An Alternative Approach to Realizations of the Medial [nt] Cluster in English*

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Chung, Chin-Wan. (2016). An Alternative Approach to Realizations of the Medial [nt] Cluster in English. *The Linguistic Association of Korean Journal, 24*(4), 1-22. This study focuses on the realizations of medial [nt] cluster and provides a foot-based account of it. The analysis argues that the deletion of the [t] occurs only within a foot when the [t] of the [nt] is the onset of a non-head syllable of a trochaic, a dactylic, and a superfoot. This optional deletion in English targets a segment occurring in a prosodically non-prominent syllable. By employing foot-based analytic assumption, we are able to explain extensive realizations of the medial [nt] cluster which includes the examples of aspiration and glottalization of the [t] instead of deletion to avoid the medial [nt] sequence. The aspiration and glottalization examples are problematic to a syllable-based analysis due to its restricted domain. The analysis reveals that English seems to use deletion, glottalization, and foot-structure to avoid the medial [nt] cluster, which is typologically interesting.

Key Words: constraints, ranking, superfoot, medial cluster, deletion

1. Introduction

Medial consonant clusters[1] in English occur over a syllable or morpheme

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boundary. There are segmental requirements and phonological processes occurring over medial cluster boundaries in English (Wolfram and Johnson, 2003). One of the interesting medial cluster requirements applying to a cluster is homorganicity when it consists of a nasal plus an obstruent stop in English. In such a cluster, two component segments must share the identical place of articulation, which is termed 'homorganic clusters.' The possible medial NC clusters in English are labial, coronal, and dorsal homorganic clusters as in *ca[mp]us*, *i[nt]ernatinal*, and *thi[ŋk]ing*. These NC clusters show asymmetrical realizations because the [t] in the [nt] is variably realized such that the [t] is optionally deleted when it appears before an unstressed vowel as in *cen[t]er* and *sen[t]ence*. On the other hand, when a post-nasal obstruent stop is voiced, the [d] is invariably realized in the output as in *sen[d]er*. Unlike such variations in the [nt], each segment in the labial and dorsal NC clusters is faithfully realized in the output. The non-realization of the [t] in the coronal [nt] cluster was noticed by Ladefoged (2001) and analyzed by Chung (2007, 2009). However, there are still some examples the previous analyses cannot explain in which the [t] in the [nt] is either aspirated or glottalized even if the [t] occurs in the same deletion environment. For example, the deletion environment defined in the previous analyses cannot be extended to explain examples such as *con[t^h]emplate* and *con[ʔ]inent*.

Thus, the main goal of this study is to provide an alternative account of the medial [nt] realizations in English by adopting a foot structure proposed by Jensen (2000), Davis and Cho (2003), Davis (2005), which is dubbed 'superfoot' consisting of {W(SW)}. A newly proposed foot-based analysis framed in OT (Prince and Smolensky, 1993, 2004; McCarthy and Prince, 1995) can explain the non-realization and realization of the [t] in the word-medial [nt] cluster. The non-realization of the [t] before an unstressed nucleus is hypothesized to occur when the medial [nt] cluster occurs within a foot. This implies that the target segment occur as an onset of non-head syllable occurring in a trochaic foot, a dactylic foot, or a superfoot. On the other hand, the realization of the [t] in the medial [nt] cluster is either the onset of the first syllable of the superfoot or it is followed by either stressed vowel or a non-neutral vowel within a foot.

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1) Medial clusters mean that consonant clusters occurring between vowels so that we do not consider word-initial or word-final consonant clusters in this study.

The format of this paper is as follows. Section 2 provides the data of the [nt] cluster with its detailed description. Section 3 briefly introduces previous analyses of the [nt] clusters along with their analytic drawbacks. Section 4 puts forth an alternative account of the medial [nt] cluster based on a specific foot structure. Section 5 summarizes the analysis and its implications for phonology.

2. Data Presentation

The examples of the medical [nt] cluster in English are divided into two groups. The first examples show optional deletion of the [t] in the [nt] when the target consonant appears in a prosodically non-prominent onset position as shown in (1). The examples are from Chung (2007, 2009) and we slightly modified the representation method.

(1) Non-realization of the [t]

a. enter	→ [énər]	e. sentence	→ [sénəns]
b. identity	→ [aydénətɪ]	f. pentagon	→ [pénəgan]
c. fantasy	→ [fǽnəsɪ]	g. quantity	→ [kwánətɪ]
d. Internet	→ [ínərnèt]	h. sentiment	→ [sénəmənt]

The [t] occurring as the onset of an unstressed nucleus which is the non-head syllable in trochaic foot structure as in (é.nər) is not realized in the output. The interesting aspect of the robust deletion pattern in (1) is that even an onset consonant which is assumed to be in a more prominent position as compared to a syllable coda is deleted while a coda segment in a stressed syllable is realized in the output. From the sense of Beckman (1997, 1998, 2004) and Lombardi (1999), it can be understood that the conflict between two syllables are resolved in favor of the stressed syllable which is implemented as the resistance to deletion of the [n] in the stressed syllable in (1).

While the [t] in the medial [nt] is deleted in prosodically non-prominent syllable in a foot, its voiced counterpart in English is faithfully realized in the output as shown in (2).

(2) Realization of the [d]

a. gender	→ [dʒéndər]	e. wonder	→ [wʌ́ndər]
b. render	→ [réndər]	f. handle	→ [hǽndəl]
c. fender	→ [féndər]	g. sander	→ [sǽndər]
d. random	→ [rǽndəm]	h. under	→ [ʌ́ndər]

As in (2) the [d] in the [nd] is realized in the output which has the identical environment where the [t] deletes. This indicates that the medial [nd] cluster is more resistant to a certain phonological pressure of deleting the post-nasal coronal stop in a prosodically non-prominent position.

The examples in (3) show that the [t] in the medial [nt] occurs in a different environment from what we observed in (1). That is, the [t] in the [nt] occurs as onset of a stressed syllable. Thus, the [t] is faithfully realized in the output from (3a) to (3c). The other different environment where the [t] is realized in the output is that the [t] is the first segment of an onset cluster. In such cases, the [t] does not undergo deletion as can be seen from (3d) to (3f). The third type of examples where the [t] does not delete in the medial [nt] cluster is that the [t] is followed by an unstressed non-neutral vowel as illustrated from (3g) to (3i).

(3) Realization of the [t] in the [nt] in a stressed syllable

a. intelligent	→ [ɪntélədʒənt]	*[ɪnéləʤənt]
b. centennial	→ [sɛnténɪəl]	*[sɛnénɪəl]
c. contain	→ [kəntén]	*[kənén]
d. contradict	→ [kántrədɪkt]	*[kánrədɪkt]
e. central	→ [sɛ́ntrəl]	*[sɛ́nrəl]
f. introvert	→ [ɪ́ntrəvə̀:rt]	*[ɪ́nrəvə̀:rt]
g. mentor	→ [mɛ́ntɔ:r]	*[mɛ́nɔ:r]
h. intern	→ [ɪ́ntə:rn]	*[ɪ́nə:rn]
i. contest	→ [kántɛst]	*[kánɛst]

The examples in (4) show rather different results of the realization of the medial [nt] cluster as compared to the examples in (1). Even though the medial [nt] cluster occurs in the identical environment where the [t] appears as the onset of an unstressed syllable preceded by a stressed syllable ending with the

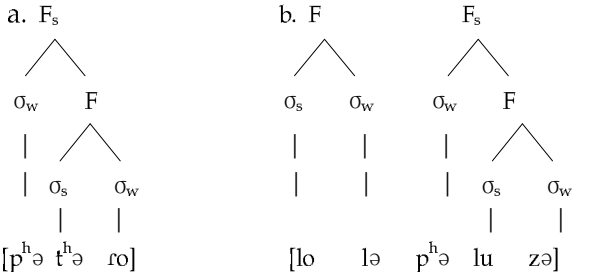
[n], the output results of the examples in (4) are different from those in (1). Glottalized examples in (4) are from Avery and Ehrlich (1992: 43).

(4) Realization of the [t] in the [nt]

a. contemplate → [kʰántʰəmplèt]
b. intimation → [ɪ̀ntʰəméʃən]
c. continent → [kánʔənənt]
d. mountain → [máwnʔən]
e. fountain → [fáwnʔən]

The onset [t] of the second syllable in (4a) and (4b) fails to undergo deletion but it is aspirated instead. This is unexpected from the prosodic perspective because the [t] is the onset of the unstressed syllable where voiceless stops in English are generally not aspirated. On the other hand, the examples from (4c) to (4e) show that the [t] becomes glottalized instead of deletion. All the examples in (4) do not seem to follow the deletion pattern we observed in (1). This may imply that the target consonant undergoes different process due to differences in foot structure or undergoing a syllabically conditioned process. In order to explain the aspiration of the [t] in (4a) and (4b), we adopt a foot structure proposed by Jensen (2000), Davis and Cho (2003), and Davis (2005). The foot structure is called "superfoot"[2] which consists of a non-prominent initial syllable plus a trochaic foot as illustrated in (5).

(5) Foot structure of *potato* and *lolapalooza*



(F=foot, F_s=superfoot, σ_w=stressless syllable, σ_s=stressed syllable)

2) The readers are referred to Davis and Cho (2003) and Davis (2005) for the detailed rationale of proposing the superfoot structure.

Davis (2005) argues that voiceless stops in English are aspirated foot-initially such that the voiceless onset stop of the unstressed first syllable in *potato* and that of the third syllable in *lolapalooza* are aspirated because two syllables occur foot-initially. That is, the first syllable of *potato* is the first syllable of the superfoot while the third syllable of *lolapalooza* is the first syllable of the superfoot occurring after the first trochaic foot. Thus, the proposed superfoot predicts the distribution of aspiration in English. If we apply this superfoot to the first two examples in (4), the second syllable in *contemplate* and *intimation* would be the first syllable of a superfoot: (k^{h}án){t^{h}əm(p^{h}lèt)} and (ìn){t^{h}ə(méʃən)} where curly brackets indicate a superfoot and parentheses signal a foot. Thus, the unexpected aspiration of the [t] in (4a) and (4b) can be explained by employing the superfoot structure.

With respect to glottalization in the examples from (4c) to (4e), glottalization can be explained by proposing an environment for glottalization where the onset [t] in a stressless syllable followed by a coronal nasal coda is glottalized as in *button, cotton, curtain, mitten,* and *certain.* Thus, the [t] in the examples *continent, mountain,* and *fountain* either being the onset of an unstressed syllable in a dactylic foot or a trochaic foot is glottalized instead of deletion. So far we have described the various realizations of the [nt]. In the next section, we will briefly review two previous analyses and their problems.

3. Previous Analyses

The realization of the medial [nt] cluster is discussed by Ladefoged (2001:58) in which the voiceless alveolar stop in English is lost when it is preceded by the [n], which is the coda of a preceding syllable. This is formulated in (6).

(6) /t/ → Ø / n.___
"In words such as *painter* and *splinter*, the /t/ is lost."

Thus, the rule in (6) implies that the onset of an unstressed syllable is deleted when it is preceded by the homorganic nasal over a syllable boundary. Ladefoged proposed an insightful concept of deletion process in English but he

did not provide any rationale when the [t] in the [nt] is deleted in those words. This idea of deletion in English can account for the examples in (1) but it cannot be extended to the examples in (4) where the target consonant does not undergo deletion.

The other previous analysis is framed in constraints and their ranking by Chung (2007, 2009) based on the proposal of Pater (1996, 1999, 2004) in which a post-nasal voiceless segment is not allowed due to phonetically grounded reasons citing Huffman (1993: 310). The phonetically grounded constraint is presented in (7).

(7) *NÇ
No nasal/voiceless obstruent sequences.

The markedness constraint indicates that nasal-voiced obstruent sequences are preferred to nasal-voiceless obstruent sequences cross-linguistically. If this markedness constraint is widely accepted by languages, it is possible for languages to avoid this phonetically undesirable nasal-obstruent clusters. Paper (1999) introduces five different strategies that languages adopt to bypass the unwanted consonant sequences as in (8) but one case is not attested.

(8) Strategies for avoiding NÇ clusters
a. Nasal substitution: Indonesian
/məN_1-p$_2$ilih/ → [mə$m_{1,2}$-ilih] 'to choose, to vote'
b. Nasal deletion: Kelantan Malay
/N_1 T_2/ → [T_2]
c. Post-nasal voicing: Puyo Pungo Quechua
/kam$_1$-p$_2$a/ → [kam$_1$-b$_2$a] 'yours'
d. Denasalization: Mandar
/maN_1-t$_2$unu/ → [mat$_1$-t$_2$unu] 'to burn'
e. Vowel insertion: unattested

In order to explain the optional deletion of the [t] in the medial [nt] cluster, Chung (2007) modified the marked sequence of a nasal plus a voiceless obstruent by confining the [NT] sequences to a homorganic coronal combination. This is a trigger constraint of the [t] deletion in English. Along

with this markedness constraints, Chung proposed the following constraints in (9) and their ranking in (10).

(9) Constraints (Chung, 2007: 160)
a. Max-CL: A prevocalic cluster should have its correspondents in the output.
b. Ident-ObsVce: Correspondent obstruents between the input and the output are identical in their specification for voice.
c. Max-IO(nas): Input nasal segments must have output correspondents.
d. Max-IO(obs): Input obstruents must have output correspondents.
e. *NÇ-Cor: No coronal nasal plus voiceless coronal stop sequence over a syllable boundary.
f. Max-Ons-V: A singleton onset consonant should be faithfully realized when no followed by a short neutral vowel [ə].

(10) Constraint ranking
a. Deletion of the [t]
Max-CL ≫ Max-Ons-V ≫ Ident-ObsVce, Max-IO(nas) ≫ *NÇ-Cor ≫ Max-IO(obs)
b. Non-deletion of the [t]
Max-CL ≫ Max-Ons-V ≫ Ident-ObsVce, Max-IO(nas) ≫ Max-IO(obs) ≫ *NÇ-Cor

As presented in (10a), Max-CL is undominated in the analysis because the first member of a consonant cluster [t] does not undergo deletion even though it is preceded by the coda [n] of the preceding syllable. Thus, this constraint must be ranked higher than *NÇ-Cor. If the ranking is reversed, the [t] in the t-initial cluster should be deleted. Max-Ons-V also dominates *NÇ-Cor in order to preserve the [t] followed by a non-neutral vowel as shown by the example given from (3g) to (3i). This ranking indicates that the target [t] is deleted when followed by a stressless neutral vowel in English. The two faithfulness constraints such as Ident-ObsVce and Max-IO(nas) dominate *NÇ-Cor because the voicing feature specification of the [t] does not change to avoid the NÇ sequence and the deletion of the nasal segment strategy is not employed in English either. The trigger of the [t] deletion, *NÇ-Cor, however dominates the lowest ranking Max-IO(obs) such that the [t] of the [nt] medial cluster is deleted to avoid the NÇ sequence. The following table explains the optional

deletion of the [t] in English. In the table, we include the relevant constraints for the evaluation.

(11) /fæntəsɪ/ → [fǽnəsɪ] 'fantasy'

/fæntəsɪ/	Id-ObsVce	Max-IO(nas)	*NÇ-Cor	Max-IO(obs)
a. fǽn.tə.sɪ			*!	
☞ b. fǽ.nə.sɪ				*
c. fǽn.də.sɪ	*!			
d. fǽ.tə.sɪ		*!		

The given ranking in (11) selects candidate (b) as optimal where the post-nasal coronal obstruent [t] is deleted to avoid the NÇ sequence. This is achieved at the cost of violating the lowest ranking Max-IO(nas).

The non-deletion of the [t] in the [nt] can be accounted for by the constraint ranking given in (10b) where the ranking between *NÇ-Cor and Max-IO(obs) is reversed. The first of its case is exemplified by an example where the [t] is the onset of a stressed syllable as shown in (12a). The second of its case is illustrated an example when the t-initiating cluster is preceded by the coda [n] in the preceding syllable as demonstrated in (12b).

(12a) /kənten/ → [kəntén] 'contain'

/kənten/	Id-ObsVce	Max-IO(nas)	Max-IO(obs)	*NÇ-Cor
☞ a. kən.tén				*
b. kən.dén	*!			
c. kə.tén		*!		
d. kə.nén			*!	

(12b) /sɛntrəl/ → [sɛntrəl] 'central'

/sɛntrəl/	Max-CL	Id-ObsVce	Max-IO(nas)	Max-IO(obs)	*NÇ-Cor
☞ a. sɛn.trəl					*
b. sɛn.rəl	*!			*	
c. sɛn.drəl		*!			
d. sɛt.rəl			*!		

The final case where the [t] does not undergo deletion is illustrated by an

example in which the deletion target [t] is not followed by a stressless neutral vowel as shown by the examples given from (3g) to (3i).

(13) /mɛntɔr/ → [mɛ́ntɔr] 'mentor'

/mɛntɔr/	Max-Ons-V	Id-ObsVce	Max-IO(nas)	Max-IO(obs)	*NÇ-Cor
☞ a. mɛ́n.tɔr					*
b. mɛ́.nɔr	*!			*	
c. mɛ́n.dɔr		*!			
d. mɛ́.tɔr			*!		

The faithful realizations of the [t] in the [nt] in (12) and (13) show that the ranking between *NÇ-Cor and Max-IO(obs) is important in that permutating the constraints induces the variable pronunciation of the medial [nt] cluster in English. It seems that the constraint-based account proposed by Chung can explain the examples given from (1) to (3) but the data given in (4) can be problematic to Chung's analysis due to the different realizations of the [t]. Furthermore, the target of deletion in (4a) and (4b) undergoes aspiration even in prosodically weak position. It has been claimed that the onset position of an unstressed syllable is not a position where voiceless stops are aspirated in English. So if we apply the constraint ranking employed by Chung (2007), it will select the incorrect optimal form as shown by the table in (14).

(14) /kantəmplet/ → [k^{h}ánt^{h}əmp^{h}lèt] 'contemplate'

/kantəmplet/	Id-ObsVce	Max-IO(nas)	*NÇ-Cor	Max-IO(obs)
☞ a. k^{h}án.t^{h}əm.p^{h}lèt			*!	
b. k^{h}án.dəm.p^{h}lèt	*!			
☜ c. k^{h}á.nəm.p^{h}lèt				*
d. k^{h}á.t^{h}əm.p^{h}lèt		*!		

The constraint ranking in (14) selects candidate (c) as optimal, which is an incorrect winner indicated by "☜." The correct optimal form is (14a), but it loses out due to its violation of *NÇ-Cor, which the incorrect optimal form satisfies. A possible way to explain this example with the proposed constraint ranking is to permute the ranking between *NÇ-Cor and Max-IO(obs). This

ranking chooses candidate (a) as optimal but this raises a question with respect to aspiration of the [t] on the onset of the stressless second syllable. This trapped unstressed second syllable is not a canonical syllable at which a voiceless stop is aspirated in English (Jensen, 2000; Davis, 2005). Thus, permuting the relevant constraints does not solve the problem.

Concerning the other set of examples from (4c) to (4e), if we apply the constraint ranking in (14) to such examples, the constraint ranking selects the glottalized post-nasal segment as optimal, which can be construed as unexpected result of the analysis. However, the deletion of the [t] is an optional process, so is glottalization for native speakers of English. Thus, in order to select the non-variant pronunciation of *mountain*, we use the ranking change between *NÇ-Cor and Max-IO(obs) as Chung did to explain the non-deletion pronunciation of the medial [nt] sequence. However, even if we change the ranking, we still get the same candidate with the glottalized [t] as our winning candidate. The constraint tables in (15) show the results of applying the constraint ranking targeting the deletion of the [t] and ranking permutation for non-deletion of the [t].

(15a) /mawntən/ → [máwn?ən] 'mountain'

/mawntən/	Id-ObsVce	Max-IO(nas)	*NÇ-Cor	Max-IO(obs)
a. máwn.tən			*!	
☜ b. máw.nən				*!
c. máw.tən		*!		
d. máwn.dən	*!			
☞ e. máwn.?ən				

(15b) /mawntən/ → [máwn?ən] 'mountain' (permutated ranking)

/mawntən/	Id-ObsVce	Max-IO(nas)	Max-IO(obs)	*NÇ-Cor
☞ a. máwn.tən				*!
b. máw.nən			*!	
c. máw.tən		*!		
d. máwn.dən	*!			
☜ e. máwn.?ən				

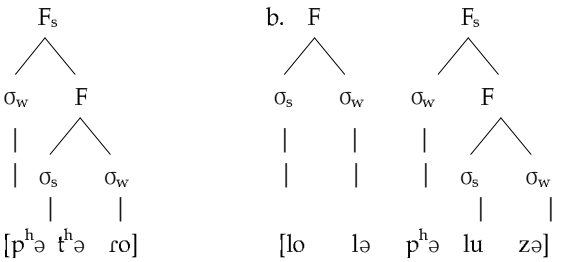
Chung's analysis can inadvertently explain the glottalization of the [t] as in (15a) but the analysis cannot explain non-glottalized realization of the [t] as shown in (15b). Thus, in the next section we provide an alternative account for the realizations of the medial [nt] cluster in English by adopting the analytic concept not based on the syllable but on the foot structure we briefly discussed in section 2.

4. An Alternative Analysis

An analysis we put forth in this section is based on an assumption that the deletion of the [t] in the [nt] medial cluster is implemented to avoid the marked NÇ cluster cross-linguistically (Pater, 1996, 1999, 2004). We also hypothesize that the domain of implementing the undesirable NÇ cluster is within a foot such that if the medial NÇ occurs in prosodically weak position inside a foot, the onset of the weak syllable optionally deletes when preceded by [n].

With respect the foot structure, we follow Davis and Cho (2003) and Davis (2005) that the standard foot structure of English is trochaic. At the same time we also employ another foot structure proposed by Jensen (2000), Davis and Cho (2003), and Davis (2005), which is an extended foot structure based on the trochaic foot. The proposed foot structure is called 'superfoot' composed of a weak syllable plus a trochaic foot {W(SW)}, which can explain the distribution of aspiration and glottal fricative [h] in North American English. The superfoot given in (5) can provide us an insightful analytic tool to account for the realization of the medial [nt] cluster in English. The superfoot is repeated in (16).

(16) Foot structure of potato and lolapalooza



(F=foot, F_s=superfoot, σ_w=stressless syllable, σ_s=stressed syllable)

Based on the foot structure we adopt, we present constraints that are used in the analysis. We use some of the constraints from Chung (2007, 2009) and Davis (2005) but with some changes in their domain and definition.

(17) Constraints for the medial [n] realizations

a. *NC̩-Cor]$_F$
No homorganic medial coronal nasal/voiceless obstruent sequences within a foot. (cf. Pater, 1999; Chung, 2007, 2009)

b. Max-nas: Input nasals have output correspondents.

c. Max-obs: Input obstruents have output correspondents.

d. Glottalization: Glottalize the onset [t] of an unstressed vowel when followed by a coronal nasal tautosyllabically.

e. *Ambi: An input segment branching into two syllables in the output is not allowed.

f. Faith-cons: A consonant before a non-neutral vowel is faithfully realized in the output. (cf. Chung, 2007)

g. AlignL(Ft, [sg]): Align the left edge of the foot with the feature [spread glottis]. (cf. Davis, 2005)

h. *[s.g]: The feature [spread glottis] is prohibited.

I. Faith-CL: Prevocalic consonant clusters in the input have their correspondents in the output. (cf. Chung, 2007)

j. *ʔ: Glottal stop [ʔ] is prohibited.

*NC̩-Cor]$_F$ is a trigger constraint which prohibits a homorganic medial coronal nasal-obstruent sequence within a foot. This constraint is not highly ranked in the analysis. Between the two faithfulness constraints such as Max-nas and Max-obs, Max-nas dominates Max-obs because avoiding the marked NC̩ sequence is generally resolved by deleting the [t].[3] Max-nas dominates *NC̩-Cor]$_F$ while *NC̩-Cor]$_F$ is ranked over Max-obs in the analysis.

3) Between nasals and obstruents, nasals generally do not become the target of deletion while obstruents are the frequent target of deletion in English. Nasals are, however, deleted when two nasals occur in the syllable coda as in *colum<n>* and *autum<n>*. Except for such a specific tatutosyllabic condition, nasals do not delete whereas when a nasal and an obstruent occur in the syllable coda, an obstruent deletes as in *si<g>n* and *paradi<g>m* on behalf of a nasal to satisfy the syllabic well-formedness condition in English (Borowsky, 1986).

AlignL(Ft, [sg]) and *NÇ-Cor]$_F$ do not show any particular ranking between them because each of them requires different conditions in the output. We rank Max-nas over AlignL(Ft, [sg]) by transitivity because Max-nas dominates *NÇ -Cor]$_F$ while AlignL(Ft, [sg]) and *NÇ-Cor]$_F$ are equally ranked. On the other hand, AlignL(Ft, [sg]) dominates *[s.g] because AlignL(Ft, [sg]) is satisfied at the cost of violating *[s.g]. Faith-cons should be ranked higher than *NÇ-Cor]$_F$ in the analysis because the segment [t] before a non-neutral vowel is still maintained in the output at the cost of violating *NÇ-Cor]$_F$, which implies that the deletion of the [t] is limited to before an unstressed schwa when preceded by the [n] inside the foot. At the same time, Glottalization also dominates *NÇ -Cor]$_F$ since glottalization of the [t] deprives the place of articulation of the [t] making the nasal-glottal sequence to avoid the violation of *NÇ-Cor]$_F$.

Glottalization also dominates *Ambi because glottalization is induced by branching an input coronal nasal into two different syllables in the output incurring a violation of *Ambi. This low-ranking constraint does not show any particular ranking with *[s.g], but these two constraints are dominated by Max-obs in the analysis. Faith-CL, requires that prevocalic sequence in the input be faithfully realized in the output. This constraint is ranked high in English because onset clusters enjoy a certain privilege as compared to a singleton onset when followed by a stressless vowel. For example, singleton coronals [t, d] are flapped in *wá[ɾ]er* and *hí[ɾ]ing* while the [t, d] of the first element in a cluster does not undergo flapping as in *mé[tr]ix* and *hý[dr]ogen*. We rank this constraint along with the high ranking Max-nas in the analysis. The final constraint, *ʔ, does not allow the glottal stop in the output. This constraint is not ranked high in the analysis and is ranked lower than Max-obst. If the ranking between them is reversed, a candidate with the deletion of an obstruent will wrongly be selected as optimal instead of a candidate with a glottalized segment. The low ranking *ʔ does not show any ranking with *[s.g] and *Ambi.

Based on the constraints and their ranking, we first present a table in which the [t] in the medial [nt] is not realized in the output. In the constraint tables, we include relevant constraints.

(18a) /fæntəsɪ/ → [fǽnəsɪ] 'fantasy'

/fæntəsɪ/	Max-nas	AlignL(Ft, [sg)	*NÇ-Cor]$_F$	Max-obst
a. (fǽn.tə.sɪ)		*	*!	
☞ b. (fǽ.nə.sɪ)		*		*
c. (fǽ.tə.sɪ)	*!	*		

(18b) /ɛntər/ → [ɛ́ntər] 'enter'

/ɛntər/	Max-nas	AlignL(Ft, [sg)	*NÇ-Cor]$_F$	Max-obst
a. (ɛ́n.tər)		*	*!	
☞ b. (ɛ́.nər)		*		*
c. (ɛ́.tər)	*!	*		

As shown in (18a) and (18b), the proposed constraint ranking can explain the deletion of the [t] in the medial [nt] cluster in English. AlignL(Ft, [sg]) is violated by all candidates because the left edge of the foot is not aligned with the feature [spread glottis]. Because of its nature, it is violated if an initial segment of the foot is either sonorants or voiced obstruents.[4)]

The ranking in (18) also can explain the examples given in (2) where the coronal nasal is not followed by the [t] but by the [d]. In such cases, the markedness constraint does not play any role since it is trivially satisfied selecting the faithful output to the input as optional which is presented in (19).

(19) /dʒɛndər/ → [dʒɛ́ndər] 'gender'

/dʒɛndər/	Max-nas	AlignL(Ft, [sg])	*NÇ-Cor]$_F$	Max-obst
☞ a. (dʒɛ́n.dər)		*		
b. (dʒɛ́.nər)		*		*!
c. (dʒɛ́.dər)	*!	*		

The faithful output to the input form in (a) is selected optimal since it only

4) Davis and Cho (2003) and Davis (2005) propose the [s.g, +voice] constraint which prohibits the realization of [spread glottis] on sonorants and voiced obstruents such that the constraint is anti-aspiration on sonorants and voiced obstruents. This constraint is undominated in English but we do not include it in the analysis because it does not bring up any particular issue in the analysis. With respect to the realization of [spread glottis] on voiceless fricatives and affricates in English, we assume that the feature [spread glottis] does not appear on them.

violates Align (Ft, [sg]) but the violation of the constraint is not crucial because all candidates incur the violation of the alignment constraint.

The next set of examples given in (3) illustrates that the post-nasal [t] does not undergo deletion. In the first case, the post-nasal [t] is followed by a stressed vowel as the examples given from (3a) to (3c). In the second environment, the post-nasal [t] is the first element of a consonant cluster as presented from (3d) to (3f). The final case of examples from (3g) to (3i) shows that the [t] in the medial [nt] is followed by a non-neutral stressless vowel. The following tables in (20) illustrate each case where relevant constraints are included in the evaluation.

(20a) /sɛntɛnɪəl/ → [sɛntɛ́nɪəl] 'centennial'

/sɛntɛnɪəl/	Max-nas	AlignL (Ft, [sg])	NÇ-Cor]$_F$	Max-obst	*[s.g]
☞ a. {sɛn(t^{h}ɛ́.nɪ)}əl		*	*		*
b. {sɛn(tɛ́.nɪ)}əl		**!	*		
c. {sɛ(nɛ́.nɪ)}əl		**!		*	
d. {sɛ(t^{h}ɛ́.nɪ)}əl	*!	*			*

(20b) /sɛntrəl/ → [sɛ́ntrəl] 'central'

/sɛntrəl/	Max-nas	Faith-CL	AlignL (Ft, [sg])	NÇ-Cor]$_F$	Max-obst	*[s.g]
☞ a. (sɛ́n.trəl)			*	*		
b. (sɛ́n.t^{h}rəl)			*	*		*!
c. (sɛ́n.rəl)		*!	*		*	
d. (sɛ́.trəl)	*!		*			

(20c) /kantɛst/ → [kántɛst] 'contest'

/kantɛst/	Max-nas	Faith-cons	AlignL (Ft,[sg])	NÇ-Cor]$_F$	Max-obst	*[s.g]
☞ a. (k^{h}án.tɛst)				*		*
b. (kán.t^{h}ɛst)			*!	*		*
c. (k^{h}án.t^{h}ɛst)				*		**!
d. (kán.tɛst)			*!	*		
e. (k^{h}á.nɛst)		*!			*	*

As shown in (20a), AlignL (Ft, [sg]) plays an important role in eliminating a candidate where the foot-initial [t] does not become aspirated as in (b) which incurs an additional violation of the alignment constraint compared to the winning candidate. Candidate (c) loses out due to its deletion of the [t] which deprives a segment capable of being aspirated and it induces an additional violation of the alignment constraint.

(20b) illustrates the important role of Faith-CL which eliminates candidate (c) which also incurs a violation of Max-obst. Candidate (b) loses out because it aspirates the onset [t] of a foot-internal syllable, which is prosodically weak position and is not the canonical position for aspiration in English. The unnecessary aspiration on the segment includes a violation of *[s.g], which eliminates the candidate from the competition. The final table shows the role of Faith-cons which eliminates candidate (e). Without this violation, candidate (e) would be selected as optimal.

The final two sets of examples in which the syllable onset [t] followed by a stressless vowel do not undergo deletion even though the [t] occurs in the deletion environment. Such examples given in (4) pose a problem to a syllable-based analysis as we briefly discussed in section 3. In order to explain such recalcitrant examples, the proposed constraints and their ranking used in this section select the most harmonious output form.

(21) /kantəmplet/ → [k^{h}ánt^{h}əmp^{h}lèt] 'contemplate'

/kantəmplet/	Max-nas	AlignL (Ft, [sg])	NÇ-Cor]$_{F}$	Max-obst	*[s.g]
☞ a. (k^{h}án){t^{h}əm(p^{h}lèt)}					***
b. (k^{h}án){təm(p^{h}lèt)}		*!			**
c. (kán){t^{h}əm(p^{h}lèt)}		*!			**
d. (k^{h}án){t^{h}əm(plèt)}		*!			**
e. (k^{h}á.nəm)(p^{h}lèt)				*!	**

An interesting issue in (21) is that the unstressed syllable trapped between two stressed syllables does not form a trochaic foot with the preceding syllable as in (a), (b), and (c) but creates a superfoot with the following stressed syllable. Candidate (e) where the onset [t] in the non-head foot syllable becomes the target of deletion and it undergoes deletion concomitantly violating Max-obst

which the winning candidate satisfies. Candidates from (b) to (d) are suboptimal due to their crucial violation of AlignL (Ft, [sg]), but they do not violate *NÇ-Cor]$_F$ because the nasal-obstruent sequence does not occur within a foot. Because of this superfoot structure, the onset [t] of the unstressed second syllable becomes the initial syllable of the superfoot which is the natural position for a voiceless stop to be aspirated to satisfy the alignment constraint. This kind of generalization for aspiration in English cannot be established if the analysis is based on syllables.

Another set of examples where the onset [t] in the unstressed syllable does not delete is given from (4c) and (4e). The [t] in these examples undergoes glottalization. The relevant constraints for the glottalization are Glottalization, *Ambi, and *ʔ. In the analysis, Glottalization dominates both *Ambi and *ʔ as illustrated in (22).

(22) /kantənənt/ → [k^{h}ánʔənənt] 'continent'

/kantənənt/	Glottal	AlignL (Ft, [sg])	NÇ-Cor]$_F$	Max-obst	*ʔ	*Ambi
a. (k^{h}án.t^{h}ə.nənt)			*!			
b. (k^{h}án.tə.nənt)			*!			
☞ c. (k^{h}án.ʔən.nənt)					*	*
d. (k^{h}á.nə.nənt)				*!		
e. (k^{h}án.tən.nənt)	*!		*			*

The stressless second syllable in (22) cannot form a superfoot with the following unstressed syllable, which forces the second syllable to be included a dactylic foot. Since the second syllable occurs within a foot, the onset [t] becomes the deletion target but the [t] is glottalized because it is in the appropriate environment for glottalization as shown in (c). The winning candidate does not violate *NÇ-Cor]$_F$ because the glottal segment is assumed to be under pharyngeal place of articulation (McCarthy, 1994), which is regarded as the least marked place of articulation. By undergoing glottalization, candidate (c) violates *ʔ and *Ambi. The given ranking Glottalization ≫ *ʔ, *Ambi implies that glottalize the [t] only when it is followed by a tautosyllabic [n]; otherwise, do not implement an unnecessary glottalization.

The final issue we need to discuss is how we deal with variant realizations

of the medial [nt]: [nt]~[n] whose data is given in (1). In constraint-based analysis, variant realizations have been explained by permutating the relevant constraints which are ranked rather low in the analysis. The variant realizations in (1) and (4c-e) can be accounted for by reversing the ranking between *NÇ -Cor]$_F$ and *ʔ which also leads Max-obst to dominate *NÇ-Cor]$_F$. If *ʔ and Max-obst dominate *NÇ-Cor]$_F$, the permutated ranking selects a candidate with both segments within a foot, which is demonstrated in (23).

(23a) /fæntəsɪ/ → [fǽntəsɪ] 'fantasy'

/fæntəsɪ/	Max-nas	*ʔ	Max-obst	*NÇ-Cor]$_F$
☞ a. (fǽn.tə.sɪ)				*
b. (fǽ.nə.sɪ)			*!	
c. (fǽ.tə.sɪ)	*!			

(23b) /kantənənt/ → [k^{h}ántənənt] 'continent'

/kantənənt/	Glot	*ʔ	Max-obst	NÇ-Cor]$_F$	*[s.g]	*Ambi
a. (k^{h}án.t^{h}ə.nənt)				*	**!	
☞b. (k^{h}án.tə.nənt)				*	*	
c. (k^{h}án.ʔən.nənt)		*!			*	*
d. (k^{h}á.nə.nənt)			*!		*	
e. (k^{h}án.tən.nənt)	*!				*	*

The ranking change in (23) does not affect other sets of examples given from (2) to (4a-b), which implies that the permutated ranking still selects the same optimal forms in other types of examples. Note that the winning candidate in table (23b) where the onset of the unstressed second syllable is not aspirated. This again shows that the voiceless stops are not generally aspirated if they occur as the onset of non-prominent syllable within a foot in English. Thus, foot-based approach to medial [nt] clusters in English can provide an account that can include different realizations of the medial [nt] clusters of English. The combined constraints ranking used in this study are given in (24).

(24) a. The [t] deletion in [nt] and other sets of data
Faith-CL, Max-nas, Glottalization, Faith-cons ≫
AlignL (Ft,[sg]), *NÇ-Cor]$_F$ ≫ Max-obst ≫ *ʔ, *[s.g], *Ambi
b. The realization of [nt]

Faith-CL, Max-nas, Glottalization, Faith-cons ≫ AlignL (Ft, [sg]) ≫ *ʔ ≫ Max-obst ≫ *NÇ-Cor]$_F$ ≫ *[s.g], *Ambi

5. Conclusion

This study has provided an alternative analysis based on a foot structure proposed by Jensen (2000), Davis and Cho (2003), and Davis (2005). The foot structure adopted in this study provides a useful analytic tool for the account of the medial [nt] realizations. The difference between a syllable-based account (Ladefoged, 2001; Chung, 2007, 2009) and a foot-based account in this study is that the former limits the target of deletion before a stressless vowel while the latter restricts the deletion target to a non-prominent syllable within a foot. The syllable-based analysis could not explain the data set where the onset [t] of an unstressed vowel is aspirated instead of deletion as in *contemplate*. Other examples that are problematic to the syllable-based account have to do with glottalization in the onset of a stressless syllable within a foot. Since the domain of the deletion in this study is a foot, we could capture the variant realizations of the medial [nt] cluster in English.

There are several implications of this study for phonology. Firstly, the foot-based account provides a phonologically important generalization that aspiration occurs at the left edge of a foot,[5] which can be construed as the implementation of strengthening (cf. Beckman, 1997, 1998, 2004; Lombardi, 1999). Secondly, in addition to the deletion of the [t], there are a few more strategies that English may adopt to avoid the marked medial [nt] sequence such as glottalization and forming a superfoot to separate the [nt] cluster into two different feet, which might be added to the typology of avoiding the NÇ cluster. Thirdly, a voiceless onset of an unstressed syllable can be aspirated if it can form a superfoot with the following trochaic foot. In view of these complicated realizations of the medial [nt] cluster in English, an experimental phonetic research should provide acoustic aspects of it in the future.

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5) The original concept and the distribution of aspiration should be credited to Davis and Cho (2003) and Davis (2005), who develop and extend the important roles of superfoot proposed by Jensen (2000).

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