https://doi.org/10.24303/lakdoi.2025.33.3.71

An Aspect of Phonological Processes Motivated by an Epenthetic Vowel*

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Chung, Chin-Wan. (2025). An aspect of phonological processes motivated by an epenthetic vowel. *The Linguistic Association of Korea Journal, 33*(3), 71-95. The study on epenthetic vowels has focused on their roles in adjusting unallowed structures in languages. However, an intriguing aspect of the vowel epenthesis is that it actively participates in and engages in phonological processes. Considering this, the current study collects and investigates the roles of epenthetic vowels. We observe that an epenthetic vowel induces or interacts with other phonological factors in spirantization, palatalization, obstruent voicing, consonant deletion, and stress attraction in languages. Their behaviors in processes suggest that they behave like lexical vowels on specific conditions in some aspect, even though they are different from lexical vowels phonetically and phonologically. In addition, epenthetic vowels act as a prosodic non-head or head foot member in stress attraction. Especially, the inserted vowel should be in an appropriate position to be a target of the stress attractor; otherwise, it may disrupt the regular stress pattern in Winnebago. The constraint-based account provided in this study highlights how relevant constraints and their ranking can explain various phonological processes. The analysis opens up a possibility of research on inserted vowels and phonological processes.

Key Words: epenthetic vowel, interaction, constraint, phonological processes, stress attraction

* This research was supported by National University Development Project (Glocal University 30 project) at Jeonbuk National University in 2024. I am thankful to anonymous reviewers for their helpful comments. Any remaining errors are my own responsibility.

1. Introduction

It has traditionally been argued that a vowel is epenthesized to repair unallowable structures in languages. According to Abdul-Karim (1980: 32-33), a vowel is obligatorily inserted to break up a consonant cluster, consisting of an obstruent and a sonorant: */ʔsm/* → *[ʔsim]* 'name.' On the other hand, a vowel epenthesis optionally occurs when an obstruent sequence forms a coda cluster: */sabt/* → *[sabit]* 'Saturday.' The insertion of a vowel to adjust the phonotactics of one language has been accounted for by different perspectives: enhancing perception of consonant phonetic signals (Broselow, 1982), licensing a drifting segment (Itô, 1989), or being inserted among consonants (Côté, 2000). In addition, other well-known issues of vowel insertion are the position and quality of an epenthetic vowel and the difference between an underlying and an inserted vowel. Concerning the first issue, the landing site of an epenthetic vowel is language particular: Cairene Arabic (Itô, 1989: 242) inserts a vowel after the second consonant in a tri-consonantal sequence (*/ʔul-t-l-u/* → *[ʔul.ti.lu]* 'I said to him'), while Iraqi Arabic epenthesizes a vowel after the first consonant in three consecutive consonants (*/gil-t-l-a/* → *[gi.lit.la]* 'I said to him.'

As to the quality of an epenthetic vowel, it is determined by either a default one, the least unmarked vowel, or contextually influenced: the frequent default epenthetic vowels are [i], [ə], or [ɨ] (cf. de Lacy, 2006: 289). On the other hand, an epenthetic vowel is affected by the surrounding vowel, and it leads to an inserted vowel to copy a preceding or following vowel. In Welsh (Awbery, 1984: 88), a coda cluster is resolved by inserting a vowel, which copies a preceding vowel (gwande → gwa:d**a**n 'soles, sole'). The final issue is the difference between an epenthetic and an underlying vowel. If an epenthetic vowel is schwa, it is shorter and less loud than a lexical vowel.

Considering all these characteristics of an epenthetic vowel, one can ask an intriguing question about the role of an inserted vowel in phonological processes. According to Hall (2011, 1586-87), an epenthetic vowel does not seem to play a role in metrical structure or plays a limited role. For example, stress falls on a CVC-penult syllable. However, when a closed penult syllable contains an epenthetic vowel, the syllable does not attract the stress in Lebanese Arabic: */fihim-na/* → *[fi.hím.na]* 'he understood us' vs. */fihm-na/* → *[fí.him.na]* 'our understanding.' In the second structure, the stress does not fall on the closed penult syllable. But it falls on the syllable before the penultimate syllable, containing an epenthetic vowel, indicated in underlined and bold-faced.

On the other hand, an epenthetic vowel can play a variable metrical role in Mohawk. If an inserted vowel to fix consonant clusters is the nucleus of a closed syllable, the inserted vowel attracts stress. Stress does not fall on an open syllable with an epenthesized vowel. Compared to this, if a vowel gets inserted to satisfy the minimal word requirement, it can be the target of stress assignment: */s-rho-s/* → *[sé̲r.hos]* 'you coat it with something' vs. */s-riht/* → *[í̲.se̲.riht]* 'cook!' (Michelson, 1989). The inserted vowel gets stressed in the first form, which is in the closed syllable. However, the epenthesized vowel in the second syllable in the penult-open syllable does not attract stress in the second structure. An interesting aspect is that the inserted vowel in the antepenult syllable for the minimal word requirement can attract stress in Mohawk.

Concerning the role of an inserted vowel in phonological processes, Hall (2011, 1588) lists spirantization triggered by an epenthetic vowel in Tiberian Hebrew: */kelb/* → *[keleß]* 'dog.' It seems that an inserted vowel has a role in phonological processes. Thus, this article examines phonological processes triggered by inserted vowels in languages and provides a theoretical account of those processes. The phonological processes the study deals with are spirantization, palatalization, obstruent voicing, consonant deletion, and stress attraction. Based on this, we argue that even though epenthetic vowels are not the same as lexical vowels in many aspects, inserted vowels play a role in various phonological processes and act like lexical vowels. This study does not include an exhaustive list of epenthetic vowels. However, we at least show the roles of epenthetic vowels in various phonological processes, motivated by markedness requirements in languages, so that this study may lead to future phonological and phonetic studies of types of inserted vowels and their diverse roles in languages.

The current study is structured as follows: Section 2 introduces examples of each phonological process. Section 3 presents an account that adopts the constraint-based theoretical framework (Prince & Smolensky, 1993, 2004; McCarthy & Prince, 1995, 2004) to show the roles of epentheic vowels in several languages. We summarize the study in Section 4.

2. Data Presentation

This section presents each set of data with a detailed description, which can reflect phonological processes. We first present the examples of spirantization. Spirantization refers to a process by which a stop segment becomes a fricative. In English, it generally occurs across the morpheme boundary when a noun-forming suffix -y occurs after an alveolar plosive ending base: intima/*t+y*/ → *intima[sɪ]* 'intimacy' (Kreidler, 1989: 272). However, spirantization can also be motivated by an epenthetic vowel, as shown by the examples in the following subsection.

2.1. Spirantization in Tiberian Hebrew

In Tiberian Hebrew (McCarthy, 1979; Hall, 2011: 1588), a post-vocalic plosive becomes a fricative. This language does not permit a type of complex coda, like a sequence of sonorant plus a plosive. When it has an unallowable sequence of consonants in the syllable coda, a vowel insertion strategy is used to break up the coda cluster. Interestingly, the epenthesized vowel then triggers spirantization of the post-vocalic plosive. An inserted vowel is underlined and bold-faced below.

(1) Spirantization in Tiberian Hebrew
  a. /katab+t/ → [kaɵaßt] 'you (FEM SG) wrote'
  b. /kelb/ → [kel<u>e</u>ß] 'dog'

As presented in (1a), two stop consonants become corresponding fricatives [ɵ] and [ß] after a vowel, respectively. Compared to (1a), the underived word in (1b) contains a non-permitted coda cluster, and it is separated into heterosyllables by an epenthetic vowel. The inserted vowel motivates the spirantization of the ultimate post-vowel stop. The role of an inserted vowel observed in (1b) shows that the epenthetic vowel seems to behave like an underlying vowel.

2.2. Palatalization

Palatalization refers to a process through which a non-palatal segment becomes a segment with the palatal feature specifications. Lithuanian does not permit two obstruents with the same place of articulation across the morpheme boundary. When such a cluster occurs, Lithuanian repairs marked sequences by inserting /i/. This inserted high-front vowel induces palatalization of the preceding consonant. We can observe two neighboring consonants with the same place when verbal prefixes /at-/ and /ap-/ appear before bases beginning with alveolar and labial place consonants, respectively.

(2) Palatalization in Lithuanian (Backvić, 2007: 346)

a. /at+deti/ → [at^{j}i̱det^{j}i] ‘to postpone’

b. /at+teisti/ → [at^{j}i̱teist^{j}i] ‘to abjudicate’

c. /ap+berti/ → [ap^{j}i̱bert^{j}i] ‘to strew all over’

The inserted vowel in (2) prevents the occurrence of consecutive segments with the identical place feature, repairing unwanted structure in the language. In addition, it also motivates the palatalization of the preceding non-palatal consonant. An intriguing fact is that both the epenthetic vowel and the underlying vowels trigger palatalization in (2).

Palatalization triggered by an inserted vowel is found in Japanese as well. Japanese does not allow a medial /-st-/ cluster, and the language fixes it by inserting /i/. The medial /-st-/ is formed when an infinitive form ending in /s/ is followed by a past-tense morpheme beginning with a /-ta/.

(3) Palatalization in Japanese (Odden, 2005: 201)

a. /kas+u/ → [kasu] ‘lend-present’

b. /kas+itai/ → [kaʃitai] ‘lend-volitional’

c. /kas+ta/ → [kasʃi̱ta] ‘lend-past’

When the base */kas/* is affixed with a non-front vowel, the base final /s/ is realized as [s] as in (3a), but when followed by an /i/-initial morpheme, the /s/ undergoes palatalization, realized as [ʃ] in (3b). In addition, the inserted vowel in (3c) to repair the unallowable medial /-st-/ cluster palatalizes the preceding /s/ to [ʃ]. The language also shows that an inserted vowel triggers palatalization just like a high-front vowel in a volitional morpheme.

Irish (Hickey, 1985: 237) has two epenthetic vowels /ə/ and /i/, and the latter triggers palatalization in the language. Irish also adopts the palatalizing of the base-final consonant to form the genitive. The following examples show the different behavior of the two inserted vowels.

(4) Palatalization in Irish (Hickey, 1985: 237)

a. ollamh /ʌləv/ → [ʌləv] ‘professor’

b. bandh /banv/ → [banə̱v] ‘child’

c. ollaimh /ʌləv/ → [ʌləv^j] ‘professor-GEN’

d. baindh /bani̱v/ → [ban^{j}i̱v^j] ‘child-GEN’

As shown by the data in (4d), the inserted /i/ palatalizes the preceding /n/ to [nʲ]. Compared to this, the inserted vowel in (4b) does not cause palatalization. Thus, an epenthetic vowel seems to motivate palatalization in Irish, as in Lithuanian and Japanese.

2.3. Obstruent voicing

When an epenthetic vowel creates an intervocalic environment with an underlying vowel, one of the weakening contexts, a voiceless obstruent becomes voiced in Pero (Frajzyngier, 1980: 49; Goldsmith, 1990: 77-78). In this language, a vowel is inserted between two consonants if they are not geminate; when two consonants are geminate and followed by a consonant-initial morpheme, a vowel is inserted after the geminate.

(5) Obstruent voicing in Pero
  a. aɗɗ-ji → aɗɗi̱-ji ‘they always eat many’
  b. yekl-na → yigɨ̱lla ‘he mixed and came’

As in (5a), a vowel is inserted after a geminate, while it lands between two consonants when they are not geminate. We can observe three phonological processes in (5b). Two of them have to do with vowel epenthesis: the inserted vowel causes vowel raising in the antepenult syllable from /e/ to [i], and the voiceless plosive /k/ becomes [g] between vowels. Finally, the stem-final lateral triggers progressive manner assimilation, changing /t/ to [l] across the morpheme boundary. Thus, an epenthetic and underlying vowel form a typical weakening environment, where the voicing of a voiceless obstruent occurs in Pero.

In English, a vowel is epenthesized when a second derivational suffix is affixed, and a voiceless plosive between the inserted vowel and a sonorant of the second suffix becomes voiced (Frankiewicz, 2001; Chung, 2020). Unlike the vowel epenthesis in regular plural or past tense formation in English, a vowel is inserted only after the second suffixation.

(6) Obstruent voicing in English (Chung, 2020: 57)
  a. fix+ed → [fɪkst]+ly → [fɪksɪ̱t-lɪ] → [fɪk.sɪ̱d.lɪ] ‘fixedly’
  b. compress+ed → [kəmprɛst]+ly → [kəmprɛsɪ̱t-lɪ] → [kəm.prɛ.sɪ̱d.lɪ] ‘compressedly’
  c. mark+ed → [markt]+ness → [markɪ̱t-nəs] → [mar.kɪ̱d.nəs] ‘markedness’

When a vowel is epenthesized right before the first suffix after second suffixation, a voiceless plosive appears between a vowel and a sonorant in (6). In this environment, a voiceless stop becomes voiced in pronunciation. Compared to this, the part of a base /-d/ in three consecutive consonants in English: */kayndnəs/* → *[kayn.nəs]* ‘kindness’ is subject to deletion in a fast speech mode. However, the adjective-forming suffix /d/ in (6) is different from the base-final /d/ in that the former is a derivational morpheme, while the latter is part of a base, which is prone to being truncated when surrounded by other consonants across the morpheme boundary. Even though the environment created by an inserted vowel for obstruent voicing in Pero and English is slightly different, an obstruent in both languages undergoes voicing.

2.4. Consonant deletion

There is a case where an epenthetic vowel and an underlying vowel form an intervocalic environment, and a sonorant appearing in that context undergoes deletion. This type of sonorant deletion occurs in the Samothraki dialect of Modern Greek (Hayes, 1989: 283; Katsika & Kavitskaya, 2015: 37). In Samothraki, a vowel is inserted to break up a sequence of consonants. If a sonorant occurs between an epenthetic vowel and an underlying vowel, the intervocalic sonorant gets deleted in the language.

(7) Sonorant deletion
  a. /θrimi/ → [θi̱rimi] → [θi̱im] ‘shared
  b. /vris/ → [vi̱ris] → [vi̱is] ‘faucet’

As shown in (7), an inserted vowel between /θr/ → [θi̱r] and /vr/ → [vi̱r] renders the retroflex to appear inside the vowel sequence, and the retroflex gets deleted in that environment in the Samothraki dialect of Modern Greek. The truncation of the retroflex also occurs when the [r] is preceded and followed by underlying vowels in Samothraki.

(8) Sonorant deletion (Katsika & Kavitskaya, 2015: 38)
  a. /θiriðɐ/ → [θiiðɐ] ‘window’
  b. /ɕɛruðɛɟɐ/ → [ɕiuðɛɟɐ] ‘little hands’

Thus, the intervocalic environment, set up by two underlying vowels or the combination of an underlying and inserted vowel, triggers the identical retroflex deletion in (7) and (8).

2.5. Stress attraction

In Winnebago (Halle & Vergnaud, 1987: 31-34; Halle & Idsardi, 1995: 430-431; Alderete, 1995; Broselow, 2008), an epenthetic vowel can be counted as a prosodic constituent: It can be a member of a foot like a lexical vowel and can even attract stress in a specific environment. A copied vowel is inserted in Winnebago between a voiceless obstruent and a sonorant in a sequence of segments due to Dorsey's Law. Concerning the stress assignment in Winnebago, following Hale and White Eagle (1980), Halle and Vergnaud explain that stress falls on each odd-numbered mora except for the first mora when a form consists of a sequence of light syllables. Thus, when a form begins with three or more light syllables, the first vowel is not parsed into a foot to avoid stress on the second syllable. However, some cases that do not follow the general pattern of stress assignment in the language. When a word consists of three light syllables and a vowel is inserted after the first mora through Dorsey's Law, one expects stress to fall on the third mora. However, stress does not fall on the third mora or syllable but falls on the fourth mora or the fourth syllable, instead. This type of stress assignment induced by a vowel epenthesis disrupts the regular stress pattern of Winnebago, as shown in (10a). In addition, when there are only two moras in a word, the stress is assigned to the second mora, as shown in (9b). The typical stress pattern of the language is in (9a) and (9c). The secondary stress is assigned to alternate more or syllable after the primary stressed mora.

(9) Stress assignment in Winnebago
  a. haatítujìk 'I pull it taut'
  b. wajé 'dress'
  c. hochichínik 'boy'

When a form contains a sequence of segments that is the target of Dorsey's Law, a vowel, which is identical to one after a sonorant, is epenthesized between a voiceless obstruent and a sonorant.

(10) Dorsey's Law application and stress assignment (Halle & Vergnaud, 1987: 31-32)

a. hosha̱wazhá 'you are ill'

b. harakíshurujìksha̱nà 'you pull taut'

c. maashá̱rach 'you promise' d. hirakó̱rohòni 'you don't dress'

e. hirakó̱rohònirà 'the fact that you do not dress' f. waki̱rípo̱ròpo̱rò 'spherical bug'

In (10), a vowel with bold-faced and underlined gets inserted to break up a consonant sequence due to Dorsey's Law. Interestingly, only the vowels in (10c, d, e) get stressed, while stress does not fall on the epenthesized vowel in (10a, b, f). Halle and Vergnaud (1987: 32) argue that the epenthesized vowel can attract stress only when it appears inside a metrical constituent; otherwise, an inserted vowel does not attract stress. That is, the stress-assigned inserted vowel occurs inside the metrical constituent: *m<a> (a)shr(á)ch* → *maashá̱rach*, where two vowels in parentheses are legitimate metrical constituents and a vowel is inserted within this metrical domain. In Winnebago, the first mora is considered extrametrical (Halle & Vogernaud, 1987: 30). However, we assume that the first mora is not extrametrical and it can act prosodically when it consists of a long vowel, which should be parsed by a foot. On the other hand, when a form begins with a light syllable, it is not contained in a foot to avoid the form a bisyllabic iambic foot, which is different from the regular stress pattern of Winnebago (Broselow, 2008). Thus, depending on the position of an epenthetic vowel, the inserted vowel can be a foot element or can attract stress in the language.

In this section, we presented the relevant examples of several phonological processes in which an epenthetic vowel behaves like a lexical or underlying vowel in phonological processes. In the following section, we propose a theoretical analysis of each process.

3. A Theoretical Analysis

This section presents a theoretical analysis of the phonological processes motivated by epenthetic vowels in several languages. To explain diverse phonological processes triggered by an epenthetic vowel, we adopt a theoretical framework that utilizes a simple mapping from input to output tradition of Optimality and Correspondence Theory (Prince & Smolensky, 1993, 2004; McCarthy & Prince, 1995, 2004).

3.1. Spirantization in Tiberian Hebrew

We need markedness constraints that trigger the insertion of a vowel in consonant sequences and do not allow a segment with the [-cont] feature specification after a vowel. In addition, we need faithfulness constraints that militate against the insertion of a vowel and feature change from [-cont] to [+cont] when spirantization applies. The constraints related to spirantization in Tiberian Hebrew are in (11).

(11) a. *Complex: No more than one C or V may associate with any syllable position node.
b. *$VC_{[-cont]}$: A post-vocalic stop consonant is not allowed.
c. Dep: Every segment of the output has a correspondent in the input.
d. Ident-$C_{[cont]}$: Corresponding segments are identical in feature [cont].

*Complex ranks very high in Tiberian Hebrew, and it should dominate Dep, even though the two constraints are not in constraint conflict because the vowel insertion strategy is adopted to avoid a sequence of segments in Tiberian Hebrew. Thus, one can break up the consecutive consonants by epenthesizing a vowel between the consonants, which is called for by ranking *Complex over Dep. The spirantization trigger, *$VC_{[-cont]}$, also ranks high because Tiberian Hebrew does not allow a stop segment after a vowel. This markedness constraint dominates Ident-$C_{[cont]}$ since a post-vocalic stop segment becomes fricative under the duress of *$VC_{[-cont]}$. The two markedness constraints do not show constraint conflict, but we rank *Complex over *$VC_{[-cont]}$ because priority is given to the former, while the violation of the latter is not so severe compared to that of *Complex. On the other hand, Dep should be ranked over Ident-$C_{[cont]}$ since vowel insertion motivates spirantization of a stop after a vowel. Based on the constraint ranking, we can explain how a stop becomes a fricative motivated by an epenthetic vowel. We do not include constraints like Max, which militate against segmental deletion.

(12) /kelb/ → [kel<u>e</u>ß] 'dog'

kelb	*Complex	*$VC_{[-cont]}$	Dep	Ident-$C_{[cont]}$
a. kelb	*!			
b. keleb		*!	*	
☞c. kele ß			*	*

Candidate (b) has an inserted vowel to avoid the consecutive consonants in the coda position at the cost of violating Dep, but is still short of becoming optimal due to its violation of $*VC_{[-cont]}$, which prevents a sequence of a vowel and a stop consonant in the syllable rime. The optimal candidate adopts the vowel insertion strategy. However, the inserted vowel affects the following stop consonant to become a fricative to bypass $*VC_{[-cont]}$, violating the lowest-ranked Ident-$C_{[cont]}$. The spirantization caused by the inserted vowel in Tiberian Hebrew can be accounted for by the constraints and their ranking in (12). It seems that the epenthetic vowel motivated by structural reasons behaves like a lexical vowel in terms of inducing changes in neighboring segments.

3.2. Palatalization

An inserted vowel induces palatalization in Lithuanian, Japanese, and Irish. In this language, two segments with the same place of articulation can appear through morpheme concatenation. When it happens, consecutive segments having identical place features are not allowed in Lithuanian. To avoid such a marked sequence of segments, a vowel gets epenthesized to break up the cluster, and the inserted vowel triggers palatalization of an alveolar stop. To explain this process, we propose a markedness constraint that prohibits the marked consonant cluster across the morpheme boundary. Another markedness constraint is needed to ban an alveolar consonant plus a high front vowel. This constraint triggers palatalization in Lithuanian. We also need faithfulness constraints that are ranked lower than markedness constraints that lead to phonological changes. The constraints for the process are in (13).

(13) a. $*C_i$-C_i: Two segments with the same place of articulation are not allowed (cf. Raffelsiefen, 1999: 236-237)
b. *Cor-i: A coronal obstruent plus a high front vowel is prohibited.
c. Dep: Every segment of the output has a correspondent in the input.
d. Ident-$C_{[+cor, +ant]}$: = Id-$C_{[+cor, +ant]}$ Correspondent segments are identical in feature [+cor, +ant].

The markedness constraint, *Ci-Ci, calls for a change in such a consonant sequence. It should dominate Dep so that a vowel insertion strategy is adopted. On the other hand, another sequence of segments newly created by the vowel epenthesis, a coronal obstruent plus a high front vowel, is also counterbalanced by *Cor-i. The markedness constraint demands a change in the structure, and the direction of the change is motivated by the lower-ranked faithfulness, Id-C[+cor, +ant]. The low-ranked nature of the faithfulness constraint indicates that the feature change to that extent is tolerable in Lithuanian. In the tables below, we exclude output candidates that may emerge by adopting the deletion strategy and place feature change from coronal to labial or dorsal to avoid the high-ranked *Ci-Ci.

(14) /at+deti/ → [$at^{j}\underline{i}det^{j}i$] ‘to postpone’

at+deti	*C_i-C_i	*Cor-i	Dep	Id-$C_{[+cor,\ +ant]}$
a. atdeti	*!	*		
b. atideti		*!*	*	
c. $at^{j}ideti$		*!	*	*
☞d. $at^{j}idet^{j}i$			*	**

Palatalization of an alveolar stop before a high front vowel applies to two alveolar stops: one by a lexical high front vowel and the other by an inserted one in the optimal candidate (14d). Palatalization applies in (14d) by violating lower-ranked Dep and Id-$C_{[+cor,\ +ant]}$. It shows that an epenthetic vowel behaves like one of the lexical vowels in the palatalization of Lithuanian. Maintaining two segments with the identical place feature militates against high-ranked *C_i-C_i and *Cor-i in (14a). The vowel insertion strategy in (14b) avoids the co-occurrence constraints, but it adds one more violation of *Cor-i due to the failure of applying palatalization, which is critical. The partial application of palatalization in (14c) does not resolve the problem, resulting in suboptimal. Thus, in Lithuanian, a coronal consonant plus a high front vowel is prohibited; it does not matter whether the vowel is inserted or lexical, as shown by the optimal candidate (14d).

To account for Japanese palatalization, we need to modify the constraints in (13a) to treat the unallowable medial /-st-/ cluster. With the modified constraint and the other constraints in (13), we can explain the palatalization in Japanese. For Japanese, we use the informal markedness constraint *st to ban the appearance of such an unwanted sequence of segments.

(15) /kas+ta/ → [kaʃ<u>i</u>ta] 'to postpone'

kas+ta	*st	*Cor-i	Dep	Id-$C_{[+cor, +ant]}$
a. kas ta	*!			
b. kasita		*!	*	
☞c. kaʃita			*	*

For Irish palatalization, we should come up with a markedness constraint, which motivates the insertion of the high-front vowel. We also need a language-specific constraint for the palatalization of the final segment to form the genitive.

3.3. Obstruent voicing

A voiceless obstruent becomes voiced when an inserted vowel between consonants creates an intervocalic environment. It occurs in Pero, where three consecutive consonants appear by morpheme concatenation. If the first two consonants are not geminate in a stem, a vowel intrudes between the first and the second consonant. A voiceless obstruent between vowels becomes voiced in Pero. There is an issue of vowel raising, triggered by an inserted vowel to a vowel occurring before the epenthesized. Since it is not a central issue in Pero, we do not discuss it in this subsection. To explain the vowel epenthesis and ensuing obstruent voicing, we use the following constraints.

(16) a.*Complex: No more than one C or V may associate with any syllable position node.
b. *$VC_{[-vd]}V$: A voiced obstruent is preferred to voiceless between vowels.
c. Agr-Son: Form a sonorant geminate with higher sonority across the morpheme boundary.
d. Dep: Every segment of the output has a correspondent in the input.
e. Ident-voice: Corresponding segments are identical in feature [voice].
f. Ident-Ma: Corresponding segments are identical in feature [manner].

*Complex calls for a change in the consonant and ranking of *Complex over Dep ensures the epenthesis of a vowel in Pero. A voiceless obstruent appears in the intervocalic environment made by a lexical and inserted vowel, and it undergoes voicing change, induced by *VC[-vd]V. The markedness constraint dominates Ident-voice, which ensures the change of a voiceless obstruent into a voiced one. Agr-Son is a constraint that deals only with a sequence of consonants, which contains at least one sonorant. It specifies that a segment with higher sonority transmits its manner feature to a consonant with lower sonority, forming a geminate across the morpheme boundary. Since manner assimilation in this sub-section is not the focus, readers should refer to Frajzyngier (1980), who discusses other types of manner assimilation in obstruent sequences across the morpheme boundary. We assume that the highest-ranked constraint, *Complex, ranks over *VC[-vd]V. In addition, Dep has the priority over Ident-voice in the analysis, and Agr-Son dominates Dep and Ident-voice but ranks lower than *VC[-vd]V. The lowest-ranked constraint is Ident-Ma, and calls for the preservation of the input manner feature in the output. Since it is ranked very low, the change in manner occurs.

(17) yekl-na → yigɨlla 'he mixed and came'

yekl-na	*Complex	*VC$_{[-vd]}$V	Dep	Ident-voice	Agr-Son	Ident-Ma
a. yekl-na	*!				*	
b. yikɨl-na		*!	*		*	
c. yigɨn-na			*	*	*!	
☞d. yigɨl-la			*	*		*

In candidate (b), the coda cluster in a stem becomes heterosyllabic by inserting a vowel satisfying *Complex, but the candidate does it at the cost of violating *VC[-vd]V and Dep, which are ranked lower than *Complex. Candidate (c) shows the voicing of a voiceless obstruent between a lexical vowel and an inserted vowel, faring well with *VC[-vd]V. However, it is still short of becoming the optimal form due to its violation of Agr-Son by forming a lower sonority sonorant geminate induced by regressive manner assimilation. The optimal candidate (d) applies progressive manner assimilation, forming a sonorant geminate with higher sonority (ll > *nn). The manner of assimilation applies at the cost of violating the lowest-ranked Ident-Ma in Pero. Thus, an epenthetic and an underlying vowel form an environment for obstruent voicing in Pero. It also shows the role of an epenthetic vowel in the language.

To explain obstruent voicing in English (6), we need a markedness constraint that bans a tri-obstruent cluster in morpheme concatenation. The voiceless coronal stop surrounded by other obstruents is a morpheme, and it should be secured to appear in the output by inserting a vowel. There should be another markedness constraint that does not allow a voiceless obstruent between a vowel and a sonorant in English to force voicing of the voiceless stop in /markɪtnəs/ → [markɪdnəs]. We can adopt the constraints, Dep and Ident-voice from (16). Thus, as seen in (6), the epenthetic vowel in English participates in a phonological process just like a lexical vowel, as we also observed it in Pero.

3.4. Sonorant deletion

In the Samothraki dialect of Modern Greek, a retroflex liquid gets deleted when it occurs between vowels, where it plays an onset role. According to Topintzi (2007: 16-17), the liquid-r is not a preferred onset element because the liquid is assumed to be placeless (cf. Akinlabi, 1993; Rice, 1992). Thus, when this weak segment appears between vowels, it undergoes deletion. To explain it, we need a markedness constraint that prohibits the occurrence of the liquid-r intervocalically. Another markedness constraint is *Complex banning more than one element in the syllable onset or coda position. In addition, we need a faithfulness constraint, which militates against segmental deletion. The constraints we adopt to explain the liquid deletion in Samothraki are in (18).

(18) a. *Complex: No more than one C or V may associate with any syllable position node.
b. *VrV: Between vowels, /r/ is disallowed (cf. Topintzi, 2007: 16).
c. Dep: Every segment of the output has a correspondent in the input.
d. Max-IO: Every segment of the input has a correspondent in the output.

Samothraki does not allow complex syllable margins, and the language controls them by *Complex. To treat such a sequence of segments, Samothraki adopts the vowel insertion strategy. It implies that *Complex dominates Dep. When a consonant cluster contains the liquid-r as the second member, an epenthetic vowel lands between the consonants, which leads the liquid to be surrounded by vowels. Since the liquid-r is not welcome between vowels, it undergoes deletion due to *VrV. *VrV dominates the faithfulness constraint, Max-IO, which should be ranked lowest to tolerate the deletion of [r]. Between *Complex and *VrV, *Complex dominates *VrV because the reversed ranking will select an incorrect output as optimal form. Between the two faithfulness constraints, we do not rank them.

(19) /θrimi/ → [θi̲rimi] → [θi̲im] 'shared'

θrimi	*Complex	*VrV	Dep	Max-IO
a. θrimi	*!			
b. θirimi		*!	*	
☞c. θiimi			*	*

The prevocalic onset cluster gets separated by the vowel insertion in (19b), which places the liquid-r between vowels, and is not an optimal candidate due to its failure to maintain the weak onset segment intervocalically, violating *VrV. The undesirable onset between vowels gets deleted in (19c), becoming optimal only by violating the lower-ranked faithfulness constraints. The behavior of the inserted vowel in (19) also indicates that an epenthetic vowel actively participates in the phonological process with underlying vowels. We may entertain an alternative procedural approach (McCarthy, 2008, 2010, 2011) for the current data; however, we maintain the simple input-to-output mapping theory to propose a parallel account with other processes in the study.

3.5. Stress attraction

An epenthetic vowel in Winnebago (Halle & Vergnaud, 1987: 31-34; Halle and Idsardi, 1995: 430-431) can attract stress when it appears within metrical constituents. As explained in 2.5, stress falls on odd-numbered mora except for the first mora in Winnebago, so when an epenthetic vowel, due to Dorsey's Law, is the second mora, that epenthetic vowel does not attract stress. Since we are focusing only on the stress attraction of an epenthetic vowel, we do not discuss the entire stress system and analysis of Winnebago. This is because the interactions between stress and vowel epenthesis are complicated, which implies several constraints to explain the data. The general stress pattern, stress on the third mora, can be disrupted by an inserted vowel by Dorsey's Law. To account for the example in (10), we use the following constraint ranking.

(20) a. *Obst-Son: A sequence of voiceless obstruent and sonorant is prohibited. (Dorsey's Law)
b. Foot Type I=Ft-Iamb: Feet are bisyllabic with final prominence (Prince and Smolensky, 193: 47; Kager, 1999: 161, 172. cf. Hayes, 1995: 65; Broselow, 2008).
c. Parse-Heavy σ=Parse-H σ: Heavy syllables are parsed by feet.

d. Parse-σ: Syllables are parsed by feet.
e. Contiguity-Feet=Conti-Ft: Feet are contiguous. (No unparsed syllables between feet)
f. *σ σ: Two unparsed adjacent syllables are not allowed.
g. Head-Dep: Every vowel contained in a prosodic head in S_2 has a correspondent in S_1. (Alderete, 1999)
h. Non-Head-Dep=NH-Dep: Every vowel contained in a prosodic non-head in S_2 has a correspondent in S_1
i. All-Ft-R: Every foot stans at the right edge of the prosodic word. (Kager, 1999: 163)
j. All-Ft-L: Every foot stands at the left edge of the prosodic word. (Kager, 1999: 157)

*Obst-Son calls for breaking up a sequence of rising sonority between a voiceless obstruent and a sonorant by inserting a copied vowel after the sonorant. It reflects what Dorsey's Law requires and motivates vowel epenthesis in Winnebago. This markedness constraint is undominated in the language. Ft-Iamb specifies foot structure, which should have two syllables where the second syllable is the head of the foot. It is also undominated in the language; when a form begins with a heavy and a light syllable or two light syllables, they form a bisyllabic foot with the prominent second syllable. Parse-Hσ is more specified than the general Parse-σ, thus the former ranks over the latter by Pāṇini's Theorem on constraint ranking (Prince and Smolensky, 1993, 2004). Whenever we have heavy syllables with long vowels, they must be parsed by a foot. On the other hand, when a prosodic word begins with three light syllables, the first syllable is skipped over in parsing, and the second and third syllables form a bisyllabic iambic foot. The high-ranked *Obst-Son, Ft-Iamb, and Parse-Hσ do not show ranking among them, and they are equally ranked.

Conti-Ft calls for the adjacency of feet, so unparsed syllables do not occur between feet in Winnebago. This constraint is ranked high but not undominated because there are cases where an unparsed syllable appears in a prosodic word with multiple syllables or moras. It is ranked lower than *Obst-Son, Ft-Iamb, and Parse-Hσ, but higher than Parse-σ. The marked constraint, *σ σ, is not undominated but is ranked high in the analysis because two neighboring unparsed syllables are potentially able to form a foot. Winnebago prefers parsing of two adjacent syllables to unparsing them. This constraint does not show a particular ranking with Conti-Ft, and they are equally ranked.

Head-Dep demands that a stressed vowel in a foot have its correspondent in the input. It implies that if it is possible, stress does not fall on an epenthetic vowel. This constraint is not ranked highest, but is ranked equally with Conti-Ft and *σσ. Compared to this, NH-Dep requires that a non-prominent member of a foot have its correspondent in the input. This constraint militates against parsing an epenthetic vowel into a foot. Since it is not highly ranked, it signals that it is not so critical to parse an inserted vowel as the non-head of a foot as it is as the head constituent of a foot. In the analysis, Head-Dep dominates NH-Dep.

All-Ft-R requires that every foot in a prosodic word stand at the right edge of the prosodic word. It is not the highest-ranked constraint but ranks equally with Conti-Ft, *σσ, and Head-Dep. It means that if it is possible, feet are packed rightward rather than leftward, required by the lowest-ranked All-Ft-L. Between two low-ranked Parse-σ and All-Ft-L, Parse-σ is ranked higher than All-Ft-L. It reflects the non-parsing of the first light syllable or a mora in the language. Based on the ranking relationship we briefly discussed, we first present a table that shows how the constraint ranking can account for a prosodic word without vowel epenthesis. In the following table, we do not adopt constraints that do not play a crucial role.

(21) hochichinik → hochichínik 'boy'

hochichinik	Ft-Iamb	All-Ft-R	*σσ	Parse-σ	All-Ft-L
a. (hochí)(chiník)		*!*			**
b. (hochí)chinik		*!*	*!	**	
c. hochi(chiník)			*	**	**!
☞d. ho(chichí)nik		*		**	*

When an input has four light syllables and has no epenthetic vowel, stress falls on the third syllable or mora, which follows the regular stress pattern in Winnebago. Candidate (a) achieves the exhaustive parsing, but it fails to become optimal due to the violations of All-Ft-R. Candidate (b) only parses the first two syllables, which results in violations of All-Ft-R, *σσ, and Parse-σ. These violations are motivated by misparsing and ensuing incorrect stress assignment. The close competitor candidate (c) parses the last two syllables, which renders it satisfaction of All-Ft-R but two violations of All-Ft-L. The best way of parsing to assign the stress on the third syllable is to form a bisyllabic iambic foot by parsing the second and third syllables, shown by (21d). The constraint ranking in (21) can account for the regular stress pattern in Winnebago.

However, the regular stress assignment gets disrupted when an epenthetic vowel is the second mora in a form consisting of three light syllables. We expect that the stress falls on the third mora after the epenthesized due to Dorsey's Law; the stress is assigned to the fourth syllable or mora instead, as shown in the following table.

(22) hoshawazha → hoshawazhá 'you are ill

hoshwazha	Ft-Iamb	*Obs-Son	All-Ft-R	*σ σ	Head-Dep	NH-Dep
a. hosh(wazhá)		*!		*		
b. (hosh**á**)(wazhà)			*!*		*!	
c. ho(sh**a**wá)zha			*			*!
d. (hosh**á**)wazha			*!*	*	*!	
☞e. hosh**a**(wazhá)				*		

When an epenthetic vowel occurs between the first and the second syllable in a three-light syllable, stress does not fall on the third syllable but on the fourth syllable to avoid the stress on the epenthetic vowel, as shown in (e). The two candidates (b) and (d) are not optimal, because the inserted vowel is stressed, violating Head-Dep and All-Ft-R. Another suboptimal candidate (c) should be the winner because it follows the regular stress pattern by stressing the third mora from the left edge of the prosodic word. However, it fails to be optimal due to the parsing of an epenthetic vowel as the non-prominent constituent of the foot. Thus, the optimal form is the last candidate that only parses the last two syllables, consisting of two lexical vowels, only violating *σ σ once. This candidate prevents the epenthetic vowel from becoming a constituent of the foot. It implies that if an epenthetic vowel does not occur within the domain of the canonical position for stress assignment, it is best not to parse the inserted vowel. If an epenthetic vowel happens to be the third syllable, it becomes a legitimate target of stress attractor: hirakrohoni → hi(rakó)(rohò)ni 'you don't dress.'

A similar stress assignment occurs when a form begins with a heavy syllable and the following vowel is epenthetic; stress falls on the third mora or the epenthetic vowel, shown in the following table.

(23) maashrach → maashárach 'you promise'

maashrach	Ft-Iamb	*Obs-Son	Parse-H σ	Head-Dep	NH-Dep
a. (maashrách)		*!			
b. maa(sharách)			*!		
c. (maasharách)	*!				*
☞d. (maashá)rach				*	

When the epenthetic vowel is the third mora as shown in (23d), it attracts stress, violating Head-Dep. It is the best choice for a candidate to opt for because all other candidates incur a violation of undominated Ft-Iamb, *Obst-Son, and Parse-σ, respectively. It also shows that even an inserted vowel acts like an underlying vowel when it occurs in the proper position for stress assignment.

An interesting aspect of vowel insertion and stress assignment in Winnebago is that the secondary stress pattern can be disorganized when the input form consists of seven light syllables and an inserted vowel occurs between the sixth and seventh syllable. In such a form, the primary stress falls on the third syllable, but the secondary stress does not fall on the fifth and seventh syllables. The secondary stress is assigned to the sixth and eighth syllables as shown by the candidate in the following table.

(24) harakishurujikshna → harakíshurujìkshanà 'you pull taut'

harakishurujikshna	Ft-Iamb	*Obs-Son	Contig-Ft	All-Ft-R	*σ σ	Head-Dep
a. ha(rakí)(shurù)(jikshnà)		*!		****,**		
b. ha(rakí)(shurù)(jikshà)na				*****,***		*!
c. (hará)(kishù)(rujìk)(shanà)				******,***!*,**		
d. ha(rakí)shu(rujìk)shana			*	*****,**	*!	
☞e. ha(rakí)shu(rujìk)(shanà)			*	*****,**		

Intriguing candidates are (24b) and (24e) because these two candidates are almost identical in their unparsed syllables and the number of feet. However, they are different in their secondarily stressed syllables; candidate (b) for the fifth and seventh syllables, while candidate (e) for the sixth and eighth syllables. It seems that candidate (b) follows the regular stress pattern of Winnebago, but it is not optimal. Instead, an output with a secondary stress pattern different from the regular stress pattern becomes optimal. This aberrant secondary stress pattern in (e) is motivated by the Head-Dep constraint. That is, assigning stress on the seventh syllable is now allowed in Winnibago. The only legitimate position for an epenthetic vowel stress is the third mora or syllable in the language. Thus, candidate (e) becomes optimal instead of (b), which is specified by the constraint ranking. The comparison between the two candidates implies that the only substantially secured position for the stress assignment in this language is the third mora from the left edge of the prosodic word. The chance for the stress assignment for the odd-numbered syllables after the primary stress depends on the constraint ranking. The interaction of epenthetic vowel and stress assignment in Winnebago shows that an epenthetic vowel can attract stress in the third mora or light syllable; otherwise, it may participate as a non-prominent member of a foot.

In this section, we have discussed several phonological processes which seem to be triggered by an epenthetic vowel: spirantization, palatalization, obstruent voicing, consonant deletion, and stress attraction. The constraint rankings we used in this section are in (25).

(25) a. Spirantization (Tiberian Hebrew)
*Complex ≫ *VC$_{[-cont]}$ ≫ Dep ≫ Ident-C$_{[cont]}$
b. Palatalization (Lithuanian, Japanese)
*C$_i$-C$_i$ ≫ *Cor-i ≫ Dep ≫ Id-C$_{[+cor,\ +ant]}$ (Lithuanian)
*st ≫ *Cor-i ≫ Dep ≫ Id-C$_{[+cor,\ +ant]}$ (Japanese)
c. Obstruent voicing (Pero, English)
*Complex ≫ *VC$_{[-vd]}$V ≫ Dep ≫ Ident-voice, Agr-Son ≫ Ident-Ma
d. Consonant deletion (Samothraki dialect of Modern Greek)
*Complex ≫ *VrV ≫ Dep ≫ Max-IO
e. Stress attraction (Winnebago)
Ft-Iamb, *Obst-Son, Parse-Hσ ≫ Contig-Ft, All-Ft-R, *σσ, Head-Dep ≫ NH-Dep ≫ Parse-σ ≫ All-Ft-L

So far, we have provided constraint-based analyses of several phonological processes, motivated by epenthetic vowels, and shown the role of an epenthetic vowel in phonology. In specific phonological processes in particular languages, an epenthetic vowel behaves like one of the lexical vowels, or it cooperates with the underlying vowel in triggering phonological operations.

4. Conclusion

This study investigates the phonological roles of epenthetic vowels. Inserted vowels are known as less marked and have shorter duration than lexical vowels (Selkirk, 1981; Itô, 1986; Kager, 1999; de Lacy, 2006). The phonological and phonetic properties of epenthetic vowels may not motivate linguistic study on inserted vowels. Concerning this issue, Hall (2011: 1585) claims that inserted vowels have very restricted phonological roles and are almost invisible in output. However, there are cases where epenthetic vowels behave just like lexical vowels in various phonological processes. To show the roles of inserted vowels in phonology, we discussed phonological processes triggered by epenthetic vowels like spirantization (Tiberian Hebrew), palatalization (Lithuanian, Japanese, and Irish), obstruent voicing (Pero and English), consonant deletion (Samothraki dialect of Modern Greek), and stress attraction (Winnebago). In phonological processes, inserted vowels act like a lexical vowel or cooperate with an underlying vowel to motivate phonological processes. To explain such processes, we adopted the input-to-output mapping of a constraint-based theoretical framework, and propose an analysis where an epenthetic vowel, induced by a markedness constraint, motivates phonological processes in several languages. This study presents only a partial aspect of an inserted vowel in languages where an inserted vowel triggers phonological processes, and a possibility of various other processes involved with epenthetic vowels for future studies. Furthermore, it is essential to discern the phonetic duration differences between copied and default inverted vowels, as well as to explore the extent to which epenthetic vowels contribute to rhythm and prosody in future studies.

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Received on August 28, 2025
Revised version received on September 25, 2025
Accepted on September 30, 2025