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Constraint reranking in diachronic OT: binary-feet and word-minimum phenomena in Austronesian

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Abstract Languages throughout the Malayo-Polynesian branch of Austronesian exhibit a range of sound changes which all appear to be triggered by the presence of a schwa in an open penultimate syllable. These changes are gemination of the final-syllable onset, deletion of penultimate schwa in three-or-more syllable words, and the shift of schwa to a full vowel in open penultimate syllables only. The changes are analyzed as a product of drift, whereby changes in daughter languages are motivated by some property of the proto-language. In this case, it is argued that schwa was a zero-mora vowel in Proto-Austronesian and Proto-Malayo-Polynesian, and that these changes worked to add a mora to a word which would otherwise contain a degenerate single-mora foot. The observed changes are then analyzed as a product of constraint promotion modeled in Diachronic Optimality Theory, whereby constraint movement over time may explain historical sound change. In the case of Malayo-Polynesian, it is shown that the promotion of the Binary Foot constraint (FT-BIN) can explain all three of the attested schwa-triggered sound changes.

Keywords Diachronic optimality theory · Sound change · Phonology · Foot binarity

Introduction

In comparative linguistics, particularly that which is confined primarily or exclusively to a single language family, it is not uncommon to find examples of recurring language change resulting in parallel convergence across languages and subgroups. In some cases, these changes have a clear phonetic motivation, such as

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the devoicing of plosive consonants in word-final or coda position or the lenition of stops in intervocalic position (changes such as *d > *r* or *b > *v*). Still other cases of recurring parallel change may not have a clear motivation. When such changes appear with repeated frequency they are commonly referred to as convergence, homoplasy, or drift (Campbell 2020; Sapir 1921). In this study, a formal distinction is made between drift and other types of convergent change following earlier work from Sapir (1921), Vennemann (1975), and others who single out drift as change with some level of directionality or motivation and a type of change which is part of the "psychological tendencies" of speakers of a certain language (Vennemann 1975, p. 274). Convergent sound change may occur between any two languages, related or unrelated, and may be motivated by linguistic universals or arise due to chance. Drift, on the other hand, is a type of convergent change which appears with relative frequency in independent parallel developments within a single family. In this study, drift is understood to occur due to a property of the proto-language which is inherited in its daughters. This inherited property provides motivation for the observed change.

In comparative linguistics, drift may be a frustrating phenomenon, as it makes tasks such as identifying exclusively shared innovations more difficult. This is because certain changes, even those which may be cross-linguistically uncommon, might occur with high frequency within a family or subgroup due to drift, making it difficult to differentiate between independent and inherited innovations. Drift may also manifest itself in the form of conspiracy. For example, a diverse set of sound changes may occur with high frequency in parallel innovations across a family and also be shown to follow from a single underlying motivation linked to a property of the proto-language.

This paper addresses an apparent case of drift in the Austronesian family and furthermore demonstrates that drift may follow straightforwardly from the relative ranking of constraints in a proto-language, and that observed sound changes can be modeled as the result of interaction among adjacent constraints. The study utilizes comparative analysis to determine historical rankings of constraints and demonstrates how constraint reranking appears to be a process whereby constraints interact with adjacent constraints, resulting in structured and semi-predictable sound change rather than random sound change.

The drift analyzed in this study involves apparent repair strategies which increase the mora count in degenerate right-bound feet from one to two. It is argued that degenerate feet arose because schwa was a zero-mora vowel in Proto-Austronesian (henceforth PAn), creating a situation where some words with two syllables had only one mora. The repairs are of three types, which appear with some frequency in a diverse range of daughter languages. These are (1) the automatic gemination of medial consonants immediately following a schwa in an open penultimate syllable, (2) the deletion of schwa in penultimate position of words with three or more syllables, and (3) the shift of schwa to a full vowel in penultimate position but not in other positions. Examples of each type are shown in the following sections.

Gemination of final-syllable onsets after a penultimate schwa

Geminate consonants follow a penultimate schwa in a considerable number of Malayo-Polynesian (henceforth MP) languages, including Ilocano (Rubino 2000), Ngadha (Djawanai 1977), Kayan (Data Dian dialect, Smith 2018), Makassarese (Jukes 2020), and many others. Some examples from each of these languages are shown in example set 1.[1]

1.

a.	*dəp:á* 'a fathom'	Ilocano (Philippine)
	dəŋ:ə́g 'hear; listen'	
b.	[bətʰ:á] 'broken, as a string'	Ngadha (CMP)
	[səpʰ:á] 'chew leaves'	
c.	*təp:áʔ* 'pound rice'	Kayan (WIN)
	mət:áŋ 'ask'	
d.	*bál:a* 'splitting' (from PMP *bəlaq)[2]	Makassarese (S. Sulawesi)
	tál:u 'three' (from PMP *təlu)	

Schwa-deletion in three-syllable words

Many MP languages reflect a stage where schwa deleted if it occurred in an open penultimate syllable in a three syllable word. The resulting output of such deletion is always a well-formed 2-syllable/2-mora word: CV$^{\mu}$(CəCV$^{\mu}$C) → (CV$^{\mu}$CCV$^{\mu}$C). Ilocano once again provides some examples in 2, where Proto-Malayo-Polynesian (PMP) *ə regularly deletes in three syllable words. Here and elsewhere, reconstructed vocabulary are from Blust et al. (2023).

2.

*qaŋəlit	→	*aŋlít* 'foul odor'
*qaləjaw	→	*aldáw* 'day'
*lisəqah	→	*lisʔá* 'nit'

The deletion of schwa in this environment is nearly universal in the Philippines, and is a regular change in the languages where it occurs. It is also attested in Chamorro (Blust 2000). Outside of the Philippines, there is a mixture of regularity and irregularity with regard to schwa deletion.

[1] Here and elsewhere in this paper a modified IPA is used following standard conventions in Austronesian linguistics. Unless written within square brackets, *j* is used for IPA [dʒ] and y for IPA [j]. Reconstructed vocabulary uses the Proto-Austronesian orthography, which is heavily IPA influenced, but uses *R for [r], *j for [gʲ], *z for [dʒ], as well as other orthographic conventions not relevant for this paper. In all examples stress is marked where available from the source material.

[2] In Makassarese, geminates appear after a historical schwa-syllable, although schwa has since merged with *a. Cases where *a* in Makassarese reflect Proto-Malayo-Polynesian *a do not trigger predictable gemination.

Vowel shift as an alternative minimal word repair strategy

The final repair strategy for subminimal words is vowel-shift, from *ə to a full vowel, allowing the historical schwa-syllable to hold a mora. There are many examples of languages that shift schwa to a full vowel in all positions, but the relevant cases for this study are from languages that have shifted schwa to a full vowel in the penult only. In such cases, schwa shifted to *o in the penultimate syllable allows that syllable to host a mora. Example 3 summarizes penultimate schwa-shift and its effect on mora count.

3.
a. PMP *CəCV$^{\mu}$C → *Co$^{\mu}$CVC$^{\mu}$
b. PMP *CəCəC$^{\mu}$ → *Co$^{\mu}$CəC$^{\mu}$
c. PMP *CV$^{\mu}$CəC$^{\mu}$ → *CV$^{\mu}$CəC$^{\mu}$

Such cases are rare, since most languages in western Austronesian areas utilize either gemination or deletion as mora repair strategies. However, cases of schwa-shift in penultimate syllables are found in the eastern Austronesian world, specifically in the South Halmahera-East New Guinea subgroup (SHWNG). As early as Blust (1978, pp. 211–12) it has been pointed out that schwa shifted to a full vowel in penultimate position but remained unchanged in the final syllable (until subsequent sound change eliminated schwa altogether). Some examples from Ma'ya, a SHWNG language, are shown in 4.

4. Ma'ya

a.	*təlu	*tol* 'three'	b.	*qinəp	*wénef* 'to sleep'
	*qatəluR	*tol* 'egg'		*bituqən	*túen* 'star'
	*dəŋəR	*don* 'to hear'		*qitəm	*mat-métem* 'black'

A constraint-movement based explanation

All three of these changes, gemination, schwa deletion, and schwa shift, had the effect of repairing a degenerate foot, creating a well-formed two-mora foot at the right edge of the word. In a theory of constraint movement, the promotion of Ft-Bin over intervening constraints may explain why so many languages have undergone these parallel changes. Through analysis of historical change, certain proto-rankings of relevant constraints are found to be favored over others and can help to pinpoint the relevant constraint rankings that defined the common starting point for the changes studied here. To summarize, it is argued that (1) Promotion of Ft-Bin over intervening constraints can adequately explain the different types of minimal word repairs attested in Austronesian, (2) It is possible to reconstruct constraint rankings based on a comparison of sound changes which are caused by Ft-Bin promotion, and (3) Promotion can be shown to happen in stages, with promotion occurring between adjacent constraints. First, however, the necessary background in both An and Diachronic OT is presented in the following sections before presenting the core analysis of constraint movement in An and its effects on word shape.

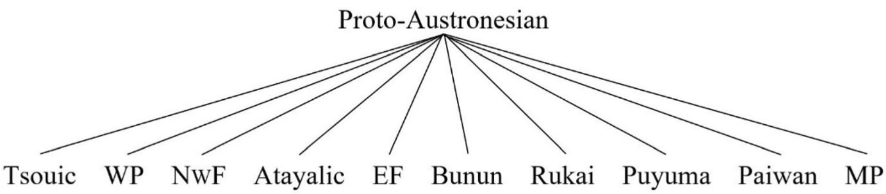


Figure 1 Austronesian internal subgrouping (Blust 1999)

Phonological properties of proto-austronesian and proto-malayo-polynesian

In this section I provide an overview of the reconstructed phonology of PAn and PMP. Both languages had similar phonological grammars, and as such much of what we reconstruct to PAn is still applicable to PMP. There are, however, a few differences, and those will be pointed out in the discussion. First, the subgrouping that informs the analysis is given below in Figs. 1 and 2[3]. Ten first-order subgroups in An are recognized, following the proposal from Blust (1999). MP subgrouping is from Smith (2017):

Word shape

PAn and PMP had a two-syllable canonical word. Roughly ninety percent of all reconstructed An vocabulary conforms to this disyllabic requirement. Exceptions are rare but include a small number of three-syllable words. Importantly, no monosyllabic content words are reconstructed. Rather, monosyllables are confined to phonologically bound grammatical words like conjunctions and case markers (Blust 2013, p. 539). Consonant cluster constraints also played a role in PAn word-shape. Consonant clusters were restricted to reduplicated monosyllables such as *bejbej 'to tie by winding', a sub-set of the lexicon, while non-reduplicated words did not allow for such medial clusters (Blust 2013; Chrétien 1965; Dempwolff 1937; Ross 1992).

Important distributional and phonotactic restrictions are found in the vowel system as well. Four vowels are reconstructed to PAn, *i, *u, *a, and *ə. The first three vowels may appear in any position in the word and were not subject to any known restrictions. Schwa, however, was the subject of numerous unique distributional restrictions, which are indicated in the list below. Restrictions 1 and 4 are from Blust (2000) and Mills (1975) respectively:

1. Schwa could not appear in word-final or word-initial position.
2. Schwa was absent from both prefixing and infixing morphology.

[3] In Fig. 1, Western Plains is abbreviated as WP, Northwest Formosan as NwF, East Formosan as EF, and Malayo-Polynesian as MP. In Fig. 2, Western Indonesian is abbreviated as WIn, Sumatran as Sum, Celebic as Cel, South Sulawesi as SS or S. Sulawesi, and Central-Eastern Malayo-Polynesian as CEMP. Eastern Malayo-Polynesian, a subgroup within CMP but not listed in Fig. 2, is abbreviated as EMP throughout this paper.

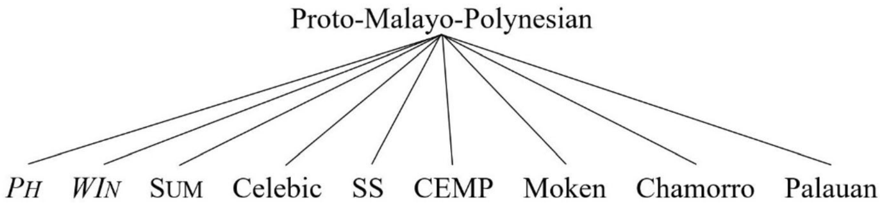


Figure 2 Malayo-Polynesian internal subgrouping (Smith 2017).

3. Schwa was absent from prepenultimate position.
4. Schwa could not immediately be followed by a semivowel, *w or *y.

There are many possible explanations for these restrictions, and they will not all be explored here. What stands out, however, is the tendency for vowel restrictions to specifically target schwa but not other vowels. An additional restriction on schwa is stress, which is discussed in greater detail in the following section.

Stress in PAn

Smith (2023) argues that stress in PAn was predictable, falling mainly on the penultimate syllable but shifting to the final syllable if the penultimate syllable was open and contained a schwa nucleus. Evidence for Smith's reconstruction was taken from three primary branches (Western Plains, Paiwan, and Malayo-Polynesian) where stress is penultimate but shifts to the final syllable if the penultimate vowel is (or was) schwa. Additional evidence is from multiple primary branches where stress has regularized to the final syllable, but reflects an earlier stage where schwa deleted in open penultimate syllables: Amis (East Formosan, Maddieson and Wright 1995), Atayalic (Huang 2018; Blust 1994), Saisiyat (Northeast Formosan, Li 1978), and Puyuma (Tsuchida 1980). Smith (2023) argues that schwa deletion in these languages suggests that schwa was historically unstressed whereas the shift to general word-final stress is a more recent innovation.

Paiwan stress and reconstruction

As mentioned earlier, Paiwan is included as an example of a primary branch that retains stress-shift after schwa. It must be noted, however, that stress shift in Paiwan is only found in Central Paiwan dialects[4]. Other Paiwan dialects have a regular penultimate stress pattern that includes schwa-syllables. Macaulay (2021) provides an overview and analyzes schwa-sensitive stress in Central Paiwan as an innovation, not a retention from an earlier stage. His analysis is based on the observation that most Paiwan varieties do not have schwa-sensitive stress. He therefore appeals to the "majority-rule" condition on reconstruction and reconstructs regular penultimate stress to Proto-Paiwan. However, since Paiwan is itself an Austronesian language,

[4] Paiwan is internally diverse, with several different "dialect" areas largely defined by geography: South, North, East, and Central Paiwan (Chang 2006, p. 1).

inferences from other subgroups can also be taken into consideration when analyzing its historical evolution. Since other primary branches, namely Western Plains and Malayo-Polynesian, support an unstressable penultimate schwa reconstruction, the Paiwan data can be analyzed as Central Paiwan retaining a system that was regularized in other Paiwan varieties.

The nature of historical analysis and the reconstruction of stress systems.

The analysis of Paiwan and Austronesian historical stress patterns in this paper assumes that the properties of a proto-language may be faithfully retained in some daughter languages, but totally altered in others. For example, in Proto-Austronesian, as discussed in more length below, schwa was restricted to certain environments: it did not appear at word boundaries, both word-initial and word-final. This inference is based on comparative analysis: we cannot reconstruct a schwa to word-final or word-initial position with the available evidence. Importantly, many Austronesian languages now allow schwa in these positions [following the PAn reconstructions of Blust et al. (2023), and additional work on word-initial schwa in Smith (2022)]. The existence of modern languages that allow schwa in previously banned positions is unsurprising given the nature of language and language change. These "exceptions" pose no issue for reconstruction since they are innovations rather than retentions. We hypothesize that schwa was eventually allowed in such positions after the breakup of Proto-Austronesian.

Stress placement will pose similar issues. Modern Austronesian languages contain a wide range of stress systems, from iambic word-final stress, to trochaic right-bound stress, to initial stress, and nearly every conceivable system in-between. Proto-Austronesian also had a stress system and the existence of so many different stress systems in Austronesian languages today implies that an older, single stress system must have diversified. Just as one cannot point to the existence of schwa in a final syllable in one language as evidence against a ban on schwa in that position in the proto-language, so too can one not simply point to an example of one stress system as evidence against a different stress system at an earlier point in the historical development of the language. Rather, it is the comparative analysis of stress systems, as well as the segmental phenomena associated with such stress systems, which can help inform our understanding of Proto-Austronesian stress and its diachronic development.

This paper therefore assumes that PAn had a disyllabic canonical word-shape, relatively simple syllable shapes, a restriction against consonant clusters except in reduplicated monosyllables, four vowels, and mostly penultimate stress. Stress did not fall on the penultimate syllable in words with a schwa in an open penultimate syllable, but rather shifted to the final syllable. This was due to some property of schwa which made it unable to bear stress in open syllables. As argued below, this is because schwa was a weightless segment and did not contribute to lexical mora count.

Schwa as a zero-mora vowel and variable coda weight

Schwa clearly had a special status in PAn and PMP, but how does this interact with stress? Many explanations for why schwa is unable to hold stress in An languages appeal to either quality or length (Blust 1995; 2017). However, recent analysis of Paiwan has suggested that schwa itself is non-moraic, and that this lack of a mora motivates stress shift (Yeh 2017; Shih 2018). More recently, Smith (2023) reconstructs a weightless schwa to PAn itself. These analyses imply that the mora is a requirement for stress, and that weightless segments are unable to hold stress, a form of quantity sensitivity (Kager 1993). If schwa is weightless, then words with a schwa will have one fewer than expected morae. A two-syllable word with a schwa syllable may have only one mora, for example. If a two-mora word minimum is in effect, then such words will need to undergo some type of repair.

Weightless segments are not rare. In addition to Paiwan, weightless syllables are proposed for Polish and Georgian (Cho and King 2003), and in both Dutch (Kager 1989) and German (Féry 2003), schwa-syllables are analyzed as being weightless. In Malayalam, Namboodiripad et al., (2015) show that schwa is weightless in word-final position and further point out how schwa's weightlessness interacts with word-minimum requirements: A two-syllable word with a weightless schwa-syllable must lengthen a consonant in order to meet a two-mora minimum.

An analysis of schwa as a zero-mora vowel in PAn and its immediate daughter languages is intuitive, considering its unstressability, positional restrictions, and various segmental phenomena associated with schwa in daughter languages. However, there are some cases where schwa must bear stress, and in these cases schwa's weight is best analyzed as variable (Rosenthall & van der Hulst 1999).

The most common type of stressed schwa in languages that otherwise ban a stressed schwa are those that appear in a closed syllable. In such cases, schwa may receive stress and there are no word-minimum repairs. There are two main types of stressed closed-syllable schwa. First, where both syllables have a schwa nucleus and only the final syllable is closed, example 5a, and second, where schwa appears in a closed penultimate syllable, example 5b.

5.
a. Cəˈ CəC
b. ˈCəCCVC

It is tempting to posit that these languages have heavy codas, but heavy codas are otherwise absent and coda weight is not typically considered a property of PAn or PMP because closed final syllables do not attract stress away from the penult in languages that have regular penultimate stress. Thus, a majority of western Austronesian languages with penultimate stress have patterns like those in 6a and not those in 6b:

6.
a. ˈCVCV, ˈCVCVC
b. ˈCVCV, **CVˈCVC

This leads both Yeh (2017, regarding Paiwan) and Smith (2023, regarding PAn) to analyze codas as having variable weight. Codas only add weight to a syllable when coerced by a schwa nucleus but are weightless in all other contexts. Shih (2018) notices the same pattern, but analyzes schwa, not the coda, as being the main weight-bearing unit in Paiwan closed syllables (with a weightless schwa in other contexts), but there may be some issues with such an analysis[5].

These patterns are assumed here to be derived from a property of PAn, namely, schwa was not only unstressable but did not contribute to lexical mora count. Further, a schwa syllable with a coda did contribute to lexical mora count via variable coda weight. PAn apparently did allow degenerate feet at the right edge of words of the shape CəCVC, and it is precisely these types of words that were the target of mora-addition strategies later on.

Language change and diachronic OT

PAn, like any other language, had a certain phonological grammar. But how can one model the changes that take place within that grammar as the language changes over time? In this paper, a Diachronic Optimality Theory approach to modeling language change is adopted (Cho 1998; Holt 2015; Oh 2002). Diachronic OT models phonological change as constraint movement. Further, the constraint movement itself is assumed to take place within the complete grammars of fluent adolescents and young adults. Thus, constraint movement occurs not as an acquisition process, but as an internal grammar-modification process.

When does language change occur?

The issue of where and how language change occurs is important, and it is necessary to review some of the assumptions which underpin the present research. Theories of language change may be somewhat simplistically split into CHILD ACQUISITION theories and USAGE-BASED theories. Child acquisition-based theories assert that language change occurs during language acquisition through what can be described as a process of imperfect learning which introduces new features during childhood (Yang 2000; Lightfoot 2013). Usage-based theories model linguistic change as occurring over the lifespan of individuals, peaking during adolescence and early adulthood, suggesting that language change is not a product of imperfect learning, but rather a socially-influenced process through which existing individual grammars change (Baxter & Croft 2016; Blythe & Croft 2021).

A usage-based approach to sound change is assumed here. Language users acquire a more-or-less caregiver like grammar which may undergo changes in adolescence and young adulthood. When discussing constraint movement it is therefore assumed that movements are taking place in the grammars of already

[5] Shih (2018, §3.4.2) measures the length of a two-mora schwa at roughly 130 ms, but also measures the length of a one mora /u/ in identical environments at 130–140 ms; a "two-mora" schwa is roughly the same length as a one-mora vowel. If the mora is a unit of syllable weight, there is no reason for its value, which should be consistent, to be halved in schwa. This discrepancy needs additional attention.

fluent individuals. What this means is that although language users do not have access to an ancestral grammar, they do have access to the grammar of their caregivers. With this assumption, it is appropriate to talk about the movements of already ranked constraints, not inaccurate acquisition, as the driver of sound change.

The mechanics of Diachronic OT and constraint interaction

Optimality Theory (OT, Prince and Smolensky 1993) explains differences in input and output as arising from the interaction of ranked violable constraints. Differences in grammars occur from differences in the relative ranking of constraints. In related languages, we may further state that the differences that arise through historical sound change also involve constraint movement (Holt 2015). For example, if a process of final-consonant deletion is observed, one might posit that the change occurred with a promotion of a constraint such as No Coda over an intervening faithfulness constraint. In such a case, a movement pattern like that shown below in example 7 may be proposed:

7.

Initial Ranking	→	Movement	→	Resultant Ranking
DEP $\gg$ MAX $\gg$ NOCODA		DEP $\gg$ MAX $\gg$ NOCODA		DEP $\gg$ NOCODA $\gg$ MAX

In such a scenario, a proto-lexeme of the shape CVCVC will undergo a coda deletion stage, resulting in an output of CVCV.

Variability and sound change

From a historical perspective, sound changes sometimes appear to apply to a language all at once, from a proto-stage with certain phonological properties to a contemporary-stage with altered phonological properties. Immediate change is modeled in a theory of constraint movement whereby a proto-ranking A $\gg$ B changes to B $\gg$ A directly, with no intermediate stages. In reality, however, sound change is known to occur with a stage of variability (Labov 1965; Weinreich et al. 1968). Before a sound change has a chance to "settle in", pronunciations will vary across both speakers and speech-acts. The sound changes that historical linguists study are simply a subset of past variations which eventually solidified into regular sound changes. It is therefore necessary that a theory of constraint movement have variability in the framework.

In this research, a stochastic model is assumed for variation following Boersma (1997) and Boersma and Hayes (2001) who propose a system of continuous ranking where constraints are not discreetly ranked but may appear within a normal distribution centered on a discrete position within a continuous ranking system (so-called Stochastic OT). Adjacent constraints may sometimes switch places due to the probabilistic nature of their realizations. It is thus the relative rankings of constraints which are "inherited" from an ancestor that determines which types of changes are most likely to occur. In such a model, adjacent constraints are much more likely to interact and rerank relative to one another than constraints which are some distance from one another.

For historical analysis, I utilize the Diachronic Reranking model, which directly incorporates variation into its model of constraint movement (Cho 1998; Oh 2002). Under the Diachronic Reranking Hypothesis constraints first enter a stage of variable ranking, indicated by the use of a dotted line (Oh 2002). If we rewrite the coda deletion example from 7, this time with tableaux as in example 8, we can see that No Coda's journey upwards begins with an intermediate stage of variation indicated by a vertical dotted line. In 8b, both CVCVC and CVCV are pronounced but the faithful output is preferred. In 8c the innovative output is preferred. Finally, in 8d the innovative output is the only licit output.

8.

a Candidate a is the only licit output

/CVCVC/	Dep	Max	NoCoda
☞ a. [CVCVC]			*
b. [CVCV]		*!	
c. [CVCVCV]	*!		

b Candidates a and b are both licit, but a is more common than b

/CVCVC/	Dep	Max ⋮	NoCoda
☞ a. [CVCVC]			*
☞ b. [CVCV]		*	
c. [CVCVCV]	*!		

c Candidates a and b are both licit, but b is more common than a

/CVCVC/	Dep	NoCoda ⋮	Max
☞ a. [CVCVC]		*	
☞ b. [CVCV]			*
c. [CVCVCV]	*!		

d Candidate b is the only licit output

/CVCVC/	Dep	NoCoda	Max
a. [CVCVC]		*!	
☞ b. [CVCV]			*
c. [CVCVCV]	*!		

Although the Diachronic Reranking model does not explicitly take a stochastic approach, such a model is assumed here to be a factor in the emergence of variation. Because of the nature of constraint interaction and variability within a stochastic continuous ranking model, constraints appear to move gradually over time. When modeling diachronic change, the interaction of constraints is formalized with a principle of gradual movement, defined below in 9:

9.
Gradual Movement: The promotion/demotion of constraints occurs in short, rather than long, movements. Given a proto-ranking A ≫ B ≫ C, constraint C may only come to dominate A if it first passes through an intermediate stage A ≫ C ≫ B.

There is so far no consensus on whether constraints can move immediately over long distances or whether they must move locally (where constraints must pass over intervening constraints one at a time). Examples of both are found in the literature (Itô & Mester 2004; Kiparsky 2015; Crist 2001; Holt 2003; Zubritskaya 1995). However, the Gradual Movement requirement of short rather than long-distance constraint reranking appears to play out in the data considered here.

Constraint movement analysis

In this section I discuss how a constraint-reranking hypothesis which targets the ranking of Ft-Bin relative to other constraints is able to explain both the types of repair strategies implemented as well as the frequency of repairs in An minimal word repair.

Regarding frequency, although three repairs have been identified they do not affect languages at the same rate. The deletion of penultimate schwa-syllables in three-or-more syllable words, for example, is attested throughout the MP subgroup. Only Palauan has no evidence of schwa-deletion as either a regular or irregular process. In Chamorro and the Philippines, schwa deletion is regular, and elsewhere it appears as an irregular process affecting some but not all lexical items. Gemination of final syllable onsets is also common. It appears in most primary branches, but less frequently than schwa deletion with several branches, including Chamorro, Palauan, Celebic, and Sumatran, lacking evidence for the process. Vowel shift, from schwa to a full vowel, is the least common and is directly attested only in SHWNG. When determining how constraints were ranked in a proto-language and how constraint movement occurs with various sound changes, it is important that the proposal explain both how constraint movement triggers sound change as well as how certain sound changes are more common than others in a particular family. The following analysis requires only one movement for schwa-deletion, two for gemination, and a specific interaction of three movements for vowel shift. The increasing complexity of constraint movement corresponds with a decrease in sound change frequency.

A relatively small number of constraints are utilized in this analysis. The proposal focuses solely on mora-addition strategies, and therefore does not attempt to explain other phenomena. For example, vowel shift from schwa to a full vowel in SHWNG generates *o* in the output. This proposal is not concerned with why schwa becomes *o* and not some other vowel, but only that schwa shift produces a full vowel with a mora. I assume the existence of a constraint against moraic schwa, *μ\ə, which is highly ranked in all tableaux. Finally, feet in Austronesian, at least at the early stages being discussed in this paper, are typically trochaic and right-aligned. The necessary foot-type and alignment constraints are assumed to be Trochee, which requires that feet be trochaic (i.e., left headed) and the alignment constraint All-Ft-R, which requires that feet be at the right edge of a word. In the Tableaux throughout this section, All-Ft-R will be assumed and left-aligned feet will not be listed as candidates. The other relevant constraints are as outlined below in 10:

10.

Ft-Bin	Feet are binary at some level of analysis. Following Hewitt (1994), Ft-Bin is assumed to be a family of constraints targeting different levels of prosodic structure and distinguishing between violations of foot minimality (Ft-Bin-x^{MIN}) and Foot maximality (Ft-Bin-x^{MAX}). In early Austronesian, Ft-Bin-σ^{MAX} and Ft-Bin-μ^{MIN} are the relevant foot binarity constraints. They operate as a unit, with Ft-Bin-σ^{MAX} always outranking Ft-Bin-μ^{MIN} and no intervening constraints separating the two. Promotions of Ft-Bin are analyzed here as always affecting both Ft-Bin-σ^{MAX} and Ft-Bin-μ^{MIN}, never one or the other.
Dep(μ)	A mora in the output must have a corresponding mora in the input. No mora addition.
Ident(V)	A vowel in the output must match features with its corresponding vowel in the input. No vowel shift.
*Gem	No geminate consonants may appear in the output.
Max	Segments in the input must have a corresponding segment in the output. No deletion.

An additional assumption of the present study is that attested repairs do not include any vowel epenthesis. For example, CəCVC words may theoretically add a mora via vowel paragoge, creating a two-mora output CəCVCV. Such cases are unattested, however. In An, vowels are sometimes added to words as a coda elimination strategy, but not as a mora addition strategy. That is, in languages where vowel paragoge is attested, all words ending in a consonant add a vowel, not only those with a schwa penult. The paragoge arises through the interaction of No Coda with faithfulness constraints, so the present study does not take epenthesis into consideration.

In the remainder of this section the three repair strategies of schwa deletion, gemination after penultimate schwa, and penultimate vowel shift, are modeled in OT using reconstructed forms as inputs. The constraint rankings needed for these models are then used to reconstruct a PMP constraint ranking in 5.4, followed by an analysis of the constraint rerankings that took place after PMP in 5.5 and 5.6. The reconstructed ranking of all relevant constraints at the PMP level is shown in 11:

11.
TROCHEE ≫ *μ\ə ≫ DEP(μ) ≫ MAX ≫ FT-BIN-σ^{MAX} ≫ FT-BIN-μ^{MIN} ≫ IDENT(V) ≫ *GEM

This PMP reconstruction, informed by constraint interaction in modern Austronesian languages, provides the following insights into MP historical constraint ranking. First, DEP(μ) and MAX both outranked FT-BIN at the PMP level. This allowed subminimal words of the shape CəCVC$^{\mu}$ and three syllable words with medial schwas and subminimal right aligned feed of the shape CV$^{\mu}$(CəCVC$^{\mu}$). FT-BIN outranked both IDENT(V) and *GEM, but because of the higher ranking of DEP(μ), neither were able to affect surface forms, at least not in the data considered here. The inference that FT-BIN outranked IDENT(V) and *GEM is made from observing the ordering of sound changes: FT-BIN must be adjacent to MAX, which is itself just below IDENT(V), in order to adequately explain the observed ordering of sound changes. The orderings are, schwa deletion first, Gemination second. This ordering is captured by FT-BIN's adjacency to MAX. Sound changes are triggered by promotion of the FT-BIN family of constraints first over MAX, and second over DEP (μ). A later promotion of *GEM over IDENT(V) triggers schwa shift to a full vowel in the penultimate syllable.

Schwa deletion

Interactions between FT-BIN and MAX-IO generate outputs where schwa is deleted in three-syllable words but retained in disyllables. Ranking FT-BIN above MAX-IO gives the desired output. Schwa deletes in a three-syllable word and a right-aligned trochaic foot with the required mora is built over the resulting disyllable in example 12a. If the input is a disyllable, then deletion fails to add a mora to the word and additionally violates MAX as in 12b. PMP reconstructed vocabulary are used as example words: *qaləjaw [qaləˈɡʲaw] 'day' and *təbuh [təˈbuh] 'sugarcane'.

12.

a.

/qa$^{\mu}$ləja$^{\mu}$w/	TROCHEE	*μ\ə	FT-BIN-σ^{MAX}	Ft-Bin-μ^{MIN}	MAX
a. [qa$^{\mu}$(lə$^{\mu}$ja$^{\mu}$w)]		*!			
b. [qa$^{\mu}$(ləja$^{\mu}$w)]	*!			*	
c. [(qa$^{\mu}$ləja$^{\mu}$w)]			*!		
d. [qa$^{\mu}$lə(ja$^{\mu}$w)]				*!	
☞ e. [(qa$^{\mu}$lja$^{\mu}$w)]					*

b.

/təbu$^{\mu}$h/	TROCHEE	*μ\ə	FT-BIN-σ^{MAX}	Ft-Bin-μ^{MIN}	MAX
a. [(tə$^{\mu}$bu$^{\mu}$h)]		*!			
b. [(təbu$^{\mu}$h)]	*!			*	
☞ c. [tə(bu$^{\mu}$h)]				*	
d. [(tbu$^{\mu}$h)]				*	*!

Gemination after penultimate schwa

Naturally, a system whereby gemination is triggered via constraint movement is likely to appeal to the anti-gemination constraint *GEM. For example, FT-BIN may outrank *GEM, thereby triggering gemination in the output as in 13:

13.

a.

/qa$^{\mu}$ləja$^{\mu}$w/	TROCHEE	*μ\ə	FT-BIN-σ^{MAX}	Ft-Bin-μ^{MIN}	*GEM
a. [qa$^{\mu}$(lə$^{\mu}$ja$^{\mu}$w)]		*!			
b. [qa$^{\mu}$(ləja$^{\mu}$w)]	*!			*	
c. [(qa$^{\mu}$ləja$^{\mu}$w)]			*!		
d. [qa$^{\mu}$lə(ja$^{\mu}$w)]				*!	
☞ e. [qa$^{\mu}$(ləjː$^{\mu}$a$^{\mu}$w)]					*

b.

/təbu$^{\mu}$h/	TROCHEE	*μ\ə	FT-BIN-σ^{MAX}	Ft-Bin-μ^{MIN}	*GEM
a. [(tə$^{\mu}$bu$^{\mu}$h)]		*!			
b. [(təbu$^{\mu}$h)]	*!				
c. [tə(bu$^{\mu}$h)]				*!	
☞ d. [(təbː$^{\mu}$u$^{\mu}$h)]					*

An alternative approach is to have FT-BIN interact with DEP(μ). The same ranking, of FT-BIN at the top of the tableau, generates the desired output in 14.

14.

a.

/qa$^{\mu}$ləjaw$^{\mu}$/	TROCHEE	*μ\ə	FT-BIN-σ^{MAX}	Ft-Bin-μ^{MIN}	DEP(μ)
a. [qa$^{\mu}$(lə$^{\mu}$jaw$^{\mu}$)]		*!			
b. [qa$^{\mu}$(ləjaw$^{\mu}$)]	*!			*	
c. [(qa$^{\mu}$ləjaw$^{\mu}$)]			*!		
d. [qa$^{\mu}$lə(jaw$^{\mu}$)]				*!	
☞ e. [qa$^{\mu}$(ləj:$^{\mu}$aw$^{\mu}$)]					*

b.

/təbu$^{\mu}$h/	TROCHEE	*μ\ə	FT-BIN-σ^{MAX}	Ft-Bin-μ^{MIN}	DEP(μ)
a. [(tə$^{\mu}$bu$^{\mu}$h)]		*!			
b. [(təbu$^{\mu}$h)]	*!			*	
c. [tə(bu$^{\mu}$h)]				*!	
☞ d. [(təb:$^{\mu}$u$^{\mu}$h)]					*

In this study, DEP(μ) is assumed to motivate gemination as a mora-repair, not *GEM. Although *GEM could be used to model the same changes, numerous MP languages innovated geminates for reasons other than mora-repair. This is the case for Batak, where geminate consonants arose out of the full assimilation of consonants in clusters but not as a mora repair strategy (Nababan 1981). Gemination itself is not rare in MP, and this suggests that *GEM was not highly ranked in PMP. FT-BIN, on the other hand, has wide-ranging impacts on AN phonology as a result of it being in a relatively high position. Since FT-BIN was ranked high, *GEM probably did not interact with it directly. The analysis here therefore has *GEM ranked low and relies on DEP(μ) to trigger gemination.

penultimate vowel shift

Penultimate vowel shift may arise if Ident(V) is ranked below Ft-Bin. In this case, penultimate vowel shift is triggered while leaving schwa in other positions unchanged in example 15. PMP *daləm ‘deep; inside’ is used as an example word in 15b.

15.

a.

/təbu$^{\mu}$h/	Trochee	*μ\ə	Ft-Bin-σ^{MAX}	Ft-Bin-μ^{MIN}	Ident(V)
a. [(tə$^{\mu}$bu$^{\mu}$h)]		*!			
b. [(təbu$^{\mu}$h)]	*!			*	
c. [tə(bu$^{\mu}$h)]				*!	
☞ d. [(to$^{\mu}$bu$^{\mu}$h)]					*

b.

/da$^{\mu}$ləm$^{\mu}$/	Trochee	*μ\ə	Ft-Bin-σ^{MAX}	Ft-Bin-μ^{MIN}	Ident(V)
☞ a. [(da$^{\mu}$ləm$^{\mu}$)]					
b. [(da$^{\mu}$lo$^{\mu}$m)]					*!

To summarize, schwa deletion in three syllable words is triggered when FT-BIN outranks MAX, gemination is triggered when FT-BIN outranks DEP(μ), and penultimate vowel shift is triggered when FT-BIN outranks IDENT(V). These observations can be used to reconstruct a PMP constraint ranking and determine how constraint movement triggered certain sound changes during post-PMP development.

Proto-Malayo-Polynesian position of FT-BIN

PMP did not have any of the aforementioned repairs; FT-BIN enforcement arose through parallel innovations after the breakup of PMP. A proto-ranking of constraints that places FT-BIN below relevant constraints is therefore reconstructed below in examples 16 and 17 with 3-syllable and 2-syllable inputs, respectively. At the PMP level, FT-BIN-σ^{MAX} must outrank FT-BIN-μ^{MIN} to rule out trisyllabic feet. For now, the relative ranking of these two constraints is considered fixed, and promotion of FT-BIN is shorthand for the promotion of the constraint family. I will continue to use PMP *qaləjaw 'day' and *təbuh 'sugarcane' in example tableaux, but note that these repairs are generalizable to any reconstructed CVCəCV(C) or CəCV(C) word. Since FT-BIN interacts with DEP(μ) and MAX during gemination and vowel deletion, it is placed below these constraints in the reconstructed ranking. Vowel identity does not need to be ranked above FT-BIN, since DEP(μ) already rules out vowel shift as a mora addition strategy. Importantly, the realized phonology of PMP alone is not enough to determine the relative positions of DEP(μ) and MAX. Both DEP(μ) ≫ MAX ≫ FT-BIN and MAX ≫ DEP(μ) ≫ FT-BIN result in the same outputs in 16a/b and 17a/b.

a

/qa$^{\mu}$ləjaw$^{\mu}$/	TROCHEE	*µ\ə	DEP(µ)	MAX	FT-BIN-σ^{MAX}	FT-BIN-µ^{MIN}	IDENT(V)	*GEM
a. [qa$^{\mu}$(lə$^{\mu}$jaw$^{\mu}$)]		*!	*					
b. [qa$^{\mu}$(ləjaw$^{\mu}$)]	*!					*		
☞ c. [qa$^{\mu}$lə(jaw$^{\mu}$)]						*		
d. [qa$^{\mu}$(ləj:$^{\mu}$aw$^{\mu}$)]			*!					*
e. [qa$^{\mu}$(lo$^{\mu}$jaw$^{\mu}$)]			*!				*	
f. [(qa$^{\mu}$ləjaw$^{\mu}$)]					*!			
g. [(qa$^{\mu}$ljaw$^{\mu}$)]				*!				

b

/qa$^{\mu}$ləjaw$^{\mu}$/	TROCHEE	*µ\ə	MAX	DEP(µ)	FT-BIN-σ^{MAX}	Ft-Bin-µ^{MIN}	IDENT(V)	*GEM
a. [qa$^{\mu}$(lə$^{\mu}$jaw$^{\mu}$)]		*!		*				
b. [qa$^{\mu}$(ləjaw$^{\mu}$)]	*!					*		
☞ c. [qa$^{\mu}$lə(jaw$^{\mu}$)]						*		
d. [qa$^{\mu}$(ləj:$^{\mu}$aw$^{\mu}$)]				*!				*
e. [qa$^{\mu}$(lo$^{\mu}$jaw$^{\mu}$)]				*!			*	
f. [(qa$^{\mu}$ləjaw$^{\mu}$)]					*!			
g. [(qa$^{\mu}$ljaw$^{\mu}$)]			*!					

17.

a

/təbu^{µ}h/	TROCHEE	*µ/ə	DEP(µ)	MAX	FT-BIN-σ^{MAX}	FT-BIN-µ^{MIN}	IDENT(V)	*GEM
a. [(tə^{µ}bu^{µ}h)]		*!	*					
b. [(təbu^{µ}h)]	*!					*		
☞ c. [tə(bu^{µ}h)]						*		
d. [(təb:^{µ}u^{µ}h)]			*!					*
e. [(to^{µ}bu^{µ}h)]			*!				*	
f. [(tbu^{µ}h)]				*!		*		

b

/təbu^{µ}h/	TROCHEE	*µ/ə	MAX	DEP(µ)	FT-BIN-σ^{MAX}	FT-BIN-µ^{MIN}	IDENT(V)	*GEM
a. [(tə^{µ}bu^{µ}h)]		*!		*				
b. [(təbu^{µ}h)]	*!					*		
☞ c. [tə(bu^{µ}h)]						*		
d. [(təb:^{µ}u^{µ}h)]				*!				*
e. [(to^{µ}bu^{µ}h)]				*!			*	
f. [(tbu^{µ}h)]			*!			**		

Although the relative ranking of Dep(μ) and Max cannot be determined from PMP phonology alone, the ordering of sound change and distribution of gemination and schwa-deletion, discussed in section 5.5, show that Dep(μ) ≫ Max (16a, 17a) is the correct ranking, since Max ≫ Dep(μ) would break the historical derivation.

Post PMP developments (schwa-deletion first, gemination second)

Post-PMP sound change worked to reinforce a two-mora minimum. In Diachronic OT this is achieved via promotion of Ft-Bin. Importantly, the gradual promotion of Ft-Bin interacts with intervening constraints in such a way as to trigger vowel deletion first, and consonant gemination second. This interaction is preferred because in the Philippines, only a subset of the languages reflect consonant gemination after a penultimate schwa, whereas vowel deletion is attested across-the-board. The deletion-first, gemination-second generalization is observable outside of the Philippines as well. In example 18, promotion of Ft-Bin over Max but not Dep (μ) triggers deletion in Palawan (Philippine), Cebuano (Philippine), and Chamorro, and in 19, promotion of Ft-Bin over both Max and Dep(μ) triggers both deletion and gemination in Ilocano (Philippine), Isnag (Philippine), and Tae' (South Sulawesi).

18. *Promotion over Max but not Dep(μ).*

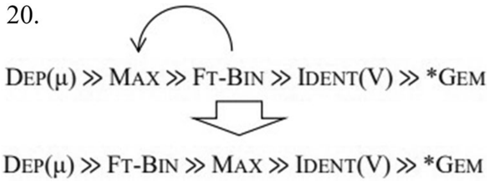
a.	Palawan						
	*bəRas	→	*bəgás* 'uncooked rice'	*qaləjaw	→	*ʔaldáw* 'day'	
b.	Cebuano						
	*bəRas	→	*bugás* 'uncooked rice'	*qaləjaw	→	*ádlaw* 'day'	
c.	Chamorro						
	*bəRas	→	*pugas* 'uncooked rice'	*qaləjaw	→	*atdaw* 'day'	

19. *Promotion over both Max and Dep(μ).*

a.	Ilocano					
	*dəŋəR	→	*dəŋ:ə́g* 'hear; listen'	*qaləjaw	→	*aldáw* 'day'
b.	Isnag					
	*bəRas	→	*bag:át* 'uncooked rice'	*qaləjaw	→	*alxáw* 'day'
c.	Tae'					
	*bəRas	→	*bar:aʔ* 'uncooked rice'	*baqəRu	→	*baʔru* 'new'

It is therefore necessary that the first promotion event trigger penultimate schwa deletion in three-syllable words but leave two-syllable words unchanged, i.e., promotion of FT-BIN over MAX but not DEP(μ). Because of the gradual movement principle, this promotion ordering requires the proto-ranking DEP(μ) ≫ MAX ≫ FT-BIN. With such a ranking, deletion in a two-syllable word generates an output which still violates FT-BIN, resulting in a tie that is broken by MAX-IO militating against deletion. In 20, the promotion event is shown and the resulting tableaux for both three-syllable and two-syllable words are shown in 21a and b respectively.

20.



21.

a

/qa$^{\mu}$ləjaw$^{\mu}$/	TROCHEE	*μ/ə	DEP(μ)	FT-BIN-σ^{MAX}	FT-BIN-μ^{MIN}	MAX	IDENT(V)	*GEM
a. [qa$^{\mu}$(lə$^{\mu}$jaw$^{\mu}$)]		*!	*					
b. [qa$^{\mu}$(ləjaw$^{\mu}$)]	*!				*			
c. [qa$^{\mu}$lə(jaw$^{\mu}$)]					*!			
d. [qa$^{\mu}$(ləj:$^{\mu}$aw$^{\mu}$)]				*!				
e. [qa$^{\mu}$(lo$^{\mu}$jaw$^{\mu}$)]			*!					*
f. [(qa$^{\mu}$ləjaw$^{\mu}$)]			*!				*	
☞ g. [(qa$^{\mu}$ljaw$^{\mu}$)]						*		

b

/təbu$^{\mu}$h/	TROCHEE	*μ/ə	DEP(μ)	FT-BIN-σ^{MAX}	FT-BIN-μ^{MIN}	MAX	IDENT(V)	*GEM
a. [(tə$^{\mu}$bu$^{\mu}$h)]		*!						
b. [(təbu$^{\mu}$h)]	*!				*			
☞ c. [tə(bu$^{\mu}$h)]					*			
d. [(təb:$^{\mu}$u$^{\mu}$h)]			*!					*
e. [(to$^{\mu}$bu$^{\mu}$h)]			*!				*	
f. [(tbu$^{\mu}$h)]					*	*!		

After promotion of Ft-Bin over Max, a second promotion of Ft-Bin is necessary to trigger consonant gemination. As already mentioned, only a subset of the languages geminated consonants after a penultimate schwa in the Philippines. After Ft-Bin was promoted over Max, penultimate schwa was deleted in three-syllable words. In the Philippines, these words were then lexicalized as two-syllable words with medial clusters. Ft-Bin continues its path upwards, eventually overtaking Dep (μ) as well. The promotion event is shown in 22, and the tableaux for formerly three-syllable words and two-syllable words are shown in 23a and b respectively. Two-syllable words now undergo a gemination repair, and formerly three-syllable words remain unchanged. This second promotion event only takes place in languages like those listed in example set 19, which have gemination, and does not take place in languages like those listed in example set 18, which do not have gemination.

22.

Dep(μ) ≫ Ft-Bin ≫ Max ≫ Ident(V) ≫ *Gem

Ft-Bin ≫ Dep(μ) ≫ Max ≫ Ident(V) ≫ *Gem

23.

a

/qa$^{\mu}$ljaw$^{\mu}$/	Trochee	*µ/ə	Ft-Bin-σ^{MAX}	Ft-Bin-µ^{MIN}	Dep(µ)	Max	Ident(V)	*Gem
a. [qa$^{\mu}$(lə$^{\mu}$jaw$^{\mu}$)]		*!			*			
b. [qa$^{\mu}$(ləjaw$^{\mu}$)]	*!			*				
c. [qa$^{\mu}$lə(jaw$^{\mu}$)]				*!				
d. [qa$^{\mu}$(ləjː$^{\mu}$aw$^{\mu}$)]			*!					
e. [qa$^{\mu}$(lo$^{\mu}$jaw$^{\mu}$)]					*!			*
f. [(qa$^{\mu}$ləjaw$^{\mu}$)]					*!		*	
☞ g. [(qa$^{\mu}$ljaw$^{\mu}$)]						*		

b

/təbu$^{\mu}$h/	Trochee	*µ/ə	Ft-Bin-σ^{MAX}	Ft-Bin-µ^{MIN}	Dep(µ)	Max	Ident(V)	*Gem
a. [(tə$^{\mu}$bu$^{\mu}$h)]		*!			*			
b. [(təbu$^{\mu}$h)]	*!			*				
c. [tə(bu$^{\mu}$h)]				*!				
☞ d. [(təbː$^{\mu}$u$^{\mu}$h)]					*			*
e. [(to$^{\mu}$bu$^{\mu}$h)]					*		*!	
f. [(tbu$^{\mu}$h)]			*!	*		*		

The observed sound changes therefore suggest the following constraint movement path: Ft-Bin was promoted first over Max, allowing deletion of medial schwa, and later over Dep(µ), allowing gemination in disyllables, as shown in example 24. If gemination were to happen first, then it would have repaired degenerate feet and bled later vowel deletion, but such a pattern is not attested in any language.

24.

a. Dep(μ) ≫ Max ≫ Ft-Bin ≫ Ident(V) ≫ *Gem

b. Dep(μ) ≫ Ft-Bin ≫ Max ≫ Ident(V) ≫ *Gem

c. Ft-Bin ≫ Dep(μ) ≫ Max ≫ Ident(V) ≫ *Gem

The stress patterns of 18 and 19 potentially cause issues with the analysis presented in 21 and 23, which have Trochee ranked at the top of the tableaux. Many, but not all, Philippine languages have a contrastive stress system. A small number of languages apparently maintain contrastive stress in words of the shape CVCCVC, but most neutralize contrastive stress in this environment (see Blust 2013 and Blust et al. 2023 for data sets with stress in some languages). If a trochaic foot were built over two closed syllables then one expects a stress pattern as in Cebuano (18b) ˈCVC.CVC, but in 18 and 19 Ilocano, Isnag, and Palawan have stress on the final syllable in such words: CVCˈCVC (See Zorc 1972 for statements on stress in Cebuano and other Visayan languages of the Philippines). Two explanations are possible, (1) languages with final stress in such words have underlying iambic feet, (CVCˈCVC), or (2) a foot is built over the final syllable, (CVC)(ˈCVC), which then naturally gets right-most foot primary stress.

Kaufman and Himmelmann (2023) show how stress in many Philippine languages interacts with vowel length. First, length is only contrastive in penultimate syllables. Kaufman & Himmelmann attribute this to phonetic lengthening in final syllables. Second, stressed penultimate syllables must be long, i.e., short penultimate syllables do not bear stress. The possible word shapes are as follows ˈCVːCV(C), CVˈCV(C), and CVCˈCV(C), with *ˈCVːC.CVC ruled out. A possible analysis of these facts posits that in Ilocano, Isnag, and Palawan, but not Cebuano, codas are heavy, resulting in underlying forms $(CV^{\mu}C^{\mu})(CV^{\mu}C^{\mu})$ in words with closed penults. Since stressed penultimate syllables always have long vowels, if the penult is closed, then the resulting long vowel creates a "superheavy" $CVː^{\mu\mu}C^{\mu}$ syllable. Kaufman suggests that superheavy syllables are banned, thus resulting in stress avoiding closed penultimate syllables in languages where codas are heavy.

The behavior of stress in these words is clearly deserving of its own full analysis, and one cannot be given here. If the Cebuano pattern is considered conservative, with heavy codas entering the grammars of some Philippine languages at a later date, then in the immediate aftermath of constraint reranking in the Philippines

Cebuano pattern would have emerged: (ˈCV$^{\mu}$CCV$^{\mu}$C). When codas were reinterpreted as heavy, stress came to fall on the final syllable in CVCCVC words due to the unavailability of long vowels in closed superheavy syllables.

Penultimate vowel shift

Finally, the less-attested repair of penultimate vowel shift is modeled with multiple constraint rerankings. The approach taken to diachronic reranking in this study predicts that sound changes which require more constraint movement will be less attested across a language family. We find such a sound change in the shift of schwa to /o/ in a single subgroup, Eastern Malayo-Polynesian. In the present model, the rarity of this change is due to the double requirement that Ft-Bin be sufficiently highly ranked while Ident(V) must be simultaneously ranked low enough to allow vowel shift to occur in the first place. For this to occur, Ft-Bin must promote, as is required anyway, to trigger vowel deletion. Note that vowel deletion is attested even in the Oceanic subgroup (PMP *qaləjaw → POc *qalcaw 'day' for example) so it is known that it was promoted at some point in all subgroups. The first promotion event therefore places Ft-Bin above Max.

Next, Ft-Bin continues its path upwards and eventually comes to overtake Dep(μ) just like in subgroups where gemination is triggered. Unlike in gemination languages, however, Ident(V) has been overtaken by *Gem, which forces vowel shift as the only licit repair. These promotion events are modeled in 25. The first promotion event (25a-b) involves the promotion of Ft-Bin over Max followed by the necessary promotion of both Ft-Bin and*Gem in the final promotion event (25b-c). The resulting tableau is shown in 26 with a two-syllable input with a schwa penult.

25.

a. Dep(μ) ≫ Max ≫ Ft-Bin ≫ Ident(V) ≫ *Gem

↙

b. Dep(μ) ≫ Ft-Bin ≫ Max ≫ Ident(V) ≫ *Gem

↙ ↙

c. Ft-Bin ≫ Dep(μ) ≫ Max ≫ *Gem ≫ Ident(V)

26

/təbu$^{\mu}$h/	Trochee	*μ\ə	Ft-Bin-σ^{MAX}	Ft-Bin-μ^{MIN}	Dep(μ)	Max	*Gem	Ident(V)
a. [(tə$^{\mu}$bu$^{\mu}$h)]		*!			*			
b. [(təbu$^{\mu}$h)]	*!			*				
c. [tə(bu$^{\mu}$h)]				*!				
d. [(təb:$^{\mu}$u$^{\mu}$h)]					*		*!	
☞ e. [(to$^{\mu}$bu$^{\mu}$h)]					*			*
f. [(tbu$^{\mu}$h)]			*!	*		*		

Although 25 and 26 require a complex series of movements that involves multiple constraints, this is desirable since the outcome, vowel-shift in penultimate but not final syllables, is relatively rare compared to other types of minimal word repair.

Conclusion

This paper proposed that historical sound change can be modeled in a system of Diachronic OT grounded in the principle of gradual constraint movement. This is a natural outcome of variation in a stochastic model, where constraints are more likely to rerank when they are adjacent in ranking. The nature of constraint interaction means that certain patterns of change may be favored over others given a certain reconstructed phonological grammar. It was shown that this approach can be applied to binary foot requirement enforcement in An.

Three sound changes, deletion of the penultimate schwa-syllable in three-syllable words, gemination of final-syllable onsets after a penultimate schwa, and the shift of schwa to a full vowel (/o/) in the penultimate syllable, all restore subminimal words to a two-mora minimum. Ft-Bin promotion over intervening constraints can motivate these changes and the inherited ranking of constraints results in specific outcomes. The initial promotion is also the most widely attested since it includes only a single movement: Max ≫ Ft-Bin → Ft-Bin ≫ Max. Gemination is triggered by a second movement of Ft-Bin: Dep(μ) ≫ Max ≫ Ft-Bin → Dep(μ) ≫ Ft-Bin ≫ Max → Ft-Bin ≫ Dep(μ) ≫ Max. The third sound change, penultimate vowel shift, requires multiple constraint movements and is predictably the least attested: DEP(μ) ≫ MAX ≫ FT-BIN ≫ IDENT(V) ≫ *GEM → FT-BIN ≫ DEP(μ) ≫ MAX ≫ *GEM ≫ IDENT (V).

When sound change occurs that eliminates a marked structure, the choice of output depends on the rankings of other constraints. In Diachronic OT, the motivation for a certain sound change to occur more frequently than another equally motivated sound change is the result of inherited rankings and the requirement that constraints must rerank in gradual movements. It is therefore apparent that more abstract components of the reconstructed phonological grammar, like constraint ranking, have an impact on the outcome of phonological change.

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