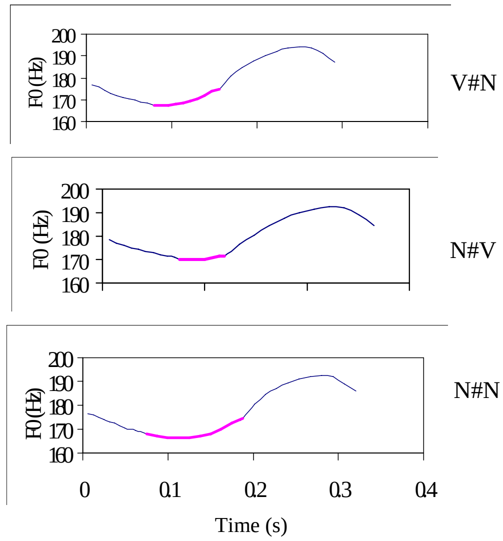


Fig. 3. Plot of mean F_0 contours for *Ella Neeson* (N#N), *Ellen Eason* (V#N) and *Ellen Neeson* (N#N) in seconds. The thick pink section in each plot corresponds to the intervocalic nasal.

2.3. Experiment 2

A number of studies have demonstrated that F_0 maximum consistently present certain pattern if focus, word position, lexical stress, and phonological length of stressed vowel (vowel length) are well controlled (Mandarin: Xu 1997, 1998, 1999, 2001; English, Dutch: Ladd et al., 1998, 1999, 2000; Xu & Xu, 2005, Dilley & Brown, 2007, Niebuhr, 2007). In this experiment, we used F_0 maximum as a reference to investigate syllable affiliation of intervocalic consonants at word boundaries in Southern British English by comparing cases where the nasal is word initial, word final or final plus initial (geminate). We predict that when all conditions are equal, the F_0 maximum always occurs early in the first syllable, but it is relatively earlier if the nasal is the onset of the second word than if it is a geminate. For a word-final nasal, if the F_0 maximum alignment is the same as the nasal geminate, then it remains as coda. If the F_0 maximum alignment is the same as nasal onset, then it is resyllabified. If the F_0 maximum is in between the two, then it is ambisyllabic.

Meanwhile, duration of word initial and word final consonant is also investigated as it is often assumed to be one of the most important characteristics for syllable initial and syllable final consonant. (Lehiste 1960)

2.3.1. Stimuli

As shown in Xu (2005:178), "F_0 maximum location is potentially related to four factors: focus, word position, lexical stress, and phonological length of stressed vowel (vowel length)". And accordingly, its F_0 alignment differs consistently in several patterns:

1. An F_0 peak occurs near the offset of a stressed syllable, provided that (a) the syllable duration is about 200 ms or longer, (b) the syllable is not both word-final and on-focus, and (c) the syllable is not sentence final.
2. An F_0 peak often occurs after the offset of a stressed syllable if the syllable duration is much shorter than 200 ms.
3. An F_0 peak occurs before the offset of a stressed syllable

> that is either (a) both word-final and under focus or (b) sentence final; and the peak becomes increasingly early relative to the syllable offset as syllable duration increases.(Xu & Xu, 2005:147)

The material for this experiment was based on the same considerations as described for experiment 1 (2.2.1). Also, the segmental environment was designed based on the same consideration as in experiment 1 (2.2.1). Seven sets of sentences were used, as shown below.

1a. It wasn't Jo Malone, but Leah Malone who just left.
1b. It wasn't Jim Alone, but Liam Alone who just left.
1c. It wasn't Jim Malone, but Liam Malone who just left.

2a. It wasn't Kim Narelle, but Gee Narelle who just left.
2b. It wasn't Jim Aranda, but Jean Aranda who just left.
2c. It wasn't John Narelle, but Jean Narelle who just left.

3a. It wasn't Rhea Nathaniel, but Gee Nathaniel who just left.
3b. It wasn't Jen Athy, but Gene Athy who just left.
3c. It wasn't Jen Nathaniel, but Gene Nathaniel who just left.

4a. It wasn't June Napolean, but Jay Napolean who just left.
4b. It wasn't Zane Apollo, but Jane Apollo who just left.
4c. It wasn't Kane Napolean, but Jane Napolean who just left.

5a. It wasn't Julie Narayan, but Dee Narayan who just left.
5b. It wasn't Dan Arita, but Dean Arita who just left.
5c. It wasn't Dan Narayan, but Dean Narayan who just left.

6a. It wasn't Ryan Nastase, but Ray Nastase who just left.
6b. It wasn't Ben Astoria, but Raine Astoria who just left.
6c. It wasn't Adrian Nastase, but Raine Nastase who just left.

7a. It wasn't Julia Nabarro, but Joe Nabarro who just left.
7b. It wasn't John Abruzzo, but Joan Abruzzo who just left.
7c. It wasn't Leah Nabarro, but Joan Nabarro who just left.

2.3.2. Measurements

The measurements were taken using the same method as in experiment 1. The event labeling are illustrated in figure 4 where the interval b corresponds to the nasal murmur while a and c correspond to the vowels on either side of the intervocalic nasal:

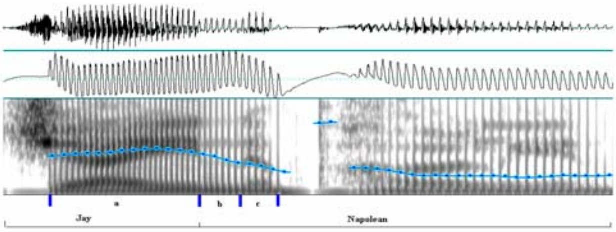


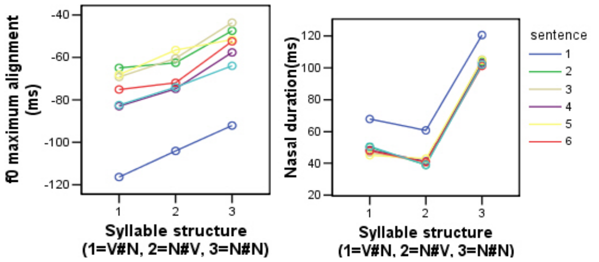
Fig.4. Illustration of event label placement in Experiment 2

2.3.3. Analysis and results

Figure 5a is the summary plot of the main effects on F_0 based on two-way repeated measures ANOVA, with sentence set (1-7) and syllable structure (V#N, N#V, N#N) as independent variables. The main effect of syllable structure was highly significant (F(2, 14)= 31.26, p < 0.001), indicating that the peak alignment differed significantly across the three different syllable structures. The main effect of sentence set was also significant (F(2,15)= 14.69, p < 0.001). However, there was no interaction between sentence set and syllable structure.

Bonferroni pairwise comparisons of peak alignment in different syllable structures showed the mean difference between V#N vs N#V, V#N vs N#N, N#V vs N#N conditions was -7.82 (p = 0.08), -21.47 (p = 0.001) and -13.65 (p = 0.001) respectively, indicating a difference between V#N vs N#N and N#V vs N#N condition, but no difference between V#N vs N#V.

Bonferroni pairwise comparisons of the peak alignment in difference sentence sets showed that in most cases, there was high probability for the null hypothesis to be true and a zero contained in the 95% confidence intervals between the seven sentences. Thus, it seems likely that there is no significant difference in peak alignment due to sentences which differed in words but the same in syllable structure.



(a) (b)

Fig.5. (a) summary plot of main effects on F_0 maximum alignment of the two-way repeated measures ANOVA; (b) summary plot of main effect on nasal duration of a two-way repeated measures ANOVA

Figure 5b is the summary plot of the main effect upon nasal duration of the two-way repeated measures ANOVA, with sentence set (1-7) and syllable structure (V#N, N#V, N#N) as independent variables. The main effect of syllable structure was highly significant (F(2, 14) = 82.74, p < 0.001), indicating that nasal duration differed significantly across the three syllable structures. The main effect of sentence set was significant (F(6, 42) = 19.80, p < 0.001). There was no interaction between sentence set and syllable structure.

Bonferroni pairwise comparisons of nasal duration in different syllable structures showed that the mean differences between V#N vs N#V, V#N vs N#N and N#V vs N#N were 7.43 (p = 0.006), -54.93 (p < 0.001) and -62.36 (p < 0.001) respectively, indicating significant differences across all three conditions.

Bonferroni pairwise comparisons nasal duration for different sentence sets with the same syllable structure showed that in most cases, there was high probability for the null hypothesis to be true and a zero contained in the 95% confidence intervals between the seven sentences. Thus, it seems likely that there is no significant difference in nasal duration due to sentences which differed in words but the same in syllable structure.

The result can be more clearly seen if the mean F_0 contours for all tokens across all speakers are plotted on actual time scale, as shown in Figure 6. Again, the thick pink section in each curve correspond to the intervocalic nasal murmur. We can see that for the word final nasal, the distance between F_0 maximum and the onset of the nasal murmur is very similar with that of the nasal onset, indicating that the word final nasal is virtually resyllabified into the following syllable.

Meanwhile, similar to experiment 1, this experiment also reveals that the duration of word final consonant is shorter than word initial consonant.

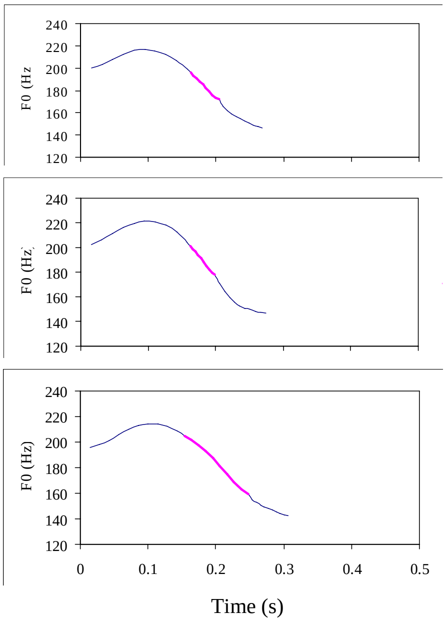


Fig. 6. An illustration of pitch alignment and nasal duration in actual time. The Y-axis is the f0. The X-axis is the actual time. The three names from left to right are *Gee Nathaniel* , *Gene Athy and Gene Nathaniel.*

2.3.4. *Discussion*

Using F_0 maximum as reference, experiment 2 obtained very similar results as experiment 1. It revealed that first, in Southern British English, the F_0 maximum alignment for both word final nasals and word initial nasals are virtually identical, indicating that word final nasals are resyllabified into the following syllable. Second, the underlying affiliation of the coda nasal is nevertheless still reflected by the shortened duration of the nasal murmur.

3. General discussion

The issue of syllable affiliation of intervocalic consonants is of crucial importance for the understanding of the nature of syllables. For many phonologists (Abercrombie 1967, Kahn 1980), syllable appears to be an intuitively recognizable unit. It plays a crucial role in phonological theory. It is a unit which connects the segmental and suprasegmental levels. It allows a succinct formulation of many phonological generalizations. However, for these phonologists, it has been difficult to say where exactly each syllable begins and where it ends.

The time structure model of the syllable (Xu and Liu, 2006), which is based on consideration of articulatory mechanism as evidenced from previous studies, offers a more mechanistic view of the syllable. According to this model, “syllable serves as a time structure that assigns temporal intervals of consonants, vowels, tones and phonation registers” (Xu, 2009:916), as illustrated in Figure 7. The alignment of the temporal intervals is hypothesized to follow three principles: 1) Co-onset of the initial consonant, the first vowel, the tone and the phonation register at the beginning of the syllable; 2) Sequential offset of all non-initial segments, especially coda C; and 3) Synchrony of laryngeal units with the entire syllable. In each case, the temporal interval of a segment is defined as the interval during which its target is being approached.

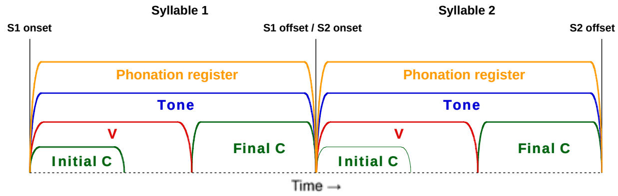


Fig. 7. The time structure model of the syllable. Adapted from Xu and Liu (2006)

The present data seem to provide clear support for the time structure model of the syllable. As has been described, the alignments of both F_0 minimum and maximum are very similar between N#V and V#N, indicating that word final nasals are virtually resyllabified into the first syllable of the next word. This means that an intervocalic syllable coda is categorically changed to an onset consonant when it is followed by an onsetless syllable. This result is also in accordance with the finding of Dilley & Brown (2007:535) that “participants produced categorical temporal alignment for F_0 peaks and valleys relative to segments, where this alignment varied consistently with the syntagmatic relative pitch levels of successive syllables in the stimuli”. However, they were not able to provide an explanation as to why pitch height alternations on adjacent syllables would lead to categorical alignment of F_0 peaks and valleys. What the present data have shown is that such systematic alignment is likely due to an articulatory constraint that makes all the syllabic components tightly aligned to one syllable or another, with little room for ambisyllabic components.

The strength of the syllable synchronization constraint is further supported by the duration data of the present study. In both experiments, the coda nasals were found to be significantly shorter than onset nasals, which seemed to resembles the short duration of the coda nasal in the geminate condition since the duration of the nasal geminates were not twice as long as that of the initial nasal. This suggests that speakers are still “aware” of the underlying affiliation of the coda nasal. The implication is that the resyllabification indicated by the F_0 alignment shift is an articulatory-phonetic process different from the morphophonemic structure of a word, which probably remains unchanged despite the resyllabification.

4. Conclusion

In this paper, with the help of a recently developed technique of using F_0 turning point as reference for segmental alignment, we explored the syllable affiliation of intervocalic consonant at word boundaries in Southern British English. From the results of the two experiments, we conclude:

1. In Southern British English, the intervocalic nasal at word boundary is resyllabified.
2. The underlying affiliation of the coda nasal is nevertheless still reflected by the shortened duration of the nasal murmur. This confirms the finding of Lehiste’s study in 1960.
3. The resyllabication of the intervocalic nasal at word boundary in Southern British English provides support

for the time structure model of syllable (Yi & Liu, 2006) which favors a CV syllable structure.

4. The seeming contradiction between alignment resyllabification and durational reflection of the underlying syllable affiliation suggests that the syllable synchronization constraint is articulatory in nature and is independent of morphophonemic processes.

5. References

[1] Abercrombie, D., 1967. *Elements of General Phonetics*. Edinburgh University Press, Edinburgh..

[2] Arvaniti, A.; Ladd, D. R.; Mennen, I., 1998. Stability of tonal alignment: the case of Greek prenuclear accents. *Journal of Phonetics* 36: 3-25.

[3] Boersma, P., 2001. Praat, a system for doing phonetics by computer. *Glot International* 5:9/10: 341-345.

[4] Jones, D., 1931. The “word” as a phonetic entity. Maître Phonét. 36: 60-65.

[5] Dilley, L. C.; Brown, M., 2007. Effects of pitch range variation on F_0 extrema in an imitation task. *Journal of Phoetics* 35:523-551.

[6] Gick, B., 2003. Articulatory correlates of ambisyllabicity in English glides and liquids. *Papers in Laboratory Phonology VI: Constraints on Phonetic Interpretation*. J. Local, R. Ogden and R. Temple (ed.). Cambridge University Press.

[7] Kahn, D., 1976. Syllable-based Generalizations in English Phonology.Reprinted, 1980. New York: Garland

[8] Krakow, R. A. 1999, Physiological organization of syllables: a review. *Journal of Phonetics* 27:23-54.

[9] Ladd, D. R.; Faulkner, D.; Faulkner, H.; Schepman, A., 1999. Constant "segmental anchoring" of F_0 movements under changes in speech rate. *Journal of the Acoustical Society of America* 106: 1543-1554.

[10] Ladd, D. R.; Mennen, I.; Schepman, A., 2000. Phonological conditioning of peak alignment in rising pitch accents in Dutch. *Journal of the Acoustical Society of America* 107: 2685-2696.

[11] Ladd. D. R.; Schepman. A., 2003. “Sagging transition” between high pitch accents in English: experimental evidence. *Journal of Phonetics*31:81-112.

[12] Lehiste, I., 1960. An acoustic-phonetic study of internal open juncture. *Phonetica*,5 (suppl.).

[13] Sproat, R.; Fujimura. O., 1993. Allophonic variation in English /l/ and its implications for phonetic implementation. *Journal of Phonetics* 21:291-311.

[14] Trager, G. L.,; Bloch, B., 1941. The syllabic phonemes of English. *Language* 17: 223-246.

[15] Turk, A., 1994. Articulatory phonetic clues to syllable affiliation: gestural characteristics of bilabial stops. In *Papers in Laboratory Phonology* 3*: Phonological Structure and Phonetic Form.* P. Keating (ed.). Cambridge: Cambridge University

[16] Xu, Y., 1994. Production and perception of coarticulated tones. *Journal of the Acoustical Society of America* 95: 2240-2253.

[17] Xu, Y., 1998. Consistency of tone-syllable alignment across different syllable structures and speaking rates. *Phonetica* 55: 179-203.

[18] Xu, Y., 1999. Effects of tone and focus on the formation and alignment of F_0 contours. *Journal of Phonetics* 27: 55-105.

[19] Xu, Y., 2001. Fundamental frequency peak delay in Mandarin. *Phonetica* 58: 26-52.

[20] Xu, Y., 2005-2009. _TimeNormalizeF0.praat. Available from: <http://www.phon.ucl.ac.uk/home/yi/tools.html>.

[21] Xu, Y., 2009. Timing and coordination in tone and intonation—An articulatory-functional perspective. *Lingua* 119(6): 906-927.

[22] Xu, Y.; Liu, F., 2007. Determining the temporal interval of approximants with the help of F_0 contours. *Journal of Phonetics* 35:398-420.

[23] Xu, Y.; Liu, F. 2006. Tonal alignment, syllable structure and coarticulation: Toward an integrated model. *Italian Journal of Linguistics* 18:125-159.

[24] Xu, Y.; Wang, Q. E., 2001. Pitch targets and their realization: Evidence from Mandarin Chinese. *Speech Communication* 33: 319-337.

[25] Xu, Y.; Xu, C. X., 2005. Phonetic realization of focus in English declarative intonation. *Journal of Phonetics* 33: 159-197.