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Correspondence at the acoustic boundaries: cluster simplification, syncope and P-map correspondence constraints

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Abstract
The C_2 dominance effect in cluster simplification, in which the second consonant is preserved over the first ($V_1C_1C_2V_2 \rightarrow V_1C_2V_2$), has been attributed to the perceptual salience of prevocalic consonants. However, this P-map account fails in classic Optimality Theory when syncope feeds cluster simplification ($V_1C_1V_0C_2V_2 \rightarrow V_1C_1C_2V_2 \rightarrow V_1C_2V_2$), as the input and output contexts do not differentiate C_1 from C_2. This article proposes a solution to this problem using correspondence constraints that reference acoustic transitions from and to vowels. Since syncope removes the targeted vowel and its associated transitions, Ident [transition] constraints cannot refer to the eliminated transitions. Specifically, the transition from C_2 is protected by the relevant Ident [release transition] constraint, while C_1's transition is not. Thus, under the ranking of Ident [release transition] over Ident [closure transition], C_1, despite being underlyingly prevocalic, remains subject to the C_2 dominance effect and is targeted for deletion. This proposal also addresses interactions between syncope and other cluster reduction processes, such as major place assimilation and debuccalisation.

Contents

1. Introduction

When a medial consonant cluster is simplified by removing one of its members, it is typically achieved by deletion of the first consonant (C_1):

(1) $V_1C_1C_2V_2 \rightarrow V_1C_2V_2$ (cf. $*V_1C_1V_2$)

In theory, cluster simplification can also be achieved by the deletion of the second consonant (C_2). However, the cross-linguistic preference for the deletion of C_1 over C_2 is dominant (Wilson 2001; Jun 2002, 2011; McCarthy 2008, 2011, among others). Cluster simplification in Basque and Diola Fogny exemplifies this effect. In both languages, when the simplification process targets a medial cluster, C_1 is always deleted, while C_2 remains unaffected.

(2) *The positional effect in cluster simplification by consonant deletion*

a. *Basque* (Hualde 1991: 127)

i.	ba**t** + **p**aratu	[ba**p**aratu]	'put one'
ii.	ba**t** + **k**urri	[ba**k**urri]	'run one'
iii.	gu**k** + **p**iztu	[gu**p**iztu]	'we light'
iv.	gu**k** + **k**endu	[gu**k**endu]	'we take away'

b. *Diola Fogny* (Sapir 1965: 17, 19)

i.	lɛ**t-k**u-dʒaw	[lɛ**k**udʒaw]	'they won't go'
ii.	ɛ-rɛ**nt-r**ɛnt	[ɛrɛ**r**ɛnt]	'it is light'
iii.	ɛ-kɛ**t-b**ɔ	[ɛkɛ**b**ɔ]	'death there'

As pointed out by Wilson (2001), the asymmetric positional effect in cluster simplification stems from the lower perceptibility of C_1. In medial cluster simplification, the prevocalic C_2 is more likely to be preserved because of its perceptual salience, while the perceptually weak preconsonantal C_1 is more prone to deletion or alteration. This Licensing-by-Cue idea (Steriade 1999) can be implemented in classic Optimality Theory (OT) (Prince & Smolensky [1993] 2004) using contextual faithfulness constraints. These constraints are ranked differently based on their contexts, assuming that a speaker's knowledge of contrast distinctiveness across positions is mapped onto the relative constraint ranking (P-map theory; Steriade 2009). For example, MAX-C /__V should outrank MAX-C /__C, as consonants are perceptually more salient prevocalically. Under this ranking, the $V_1C_1C_2V_2$ cluster is neutralised to $V_1C_2V_2$ rather than $V_1C_1V_2$ when simplification occurs, as schematised in (3).

(3) MAX-C /__V ≫ MAX-C /__C

VC_1C_2V	*CC	MAX-C /__V	MAX-C /__C
a. VC_1C_2V	*! (C_1C_2)		
b. VC_1V		*! (C_2)	
☞ c. VC_2V			* (C_1)

This C_2 dominance effect is evident even when syncope creates the target cluster for simplification. The following examples from Carib of Suriname demonstrate this interaction between syncope and cluster simplification:

(4) *Syncope and cluster simplification in Carib* (Hoff 1968; Gildea 1995; Courtz 2008)

a.	ena**pɨ-p**otɨ	[enaː**p**otɨ]	'to eat (repet.)'
b.	ena**pɨ-t**aŋ	[enaː**t**aŋ]	'he will eat'
c.	ena**pɨ-k**o	[enaː**k**o]	'eat it'

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In this language, a stem-final high vowel is deleted when it is followed by a CV-initial suffix. Then, the consonant preceding the deleted vowel is also removed to avoid creating a geminate or a medial cluster. Notably, the C_2 dominance effect remains consistent regardless of whether syncope has occurred: the simplification process removes C_1 rather than C_2. This asymmetric effect is not limited to Carib, but is also observed in other languages where syncope interacts with cluster simplification, such as Tangale (Kidda 1993), Tunica (Haas 1946) and Nishnaabemwin (Valentine 2001).

However, within classic OT, the contextual faithfulness analysis in (3) encounters a significant challenge in capturing the C_2 dominance effect when syncope is involved (e.g., Wilson 2001; McCarthy 2011). The main issue stems from the contextual information specified in the faithfulness constraints. In simple cases where cluster simplification occurs without syncope, it is sufficient to assume that the faithfulness constraints specify the input context: C_1 is deleted because it is preconsonantal in the input. However, this assumption fails when syncope feeds simplification, as both members of the targeted cluster are prevocalic in the underlying representation. Consider the following tableau with an *ad hoc* Syncope constraint that removes a medial vowel between two consonants (V_0):

(5) *The input-oriented analysis of cluster simplification fed by syncope*

$VC_1V_0C_2V$	Syncope	*CC	Max-C /__V_{INPUT}	Max-C /__C_{INPUT}
a. $VC_1V_0C_2V$	*! (V_0)			
b. VC_1C_2V		*! (C_1C_2)		
!☞ c. VC_1V			* (C_2)	
☞ d. VC_2V			* (C_1)	

The tableau in (5), where the relevant faithfulness constraints refer to the input contexts, predicts that deleting either C_1 or C_2 is equally viable, as both consonants are protected by the same constraint (i.e., Max-C /__V_{INPUT}). The given faithfulness constraints and their ranking cannot distinguish between C_1 and C_2 by penalising only the deletion of C_2, unlike in (3).

An alternative approach that assumes faithfulness constraints specifying the surface context also fails:

(6) *The output-oriented analysis of cluster simplification fed by syncope*

$VC_1V_0C_2V$	Syncope	*CC	Max-C /__V_{OUTPUT}	Max-C /__C_{OUTPUT}
a. $VC_1V_0C_2V$	*! (V_0)			
b. VC_1C_2V		*! (C_1C_2)		
!☞ c. VC_1V				
☞ d. VC_2V				

In (6), neither deletion of C_1 nor of C_2 is penalised by the relevant faithfulness constraints. In both (6c) and (6d), a deleted consonant is absent from the surface forms, making it impossible to penalise consonant deletion based on the output context.

This study aims to capture the patterns of cluster simplification, regardless of whether syncope is involved or not, keeping the P-map approach's core idea that faithfulness constraints are ranked according to the perceptual hierarchy (Steriade 2009). The central claim is that the C_2 dominance effect can be consistently captured through correspondence constraints that refer to subsegments. Specifically, following Flemming (2008b), this article proposes that P-map correspondence constraints can refer to phonetic details conveyed by transitions from and out of a consonant, and these constraints are ranked hierarchically according to the perceptual salience of the phonetic properties they refer to. For instance, Ident [release transition], which penalises changes in the transitional phase from a consonant

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to a following vowel, should be ranked over Ident [closure transition], which evaluates changes in the transition from a vowel to a following consonant. This ranking is necessary because the release transition from a consonant to a vowel carries more perceptually reliable cues for the consonant than the closure transition from a vowel to a consonant. Given this ranking, the C_2 dominance effect is easily captured: when cluster simplification is enforced, C_1 is removed instead of C_2 to avoid violating the higher-ranked Ident [release transition] constraint, at the cost of violating the lower-ranked Ident [closure transition].

These P-map constraints that refer to subsegmental transitions have advantages over conventional faithfulness constraints when cluster simplification interacts with syncope. This is because the changes in consonant properties are governed by correspondence constraints that evaluate the acoustic transitions occurring outside the consonant itself. In the context of syncope, C_1 and C_2 are differentiated by the fact that the underlying vowel following C_1 is removed on the surface, whereas the vowel following C_2 remains intact. As a result, potential C_2 deletion is still penalised by Ident [release transition], while C_1 deletion is not evaluated by the same constraint due to the lack of a surface correspondent of the input transition. Similarly, the transition from the preceding vowel to C_1 is preserved on the surface, whereas the transition to C_2 is removed by syncope. Therefore, Ident [release transition] selectively penalises only changes related to C_2, while Ident [closure transition] only concerns changes related to C_1. Such an evaluation is not possible with contextual faithfulness constraints, as outlined above. Thus, the hypothesis that correspondence constraints refer to acoustic transitions is crucial for capturing the C_2 dominance effect in the context of syncope.

The remainder of the article is structured as follows. §2 outlines the proposal, which serves as the basis for the analyses of various cluster simplification processes provided in §3. §4 extends this analysis to other cluster reduction processes, such as major place assimilation and debuccalisation, where the C_2 dominance effect is also observed in the context of syncope. §5 discusses exceptions to the C_2 dominance effect and provides solutions to them. §6 compares the current proposal with two alternatives: the derivational framework of Harmonic Serialism (HS) (McCarthy 2008, 2011) and Contiguity constraints (e.g., Kenstowicz 1994; McCarthy & Prince 1995). Finally, §7 concludes the article.

2. Proposal

This section consists of three subsections. In §2.1, the core elements of the proposal are outlined in detail, emphasising the crucial role of subsegmental transitions in analysing the C_2 dominance effect in the syncope context. The remaining two subsections address topics that refine the theoretical aspects of the proposal. §2.2 discusses the representation of features within subsegments, adopting the view that these features are phonetically detailed. Then, §2.3 provides a brief overview of Flemming's (2008b) Realised Input model, within which the main proposal is couched.

2.1. Key proposal

The central claim of the current proposal is that transitions into or out of consonants are represented in the relevant forms, and their correspondence relations are accessible to faithfulness constraints. This claim raises three related questions. First, how are these transitions represented? Second, why should faithfulness constraints evaluate these transitions? Third, and most importantly, how do these faithfulness constraints for transitions solve the syncope problem? This subsection focusses on these questions, while related but less central aspects of the proposal, such as the representational assumptions with regard to features and the grammatical architecture to be adopted, are explored separately in subsequent subsections.

First, regarding how the transitions are represented, it is assumed here, following Flemming (2002: 23 ff., 2006: 19, 2008b: 16 ff.), that they are specified as subsegments occupying time intervals starting

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Segments	a		t	p		u	
Auditory subsegments	V_{mid}	closure transition	closure	closure	burst noise	release transition	V_{mid}
Auditory features	[F1] [F2] [F3] (etc.)	[F1] [F2] [F3] (etc.)	[Loudness]	[Loudness]	[NF] [NL]	[F1] [F2] [F3] (etc.)	[F1] [F2] [F3] (etc.)

Figure 1. *The auditory subsegments and features of the sound string [atpu] (NF = noise frequency; NL = noise loudness).*

or ending at consonant–vowel boundaries. These subsegments can contain relevant auditory features, such as F2 frequencies. Additionally, it is assumed that subsegments are subordinate to their host phonological segments: no subsegment can stand alone without a host segment.[1] The schema in Figure 1 illustrates this with a hypothetical configuration of a medial cluster composed of two stops differing in place of articulation (cf. Flemming 2002: 24). Dotted lines indicate associations between subsegments and their host phonological segments.

Each segment illustrated in Figure 1 comprises at least one subsegment. For example, the initial vowel [a] consists of two distinct subsegments: V_{mid}, which represents the vowel's steady state, and the closure transition, which is the transitional phase from the vowel to [t]. Likewise, the final vowel [u] also has two subsegments: the release transition, the transitional phase from the preceding consonant [p] to the vowel, and V_{mid}.[2] Crucially, these subsegments, rather than the host segments themselves, serve as the repositories of features, the building blocks of phonetic detail. This implies that changes in feature values are computed in the grammar at the subsegmental level rather than the segmental level.

This assumption that features are computed at the subsegmental level answers the second question: why do faithfulness constraints need to refer to transitions? As illustrated above, most consonant features are represented in the adjacent transitions rather than the phonological consonant itself. Thus, changes in consonant properties due to cluster simplification or other phonological processes are likely to be manifested as changes in feature values within the transitions. For instance, when cluster simplification occurs, a sequence like $V_1C_1C_2V_2$ is neutralised to $V_1C_2V_2$, invoking changes in the closure transition carried by V_1 due to the removal of C_1. If the sequence [atpu] in Figure 1 neutralises to [apu], the closure transition into [t] in the source representation differs from its output correspondent aiming at [p], specifically in terms of F2 frequencies, which provide primary place cues to a consonant (Dorman *et al.*, 1977). Thus, for faithfulness constraints to properly assess the changes in consonantal place of articulation resulting from cluster simplification, they must be capable of referring to the F2 values present in the transitions.[3]

[1] As an anonymous reviewer noted, no current subsegmental theories propose that subsegments can exist independently of segments; thus, discussing this assumption in detail may be unnecessary. However, certain scenarios remain where this assumption becomes relevant. For instance, release transitions could be maintained within an open transition or a significantly reduced vowel rather than a full vowel. In such cases, if subsegments cannot exist independently, the only remaining possibility is that the transition loses its connection to the original host vowel and attaches to an adjacent consonant to survive, thereby ruling out the possibility that subsegmental transitions stand alone without a host segment.

[2] In Figure 1, the transitional subsegments belong only to the vowels, not to the consonants.

[3] Other auditory qualities in transitions can also be affected, depending on the consonants involved in simplification. For example, when [anpu] is neutralised to [apu], not only the F2 values but also the nasality of the transition is affected (e.g., Hawkins & Stevens 1985; see also Stanton 2017 and the references therein). Similarly, changes in laryngeal status (F1 with F0 and VOT; e.g., Lisker 1975; Abramson & Lisker 1985) or changes related to the distinction between approximants and other consonants (continuity and gradualness of the transition; e.g., Liberman *et al.* 1956; see also Kawahara & Pangilinan 2017) may be observed.

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To illustrate how faithfulness constraints that refer to auditory features can effectively regulate cluster simplification, suppose that changes in release and closure transitions are evaluated by constraints of types schematised in (7) and (8). Adopting Correspondence Theory (McCarthy & Prince 1995), I use IDENT constraints for featural changes while reserving MAX and DEP constraints for the deletion and insertion of segmental and subsegmental units.[4]

(7) IDENT$_{ij}$ [release transition: *f*]
The specifications of auditory feature *f* in the release transition between two corresponding representations, *i* and *j*, must be the same.

(8) IDENT$_{ij}$ [closure transition: *f*]
The specifications of auditory feature *f* in the closure transition between two corresponding representations, *i* and *j*, must be the same.

The tableau in (9) illustrates how these IDENT [transition] constraints evaluate the relevant changes (the transitions are denoted by superscripts). When a cluster consisting of two consonants, such as a [tp] sequence, is simplified, C_2 deletion would change the transition from [p] to [u] into a transition from [t] to [u], thus violating IDENT [release transition: F2]. On the other hand, C_1 deletion would alter the transition from [a] to [t] into a transition from [a] to [p], consequently incurring a violation of IDENT [closure transition: F2].

(9) *Evaluations made by IDENT [transition] constraints*

$a^t tp^p u$	IDENT [rel. trans.: F2]	IDENT [clos. trans.: F2]
a. $a^t t^t u$	* ($^p u \rightarrow {}^t u$)	
b. $a^p p^p u$		* ($a^t \rightarrow a^p$)

The C_2 dominance effect in cluster simplification can be captured by the hierarchical relationship between the IDENT [release transition] and IDENT [closure transition] constraints. The P-map idea is crucial here, stating that a constraint evaluating a perceptually more significant change must outrank a constraint evaluating a less significant change. The ranking IDENT [release transition] ≫ IDENT [closure transition] can be set based on the fact that listeners weigh onset signals more heavily than offset signals in perception (e.g., Fujimura *et al.* 1978; Phillips *et al.* 2002; Wright 2004: 43). For instance, release cues are perceptually more important than closure cues in detecting a consonant and its features (Ohala 1990; Kingston 1994). These faithfulness constraints formulated in (7) and (8) are thus P-map correspondence constraints, and they are universally ranked based on perceptual differences across distinct contexts:

(10) IDENT [release transition: *f*] ≫ IDENT [closure transition: *f*]

The tableau in (11) illustrates how this ranking condition captures the C_2 dominance effect:

(11) *The C_2 dominance effect in cluster simplification*

$a^t tp^p u$	*CC	IDENT [rel. trans.: F2]	IDENT [clos. trans.: F2]	MAX-C
a. $a^t tp^p u$	*! (tp)			
b. $a^t t^t u$		*! ($^p u \rightarrow {}^t u$)		* (p)
☞ c. $a^p p^p u$			* ($a^t \rightarrow a^p$)	* (t)

[4]The correspondence between input and output subsegments is based on the principle of one-to-one correspondence: each input subsegment corresponds to a single output subsegment, and vice versa. Therefore, one input subsegment cannot correspond to multiple output subsegments, nor can one output subsegment correspond to multiple input subsegments. Additionally, it is assumed that correspondence occurs between subsegments of the same type. Consequently, an input release transition corresponds only to an output release transition, and an input closure transition corresponds only to an output closure transition.

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In the given grammar, candidate (11a) is ruled out by the top-ranked *CC constraint, which prohibits consonant sequences. Then, the consonant to be deleted is determined by the ranking condition in (10). Candidate (11c), which removes the first stop, is preferred over candidate (11b), which deletes the second. The former candidate only violates the lower-ranked IDENT [closure transition: F2], while the latter is penalised by the higher-ranked IDENT [release transition: F2].

Now that correspondence constraints capable of addressing the C_2 dominance effect have been established, the final question can be tackled: how do these correspondence constraints for transitions solve the syncope problem? To answer this, imagine a hypothetical source sequence [atipu] with a high vowel between two consonants, which ultimately neutralises to [apu]. The tableau in (12) describes how the C_2 dominance effect in this neutralisation can be captured. In this tableau, neither IDENT [closure transition] nor IDENT [release transition] is violated due to vowel deletion, as both the release transition from the first consonant and the closure transition into the second consonant are removed together with the medial vowel by syncope. In other words, IDENT [release transition] is only violated by the changes in the release transition that are present both in the source and the output, as in (12c). Likewise, IDENT [closure transition] penalises only the closure transition whose correspondence relationship is maintained, as in (12d). The transitions removed by syncope cannot affect the evaluations since they lack their correspondents on the surface. Consequently, (12d) is selected as the optimal output by the ranking condition IDENT [release transition] ≫ IDENT [closure transition].

(12) *Medial cluster simplification interacting with syncope*

$a^tt^ti^pp^pu$	SYNCOPE	*CC	IDENT [rel. trans.: F2]	IDENT [clos. trans.: F2]	MAX-C	MAX-V
a. $a^tt^ti^pp^pu$	∗! ($^ti^p$)					
b. a^ttp^pu		∗! (tp)				∗ ($^ti^p$)
c. a^tt^tu			∗! ($^pu \rightarrow {}^tu$)		∗ (p)	∗ ($^ti^p$)
☞ d. a^pp^pu				∗ ($a^t \rightarrow a^p$)	∗ (t)	∗ ($^ti^p$)

To sum up, the C_2 dominance effect can be captured by the ranking of IDENT [release transition] over IDENT [closure transition], regardless of whether syncope is involved. In the current proposal, vowel deletion entails the removal of the transitions contained by the deleted vowel; thus, the correspondence in transitions between the source and output representations cannot be maintained. Consequently, IDENT [release transition] and IDENT [closure transition] are vacuously satisfied with regard to the removed transitions. The remaining transitions are evaluated by the correspondence constraints because they are present in the adjacent vowels even after one member of the cluster is removed. In this sense, syncope provides an environment that is not technically different from the condition where a vowel does not intervene between the two consonants.

2.2. Representation of the features

In (7) and (8), I formalised the IDENT constraints for subsegmental features without detailing their nature. Since the crucial aspect of the proposal is the presence of consonantal features in transitions, the proposal is compatible with various feature specifications, provided that transitions are represented in relevant forms and referenced by faithfulness constraints. For instance, transitions may be represented with conventional SPE-style binary features like [±labial] or [±nasal] instead of the auditory features in Figure 1. Using these conventional features raises no critical issue in addressing the syncope problem.

Consider in detail how such binary features can be employed with the current proposal. For this purpose, it is assumed that release and closure phases are inserted during consonant adjacency, inheriting relevant binary features from it. Specifically, in some existing subsegmental theories, the proposal could be implemented with the assumption that featural inheritance is controlled by surface

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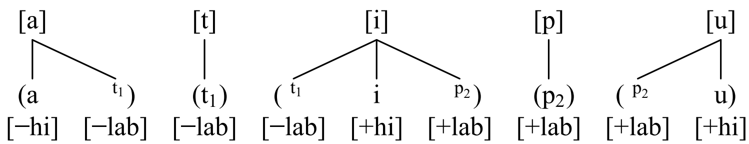
correspondence relationships, as in Agreement by Correspondence (ABC) theories (e.g., Walker 2000; Rose & Walker 2004). The following schema illustrates a potential subsegmental representation within a framework drawing on ABC+Q-theory, which combines ABC with Q-theory (Shih & Inkelas 2019).[5] Consonantal subsegments and transitions are coindexed, allowing features to be inherited from a consonant by its adjacent subsegmental transitions. This inheritance occurs when two conditions are met: first, a constraint enforcing surface agreement between these subsegments is ranked high; and second, a change in transition is preferred over a change in the consonantal subsegment itself.[6]

(13) *Subsegmental representations with conventional binary features (subscript indices show surface correspondences)*



With these binary features and surface correspondence relationships, the analytic consequences are the same as in (12), as illustrated in the tableau in (14):

(14) *Subsegmental analysis with conventional binary features*

$a^{[-lab]}t^{[-lab]}i^{[+lab]}p^{[+lab]}u$	Syncope	*CC	Ident [rel.: place]	Ident [clos.: place]	Max-C	Max-V
a. $a^{[-lab]}t^{[-lab]}i^{[+lab]}p^{[+lab]}u$	*!					
b. $a^{[-lab]}tp^{[+lab]}u$		*!				*
c. $a^{[-lab]}t^{[-lab]}u$			*! ($^{[+lab]}u \rightarrow {}^{[-lab]}u$)		*	*
☞ d. $a^{[+lab]}p^{[+lab]}u$				* ($a^{[-lab]} \rightarrow a^{[+lab]}$)	*	*

Alternatively, auditory dimensions like F1 or F2 can be represented using simple discrete values (Flemming 2002). For instance, the F2 feature in a transition adjacent to [t] can be specified with a higher value (e.g., 4), while a transition adjacent to [p] can be assigned a lower value (e.g., 1), as in (15). These values reflect the F2 loci of the relevant consonants. This strategy remains compatible with the current proposal, provided that changes in these discrete values are penalised by the relevant P-map constraints.

(15) *Subsegmental analysis with discrete auditory features*

$a^{[F2:4]}t^{[F2:4]}i^{[F2:1]}p^{[F2:1]}u$	Syncope	*CC	Ident [rel. trans.: F2]	Ident [clos. trans.: F2]	Max-C	Max-V
a. $a^{[F2:4]}t^{[F2:4]}i^{[F2:1]}p^{[F2:1]}u$	*!					
b. $a^{[F2:4]}tp^{[F2:1]}u$		*!				*
c. $a^{[F2:4]}t^{[F2:4]}u$			*! ($^{[F2:1]}u \rightarrow {}^{[F2:4]}u$)		*	*
☞ d. $a^{[F2:1]}p^{[F2:1]}u$				* ($a^{[F2:4]} \rightarrow a^{[F2:1]}$)	*	*

[5] In standard Q-theory, each segment consistently has three subsegments. For the sake of concise description, I have focussed on representing only the transitional subsegments. It is also worth noting here that Q-Theory does not necessarily assume binary features, as an anonymous reviewer points out. Indeed, in Q-Theory, subsegments are assumed to be associated with articulatory phases, such as vowel targets, release transitions and closure transitions (Shih & Inkelas 2019). Thus, it should be acknowledged that the binary feature analysis couched within the framework of Q-Theory is not the only option within Q-Theory. More phonetically detailed features, such as those proposed in this article, would also be compatible with the theory.

[6] Although the inheritance of features through surface correspondence is assumed here to demonstrate that the current proposal can be implemented within pre-existing subsegmental theories, such as Q-Theory or Aperture Theory (Steriade 1993), this article does not necessarily assume that subsegmental transitions obtain features in this way. Instead, the manifestation of consonantal properties in transitions is captured through a cue realisation constraint, rather than relying on surface correspondences. See §2.3 for details.

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Transition features may not have specific values but rather exist as unary phonetic cues. For example, coronal transitions can be manifested by [high F2 frequency], while labial transitions are represented by [low F2 frequency], without the need for specific feature values. Within the Bidirectional Phonetics and Phonology (BiPhon) framework (Boersma 2007, 2011, 2012; Boersma & Hamann 2008, 2009; Boersma & Leussen 2017), cue constraints that refer to such transitional cues can theoretically capture the C_2 dominance effect in the syncope context. This is illustrated in the tableau in (16), where [^{t}] represents [high F2 frequency], and [^{p}] denotes [low F2 frequency].

(16) *Subsegmental analysis with unary phonetic cue features*

|atipu|	Syncope	*[V^{t}_^{p}V]	Max-C	*/pV/[_^{t}V]	*/Vt/[V^{p}_]
a. /atipu/ [a^{t}_^{t}i^{p}_^{p}u]	*!				
b. /atpu/ [a^{t}_^{p}u]		*!			
c. /atpu/ [a^{t}_^{t}u]				*! (/pu/ → [_^{t}u])	
☞ d. /atpu/ [a^{p}_^{p}u]					* (/at/ → [a^{p}_])
e. /atu/ [a^{t}_^{t}u]			*!		
f. /apu/ [a^{p}_^{p}u]			*!		

In (16), the BiPhon model is implemented within parallel OT. For the underlying form |atipu|, potential pairs of a surface form (in slashes) and phonetic form (in square brackets) are given as candidates. The faithfulness constraints presented here are of two types: those evaluating the mapping from an underlying representation to a surface form (e.g., Max-C) and cue constraints regulating the mapping from a surface form to a phonetic form (e.g., */pV/[_^{t}V] and */Vt/[V^{p}_]). Similarly, markedness constraints operate on different representational levels: some evaluate surface forms (e.g., Syncope), while others evaluate phonetic forms (e.g., *[V^{t}_^{p}V]). With these constraints, the grammar correctly selects candidate (16d) as optimal. Details are as follows. For |atipu|, its surface representation should be /atpu/ due to the high-ranked Syncope constraint and Max-C. This surface form is then phonetically realised as [a^{p}_^{p}u] under the pressure of the constraint that demands the same frequency feature on both sides of the acoustic silence (i.e., *[V^{t}_^{p}V]). The alternative phonetic form [a^{t}_^{t}u] in (16c) is ruled out due to the P-map ranking between the cue constraints, in which */pV/[_^{t}V], which protects the release transition, outranks */Vt/[V^{p}_], which preserves the closure transition. Once again, the crucial role is played by the distinction between the release transition and the closure transition, as determined by the constraint ranking reflecting the P-map hierarchy.

Although there are various potential ways to specify transitional features, including those previously mentioned, I assume that considerable phonetic detail is represented in relevant forms for the complete formulation of the P-map constraints. Given that subsegmental transitions are assumed to represent real acoustic events at consonant–vowel boundaries rather than being abstract units, it is natural to suppose that features encoded by such subsegmental units reflect detailed acoustic events. Therefore, I assume that transitions encode auditory features like F1 or F2, rather than abstract features.

In addition, it is assumed that these auditory features are context-dependent and continuous. This is based on the phonetic observation that there are no clear invariant acoustic cues for some features, a phenomenon known as the lack of invariance in the speech signal (see Delattre *et al.* 1955). For example, a consonant's place of articulation can be detected by F2 transition properties, but there are no absolute values serving as invariant landmarks for each place feature, since relevant F2 frequencies vary as a function of the vocalic context. In fact, not only the F2 transition but also many other acoustic cues are context-dependent, while invariant acoustic cues are rare (Reetz & Jongman 2020: 227; cf. Blumstein & Stevens 1980). Note that this assumption has additional advantages: grammatically controlled language-specific phonetic events, such as coarticulation, can be consistently analysed within the same framework as their phonological counterparts, such as place assimilation or cluster simplification (e.g., Flemming 2001, 2011). While this article focusses on phonological processes with contrastive outcomes, the boundary between such processes and their corresponding phonetic events is often unclear. Given this, I maintain the position that phonological processes, such as cluster simplification, can be derived through the computation of continuous auditory features, leaving open the possibility of a unified model of phonetics and phonology.[7] However, as mentioned earlier, the assumptions about the nature of these features are not central to the proposal. Readers should have no problem understanding the analyses from §3 onward, even if they assume one of the alternatives mentioned above instead of the specific suggestion that the features are continuous and context-dependent.

On the assumption that features are considerably detailed, I propose that the correspondence constraints for the transitions, previously introduced in (7) and (8), can be more precisely defined as follows:

(17) IDENT_{ij} [release transition] > *d*
The perceptual differences in the release transition between two corresponding representations *i* and *j* must be less than *d*.

(18) IDENT_{ij} [closure transition] > *d*
The perceptual differences in the closure transition between two corresponding representations *i* and *j* must be less than *d*.

These constraints evaluate the perceptual differences in the release and closure transitions between representations *i* and *j*. Assuming that the transitions contain only features representing the first three formant frequencies (F1, F2 and F3) at the onset or offset of the trajectory, these specifications can be quantified as in (19).[8] The *d*-value denotes the perceptual distance between two transitions.

(19) $$d_{ij} = \sqrt{a(\mathrm{F1}_i - \mathrm{F1}_j)^2 + b(\mathrm{F2}_i - \mathrm{F2}_j)^2 + c(\mathrm{F3}_i - \mathrm{F3}_j)^2}$$

This models the perceptual distances of Bark-scaled formant frequencies (Traunmüller 1990) between *i* and *j*. To illustrate, consider English preconsonantal t/d deletion, such as /bæd bɔɪ/ → [bæ^{b}b^{b}ɔɪ] (Dilley & Pitt 2007). In English, the onset frequencies of the first three formants in Barks for [bɔ] are 3.80 (F1), 9.26 (F2) and 14.17 (F3), while the values for [dɔ] are 3.53 (F1), 11.66 (F2) and 14.63 (F3) (Kewley-Port 1982). Using these measurements and the metric in (19), the *d*-value between [bɔ] and [dɔ] at the onset of [ɔ] can be calculated as 1.42, assuming $a = b = c = 0.\bar{3}$ (summing to 1.00). Thus, the change from [bɔ] to [dɔ] violates IDENT [release transition] > 0.5, which penalises onset changes with *d*-values exceeding 0.5, but not IDENT [release transition] > 1.5, as the *d*-value is less than 1.5. Similarly, the *d*-value for the perceptual difference between [æb] and [æd] can be obtained as 0.94,

[7] Dilley & Pitt (2007) demonstrate that when a heterorganic cluster is reduced in English, the result is phonetically varied rather than consistently phonological. The /np/ sequence in *pinpoint* /pɪ**np**ɔɪnt/ may maintain the alveolar gesture ([pɪ**np**ɔɪnt]), undergo place assimilation ([pɪ**mp**ɔɪnt]), or be fully simplified ([pɪ**p**ɔɪnt]). Notably, the F2 value of the closure transition from [ɪ] varies gradually for each outcome. In [pɪ**np**ɔɪnt], it is around the midpoint between coronal and labial transitions. In [pɪ**mp**ɔɪnt] or [pɪ**p**ɔɪnt], it is higher than a typical labial transition, suggesting remnant alveolar gesture. This unclear boundary between phonology and phonetics can be uniformly dealt with if the two share continuous features. For instance, it is possible to imagine a version of Harmonic Grammar with weighted phonetic realisation constraints that evaluate such continuous values (e.g., Flemming 2001). In such an approach, cluster reduction could be triggered by a constraint $(\mathrm{F2}_{C1}-\mathrm{F2}_{C2})^2$ requiring F2 assimilation in C_1 closure and C_2 release transitions, countered by other constraints $(\mathrm{F2}_{C1}-\text{Target } \mathrm{F2}_{C1})^2$ and $(\mathrm{F2}_{C2}-\text{Target } \mathrm{F2}_{C2})^2$ that demand preserving target F2 values. The result depends on their relative weighting. For instance, even if $(\mathrm{F2}_{C2}-\text{Target } \mathrm{F2}_{C2})^2$ always outweighs $(\mathrm{F2}_{C1}-\text{Target } \mathrm{F2}_{C1})^2$ according to the P-map, a higher-than-expected weight for the latter would yield more coronal F2 transition maintenance and a higher F2 value compared to a typical labial transition. While this article does not develop such a sophisticated model, it is advisable to keep open the possibility of implementing the current proposal within such a more refined framework in future research.

[8] Other potential transitional properties, such as nasality or continuity of the transition, can be integrated into this formalisation with appropriate constants that mediate the differences in the measurement scales. For instance, nasality of the transition might be quantitatively translated in terms of the nasal proportion within a given interval (cf. Stanton 2017: 79 ff.), or changes in the formant properties by the nasality of the adjacent consonant (Wright 1986; Flemming 2008a: 14). This means that a squared difference in the nasalised transitions, multiplied by an appropriate constant, can be added to the metric given in (19). These properties, particularly nasality, will be mentioned when necessary.

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given the formant values in Barks: 4.32 (F1), 11.21 (F2) and 13.51 (F3) for [æb] and 3.73 (F1), 12.25 (F2) and 14.62 (F3) for [æd]. In principle, the English cluster simplification case can be analysed based on these *d*-values, as in the tableau in (20).

(20) *English cluster simplification (full version)*

bæ^{d}db^{b}ɔɪ	*CC	IDENT [rel. trans.] > 1.5	IDENT [rel. trans.] > 0.5	IDENT [clos. trans.] > 1.5	IDENT [clos. trans.] > 0.5
a. bæ^{d}db^{b}ɔɪ	*! (db)				
b. bæ^{d}d^{d}ɔɪ			*! ($d_{rel.}$: 1.42)		
☞ c. bæ^{b}b^{b}ɔɪ					* ($d_{clos.}$: 0.94)

In (20), the faithfulness constraints are ranked hierarchically according to the P-map principle. In other words, this stratification means that more perceptually distinct changes incur more severe faithfulness violations. In addition to this basic principle that larger changes in the transition correspond to a larger *d*-value, considering that onset changes are perceptually weighted more than offset changes, the P-map principle implies the following hierarchical relationship among the IDENT [transition] > d_{ij} constraints:

(21) For any specific d_{ij},
IDENT [release transition] > d_{ij} ≫ IDENT [closure transition] > d_{ij}

The condition in (21) states that changes in the release transition are perceptually more significant than those in the closure transition for the same *d*-value, allowing the possibility that a minor change in the release transition can be overridden by a more significant change in the closure transition.

This formalisation directly implements the P-map by being sensitive to actual acoustic-perceptual differences. The core proposal of the P-map is that it guides speakers to identify the smallest perceptual change from the input, minimising overall deformation (Steriade 2009). This idea can, in theory, be grammatically encoded using correspondence constraints in various formalisations. However, the extent to which these different forms of faithfulness constraints reflect the P-map can vary. For instance, a P-map ranking of contextual faithfulness constraints such as IDENT (place) /__V ≫ IDENT (place) /__C suggests that the perceptual difference for the same place contrast is invariably greater in the prevocalic context than in the preconsonantal context. However, in fact, small differences in CV transitions can be overshadowed by significant differences in VC transitions. As Steriade (2001) points out, the t/ʈ apical contrast relies primarily on formant differences in the closure transition, particularly in F3, while the release transition's contribution is negligible because the tongue tip slides towards the alveolar position during the retroflex closure. Consequently, in a Swedish word like /væ**ɖs**lig/ 'worldly', realised as [væ**ɖʂɭ**ig] (Eliasson 1986: 280; Hamann 2003), apical assimilation shows a progressive direction, indicating a preference for a minimal change in the release transition over significant changes in the closure transition.[9] In contrast, the IDENT [transition] constraints, which reflect the exact acoustic difference between forms, more effectively explain such progressive apical assimilation. One hypothesis consistent with (21) is that changes in the closure transition take precedence over changes in the release transition when the *d*-value associated with the closure transition is significantly larger. For example, while IDENT [closure transition] > 0.5 should be outranked by IDENT [release transition] > 0.5 according to the condition in (21), IDENT [closure transition] > 2.5 does not necessarily need to be outranked by IDENT [release transition] > 0.5. A ranking in which IDENT [closure transition] > 2.5 dominates IDENT [release transition] > 0.5 could lead to progressive assimilation. Therefore, this formulation, which directly refers to the *d*-value, more realistically reflects the P-map.

[9] Although this progressive apical assimilation can, in principle, be explained by introducing very specific contextual faithfulness constraints targeting only clusters involving a retroflex, such as IDENT (anterior) /V[__, apical, stop]C ≫ IDENT (anterior) /C[__, apical, stop]V (e.g., Steriade 2001: 240), it remains difficult to directly compare these P-map constraints with others referring to different contexts.

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However, despite these considerations, it is true that (21) is too intricate for analytical convenience, requiring exact *d*-values for each change and the threshold where strict onset dominance can be subverted. I henceforth assume that the perceptual effects of potential onset changes from cluster simplification generally exceed those of offset changes, as shown in (22).[10]

(22) For any two different *d*-values d_{ij} and e_{ij},
IDENT [release transition] > d_{ij} ≫ IDENT [closure transition] > e_{ij}

This allows further simplifications of the relevant constraints, abstracting away from detailed measurements. Consider again the English cluster simplification case analysed in (20). Given the condition in (22), the tableau in (20) can be reduced to the simpler grammar in (23):

(23) *English cluster simplification (simplified version)*

bæ^{d}db^{b}ɔɪ	*CC	IDENT [rel. trans.]	IDENT [clos. trans.]	MAX-C
a. bæ^{d}db^{b}ɔɪ	∗! (db)			
b. bæ^{d}d^{d}ɔɪ		∗! (^{b}ɔ → ^{d}ɔ)		∗ (b)
☞ c. bæ^{b}b^{b}ɔɪ			∗ (æ^{d} → æ^{b})	∗ (d)

This is similar to (11), except that more features, that is, F1 and F3, are considered here according to the metric in (19). By assuming the ranking condition in (22), it is possible to reduce the effort involved in measuring *d*-values and thresholds while maintaining formal rigour.

Considering the above, for the remainder of this article, I will adopt two simplifications for analytical convenience. First, given that the relevant onset changes are, in general, perceptually more significant than the offset changes in the cluster simplification contexts, the *d*-values are not fully specified. Second, all relevant feature specifications are calculated by a metric, so features are not manifested on constraints unless necessary. These strategies allow capturing C_2 dominance with a simple ranking of IDENT [release transition] over IDENT [closure transition], abstracting away from detailed measurements.

2.3. Framework: the Realised Input model

I adopt the Realised Input model of phonological grammar (Flemming 2008b) as a framework for the current proposal. This decision is not based on the superiority of this model over alternatives in treating the syncope problem with subsegmental features. Rather, it is due to the fact that the Realised Input model is specifically designed to allow P-map correspondence constraints to reference phonetic details, thereby connecting the P-map principle with the roles of phonetic details in phonology. Since the current proposal argues for the role of subsegmental details in conjunction with the P-map principle, it would be a good choice to rely on a framework designed to address faithfulness to phonetic details, without further assumptions. Additionally, adopting the Realised Input model provides an ancillary benefit in the context of cluster simplification, because cross-linguistic patterns of cluster reduction processes, including cluster simplification, are determined by phonetic generalisations beyond simple phonological considerations: cluster reduction is not reported in languages where C_1 has a phonetically audible release (e.g., Jun 2002; Flemming 2008b).[11] If cluster reduction is at least partially determined

[10]In most situations, it can be safely assumed that release transitions generally dominate closure transitions. Since this article does not directly address apical assimilation and our primary concern is the C_2 dominance effect in cluster reduction processes, the condition in (22) will adequately serve our purposes without causing any particular issues.

[11]For example, in languages where C_1 stops are canonically released, such as Arabic, Chontal, Hindi, Kutenai, Motilone, Russian, Tillamook, Upper Chehalis, Wikchamni and Zoque, place assimilation or consonant deletion is reportedly unattested. In contrast, in languages where C_1 stops are not audibly released, such as Basque, Catalan, German, Diola-Fogny, English, Korean, Yakut and West Greenlandic, place assimilation or cluster simplification is widely attested (Jun 2002: 5 and the references therein).

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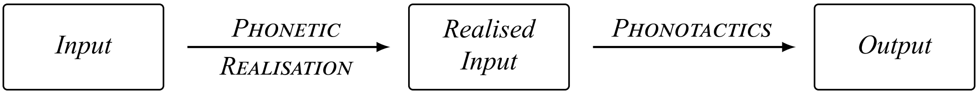

Figure 2. *Simplified version of the Realised Input model of phonology.*

by such phonetic factors, the grammar needs to refer to those facts. Thus, introducing subsegments alone may be insufficient for modelling cluster reduction, as it only provides a solution to the syncope problem, which is just one of several issues related to cluster reduction processes. Although this article focusses on solving the syncope problem, it is ideal if the solution to the syncope problem is carried out within a framework that is claimed to provide a solution to other issues concerning cluster reduction processes.[12]

Figure 2 illustrates the basic architecture of a simplified version of the Realised Input model. For the current purposes, the model's details are simplified by assuming there are only two grammatical components: Phonetic Realisation and Phonotactics. For the full version of the model and a detailed discussion, see Flemming (2008b) or Kim (2024c: ch. 2).

In this model, raw inputs with abstract sound strings are first sent to the Phonetic Realisation component, which assigns phonetic substance to a raw input and returns a realised input. This component is called Phonetic Realisation in that it determines language-specific phonetic patterns, resulting in phonetically enriched representations. The Phonotactics component receives the realised input and returns the surface output. This component essentially determines a language's surface phonological patterns through the interplay between markedness constraints that encode phonotactic requirements and faithfulness constraints that refer to phonetic details. This component is referred to as Phonotactics to differentiate it from Phonetic Realisation, as it regulates surface phonotactic patterns. Although these two components share constraints and their rankings, they differ in that Phonetic Realisation activates only a subset of those constraints, while Phonotactics activates all constraints. Following Kim (2024c), it is assumed here that Phonetic Realisation activates, in particular, two types of constraints: phonetic articulatory constraints that determine gestural coordination or segmental duration, and cue realisation constraints that demand the realisation of target phonetic cues.

To illustrate how this architecture works and how phonology can refer to language-specific phonetic details, consider a hypothetical example where a coronal stop is deleted before another stop (as in /atpa/ → [a^{p}p^{p}a]). As already mentioned, empirical evidence suggests that cluster reduction processes, including simplification, largely depend on the presence or absence of an audible release of C_1. For a language to allow cluster reduction, it should not have a release of C_1, possibly due to the fact that such a release strongly signals the presence of C_1 (e.g., Jun 2002; Flemming 2008b). The tableau in (24) illustrates how such phonetic details are provided to /atpa/ by the Phonetic Realisation component:

(24) *Phonetic Realisation:* /atpa/$_{\mathrm{I}}$ → [a^{t}t˺p^{p}a]$_{\mathrm{RI}}$

I: /atpa/	Overlap	Realise [transition]
a. a^{t}t^{t}∘^{p}p^{p}a	∗! (t^{t}∘^{p}p)	
☞ b. a^{t}t˺p^{p}a		∗∗ (/t/$_{\mathrm{rel}}$, /p/$_{\mathrm{clos}}$)

When the two consonants are not overlapped, subsegmental transitions could be realised by connecting them to the adjacent consonants even without a host vowel (see fn. 1). However, in the

[12] Adopting the Realised Input model also facilitates the analysis of opaque interactions (Kim 2024a,b,c). In §3.3, it will be shown that Lardil, where apocope and final cluster simplification interact opaquely, can be effectively analysed within this framework.

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given grammar, such an open transition is not allowed because the Overlap constraint, which requires adjacent consonants in the input to be articulatorily overlapped, outranks the cue realisation constraint for transitions, ruling out candidate (24a) (cf. Gafos 2002). Although the cue realisation constraint requires the realisation of release and closure transitions with target feature values, such as F2 target values, for each consonant in the input, the enforced gestural overlap between two consonants prevents /t/ from realising its release transition and /p/ from realising its closure transition.[13] Consequently, the grammar selects (24b) as optimal, where the consonants are articulatorily overlapped without the realisation of the transitions between them.

Then, constraints in Phonotactics, including the P-map correspondence constraints and *CC, can access the relevant phonetic detail: whether C_1 is released or not. This component is where our main interest lies: all processes that have contrastive and phonological consequences, such as neutralisation, deletion, or insertion, take place as a result of interactions between the relevant markedness constraints and the faithfulness constraints in this component. The tableau in (25) shows how cluster simplification can occur in Phonotactics when C_1 is not released. Suppose that Ident [release transition] is universally undominated, in that there is no convincing evidence demonstrating that cluster reduction processes effectively remove buccal C_2 or alter its major place of articulation.[14] This implies that other constraints, including *CC, are generally dominated by Ident [release transition], or at best, tied with it as in (25). Suppose that *CC is sensitive only to clusters without C_1 release, reflecting the observation that cluster reduction processes do not affect clusters where C_1 is released. Given these assumptions and the fact that Overlap outranks Realise [transition], when *CC triggers cluster reduction by dominating Ident [closure transition], the outcome must be (25d), which removes C_1.

(25) *Phonotactics:* [a^{t}t˺p^{p}a]$_{RI}$ → [a^{p}p^{p}a]$_{O}$

I: /atpa/ RI: [a^{t}t˺p^{p}a]	Overlap	Ident [rel. trans.]	*CC	Ident [clos. trans.]	Max-C	Realise [transition]
a. a^{t}t˺p^{p}a			∗! (t˺p)			∗∗ (/t/$_{rel}$, /p/$_{clos}$)
b. a^{t}t$^{t∘p}$p^{p}a	∗! (t$^{t∘p}$p)					
c. a^{t}t^{t}a		∗! (^{p}a → ^{t}a)			∗ (p)	∗∗ (/p/$_{rel}$, /p/$_{clos}$)
☞ d. a^{p}p^{p}a				∗ (a^{t} → a^{p})	∗ (t)	∗∗ (/t/$_{rel}$, /t/$_{clos}$)

In contrast, the Phonotactics component does not yield cluster simplification when the given realised input form has an open transition between the two consonants. Given that a realised input form with a released C_1 suggests that the Realise [transition] constraint outranks the Overlap constraint in Phonetic Realisation (cf. (24), where Overlap outranks the cue realisation constraints), Realise [transition] is also ranked over Overlap in Phonotactics. Under this ranking condition, although the relative ranking of other constraints, including *CC, remains unchanged, the result is now different: cluster simplification is blocked by Realise [transition]. Since Realise [transition] requires the realisation of the release and closure transitions of the consonants in the input forms, the grammar opts to maintain the open transition of the realised input form, ruling out candidates that do not meet this requirement.

[13] Since Realise [transition] constraints require transitions to have target feature values of the adjacent consonant, realising a release transition like [p^{t}a] instead of [p^{p}a] does not, in principle, satisfy this constraint.

[14] It is worth noting that some reported cases prefer preservation of root C_1 features over affixal C_2 features. However, these cases can be attributed to the morphological root–affix asymmetry rather than to any inherent perceptual asymmetry between C_1 and C_2. Importantly, the root C_2 remains unaffected in contexts where the affixal C_2 may be subject to the reduction process. For further discussion of these cases and analyses, see §5.

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(26) *Phonotactics:* [a^{t}t$^{t\circ p}$p^{p}a]$_{RI}$ → [a^{t}t$^{t\circ p}$p^{p}a]$_{O}$

I: /atpa/ RI: [a^{t}t$^{t\circ p}$p^{p}a]	Realise [transition]	Ident [rel. trans.]	*CC	Ident [clos. trans.]	Max-C	Overlap
☞ a. a^{t}t$^{t\circ p}$p^{p}a						* (t$^{t\circ p}$p)
b. a^{t}t̚p^{p}a	*!* (/t/$_{rel}$, /p/$_{clos}$)		* (t̚p)			
c. a^{t}t^{t}a	*!* (/p/$_{rel}$, /p/$_{clos}$)	* (^{p}a → ^{t}a)			* (p)	
d. a^{p}p^{p}a	*!* (/t/$_{rel}$, /t/$_{clos}$)			* (a^{t} → a^{p})	* (t)	

Although a serial implementation of the grammatical architecture has been shown thus far for illustrative purposes, it is, in principle, possible to perform a parallel implementation without separating the two components of Phonetic Realisation and Phonotactics, as these two components share the same constraint ranking (see also Kim 2024a,b,c). The tableau in (27) shows an example of such a parallel implementation.

(27) *Parallel implementation*

I: /atpa/	Overlap^{PR}	Ident [rel. trans.]	*CC	Ident [clos. trans.]	Max-C	Realise [transition]^{PR}
D a. a^{t}t̚p^{p}a			*! (t̚p)			** (/t/$_{rel}$, /p/$_{clos}$)
b. a^{t}t$^{t\circ p}$p^{p}a	*! (t$^{t\circ p}$p)					
c. a^{t}t^{t}a		*! (^{p}a → ^{t}a)			* (p)	** (/p/$_{rel}$, /p/$_{clos}$)
☞ d. a^{p}p^{p}a				* (a^{t} → a^{p})	* (t)	** (/t/$_{rel}$, /t/$_{clos}$)

Constraints in the tableau are categorised into two groups: phonetic realisation constraints (marked with a superscript PR) and general phonological markedness and correspondence constraints. Phonetic realisation constraints, such as Overlap and Realise [transition], were the only activated constraints in the Phonetic Realisation component in the serial implementation (see (24)). It is worth noting that the correspondence constraints here evaluate the relationship between the designated candidate (here (27a), marked with D) and other candidates rather than directly referring to the input (cf. McCarthy 1999; Jun 2002). The designated candidate is chosen only by phonetic realisation constraints from candidates that have not undergone contrastive changes like neutralisation, deletion or insertion (Flemming 2008b; Kim 2024a,b,c). In this tableau, (27a) and (27b) are such candidates. Between these two, which differ only in the phonetic release of C_1, (27a) is selected as the designated candidate because it satisfies the higher-ranked Overlap constraint among the phonetic realisation constraints. The optimal candidate is then determined by evaluating all constraint violations, with (27d) preserving the release transition specified in (27a).

Within this Realised Input model, whether serial or parallel, the introduced constraint set generates a stable prediction about potential typological patterns involving syncope. When the top-ranked Syncope constraint enforces interconsonantal vowel deletion, only three patterns can emerge from the given constraints and their P-map ranking: [a^{t}t$^{t\circ p}$p^{p}a] (syncope with released C_1), [a^{t}t̚p^{p}a] (syncope with unreleased C_1), and [a^{p}p^{p}a] (syncope with C_1 deletion). The grammar does not predict the potential output with C_2 deletion, *[a^{t}t^{t}a], due to the ranking Ident [release transition] ≫ Ident [closure transition]. For instance, when Ident [release transition] is ranked highest with Syncope, and Ident [closure transition] is dominated by the constraints in the top and second tiers, it is possible to posit the factorial typology in (28) based on the relative ranking of the remaining constraints (Max-C is assumed

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to be ranked lowest, ensuring cluster simplification as a response to the *CC constraint).[15] The model is implemented in a parallel way, as in (27).

(28) *Typology with syncope*

a. *Syncope with C_1 release* (Realise [transition] ≫ Overlap ≫ *CC)

I: /atipa/	Syncope	Ident [rel. trans.]	Realise [transition]^{PR}	Overlap^{PR}	Ident [clos. trans.]	*CC	Max-C
D i. $a^{t}t^{t}i^{p}p^{p}a$	*!						
☞ ii. $a^{t}t^{t}{\circ}^{p}p^{p}a$				*			
iii. $a^{t}t^{\urcorner}p^{p}a$			*!*			*	
iv. $a^{t}t^{t}a$		*!	**				*
v. $a^{p}p^{p}a$			*!*		*		*

b. *Syncope with C_1 release* (Realise [transition] ≫ *CC ≫ Overlap)

I: /atipa/	Syncope	Ident [rel. trans.]	Realise [transition]^{PR}	*CC	Ident [clos. trans.]	Overlap^{PR}	Max-C
D i. $a^{t}t^{t}i^{p}p^{p}a$	*!						
☞ ii. $a^{t}t^{t}{\circ}^{p}p^{p}a$						*	
iii. $a^{t}t^{\urcorner}p^{p}a$			*!*	*			
iv. $a^{t}t^{t}a$		*!	**				*
v. $a^{p}p^{p}a$			*!*		*		*

c. *Syncope with unreleased C_1* (Overlap ≫ Realise [transition] ≫ *CC)

I: /atipa/	Syncope	Ident [rel. trans.]	Overlap^{PR}	Realise [transition]^{PR}	Ident [clos. trans.]	*CC	Max-C
D i. $a^{t}t^{t}i^{p}p^{p}a$	*!						
ii. $a^{t}t^{t}{\circ}^{p}p^{p}a$			*!				
☞ iii. $a^{t}t^{\urcorner}p^{p}a$				**		*	
iv. $a^{t}t^{t}a$		*!		**			*
v. $a^{p}p^{p}a$				**	*		*!

d. *Syncope with C_1 deletion* (Overlap ≫ *CC ≫ Realise [transition])

I: /atipa/	Syncope	Ident [rel. trans.]	Overlap^{PR}	*CC	Ident [clos. trans.]	Realise [transition]^{PR}	Max-C
D i. $a^{t}t^{t}i^{p}p^{p}a$	*!						
ii. $a^{t}t^{t}{\circ}^{p}p^{p}a$			*!				
iii. $a^{t}t^{\urcorner}p^{p}a$				*!		**	
iv. $a^{t}t^{t}a$		*!				**	*
☞ v. $a^{p}p^{p}a$					*	**	*

[15] Note that, although the factorial typology presented here is based on the relative ranking changes among Realise [transition], Overlap and *CC as an example, an even more complex factorial typology constructed by flexibly altering the rankings of Ident [closure transition] and Max-C still does not predict outcomes such as *$[a^{t}t^{t}a]$, where C_2 deletion applies (cf. McCarthy 2009, who provides a comparable typology within the framework of HS).

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e. *Syncope with C_1 release* (*CC ≫ REALISE [transition] ≫ OVERLAP)

I: /atipa/	SYNCOPE	IDENT [rel. trans.]	*CC	REALISE [transition]^{PR}	IDENT [clos. trans.]	OVERLAP^{PR}	MAX-C
D i. $a^tt^ti^pp^pa$	*!						
☞ ii. $a^tt^t\circ^pp^pa$						*	
iii. $a^tt^{\urcorner}p^pa$			*!	**			
iv. a^tt^ta		*!		**			*
v. a^pp^pa				*!*	*		*

f. *Syncope with C_1 deletion* (*CC ≫ OVERLAP ≫ REALISE [transition])

I: /atipa/	SYNCOPE	IDENT [rel. trans.]	*CC	OVERLAP^{PR}	IDENT [clos. trans.]	REALISE [transition]^{PR}	MAX-C
D i. $a^tt^ti^pp^pa$	*!						
ii. $a^tt^t\circ^pp^pa$				*!			
iii. $a^tt^{\urcorner}p^pa$			*!			**	
iv. a^tt^ta		*!				**	*
☞ v. a^pp^pa					*	**	*

From the typology presented above, it is evident that cluster simplification is possible only when both OVERLAP and *CC dominate REALISE [transition]. The ranking of OVERLAP over REALISE [transition] means that a consonant cluster could be realised without C_1 release if there were no cluster simplification, aligning with the observation that cluster reduction processes only affect clusters without C_1 release. In other words, the typology predicts that cluster simplification, even in the syncope context, can only take place in a grammar where it could result in a cluster without C_1 release if there were no cluster simplification (i.e., only in the grammar where OVERLAP ≫REALISE [transition]). In contrast, a grammar that would result in a cluster with C_1 release never undergoes cluster simplification, even with a higher ranked *CC, as in (28e). When REALISE [transition] outranks OVERLAP, the expected outcome is a cluster with C_1 release, even after the application of syncope.

Given that our primary focus is on the interaction between cluster simplification and syncope, subsequent sections will operate under the assumption that in the full grammar *CC is undominated and OVERLAP outranks REALISE [transition], invariably resulting in cluster simplification, as in (28f). Under this assumption, I will not present constraints that are not central to the discussion, such as OVERLAP and REALISE [transition], and will instead focus on the P-map ranking of the IDENT [transition] constraints and their interaction with phonotactic markedness constraints.

In summary, the Realised Input model provides a formal apparatus for P-map constraints that require reference to substantial phonetic details. Regardless of whether the model is implemented serially or in parallel, it allows phonological patterns to be determined based on phonetic details such as the realisation of C_1 release or formant transitions. In this respect, the Realised Input model is beneficial in explaining the syncope problem within a broader context involving phonetic details such as C_1 release. It can be used not only to solve the syncope problem but also to provide a grammatical account of the phonetic generalisation underlying cluster reduction processes.

3. Analysis

This section illustrates how the current proposal can successfully be applied to cluster simplification processes in various contexts. In §3.1, I begin with analyses of typical medial cluster simplification cases from Basque and Tunica, with the latter showing an interaction between syncope and cluster simplification. Then, §3.2 demonstrates that the proposal consistently accounts for triconsonantal

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cluster simplification, using Hungarian and Tangale as primary examples. Finally, §3.3 analyses final cluster simplification in Lardil, which is fed by apocope.

3.1. Medial cluster simplification

As a motivation for cluster simplification, I reformulate the *CC constraint to penalise only sequences of supralaryngeal heterorganic consonants, excluding a cluster with a glottal consonant.

(29) *CC$_{\text{HETERORGANIC}}$ (abbr.: *CC)
Assign one violation mark for every surface sequence of heterorganic supralaryngeal consonants.

Languages may remove one consonant in the target cluster to satisfy this constraint unless a potential violation of MAX-C is fatal. However, this markedness constraint can also be satisfied by a geminate or a homorganic cluster, which preserves the total duration of the consonants without a violation of MAX-C. Therefore, it is necessary to consider factors that favour deletion over forming a geminate or homorganic cluster. The constraint in (30) penalises lengthened gestures formed by geminates and homorganic clusters:

(30) *LONG CONSONANT (abbr.: *LONGC)
Assign one violation mark for every surface supralaryngeal consonant gesture that exceeds the typical singleton duration.

Ranking this constraint over MAX-C enables cluster simplification instead of place assimilation. For example, consider the Basque cluster simplification in (2a), repeated in (31):

(31) *Cluster simplification in Basque* (Hualde 1991; repeated from (2a))

a.	ba**t** + **p**aratu	[ba**p**aratu]	'put one'
b.	ba**t** + **k**urri	[ba**k**urri]	'run one'
c.	gu**k** + **p**iztu	[gu**p**iztu]	'we light'
d.	gu**k** + **k**endu	[gu**k**endu]	'we take away'

In this language, neither heterorganic clusters nor geminates are preferred over consonant deletion, suggesting that both *CC and *LONGC outrank MAX-C.[16] The tableau in (32) illustrates this:

(32) *Analysis of Basque cluster simplification*

I: /bat kurri/ RI: [ba^{t}tk^{k}urri]	*CC	*LONGC	IDENT [rel. trans.]	IDENT [clos. trans.]	MAX-C
a. ba^{t}tk^{k}urri	∗! (tk)				
b. ba^{t}tt^{t}urri		∗! (tt)	∗ (^{k}u → ^{t}u)		
c. ba^{k}kk^{k}urri		∗! (kk)		∗ (a^{t} → a^{k})	
d. ba^{t}t^{t}urri			∗! (^{k}u → ^{t}u)		∗ (k)
☞ e. ba^{k}k^{k}urri				∗ (a^{t} → a^{k})	∗ (t)

As presented in the tableau, consonant deletion results in changes in the relevant transitions.[17] Deleting [t] in the realised input can change the closure transition, as in candidate (32e), while removing

[16]Geminates are interpreted here as the preservation of the existing consonant, rather than the deletion of a consonant accompanied by compensatory lengthening of the adjacent consonant. Therefore, the change from a heterorganic cluster to a geminate does not violate MAX-C.

[17]Although not represented in the tableau, as explained in §2.3, such changes are controlled by the REALISE [transition] constraint, which requires the realisation of transitions with target feature values of the adjacent consonant. Even when the

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[k] can alter the following release transition as in (32d). The perceptual significance of these changes determines which consonant is targeted for deletion. The ranking of Ident [release transition] over Ident [closure transition] reflects the perceptual difference between release and closure transition, favouring (32e) over (32d).

Note that potential geminate formation can also result in changes in transitions. This suggests that the directional asymmetry in place assimilation can also be accounted for by the ranking of the same Ident constraints. This possibility will be discussed in detail in §4. In the present case, the C_2 dominance effect is accompanied by cluster simplification. Candidate (32c), which preserves consonant duration, is ruled out by *LongC, although both (32c) and (32e) satisfy Ident [release transition].

An example of cluster simplification fed by syncope can be found in Tunica. In this language, word-final high vowels are syncopated when they are followed by another word with initial-syllable stress, creating a potential V^{h}kCV cluster, which is illicit in the language. Thus, to avoid this illegal cluster, a further application of the simplification process is enforced, removing the velar stop. If the second consonant is another stop, only [k] is deleted, leaving its pre-aspiration as in (33a). If the second consonant is a sonorant, then both [k] and the pre-aspiration are removed as in (33b).[18]

(33) *Cluster simplification in Tunica* (Haas 1946: 345)

a. titi**^{h}k**i + **p**írʔutakʔahtʃa [títi**^{h}p**írʔutakʔahtʃa] 'it will turn into a bayou'

b. kana**^{h}k**u + **r**apʔantʃ [kána**r**ápʔantʃ] 'if I kill something'

The key to capturing the C_2 dominance effect in the syncope context is identifying the relevant correspondence relationships. Since syncope removes the interconsonantal high vowel, its associated transitions are also absent from the surface. The Ident [transition] constraints only evaluate changes in transitions with correspondences between the relevant representations, meaning that the removed transitions do not affect the evaluations given by these correspondence constraints. In other words, the Ident [transition] constraints do not penalise the loss of the transitions in the syncopated vowels, although they may be penalised by other constraints such as Max [transition] or Realise [transition].

(34) *Analysis of Tunica cluster simplification*

I: /…i^{h}ki + pi…/ RI: […i^{kh}k^{k}i^{p}p^{p}í…]	Syncope	*CC	*LongC	Ident [rel. trans.]	Ident [clos. trans.]	Max-C
a. …i^{kh}k^{k}i^{p}p^{p}í…	*! (^{k}i^{p})					
b. …i^{kh}kp^{p}í…		*! (kp)				
c. …i^{kh}kk^{k}í…			*! (kk)	* (^{p}í → ^{k}í)		
d. …i^{ph}pp^{p}í…			*! (pp)		* (i^{kh} → i^{ph})	
e. …i^{kh}k^{k}í…				*! (^{p}í → ^{k}í)		* (p)
☞ f. …i^{ph}p^{p}í…					* (i^{kh} → i^{ph})	* (k)

In (34), the vowel deletion process is controlled by the top-ranked Syncope constraint, which eliminates candidate (34a), and *CC disallows an intervocalic heterorganic cluster as in (34b). The

Realise [transition] constraint is ranked lower than the Ident [transition] constraints, there should be no instances where [a^{t}k] is realised instead of [a^{k}k] to satisfy Ident [transition]. This is naturally regulated by assuming that constraints such as *ShortGesture, which prohibit excessively short consonantal gestures (like those that occur briefly in the transition between vowels and consonants), are generally undominated. However, it is possible to consider cases where *ShortGesture is ranked lower. In such instances, remnant consonantal gestures may appear, similar to how English *pinpoint* can be realised as [pɪ^{n}**p**ɔɪnt]. In this case, the deletion is executed incompletely (see also fn. 7).

[18] I interpret [h] that precedes [k] as a pre-aspiration, following Anderson's (2017: 25) description of Tunica phonetics and phonology. In a medial cluster, this [h] systematically occurs only before a voiceless stop (i.e., [p, t, k] and [tʃ]). Why this pre-aspiration is removed before a sonorant but preserved before a stop could be understood in terms of the general dispreference for a pre-aspirated sonorant (e.g., *^{h}C$_{[+son]}$).

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remaining grammar determines which consonants are affected and how the cluster is repaired. The ranking of IDENT [release transition] over IDENT [closure transition] identifies C_1 as the target based on changes in transitions present in both the realised input and the provided surface candidates. The ranking of *LONGC over MAX-C favours cluster simplification over place assimilation as a repair strategy.

3.2. Simplification of triconsonantal clusters

The P-map principle predicts that, in $VC_1C_2C_3V$ clusters, the second consonant is the target for deletion because it is less distinct from ∅ than the first and the third consonants are. Experimental literature supports this prediction (Haggard 1973; Klatt 1973), as discussed by Steriade (2009: 169). When $VC_1C_2C_3V$ clusters are shortened, they are confused with $VC_1{:}C_3V$ and, in turn, with further simplified VC_1C_3V. This prediction is derivable from the current implementation of the P-map theory. To illustrate this more clearly, consider optional interconsonantal stop deletion in Hungarian, in which a stop surrounded by two non-approximant consonants may undergo optional deletion, reducing triconsonantal clusters to biconsonantal clusters (Côté 2000; Siptár & Törkenczy 2000).

(35) *Cluster simplification in Hungarian* (Côté 2000: 38)

	No simplification	*Simplification*	
a. *lambda*	[lɔ**mbd**ɔ]	[lɔ**md**ɔ]	'lambda'
b. *asztma*	[ɔ**stm**ɔ]	[ɔ**sm**ɔ]	'asthma'
c. *röntgen*	[rø**ndg**ɛn]	[rø**ŋg**ɛn]	'X-ray'
d. *dombtető*	[do**mpt**ɛtøː]	[do**mt**ɛtøː]	'hilltop'

To analyse this triconsonantal cluster simplification, following Steriade (2009: 170), I assume that the process is motivated by the size-of-cluster constraint C//V, defined in (36):

(36) C//V
Assign one violation mark for every surface consonant that is not adjacent to a vowel.

With this markedness constraint, the default ranking of IDENT [transition] constraints predicts C_2 to be the target consonant, since its deletion does not yield a change in transitional properties. In other words, C_2 deletion in the triconsonantal cluster does not violate any IDENT [transition] constraints because this consonant lacks transitions into or out of it.[19]

(37) *Analysis of Hungarian cluster simplification*

I: /lɔmbdɔ/ RI: [lɔᵐmbdᵈɔ]	C//V	IDENT [rel. trans.: F2 & nas.]	IDENT [clos. trans.: F2 & nas.]	MAX-C
a. lɔᵐmbdᵈɔ	*! (b)			
b. lɔᵐmbᵇɔ		*! (ᵈɔ → ᵇɔ)		* (d)
c. lɔᵇbdᵈɔ			* (ɔᵐ → ɔᵇ)	*! (m)
☞ d. lɔᵐmdᵈɔ				* (b)

Here, the IDENT [transition] constraints are specified for F2 and nasality, meaning that the perceptual difference between transitions is evaluated mainly based on factors such as nasality and second formant frequencies. The emphasis on nasality is due to the homorganic nature of the first two consonants in the cluster, which have similar formant values, with the main difference being their potential to nasalise

[19] In Hungarian, when a stop consonant appears as the second element in a sequence of three consecutive consonants, it may exhibit a very brief release accompanied by a weak burst. However, even in such instances, it is evident that the stop is not followed by an open transition interval (see Bárkányi & Kiss 2020: Figures 7 and 8).

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adjacent transitions. As can be seen in the tableau, the optimal output is (37d), because deleting C_2 does not result in any changes to the F2 or nasality of the transitions.

The current proposal also captures the interaction between syncope and simplification of triconsonantal clusters. Consider cluster simplification in Tangale, a West Chadic language spoken in Nigeria. In Tangale, a stem-final vowel is removed when it is followed by an inflectional suffix or an NP complement. As illustrated in (38), when this syncope process results in a triconsonantal cluster whose first two members are homorganic, cluster simplification occurs as a repair strategy.

(38) *Cluster simplification in Tangale* (Kidda 1993: 45)

a.	la**nd**á-**n**ɔ́	[la**nn**ɔ́]	'my dress'
b.	kú**mb**i-**d**ó	[kú**md**ó]	'her navel'
c.	kɔ**nd**ɔ-**g**ɔ́	[kɔ**ng**ɔ́]	'your peanuts'
d.	kɔ**ld**ɔ-**n**ɔ́	[kɔ**ln**ɔ́]	'my pen'

The analysis of this process is illustrated in the tableau in (39).

(39) *Analysis of Tangale cluster simplification*

I: /kumbi-do/ RI: [kú^{m}mb^{b}i^{d}d^{d}ó]	Syncope	C//V	Ident [rel. trans.: F2 & nas.]	Ident [clos. trans.: F2 & nas.]	Max-C
a. kú^{m}mb^{b}i^{d}d^{d}ó	∗! (^{b}i^{d})				
b. kú^{m}mbd^{d}ó		∗! (b)			
c. kú^{m}mb^{b}ó			∗! (^{d}ó → ^{b}ó)		∗ (d)
d. kú^{b}bd^{d}ó				∗ (ú^{m} → ú^{b})	∗! (m)
☞ e. kú^{m}md^{d}ó					∗ (b)

In the analysis, the top-ranked Syncope constraint removes the stem-final interconsonantal vowel, eliminating candidate (39a) and the C//V constraint disallows the resulting triconsonantal cluster in (39b). The consonant to be deleted is determined by the hierarchy of the Ident [transition] constraints. C_3 cannot be removed, as in (39c), as it causes a change in F2 values, violating Ident [release transition: F2 & nasal]. Similarly, removing C_1 in (39d) yields a change in the nasality of the closure transition, violating Ident [closure transition: F2 & nasal]. Since removing the second consonant does not violate any Ident [transition] constraints, candidate (39e) is selected as the optimal output.

Note that the contextual faithfulness analysis fails to predict the Tangale pattern. Although a ranking of the relevant P-map constraints for segmental contexts – such as Max-C/V__V ≫ Max-C/C__V ≫ Max-C/V__C ≫ Max-C/C__C – can generally capture the simplification process targeting triconsonantal clusters, these constraints lose their analytical power when the target cluster is fed by syncope, as in Tangale. The tableaux in (40) show that both input- and output-oriented contextual faithfulness constraints fail to predict the correct optimal output.

(40) a. *Input-oriented analysis of Tangale cluster simplification*

kumbi-do	Syncope	C//V	Max-C /V_V$_I$	Max-C /C_V$_I$	Max-C /V_C$_I$	Max-C /C_C$_I$
a. kúmbidó	∗! (i)					
b. kúmbdó		∗! (b)				
c. kúmbó			∗! (d)			
☞ d. kúbdó					∗ (m)	
☜ e. kúmdó				∗! (b)		

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b. *Output-oriented analysis of Tangale cluster simplification*

kumbi-do	SYNCOPE	C//V	MAX-C /V_V$_O$	MAX-C /C_V$_O$	MAX-C /V_C$_O$	MAX-C /C_C$_O$
a. kúmbidó	∗! (i)					
b. kúmbdó		∗! (b)				
!☞ c. kúmbó						
!☞ d. kúbdó						
☞ e. kúmdó						

3.3. *Apocope and final cluster simplification*

A final cluster can also be targeted by simplification processes, as seen in Lardil. In this language, a non-apical second consonant of a final cluster cannot surface due to restrictions on complex final clusters. This final cluster simplification can be fed by apocope, which targets nominals with more than two morae. The examples in (41) demonstrate that final vowels and C_2s in clusters, which are present in future and non-future forms, are absent in uninflected forms. In these uninflected forms, the vowels and C_2s are not followed by a suffix and are therefore subject to apocope and final cluster simplification.

(41) *Cluster simplification in Lardil* (Hale 1973: 424)

	Uninflected	*Non-future*	*Future*	
a.	kantukan	kantukan**tu**-n	kantukan**tu**-ɻ	‘red’
b.	jukaɾ	jukaɾ**pa**-n	jukaɾ**pa**-ɻ	‘husband’
c.	pulŋaɾ	pulŋaɾ**pa**-n	pulŋaɾ**pa**-ɻ	‘huge’
d.	paɳtʲipaɳ	paɳtʲipaɳ**tʲi**-n	paɳtʲipaɳ**tʲi**-wuɻ	‘hat’

Because final cluster simplification in Lardil involves apocope, conventional contextual faithfulness constraints face again the same problem as in syncope contexts. If the relevant faithfulness constraints are input-oriented, the grammar predicts that C_1 will be the target consonant rather than C_2, since C_2 can be protected by higher-ranked MAX-C/__V$_{INPUT}$ as the final vowel is present in the input. This is shown in (42):

(42) *Input-oriented analysis of cluster simplification fed by apocope*

paɳtʲipaɳtʲi	APOCOPE	C//V	MAX-C /__V$_{INPUT}$	MAX-C /__ ¬V$_{INPUT}$
a. paɳtʲipaɳtʲi	∗! (i)			
b. paɳtʲipaɳtʲ		∗! (tʲ)		
☜ c. paɳtʲipaɳ			∗! (tʲ)	
☞ d. paɳtʲipatʲ				∗ (ɳ)

The output-oriented alternative also cannot rescue the contextual faithfulness constraints. The tableau in (43) shows that output-oriented faithfulness constraints cannot identify the target consonant, since whichever of C_1 and C_2 is retained in the surface form will be postvocalic and word-final, as in candidates (43c) and (43d).

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(43) *Output-oriented analysis of cluster simplification fed by apocope*

paɳʈʲipaɳʈʲi	Apocope	C//V	Max-C /__V_{output}	Max-C /__ ¬V_{output}
a. paɳʈʲipaɳʈʲi	∗! (i)			
b. paɳʈʲipaɳʈʲ		∗! (ʈʲ)		
☞ c. paɳʈʲipaɳ				
!☞ d. paɳʈʲipaʈʲ				

In contrast to the contextual faithfulness account, the interaction with apocope is not problematic in the current approach, as illustrated in (44):

(44) *Analysis of Lardil cluster simplification*

I: /paɳʈʲipaɳʈʲi/ RI: [paɳʈʲipaᶯɳʈᵗʲi]	Apocope	C//V	Ident [rel. trans.]	Ident [clos. trans.]	Max-C
a. paɳʈʲipaᶯɳʈᵗʲi	∗! (ᵗʲi)				
b. paɳʈʲipaᶯɳʈʲ		∗! (ʈʲ)			
☞ c. paɳʈʲipaᶯɳ					∗ (ʈʲ)
d. paɳʈʲipaᵗʈʲ				∗ (aᶯ → aᵗ)	∗! (ɳ)

As shown in (44), since the release transition hosted by the final vowel in the realised input form is removed by apocope, there is no surface correspondent of the release transition out of the derived final consonant. Therefore, the removal of the final consonant in candidate (44c) does not critically violate any Ident [transition] constraints. In contrast, a potential deletion of the first consonant of the cluster, as in candidate (44d), is correctly ruled out because it fatally violates Ident [closure transition].

It is worth noting that what happens in Lardil is, in fact, more complicated than what has been analysed above. In Lardil, labial and velar consonants are deleted in final position even when they are not part of final clusters (e.g., /wuŋkunu**ŋ**/ → [wuŋkunu] 'queenfish'; Staroverov 2014: 431).[20] This invokes a complex opacity problem called 'fed counterfeeding' by Kavitskaya & Staroverov (2010), in which apocope and final deletion have both feeding and counterfeeding relationships. As a result of this opaque interaction, apocope underapplies when it and final consonant deletion have already applied, as in (45).

(45) *Feeding and counterfeeding between apocope and final C deletion in Lardil* (Kavitskaya & Staroverov 2010: 257)

	'boomerang'	'oyster'	'rock cod'
Input	wangalk	jilijili	dibiɾdibi
Apocope	—	jilijil	dibiɾdib
C-deletion	wangal	—	dibiɾdi
Output	wangal	jilijil	dibiɾdi

[20]I assume that cluster simplification and velar or labial deletion are regulated by different purposes in Lardil, considering them as separate phonological processes. In fact, laminal palatal consonants such as [ʈʲ ɲ] are always deleted when they are the second member of the final cluster, but can be preserved when they occupy the final position alone (e.g., /piɳʈa**ɲi**/ → [piɳʈa**ɲ**] 'rainbow type', Staroverov 2014: 432), suggesting such a possibility. Compare this with (41d), in which the final palatal [ʈʲ] is removed as a consequence of apocope. In contrast, when a final homorganic consonant cluster whose members are both non-coronal is formed by apocope, the whole cluster is removed, as in /muŋkumuŋk**u**/ → muŋkumu**ŋk** → [muŋkumu] 'wooden axe' (Staroverov 2014: 431).

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The mapping from /dibiɾdibi/ to [dibiɾdi] is opaque because both the input and output forms end in a vowel, demonstrating the underapplication of the apocope process. In other words, although the final vowel in [dibiɾd**i**] meets the environmental condition for apocope, it remains unaffected, resulting in opacity. This is because apocope has already occurred before this final vowel emerges in the derivation. While such an opaque interaction is challenging to analyse within classic OT, the current approach, in which correspondence constraints can reference phonetically detailed realised inputs, handles it effectively. In recent studies (Kim 2024a,b,c), I have demonstrated that faithfulness to phonetically enriched representations provides a comprehensive solution to opacity. For instance, in the Lardil case, it can be assumed that phonetically longer vowels are more strongly protected by the relevant faithfulness conditions than phonetically shortened vowels, which may instead undergo complete deletion. Indeed, cross-linguistically, vowels in final positions frequently have shortened durations due to factors such as devoicing (e.g., Myers & Hansen 2007). If the Phonetic Realisation component derives this vowel shortening, the resulting shortened vowels can be clearly distinguished from regular vowels that fully maintain their duration in realised input forms. The tableau in (46) illustrates how these shortened vowels are derived within the Phonetic Realisation component:

(46) *Phonetic Realisation:* /dibiɾdibi/$_{\text{I}}$ → [dibiɾdibi̯]$_{\text{RI}}$

I: /dibiɾdibi/	Final V Shortening (*[V: duration] > 40 ms/__#)	Realise [V: duration] = 80ms
a. dibiɾdibi	∗! (i)	
b. dibiɾdibi̯		∗ (/i/ → i̯)

Suppose that the shortened vowel has a duration between zero and that of the full vowel [i] (e.g., [i] = 80ms and [i̯] = 40ms). This phonetically shortened final vowel is subsequently eliminated on the surface by the *V̯ constraint, which penalises overly shortened vowels. Ident [V: duration] > 30ms, which penalises changes in length of the degree of the difference between [i̯] and ∅ or [i̯] and [i] (40ms), is ranked lower than Ident [V: duration] > 60ms, which penalises changes of a greater degree, such as a change from [i] to ∅ (80ms), according to the P-map hierarchy. Consequently, in Phonotactics, short vowels (i.e., underlyingly word-final vowels) are deleted, whereas vowels of normal length (including vowels whose word-final position is derived) are preserved. The tableau in (47) illustrates how this surface opacity is derived. Note that a transparent output like candidate (47e) could be optimal if Final V Shortening were ranked above all Ident [V: duration] constraints.

(47) *Phonotactics:* [dibiɾdibi̯]$_{\text{RI}}$ → [dibiɾdi]$_{\text{O}}$

I: /dibiɾdi$_1$bi$_2$/ RI: [dibiɾdi$_1$bi̯$_2$]	*V̯	*C$_{[\text{-cor}]}$#	Ident [V: dur.] > 60ms	Ident [V: dur.] > 30ms	Final V Shortening	Realise [V: dur.] = 80ms
a. dibiɾdi$_1$bi̯$_2$	∗! (i̯$_2$)					∗ (/i$_2$/ → [i̯$_2$])
b. dibiɾdi$_1$b		∗! (b)		∗ (i̯$_2$ → ∅)		∗ (/i$_2$/ → ∅)
☞ c. dibiɾdi$_1$				∗ (i̯$_2$ → ∅)	∗ (i$_1$)	∗ (/i$_2$/ → ∅)
d. dibiɾdi̯$_1$	∗! (i̯$_1$)			∗ (i$_1$ → i̯$_1$) ∗ (i̯$_2$ → ∅)		∗ (/i$_1$/ → [i̯$_1$]) ∗ (/i$_2$/ → ∅)
e. dibiɾd			∗! (i$_1$ → ∅)	∗ (i$_1$ → ∅) ∗ (i̯$_2$ → ∅)		∗ (/i$_1$/ → ∅) ∗ (/i$_2$/ → ∅)

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4. Extension

This section extends the current proposal to major place assimilation and debuccalisation. Like cluster simplification, these processes usually target medial clusters and display the C_2 dominance effect (Jun 2002, 2011; McCarthy 2008, 2011). It is argued here that place assimilation and debuccalisation result in changes in transitions and thus can also be regulated by IDENT [transition] constraints. This allows us to analyse the patterns of these processes in the same way as cluster simplification, regardless of whether syncope is involved or not.

4.1. Place assimilation

Cross-linguistically, place assimilation in medial clusters is typically regressive, targeting the first member of the cluster rather than the second (Webb 1982; Mohanan 1993; Jun 1995, 2004). This directional asymmetry in place assimilation is illustrated in (48) with Korean examples, where non-velar nasals and stops assimilate in place to the following stops.

(48) *Place assimilation in Korean* (Jun 1995; Walker 2020)

a.	pa**tʰ-p**ota	[pa**pp'**oda]	'(rather) than the field'
b.	so**n-p**atak	[so**mp'**adak]	'palm (of the hand)'
c.	pa**tʰ-k**wa	[pa**kk'**wa]	'the field and'
d.	so**n-k**alak	[so**ŋk'**aɾak]	'finger'
e.	tʰo**p-kʰ**al	[tʰo**kkʰ**al]	'handsaw'
f.	ka**mk**i	[ka**ŋg**i]	'cold'
g.	i**p-k**o	[i**kk**o]	'wear and'

Unlike cluster simplification, the emergence of place assimilation as a repair strategy for *CC can be attributed to the ranking of MAX-C over *LONGC. To satisfy the higher-ranked MAX-C constraint, this language prefers forming a geminate consonant or homorganic sequence over deleting a consonant, as shown in (49):

(49) *Analysis of Korean place assimilation*

I: /ip-ko/ RI: [$i^p pk^k o$]	*CC	MAX-C	IDENT [rel. trans.]	IDENT [clos. trans.]	*LONGC
a. $i^p pk^k o$	*! (pk)				
b. $i^p pp^p o$			*! ($^k o \rightarrow {}^p o$)		* (pp)
☞ c. $i^k kk^k o$				* ($i^p \rightarrow i^k$)	* (kk)
d. $i^p p^p o$		*! (k)	* ($^k o \rightarrow {}^p o$)		
e. $i^k k^k o$		*! (p)		* ($i^p \rightarrow i^k$)	

In (49), place assimilation is triggered by the high-ranked *CC constraint, which rules out the faithful candidate (49a), similarly to typical cluster simplification cases. The C_2 dominance effect is also captured by the same IDENT constraints, and their ranking, that were implemented for the analyses of cluster simplification (cf. Flemming 2008a, who employs similar correspondence constraints to explain the manner asymmetry in place assimilation). C_1 is the target of place assimilation, since changing its place incurs only a non-fatal violation of IDENT [closure transition], as in the winning candidate (49c), while changing the place of C_2, as in (49b), is penalised by the higher-ranked IDENT [release transition] constraint.

Place assimilation fed by syncope can also be captured by the same analysis. Keley-i (Austronesian, spoken in the Philippines) presents such a case. In this language, when an infix with a nasal attaches to

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referent-focus past roots with CeCeC or CeCaC forms, the first root vowel is removed, and the infix-final nasal assimilates in place to the following consonant.

(50) *Place assimilation in Keley-i* (Hohulin & Kenstowicz 1979: 249)

a.	ʔ-i**n**-e**d**ep-an	[ʔi**nd**epan]	'extinguished'
b.	d-i**n**-e**g**eh-an	[di**ŋg**ehan]	'was sick'
c.	d-i**n**-e**ŋ**el-an	[di**ŋŋ**elan]	'heard'
d.	h-i**n**-e**g**ep-an	[hi**ŋg**epan]	'entered'
e.	d-i**n**-e**p**ap-an	[di**mp**apan]	'wrestled'

The same set of IDENT constraints accounts for the C_2 dominance effect in both cluster simplification and place assimilation, so the regressive direction of place assimilation conditioned by syncope should also be explainable by these constraints. This is depicted in the tableau in (51). The ranking of the IDENT [transition] constraints determines the direction of the process, and MAX-C outranking *LONGC prevents deletion from being a potential repair for heterorganic clusters.

(51) *Analysis of Keley-i place assimilation*

I: /d-in-epap-an/ RI: [di^{n}n^{n}e^{p}p^{p}apan]	SYNCOPE	*CC	MAX-C	IDENT [rel. trans.]	IDENT [clos. trans.]	*LONGC
a. di^{n}n^{n}e^{p}p^{p}apan	*! (^{n}e^{p})					
b. di^{n}np^{p}apan		*! (np)				
c. di^{n}nt^{t}apan				*! (^{p}a → ^{t}a)		* (nt)
☞ d. di^{m}mp^{p}apan					* (i^{n} → i^{m})	* (mp)
e. di^{n}n^{n}apan			*! (p)	* (^{p}a → ^{n}a)		
f. di^{p}p^{p}apan			*! (n)		* (i^{n} → i^{p})	

4.2. Debuccalisation

In some languages, cluster reduction is achieved by debuccalising the first member of the cluster, showing the C_2 dominance effect (McCarthy 2008). For instance, when a medial cluster undergoes debuccalisation, it always results in the form [VʔCV], not [VCʔV], as observed in languages such as Arbore (Hayward 1984), Cariban languages (Gildea 1995), Malay, Thai (Lodge 1992) and Toba Batak (Hayes 1986). This subsection demonstrates that debuccalisation affects adjacent transitions and can be regulated by the IDENT [transition] constraints, resulting in the C_2 dominance effect. This effect is consistent regardless of the presence of syncope.

Before performing a specific analysis, let us consider the acoustic characteristics that make glottal consonants distinct from buccal ones. As is well-known, glottal stops are usually not realised with complete closure in most languages (Ladefoged & Maddieson 1996: 74–76). These articulatory properties of glottal stops also influence their acoustic realisation. Although they inherently impose characteristics such as creaky voice or stiff phonation, in intervocalic positions they are likely to display formant structures mediating between surrounding vowels. Similarly, in consonant clusters like [VʔCV], glottal stops exhibit evident formant transitions reflecting the characteristics of the adjacent supralaryngeal consonant (cf. Foulkes & Docherty 1999). Glottal fricatives also show similar transitional characteristics. The vocal tract shape of the glottal fricative is usually similar to its neighbouring vowels, and its transitional characteristics reflect its surrounding environment (Keating 1988). Although [h] is voiceless, major formant landmarks are apparent during its production, suggesting that glottal fricatives in clusters can also mediate transitions between vowels and adjacent buccal consonants.

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These acoustic facts demonstrate that debuccalising a consonant can affect the properties of the adjacent transition by projecting the adjacent consonant's characteristics to a vowel. For instance, when [a^{t}tp^{p}a] undergoes C_1 debuccalisation, the properties of C_2 [p] can be projected across the resulting glottal consonant, as in [a^{p}ʔp^{p}a] or [a^{p}hp^{p}a].

These acoustic properties of glottal consonants suggest that debuccalisation can also be regulated by IDENT [transition] constraints. To illustrate, consider the debuccalisation process in Toba Batak, exemplified in (52). In this case, a word-final stop undergoes debuccalisation when it is followed by another consonant.

(52) *Debuccalisation in Toba Batak* (Hayes 1986: 482)

a.	ganu**p**+**t**aɔn	[ganu**ʔ** **t**aɔn]	'every year'
b.	dɔhɔ**t**+**l**ali+i	[dɔhɔ**ʔ** **l**ali i]	'and the hen-harrier'
c.	hala**k**+**b**atak	[hala**ʔ** **b**atak]	'Batak person'
d.	hala**k**+**k**ɔrɛa	[hala**ʔ** **k**ɔrɛa]	'Korean person'

To analyse this pattern, I introduce a constraint that penalises voiceless transitions. This constraint reflects the need to ensure that the transitions are as amplified as possible, keeping the higher perceptual resolution. To put it more simply, this constraint prohibits consonantal properties from being projected onto transitions in a weakened manner as they pass through the glottal consonant.

(53) *VOICELESS TRANSITION (abbr.: *VLSTRANS)
Assign one violation mark for every voiceless transition.

With this constraint, debuccalisation in Toba Batak can be analysed as in (54). In this tableau, the ranking of *LONGC over *VLSTRANS determines that reduction is achieved through debuccalisation rather than place assimilation. Then, the ranking of IDENT [release transition] over IDENT [closure transition] captures the C_2 dominance effect.

(54) *Analysis of Toba Batak debuccalisation*

I: /ganup + taɔn/ RI: [ganu^{p}pt^{t}aɔn]	*CC	*LONGC	IDENT [rel. trans.]	IDENT [clos. trans.]	*VLSTRANS
a. ganu^{p}pt^{t}aɔn	*! (pt)				
b. ganu^{p}pp^{p}aɔn		*! (pp)	* (^{t}a → ^{p}a)		
c. ganu^{t}tt^{t}aɔn		*! (tt)		* (u^{p} → u^{t})	
d. ganu^{p}pʔ^{p}aɔn			*! (^{t}a → ^{p}a)		* (ʔ^{p})
☞ e. ganu^{t}ʔt^{t}aɔn				* (u^{p} → u^{t})	* (^{t}ʔ)

Syncope does not pose a problem for the analysis of debuccalisation. Consider the Panare examples in (55), where syncope feeds debuccalisation. In this language, when the verb *-utu-* 'give' is followed by a CV-initial suffix, the stem's final high vowel is deleted, feeding debuccalisation of the preceding stop.

(55) *Debuccalisation in Panare* (Gildea 1995: 65)

a.	n-u**tu**-**tʃ**ah	[nu**htʃ**ah]	'he gave it (immediate past)'
b.	n-u**tu**-**p**əh-tʃah	[nu**hp**əhtʃah]	'he gave it (iterative)'
c.	n-u**tu**-**tʃ**ake	[nu**htʃ**ake]	'he gave it (historical past)'
d.	j-u**tu**-**ɲ**e	[ju**ʔɲ**e]	'he will give it'

The tableau in (56) analyses this pattern. First, candidate (56a), which preserves the realised input structure, violates the top-ranked SYNCOPE. Since this syncope removes all correspondence

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relationships the deleted vowel could host, further deletion of a consonant does not affect the evaluation provided by IDENT [release transition] or IDENT [closure transition]. Then, C_1 is determined as the target by the violations related to the remaining surface vowels. C_1 undergoes debuccalisation, not place assimilation, since *LONGC outranks *VLSTRANS.[21]

(56) *Analysis of Panare debuccalisation*

I: /n-utu-pəh-tʃah/ RI: [nu^{t}t^{t}u^{p}p^{p}əhtʃah]	SYNCOPE	*CC	*LONGC	IDENT [rel. trans.]	IDENT [clos. trans.]	*VLSTRANS
a. nu^{t}t^{t}u^{p}p^{p}əhtʃah	*! (^{t}u^{p})					
b. nu^{t}tp^{p}əhtʃah		*! (tp)				
c. nu^{t}tt^{t}əhtʃah			*! (tt)	* (^{p}ə → ^{t}ə)		
d. nu^{p}pp^{p}əhtʃah			*! (pp)		* (u^{t} → u^{p})	
e. nu^{t}th^{t}əhtʃah				*! (^{p}ə → ^{t}ə)		* (h^{t})
☞ f. nu^{p}hp^{p}əhtʃah					* (u^{t} → u^{p})	* (^{p}h)

5. Exceptions to the C_2 dominance effect

While the C_2 dominance effect is observed in most languages exhibiting cluster simplification, place assimilation or debuccalisation, it is not invariably absolute across all languages. Two primary exceptions are attested cross-linguistically: cases in which a glottal C_2 undergoes deletion or assimilation, and instances where the C_2 dominance effect is overridden by morphological asymmetry.

Consider the C_2 glottal deletion first. The C_2 dominance effect fails to manifest when C_2 is glottal, as observed in Afar (Bliese 1981), Arbore (Hayward 1984), Chitimacha (Swadesh 1946) and Tonkawa (Hoijer 1946), among others. For example, in Arbore, underlying /h/ following another consonant undergoes total assimilation to the preceding consonant, as in (57).

(57) *C_2 /h/ assimilation in Arbore* (Hayward 1984; McCarthy 2007)

a. /mi**n-h**-aw/ [mí**nn**aw] 'my house'

b. /ʔaba**s-h**-aw/ [ʔabá**ss**aw] 'my stew'

This assimilatory process targets glottal fricatives, not buccal consonants, possibly to preserve subsegmental transitions. As hypothesised in §4.2, glottal consonants lack inherent transitions adjacent to vowels; such transitions exist only when an influential buccal consonant is nearby. Thus, removing the buccal consonant from a buccal–glottal sequence eliminates the transitions. Constraints protecting subsegments, such as MAX [transition], can prevent this by requiring the preservation of realised input transitions. In the Arbore case, MAX [transition] compels the preservation of the buccal consonant and the change of the glottal consonant when *VOICELESS TRANSITION prohibits buccal–glottal sequences.[22]

[21] It is unclear why an oral stop is mapped onto a glottal fricative instead of a glottal stop in this context, given that a glottal stop exists in the phonemic inventory of Panare. One possible explanation for this mapping could be the avoidance of a glottal stop before an obstruent consonant. Payne & Payne (2013) hypothesise that /h/ is realised as [ʔ] before $C_{[+son]}$ while remaining [h] before $C_{[-son]}$. Based on this observation, it is possible to posit a higher-ranked constraint such as $*ʔC_{[-son]}$, which prohibits the realisation of a glottal stop before an obstruent. This constraint would result in the mapping of an oral stop to a glottal fricative rather than a glottal stop.

[22] Alternatively, these transitions may be protected by REALISE [transition] instead of MAX [transition]; see §3.2.

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(58) *Analysis of C_2 /h/ assimilation in Arbore*

I: /ʔabas-h-aw/ RI: [ʔabáˢshˢaw]	*VLS TRANS	MAX-C	MAX [transition]	IDENT [rel. trans.]	IDENT [clos. trans.]	*LONGC
a. ʔabáˢshˢaw	∗! (hˢ)					
b. ʔabáhaw		∗! (s)	∗∗ (áˢ, ˢa)			
c. ʔabáˢsˢaw		∗! (h)				
d. ʔabáhhaw			∗!∗ (áˢ, ˢa)			∗ (hh)
☞ e. ʔabáˢssˢaw						∗ (ss)

This formalisation yields an intriguing prediction: when a cluster containing a glottal consonant undergoes change, the glottal consonant, rather than the buccal consonant, is invariably targeted (see also McCarthy 2007, who makes the same prediction). This is supported by the fact that most, if not all, non-morphological exceptions to the C_2 dominance effect involve the deletion or modification of glottal consonants. Additionally, to the best of my knowledge, there are no known cases where a buccal consonant invariably undergoes reduction before a glottal consonant.

In summary, the current approach differentiates between the reduction of supralaryngeal consonant sequences and the modification of sequences containing glottal consonants. General reduction processes, including cluster simplification, are motivated by *CC to avoid heterorganic buccal consonant sequences, and consistently target C_1 by the ranking of the P-map constraints. In contrast, the modification of sequences containing glottals is triggered by constraints like *VOICELESS TRANSITION, with MAX [transition] ensuring that the glottal consonant is targeted regardless of its position.

The second type of exception to the C_2 dominance effect comprises cases in which the positional asymmetry is overturned by a morphological asymmetry (e.g., Jun 1995; McCarthy 2007; Lamont 2015). For instance, when C_1 belongs to a root and C_2 is at the beginning of a suffix, the affixal C_2 may undergo deletion or assimilation instead of the root C_1. Such a morphological dominance effect is found in many languages, including Dutch (McCarthy 2007), Nankina, Bari dialects, Nungon and Ma Manda (see Lamont 2015 and the references therein). An example of the morphological dominance effect is provided in (59) with place assimilation in the Kukú dialect of Bari, where the initial palatal consonant of qualitative suffixes assimilates to the place of the preceding root-final consonant.

(59) *Palatal-initial qualitative suffix /-ɟa/ in the Kukú dialect of Bari* (Cohen 2000; Lamont 2015)

a.	/ŋɛ**r-ɟ**a/	[ŋɛ**rɟ**a]	'shave'
b.	/lɪ**n-ɟ**a/	[lɪ**nd**a]	'become comatose'
c.	/ʔjɛ**m-ɟ**a/	[ʔjɛ**mb**a]	'cast the evil eye'
d.	/dɛ**ŋ-ɟ**a/	[dɛ**ŋg**a]	'perform surgery'

This morphological dominance effect can be captured by introducing P-map faithfulness constraints sensitive to morphology: $\text{IDENT}_{\text{ROOT}}$ [release transition] ≫ $\text{IDENT}_{\text{ROOT}}$ [closure transition] ≫ $\text{IDENT}_{\text{AFFIX}}$ [release transition]. This ranking prioritises the root's closure transition over the affix's release transition.[23]

[23] Split root/affix faithfulness constraints have already been discussed by McCarthy (2008) as one option to address cluster reduction processes targeting C_2. The novel aspect of the constraints used in (60) is that they refer to acoustic transitions rather than to the segments themselves.

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(60) *Analysis of C_2 /ɟ/ assimilation in Kukú Bari*

I: /lɪn-ɟa/ RI: [lɪ^{n}n-ɟ^{ɟ}a]	*CC	Max-C	Ident$_{ROOT}$ [rel. trans.]	Ident$_{ROOT}$ [clos. trans.]	Ident$_{AFFIX}$ [rel. trans.]
a. lɪ^{n}n-ɟ^{ɟ}a	∗! (nɟ)				
b. lɪ^{n}n-^{n}a		∗! (ɟ)			∗ (^{ɟ}a → ^{n}a)
c. lɪ^{ɟ}-ɟ^{ɟ}a		∗! (n)		∗ (ɪ^{n} → ɪ^{ɟ})	
☞ d. lɪ^{n}n-d^{d}a					∗ (^{ɟ}a → ^{d}a)
e. lɪ^{ɲ}ɲ-ɟ^{ɟ}a				∗! (ɪ^{n} → ɪ^{ɲ})	

In the tableau in (60), the optimal output is (60d), where C_2 assimilates its place to C_1. This is because the root closure transition is prioritised over the affixal release transition by the ranking of the morphologically indexed P-map constraints. Candidate (60e), which modifies the root transition by assimilating C_1 to C_2, cannot win because it violates Ident$_{ROOT}$ [closure transition].

6. Alternatives

This section compares the current proposal with two alternative approaches to the syncope problem, namely HS (McCarthy 2010, 2016) and Contiguity constraints (Kenstowicz 1994; McCarthy & Prince 1995).[24] It provides a concise overview of how these alternative approaches treat the syncope problem and examines potential issues that have been or could be raised regarding these alternatives in cluster reduction contexts. It is important to emphasise that this discussion is not intended to invalidate alternative approaches in a general sense. Rather, the aim is to argue that a broader and more coherent explanation for cluster reduction processes can be given by the current approach, particularly in light of the P-map principle, by addressing aspects that may not have been fully or explicitly considered in these alternative approaches.

6.1. Harmonic Serialism

McCarthy (2008, 2009, 2011) argues that C_2 dominance effects in cluster reduction processes and the associated syncope problem can be accounted for within the framework of HS. As outlined in McCarthy (2011), P-map correspondence constraints in the form of contextual faithfulness constraints can be implemented in HS to derive the expected results correctly. The tableaux in (61) illustrate how McCarthy's suggestion addresses the syncope problem.[25]

(61) a. *Step 1*

atipa	Syncope	*CC	Max-C/_V	Max-C/_C
a. atipa	∗! (i)			
☞ b. atpa		∗ (tp)		

[24]Due to space limitations, it is not possible to discuss all major alternative approaches here. Readers interested in the Targeted Constraint approach to the syncope problem, which is not covered in this article, are referred to Wilson (2001) for an outline of the proposal, and to McCarthy (2002) for a critical discussion of this approach.

[25]The following is a brief description of how HS works: HS makes optimisation a sequential process by changing the nature of Gen, in contrast to the single global optimisation process in parallel OT. In order to enable the grammar to choose an optimal output that differs from the underlying form by more than one step, optimisation applies serially. The output generated from the first step serves as the input for the subsequent optimisation step, in which all candidates that are a single step away from this new input are taken into consideration. This iterative process continues until the input and the optimised output converge, meaning they become identical.

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b. *Step 2*

atpa	Syncope	*CC	Max-C/_V	Max-C/_C
a. atpa		*! (tp)		
b. ata			*! (p)	
☞ c. apa				* (t)

In the HS grammar illustrated in (61), Syncope must outrank *CC to allow syncope to create a cluster targeted by *CC. At Step 1, the grammar selects [atpa] as the output, which serves as the input for Step 2. The optimal output at Step 2 is a candidate with C_1 deletion, that is, [apa], by the ranking condition Max-C/_V ≫ Max-C/_C. Crucially, syncope applies at Step 1, and because the Syncope constraint is ranked highest, it can condition the environment for further cluster reduction processes.

Although implementing P-map constraints as contextual faithfulness constraints in HS seems to work for the core patterns, there are situations where HS appears to be incompatible with the P-map principle. One such case arises when dealing with instances of irreducible parallelism, a phenomenon known to be challenging for HS (Flemming 2013; Adler & Zymet 2021). An illustrative example of this problem is root fusion in Sino-Japanese vocabulary (Itô 1986; Itô & Mester 1996; Kurisu 2000; Adler & Zymet 2021, among others). In Japanese, a sequence of one- or two-syllable roots fuses, deleting the first root's final vowel and resulting in a voiceless geminate with place assimilation. However, syncope is blocked if it conditions place assimilation that yields a voiced geminate. For example, /be**t**u-**k**aku/ 'different style' undergoes both syncope and place assimilation, resulting in [be**kk**aku], while /be**t**u-**b**in/ 'separate carrier' does not undergo syncope, as it would create an illegal voiced geminate. Thus, it is realised as [be**tsub**in] instead of *[be**bb**in] (examples from Itô & Mester 1996: 15). This type of interaction is recognised as being problematic for HS because of the restriction that only a single operation can be applied at each derivational step.[26]

The issue can be illustrated as follows. As demonstrated in the tableaux in (62), Syncope must be ranked high enough to create the environment for place assimilation between voiceless obstruents.

(62) a. *Step 1: syncope*

betu-kaku	Syncope	*VdGem	*CC	Ident (pl) /_V	Ident (pl) /_C
a. betukaku	*! (u)				
☞ b. betkaku			* (tk)		

b. *Step 2: place assimilation with convergence*

betkaku	Syncope	*VdGem	*CC	Ident (pl) /_V	Ident (pl) /_C
a. betkaku			*! (tk)		
b. bettaku				*! (k)	
☞ c. bekkaku					* (t)

However, the same grammar fails to capture the case where syncope is blocked to avoid creating a voiced geminate. Since Syncope is ranked high and Gen in HS allows only one derivational change per step, the grammar returns a candidate with vowel deletion at Step 1, failing to block syncope. The constraint that penalises voiced geminates, *VdGem, cannot play any role in the evaluation.

[26] Many recent studies have raised the issue of irreducible parallelism in HS (Adler 2017; Wei 2018; Wei & Walker 2018, 2020; Stanton 2020; Adler & Zymet 2021, among others). However, Lamont (2023) suggests that, at least in some previously cited cases involving reduplication, such as those in Mbe and Logoori, these putative derivational lookahead effects do not actually pose a challenge for HS.

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(63) *A failed analysis of* /betu-bin/ → [betsubin]

betu-bin	SYNCOPE	*VDGEM	*CC	IDENT (pl) /_V	IDENT (pl) /_C
☜ a. betubin	∗! (u)				
☞ b. betbin			∗ (tb)		

In principle, this issue could be circumvented by allowing /u/ before a voiceless obstruent and that before a voiced obstruent to interact differently with syncope through constraint rankings rather than derivational steps. For instance, an undominated contextual faithfulness constraint like MAX-V/__$C_{[+voi]}$ could block the vowel deletion process before a voiced obstruent, resulting in (63a) rather than (63b). However, while such an analysis is technically possible, it remains unclear how such a constraint and its ranking would be motivated under the P-map principle: why, for instance, is MAX-V/__$C_{[-voi]}$ outranked by MAX-V/__$C_{[+voi]}$, rather than *vice versa*? As long as the P-map principle is assumed to be the key element for analysing the syncope problem, introducing such a constraint becomes problematic. Given that this constraint refers to perceptually arbitrary contexts, its justification under the P-map principle is difficult.

Contrary to HS, such a situation is not a problem for the current model, where syncope and place assimilation can be applied simultaneously, as shown in (64):

(64) a. /betu-kaku/ → [bekkaku]

I: /betu-kaku/ RI: [be^{t}t^{t}u^{k}k^{k}aku]	*CC	*VDGEM	IDENT [rel. trans.]	SYNCOPE	IDENT [clos. trans.]	*LONGC
a. be^{t}t^{t}u^{k}k^{k}aku				∗! (u)		
b. be^{t}tk^{k}aku	∗! (tk)					
c. be^{t}tt^{t}aku			∗! (^{k}a → ^{t}a)			∗ (tt)
☞ d. be^{k}kk^{k}aku					∗ (e^t → e^k)	∗ (kk)

b. /betu-bin/ → [betsubin]

I: /betu-bin/ RI: [be^{t}t^{t}u^{b}b^{b}in]	*CC	*VDGEM	IDENT [rel. trans.]	SYNCOPE	IDENT [clos. trans.]	*LONGC
☞ a. be^{t}ts^{t}u^{b}b^{b}in				∗ (u)		
b. be^{t}tb^{b}in	∗! (tb)					
c. be^{t}tt^{t}in			∗! (^{b}i → ^{t}i)			∗ (tt)
d. be^{b}bb^{b}in		∗! (bb)			∗ (e^t → e^b)	∗ (bb)

A similar situation where the explanatory powers of HS and the P-map principle are difficult to reconcile can be found in opaque contexts. Recall from §3.3 that in Lardil, /dibiɾdibi/ is realised as [dibiɾdi], with underapplication of apocope. In HS, the apocope constraint must be top-ranked to induce final vowel deletion in the underlying form at the first step, but this hierarchy forces the deletion of [i] in [dibiɾdi] as well. Although introducing a hierarchy of contextual faithfulness constraints (e.g., MAX-V/_C ≫ APOCOPE ≫ MAX-V) may avoid this issue in HS (cf. Hauser & Hughto 2020), such an approach encounters a similar problem to the one identified for the irreducible parallelism case: it is unclear why this preconsonantal-specific faithfulness constraint should dominate other constraints. Justifying this ranking proves difficult. In particular, granting legitimate status to P-map faithfulness constraints as an HS solution to the syncope problem, as illustrated in (61) above, directly conflicts with attempts to incorporate contextual faithfulness constraints into HS to resolve the opacity problem. This conflict arises because it is difficult to establish perceptual justification for assigning greater protection to underlyingly preconsonantal vowels than to final vowels.

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In summary, the aforementioned issues show that, in certain contexts, the compatibility between the HS model and the P-map principle is questionable. It is worth noting, however, that this discussion does not preclude the possibility of reconciling P-map faithfulness constraints with HS in contexts of irreducible parallelism or opacity through alternative means. The focus of the argument is not to demonstrate an inherent structural flaw in HS, but rather to highlight that the current approach, centred on a set of proposed P-map constraints, offers greater flexibility in analysing cluster reduction processes across diverse environments, without introducing additional assumptions or mechanisms to deal with irreducible parallelism or opacity.

6.2. Contiguity

As discussed throughout this article, subsegments are crucial in analysing the C_2 dominance effect in the syncope context. However, one may ask whether the proposal can be more formally implemented without referring directly to transitions, using a P-map version of Contiguity constraints. This is a valid question, and at least for cluster simplification, it is possible to account for the C_2 dominance effect by ranking Contiguity (CV), which specifically preserves a CV sequence, above Contiguity (VC), which protects a VC sequence, as shown in (65) (cf. Kenstowicz 1994; McCarthy & Prince 1995: 123; Lamontagne 1997). Suppose that these constraints assign a violation mark specifically when an input consonant originally adjacent to a vowel surfaces adjacent to a different consonant or vowel, thus losing its original adjacency relationship.

(65) *The C_2 dominance effect in cluster simplification with Contiguity constraints*

$a_1t_2i_3p_4u_5$	Syncope	*CC	Contiguity (CV)	Contiguity (VC)
a. $a_1t_2i_3p_4u_5$	*!			
b. $a_1t_2p_4u_5$		*!	*	*
c. $a_1t_2u_5$			*!	
☞ d. $a_1p_4u_5$				*

However, this analysis has a critical problem. With this type of Contiguity constraints, cluster simplification is enforced in the syncope context regardless of the relative ranking of *CC. This predicts unconditional cluster simplification whenever syncope occurs because, for an input form like /atipu/, when /i/ is deleted, a surface output like [atpu] will inevitably violate both Contiguity (CV) and Contiguity (VC). First, when the CV sequence /ti/ loses its vowel, [t] becomes adjacent to [p], violating Contiguity (CV). Similarly, the loss of the vowel in the VC sequence /ip/ leads to a violation of Contiguity (VC), as [p] becomes adjacent to [t]. The tableau in (66) illustrates this:

(66) *Unconditional cluster simplification under syncope with Contiguity constraints*

$a_1t_2i_3p_4u_5$	Syncope	Contiguity (CV)	Contiguity (VC)	*CC
a. $a_1t_2i_3p_4u_5$	*! (i)			
☜ b. $a_1t_2p_4u_5$		*!	*	*
c. $a_1t_2u_5$		*!		
☞ d. $a_1p_4u_5$			*	

This result is undesirable because not all languages with a syncopated interconsonantal vowel undergo cluster simplification. Using Contiguity constraints sacrifices explanatory power for cases of syncope without simplification, in return for resolving the syncope problem.

To address this issue while retaining the Contiguity constraints, one might consider a scenario where Max-C is also ranked high, thereby excluding candidates with cluster simplification such as

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(66c) or (66d). However, this approach proves ineffective, as the top-ranked MAX-C constraint actually results in place assimilation rather than preserving a cluster without reduction, as demonstrated in (67).

(67) *Place assimilation under syncope with CONTIGUITY constraints*

$a_1t_2i_3p_4u_5$	SYNCOPE	MAX-C	CONTIGUITY (CV)	CONTIGUITY (VC)	*CC
a. $a_1t_2i_3p_4u_5$	*!				
b. $a_1t_2p_4u_5$			*	*	*!
c. $a_1t_2u_5$		*!	*		
d. $a_1p_4u_5$		*!		*	
☞ e. $a_1t_2t_4u_5$			*	*	
☞ f. $a_1p_2p_4u_5$			*	*	

Again, in response to this, one could propose introducing a new faithfulness constraint, such as IDENT [place], to make (67b) optimal. However, the introduction of IDENT [place] engenders additional complexities. For instance, the IDENT [place] constraint fails to capture the C_2 dominance effect in place assimilation: it cannot differentiate between candidates (67e) and (67f). Attempts to resolve this issue by refining IDENT [place] through stratified contextual faithfulness constraints (e.g., IDENT [place]/_V ≫ IDENT [place]/_C) would reintroduce the original problem, in which these contextual faithfulness constraints function inadequately in syncope contexts.

7 Conclusion

In this article, it has been argued that the syncope problem in cluster simplification can be resolved by constraints that refer to the transitions into and out of the vowels adjacent to the target cluster. Cluster simplification results in changes in the adjacent transitions; therefore, IDENT [transition] constraints that evaluate such changes can also regulate the process and its patterns. Since syncope removes not only the targeted vowel itself but also the transitions contained in that vowel, IDENT [transition] constraints cannot enforce faithfulness to those transitions, as they have no output correspondents. This explains why the C_2 dominance effect can be consistent even in the syncope context. It has also been shown that the same approach accounts for the syncope problem not only in cluster simplification, but also in major place assimilation and debuccalisation, demonstrating the extensibility of the current proposal.

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