Idiosyncratic Hiatus Resolution: An Argument for Gradient Harmonic Grammar*

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1 Introduction

This paper discusses implications for generative theories of phonological idiosyncrasy, based on two vowel reduction patterns exhibited in Palauan (Wilson, 1972; Flora, 1974; Josephs, 1975; Zuraw, 2003). The first key property of Palauan vowel reduction is that it involves *multiple degrees of idiosyncrasy*. Palauan stem vowels occur in their full forms in stressed syllables. In the presence of a possessor suffix, all of which attract stress to the final syllable, stem vowels are subject to various degrees of reduction, shown in (1). Depending on the stem, individual vowels in this environment may surface with the same quality as their stressed counterpart (1a), reduced to a mid vowel (1b), reduced to schwa (1c), or deleted altogether (1d). In spite of the unpredictable behavior of individual stems, the overall pattern is principled and markedness-reducing in the sense that fewer vowels and fewer peripheral vowel place features are realized in non-prominent, unstressed positions.[1]

(1) *Stem-conditioned degrees of vowel reduction on single vowels*

		Unaffixed stem		Stem+possessor suffix
a.	Faithful surfacing	[ð**í**ŋ]	'ear'	[ð**i**ŋá-l]
b.	Reduction to mid V	[b**á**b]	'surface'	[b**ɛ**bú-l]
c.	Reduction to schwa	[ɾ**í**ŋəl]	'pain'	[ɾ**ə**ŋəl-ɛ́l]
d.	Deletion	[ð**í**k]	'wedge'	[θk-ɛ́l]

While there may be some correlation between vowel quality and (non)reduction, the pattern is not fully predictable from vowel quality, as revealed by the variable patterning of stems with /i/ in the examples above.[2] It is noteworthy that suffixed and unsuffixed forms of nouns are given distinct dictionary entries by Josephs (1990) in light of this unpredictability.[3]

The second crucial property of Palauan vowel reduction is that *idiosyncrasy is defined at the level of individual segments, not the morpheme*. This is apparent in the patterning of stems that contain a stressed /VV/ sequence in unsuffixed forms and either a /VV/ sequence or a single vowel when stress is shifted to a possessor suffix, shown in (2). Depending on the stem, an unstressed stem VV sequence may surface with the same vowel qualities as its stressed counterparts (2a), delete either the first vowel (2b) or the second vowel (2c) in the sequence while preserving the other, or reduce to a mid vowel (2d) or schwa (2e). We interpret the alternations exhibited by (2b-e) as involving the deletion of one vowel and the potential reduction of the other. While the choice of which vowel deletes appears to be conditioned to some extent by vowel quality

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[1] On a minority of stems, the presence of the suffix correlates with the appearance of a latent stem-final vowel that occurs only on suffixed forms (Flora, 1974). Possessor suffixes are realized as -ɛ́C after stems that lack a latent final vowel.

[2] /i/ is described as more likely to surface faithfully than other vowels (Wilson, 1972:52-54), particularly when flanked by stem consonants (Flora, 1974:45-46), and Wilson (1972:47-49) describes /u/ as more likely to delete than change in quality (Wilson, 1972:47-49). However, both authors note exceptions to these trends; the unpredictable patterning of /i/ is shown in (1), and the unpredictable patterning of /u/ is seen in examples like [ʔúr] versus [ʔur-ák] 'tongue,' [kúθ] versus [kθ-úk] 'house,' [dúʔ] versus [dəʔ-ál] 'ability.'

[3] To our knowledge, no prior work has described effects of speech rate on (non-)reduction; while we cannot preclude the existence of such an effect, it would likely be orthogonal to the patterns of interest.

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(the higher and/or fronter vowel is maintained in most forms), it is again ultimately idiosyncratic, as apparent in pairs like (2b) versus (2c).

(2) *Stem-conditioned degrees of reduction on /VV/ sequences*

		Unaffixed stem		Stem+possessor suffix
a.	Both Vs preserved	[ʔ**ɛú**ʔəl]	'space between islands'	[ʔ**ɛu**ʔəl-ɛ́l]
b.	Deletion of V1	[bər**óɛ**l]	'spears'	[bər**ɛ**l-ɛ́l]
c.	Deletion of V2	[b**óɛ**s]	'gun'	[b**o**s-ɛ́l]
d.	Deletion + reduction to mid V	[**jó**lt]	'wind'	[**ɛ**lt-ɛ́k]
e.	Deletion + reduction to schwa	[d**áo**b]	'ocean'	[d**ə**b-ɛ́k]

In this paper, we argue that Palauan vowel reduction provides key support for an analysis of phonological idiosyncrasy in Gradient Harmonic Grammar (Smolensky & Goldrick, 2016), in which idiosyncratic patterning emerges from contrasts in the input *activity* values specified on vowel root nodes. In brief, we first show that the numerically continuous nature of activity in this framework can straightforwardly generate multiple degrees of idiosyncratic patterning. Second, the Gradient Harmonic Grammar approach can generate idiosyncrasy as to whether a vowel in an input /VV/ sequence deletes, and if so, which one is targeted for deletion. This is possible in this framework because individual segments within a morpheme can be specified with different levels of input activity. Such patterns are challenging for alternative theories of phonological idiosyncrasy, in which the evaluation of constraint penalties depends on the presence of morpheme-level diacritics or indices (Pater, 2000; Coetzee & Pater, 2011; Sande et al., 2020).

The rest of the paper is structured as follows. Section 2 reviews the basic mechanics of Gradient Harmonic Grammar and analyses of idiosyncrasy in terms of gradient activity. Section 3 presents our analysis of Palauan vowel reduction within the framework. Section 4 discusses the challenges that Palauan poses to alternative analyses of idiosyncrasy that rely on morpheme-level diacritics. Section 5 concludes.

2 Phonological Idiosyncrasy in Gradient Harmonic Grammar

As in "categorical" Harmonic Grammar (Smolensky & Legendre, 2006; Legendre et al., 1990), optimization in Gradient Harmonic Grammar is driven by the interaction of violable, numerically weighted constraints. The defining property of Gradient Harmonic Grammar (Smolensky & Goldrick, 2016) involves the nature of linguistic representations. Specifically, all structures are represented with a potentially *non-integer level of activity* (in other words, its *degree of presence* or *representational strength*) between 0 and 1 . This places it in contrast with the traditional assumption of other phonological frameworks that all structures are categorically present or absent. The consequence of gradient activity for the computation of optimality is that each faithfulness constraint assigns a penalty that is proportional to the activity of the structure that incurs a violation of that constraint. Crucially, two input representations may contain structures that differ only in input activity value specifications and therefore incur different penalties from the faithfulness constraints that they violate.

We illustrate these aspects of the framework with the toy examples in (3) and (4). This hypothetical language contains two inputs that contain the segments /bap/. However, the two inputs differ in the activity specified on the final consonant, /$p_{0.9}$/ versus /$p_{0.5}$/. We assume that input structures with partial activity must be either deleted or realized with full activity (1.0) in the output (cf. Zimmermann (2019) on the use of gradience in output representations). As a result, gradient activity affects only the calculation of penalties assigned by faithfulness constraints, but not markedness constraints. We consider the evaluation of two familiar constraints, MAX and NOCODA.[4] The penalty of each violation of MAX is proportional to the amount of activity that is deleted in the input-output mapping.

[4] In principle, the realization of partially-present input vowels in the output incurs penalties of DEP constraints, proportional to the difference between 1 (the discrete output activity value) and the amount of activity in the input. Here and in our analysis of Palauan, we assume that all relevant DEP constraints are sufficiently low-ranked as to be inconsequential to the analysis.

(3) *Higher input activity of final consonant: surfacing optimal*

Input: /$\text{bap}_{0.9}$/	MAX w=10	NOCODA w=8	H
a. ba	−0.9		−9
☞b. bap		−1	−8

(4) *Lower input activity of final consonant: deletion optimal*

Input: /$\text{bap}_{0.5}$/	MAX w=10	NOCODA w=8	H
☞a. ba	−0.5		−5
b. bap		−1	−8

In the tableau in (3), the MAX penalty incurred by deleting the final consonant in candidate (a) is the constraint weight times the amount of deleted activity ($10 \times -0.9 = -9$). Due to the relatively high penalty assigned to candidate (a) by MAX, faithful candidate (b) is optimal. In the tableau in (4), the final consonant is specified for a lower input activity value of 0.5. This results in the MAX penalty incurred by deletion in candidate (a) being proportionally reduced ($10 \times -0.5 = -5$); candidate (a) is thus optimal. With this set of constraint weights, then, the contrast in activity specifications for the final consonant in two otherwise identical inputs results in two distinct optimal outputs.

Our adoption of Gradient Harmonic Grammar to account for idiosyncratic vowel reduction in Palauan builds on other works showing that the framework is uniquely able to generate key formal properties of idiosyncratic phonological patterns; see Hsu (2022) for an overview. This includes implicational relations among the idiosyncratic processes that lexical items can undergo (Hsu, 2019; Zimmermann, 2019; Revithiadou & Markopoulos, 2021), non-accidental similarity between exceptional patterns at morpho-syntactic junctures and regular patterns found in smaller domains (Hsu, 2019; Revithiadou & Markopoulos, 2021), and idiosyncratic patterns conditioned by combinations of morphemes (Rosen, 2016, 2018).

3 Analysis

3.1 *Gradient activity on vowel root nodes and place features* We propose that each reduction pattern in Palauan be analyzed as the deletion of structure between the phonological input and output. While this is straightforward in the case of full segmental deletion, changes in vowel quality are generated via the deletion of vowel place features, which we define privatively. Specifically, high vowels and low vowels have a specified [Height] feature node, while the mid vowels [ɛ, o, ə] lack a [Height] node. Front vowels and back vowels have a specified [Backness] feature node, while the only central vowel [ə] lacks a [Backness] node. For instance, mappings of /i/ to [ɛ] or /u/ to [o] involve the deletion of [Height] alone. Mappings of /i/, /u/, or /a/ to [ə] are generated by deleting both the [Height] and [Backness] features of the input vowel.

As discussed in section 2, individual segments may differ in their specified input activity. The key consequence of this for our analysis of Palauan is that vowels represented with higher input activity incur greater faithfulness penalties and are therefore more resistant to the deletion of place features and to deletion of their root nodes. We propose that each stem vowel is represented with a specific input activity value between 0 and 1, e.g. /$\text{i}_{0.75}$/ versus /$\text{i}_{0.3}$/. We further assume that the activity of each place feature and feature node is equal to the activity of its associated root node (for example, /$\text{u}_{0.75}$/ is specified for a [Height] activity of 0.75 and [Backness] activity of 0.75). While we do not preclude the possibility for place features and their associated root nodes to differ in activity, we find no need to adopt this on the basis of Palauan vowel reduction.

3.2 *Vowel reduction and deletion* We propose that the reduction of unstressed vowels in Palauan is driven by a series of markedness constraints that penalize vowels and vowel place features in unstressed positions. They are defined in (5).

(5) a. *UNSTRESSEDV
Assign a violation for any unstressed vowel.

b. *UNSTRESSEDV[Height]
Assign a violation for any [Height] feature associated with an unstressed vowel.

c. *UNSTRESSEDV[Backness]
Assign a violation for any [Backness] feature associated with an unstressed vowel.

The first of these constraints, *UNSTRESSEDV, is violated by all unstressed vowels, regardless of their height or backness. The other two constraints are violated by unstressed vowels bearing specific vowel place features. *UNSTRESSEDV[Height] is violated by all unstressed vowels specified for height, i.e. the non-mid vowels ([i, u, a]). Finally, *UNSTRESSEDV[Backness] is violated by unstressed vowels specified for backness, i.e. the non-central vowels; in Palauan, this is all vowels except [ə]. Because markedness constraints refer only to output structures, in which all structure must be fully active, their evaluation does not depend on the input activity value of any penalized structures.

Turning to faithfulness constraints, the Palauan vowel reduction patterns violate a series of MAX constraints against the deletion of structure between an input and output. They are defined in (6).

(6) a. MAXV
Assign a violation *A* for any vowel root node whose input activity *A* is absent in the output.

b. MAX[Height]
Assign a violation *A* for any [Height] feature whose input activity *A* is absent in the output.

c. MAX[Backness]
Assign a violation *A* for any [Backness] feature whose input activity *A* is absent in the output.

The first of these constraints, MAXV, is violated by vowel deletion, while the other two are violated by the loss of specific vowel place features. MAX[Height] is violated by candidates in which an input vowel is either deleted or reduced to a mid vowel (including [ə]). MAX[Backness] is violated by candidates in which an input vowel is either deleted or reduced to the central vowel [ə].

Each of the markedness constraints in (5) can be thought of as "paired" with one of the faithfulness constraints in (6): *UNSTRESSEDV versus MAXV, *UNSTRESSEDV[Height] versus MAX[Height], and *UNSTRESSEDV[Backness] versus MAXV[Backness]. In each conflicting constraint pairing, their violations form a symmetric trade-off relation. In categorical Harmonic Grammar, a faithful mapping is motivated by weighting each faithfulness constraint higher than the markedness constraint it conflicts with. In Gradient Harmonic Grammar, on the other hand, an unfaithful candidate's degree of violation of any faithfulness constraint is proportional to the amount of activity present in a relevant input structure. In the case of Palauan, vowels with less input activity incur lower MAX penalties for segment and/or feature deletion in an output candidate, because less activity is being deleted between the input and the output. This alters the tradeoff relation between a conflicting markedness and faithfulness constraint such that an unfaithful mapping becomes less costly. As a result, even with a weighting in which a faithfulness constraint F outweighs a markedness constraint M, a phonological repair could be favored for low-activity input structures.

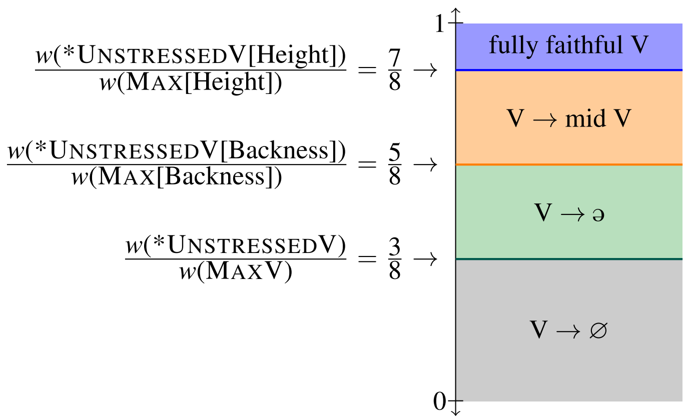
More precisely, for each conflicting pair of a markedness and a faithfulness constraint, their relative weights determine a *threshold* input activity value above which an input structure surfaces faithfully and below which an input structure is repaired. This is the activity value for which an output candidate that violates only the markedness constraint has the same harmony as a candidate that violates only the faithfulness constraint. The calculation of that threshold value is shown in (7).

(7) *Activity threshold for faithful surfacing of a structure violating M*

$$\text{Activity threshold} = \frac{w(\text{M})}{w(\text{F})}$$

Each of the three conflicting pairs of markedness and faithfulness constraints in (5) and (6) establishes one such threshold value. In Palauan, we observe that there are four possible types of vowel reduction patterns, suggesting that vowels fall into one of four *activity ranges* separated by three distinct threshold values. In our analysis, we achieve this by assuming that all of the faithfulness constraints have a weight of 8, while the markedness constraints each have lower, distinct weights, resulting in three distinct threshold values. These threshold values and their effects on which input-output mappings are chosen as optimal are illustrated in (8).

(8) *Constraint weights, activity thresholds, and vowel outcomes*



The figure in (8) shows that with *UNSTRESSEDV at a weight of 3 and MAXV at a weight of 8, only a vowel with an input activity above 0.375 (or 3/8) surfaces when unstressed, while a vowel with a lower input activity is deleted in an unstressed position. The relative rankings of the other two constraint pairs set threshold values that further determine the quality of a vowel that is of sufficient input activity to surface in an output form. With *UNSTRESSEDV[Backness] at a weight of 5 and MAX[Backness] at a weight of 8, only a vowel with an input activity above 0.625 (or 5/8) surfaces faithfully as front or back when unstressed. Similarly, with *UNSTRESSEDV[Height] at a weight of 7 and MAX[Height] at a weight of 8, only a vowel with an input activity above 0.875 (or 7/8) surfaces faithfully as high or low when unstressed.

This analysis is illustrated in the following tableaux, one for each of the Palauan vowel reduction patterns exhibited by the data in (1). Each tableau contains a stem vowel whose input activity falls within one of the four activity ranges in (8), each resulting in a distinct optimal output.

The tableau in (9) illustrates the input-output mapping for a vowel with input activity above 0.875, the threshold established by the weights of MAXV and *UNSTRESSEDV. We use an input vowel with an activity of 1.0.

(9) *Input activity above 0.875: Faithful surfacing optimal*

Input: /ði$_{1.0}$ŋa-ɛl/	MAX[Ht]	MAX[Bk]	MAX	*UNSTV[Ht]	*UNSTV[Bk]	*UNSTV	H
	w=8	*w*=8	*w*=8	*w*=7	*w*=5	*w*=3	
☞a. ...i...				−1	−1	−1	−15
b. ...ɛ...	−1				−1	−1	−16
c. ...ə...	−1	−1				−1	−19
d. ...∅...	−1	−1	−1				−24

In (9), the input vowel /i$_{1.0}$/ surfaces faithfully as candidate (a). For all other candidates, the penalty assigned for each faithfulness constraint violation exceeds the penalty of its tradeoff markedness constraint violation, due to the high weighting of those faithfulness constraints.

With the introduction of input vowels with lower gradient activity values, the picture is different. The tableau in (10) illustrates the input-output mapping for a vowel with an input activity value between the threshold values 0.625 and 0.875; we use an activity value of 0.75.

(10) *Input activity between 0.625 and 0.875: Reduction to mid vowel optimal*

Input: /ba$_{0.75}$bu-ɛl/	MAX[Ht] w=8	MAX[Bk] w=8	MAX w=8	*UNSTV[Ht] w=7	*UNSTV[Bk] w=5	*UNSTV w=3	H
a. ...a...				−1	−1	−1	−15
☞b. ...ɛ...	−0.75				−1	−1	−14
c. ...ə...	−0.75	−0.75				−1	−15
d. ...∅...	−0.75	−0.75	−0.75				−18

The violation profiles for the candidates in (10) are identical to those in (9). However, the *amount* of the penalty for each faithfulness constraint violation is reduced due to the lower input activity of the vowel root node or feature node being deleted in candidates (b–d). The optimal candidate in this condition, candidate (b), has a deleted height feature because the proportionally reduced penalty assigned by MAX[Height] ($8\times-0.75 = -6$) is now less than the penalty assigned by its paired markedness constraint *UNSTRESSEDV[Height] ($7\times-1 = -7$). As in the previous condition in (9), the penalties of MAX[Backness] and MAX still exceed the penalties of their tradeoff markedness constraints, *UNSTRESSEDV[Backness] and *UNSTRESSEDV, respectively. This rules out candidates (c) and (d).

The tableau in (11) illustrates the input-output mapping for a vowel with an input activity value between the threshold values 0.375 and 0.625; we use an input vowel with an activity of 0.5.

(11) *Input activity between 0.375 and 0.625: Reduction to schwa optimal*

Input: /ri$_{0.5}$ŋəl-ɛl/	MAX[Ht] w=8	MAX[Bk] w=8	MAX w=8	*UNSTV[Ht] w=7	*UNSTV[Bk] w=5	*UNSTV w=3	H
a. ...i...				−1	−1	−1	−15
b. ...ɛ...	−0.5				−1	−1	−12
☞c. ...ə...	−0.5	−0.5				−1	−11
d. ...∅...	−0.5	−0.5	−0.5				−12

Again, the violation profiles for the candidates in (11) are identical to those in (9) and (10). The amount of the penalty for each faithfulness constraint violation is reduced even further due to the lower input activity of the vowel root node or feature node being deleted in output candidates (b–d). In this condition, vowel height and backness features are optimally deleted because the penalties of both MAX[Height], ($8\times-0.5 = -4$) and MAX[Backness] ($8\times-0.5 = -4$) are less than the penalties of their paired markedness constraints *UNSTRESSEDV[Height] ($7\times-1 = -7$) and *UNSTRESSEDV[Backness] ($5\times-1 = -5$). However, the full deletion candidate (d) is still ruled out as the penalty of MAX ($8\times-0.5 = -4$) still exceeds the penalty of its tradeoff markedness constraint *UNSTRESSEDV ($3\times-1 = -3$).

Finally, the tableau in (12) illustrates the input-output mapping for a vowel with an input activity below the 0.375 threshold value; we use an input vowel with an activity of 0.25. Below this threshold, the penalties of all faithfulness constraints, including MAX, are sufficiently reduced for candidate (d), the full deletion candidate, to be chosen as optimal despite the high weights of the faithfulness constraints.

(12) *Input activity below 0.375: Vowel deletion optimal*

Input: /ði$_{0.25}$k-ɛl/	MAX[Ht] w=8	MAX[Bk] w=8	MAX w=8	*UNSTV[Ht] w=7	*UNSTV[Bk] w=5	*UNSTV w=3	H
a. ...i...				−1	−1	−1	−15
b. ...ɛ...	−0.25				−1	−1	−10
c. ...ə...	−0.25	−0.25				−1	−7
☞d. ...∅...	−0.25	−0.25	−0.25				−6

Taken together, the tableaux in (9–12) illustrate that the idiosyncratic vowel reduction exhibited by unstressed Palauan stem vowels can be attributed to distinctions in their input activities alone. While highly active input vowels are compelled to be more faithful in order to avoid violating high-weighted faithfulness constraints, less active input vowels are permitted to undergo repairs as their faithfulness constraint violations are comparatively less costly.

3.3 *Hiatus resolution and vowel reduction* The analysis proposed in section 3.2 can be straightforwardly extended to account for reduction in sequences of adjacent vowels (as in the data in (2) above) with the addition of a single constraint. We adopt *VV, a general constraint against hiatus, and define it in (13).

(13) *VV
Assign a violation for any pair of adjacent vowel root nodes.

Given this additional constraint, we now turn to the weighting conditions that generate hiatus resolution and vowel reduction in unstressed syllables in Palauan. First, we observe that hiatus resolution does not apply to stress-bearing VV sequences in unaffixed stems, indicating that *VV has a lower weight than MAXV. Second, for stems that do not bear stress, the inclusion of *VV raises the input activity threshold necessary to surface for each vowel that is adjacent to another vowel. This is because the surfacing of two adjacent vowels violates *VV in addition to the constraints against unstressed vowels in (5). The calculation of this input activity threshold for vowels in a VV sequence is shown in (14). In order for both input vowels to surface faithfully in an unstressed VV sequence, the combined weight of our four markedness constraints must fall below the combined weight of our three faithfulness constraints.

(14) *Activity threshold for faithful surfacing of both vowels in a VV sequence*

$$\text{Activity threshold} = \frac{w \text{ of all four M constraints}}{w \text{ of all three F constraints}}$$

Given the constraint weights already established in section 3.2, one weight of *VV that satisfies the conditions above is 6. Hiatus resolution will occur for any input /VV/ sequence in which at least one vowel falls below the relatively high activity threshold of 0.875 (or (7 + 5 + 3 + 6) / (8 + 8 + 8) = 7/8). All inputs in which at least one vowel has an input activity value below this threshold have an optimal output candidate in which one vowel is deleted. This is because deletion of one vowel eliminates not just a violation of *VV, but violations of all of the markedness constraints against unstressed vowels in (5), yielding the greatest reduction of total markedness penalties. Crucially, in Gradient Harmonic Grammar each vowel root node can be represented with a distinct activity value from other vowel root nodes in the same morpheme. We can therefore account for idiosyncrasy as to which vowel in a stem /VV/ sequence is deleted in terms of relative activity values. Deletion of the input /V/ with less activity is optimal, because it incurs a smaller summed penalty of faithfulness constraint violations.

The following tableaux illustrate how our proposed constraint weights and input activity values determine which vowel is deleted from a VV sequence and the degree of reduction exhibited by the non-deleted vowel. The inputs in each tableau include a sequence of stem vowels /ui/, with various activity values for each vowel. The tableau in (15) illustrates the input-output mapping for an input where the activity value of each vowel is 1.0, exceeding the 0.875 threshold established in (14). For presentational clarity, the tableau only includes output candidates in which both vowels surface fully faithfully or in which one of them is deleted in an unstressed syllable.

(15) *Activity of both Vs above 0.875: Both vowels surface faithfully*

Input: /$u_{1.0}i_{1.0}$/	MAX[Ht] *w*=8	MAX[Bk] *w*=8	MAXV *w*=8	*UNSTV[Ht] *w*=7	*UNSTV[Bk] *w*=5	*UNSTV *w*=3	*VV *w*=6	H
☞a. ui				−2	−2	−2	−1	−36
b. u∅	−1	−1	−1	−1	−1	−1		−39
c. ∅i	−1	−1	−1	−1	−1	−1		−39

In (15), the optimal candidate is fully faithful (a). Each of the losing deletion candidates (b) and (c) incurs one fewer violation of the three markedness constraints against unstressed vowels and vowel features, and avoids a violation of *VV. However, this reduction in markedness penalty is outweighed by the penalties assigned by violations of the three highly-weighted faithfulness constraints.

The tableaux in (16) and (17) illustrate input-output mappings for inputs in which the activity of one vowel falls below the 0.875 threshold value. We use values of 1.0 and 0.75, respectively, for the two input vowels. The only distinction between these tableaux lies in whether it is the first or the second vowel that falls below this threshold.

(16) *One vowel has activity below 0.875: Vowel with lower activity deletes (first vowel)*

Input: /$u_{0.75}i_{1.0}$/	MAX[Ht] w=8	MAX[Bk] w=8	MAXV w=8	*UNSTV[Ht] w=7	*UNSTV[Bk] w=5	*UNSTV w=3	*VV w=6	H
a. ui				−2	−2	−2	−1	−36
b. u∅	−1	−1	−1	−1	−1	−1		−39
☞c. ∅i	−0.75	−0.75	−0.75	−1	−1	−1		−33

(17) *One vowel has activity below 0.875: Vowel with lower activity deletes (second vowel)*

Input: /$u_{1.0}i_{0.75}$/	MAX[Ht] w=8	MAX[Bk] w=8	MAXV w=8	*UNSTV[Ht] w=7	*UNSTV[Bk] w=5	*UNSTV w=3	*VV w=6	H
a. ui				−2	−2	−2	−1	−36
☞b. u∅	−0.75	−0.75	−0.75	−1	−1	−1		−33
c. ∅i	−1	−1	−1	−1	−1	−1		−39

The violation profiles of the candidates in (16) are identical to those in (15). However, the lower input activity of /u/ results in proportionally reduced penalties of the three faithfulness constraints for /u/-deleting candidate (c), whose combined penalty is now lower than the combined penalty of the markedness constraints that are violated by the surfacing of the vowel in losing candidates (a) and (b).

The tableau in (17) can be interpreted in the same way and serves to illustrate that it is the input vowel with the lower activity value that is deleted in hiatus contexts, regardless of ordering. This is consistent with the fact that Palauan exhibits idiosyncrasy as to which input vowel is retained in unstressed syllables with vowel hiatus, as observed in pairs like /**ui**ŋgəl/ → [**u**ŋgəl-ɛl] 'tooth' and /b**ui**k/ → [b**i**k-ɛ́l] 'boy' (Josephs, 1975). In our analysis, this idiosyncrasy depends on which of the two stem vowels is specified for the lower input activity value.

Hiatus resolution in Palauan is not limited to cases in which one vowel surfaces faithfully while the other deletes, however. In some cases, some stem-internal /VV/ sequences surface as a single mid vowel (2d) or schwa (2e) when unstressed. Our analysis generates such vowel reduction patterns when the input activity values of both vowels falls below 0.875, the threshold value below which both hiatus resolution and reduction to a mid vowel take place. In this case, the vowel with less input activity is deleted, and the optimal degree of reduction of the remaining vowel is determined by its input activity, consistent with the activity thresholds for individual vowels discussed in section 3.2.

This is illustrated by the tableaux in (18) and (19). In (18), the two vowels have input activity values of 0.5 and 0.75, respectively.

(18) *Activity of both vowels below 0.875; more active vowel's activity between 0.625 and 0.875: Vowel deletion and reduction to mid vowel optimal*

Input: /$u_{0.5}i_{0.75}$/	MAX[Ht] w=8	MAX[Bk] w=8	MAXV w=8	*UNSTV[Ht] w=7	*UNSTV[Bk] w=5	*UNSTV w=3	*VV w=6	H
a. ui				−2	−2	−2	−1	−36
☞b. ∅ɛ	−0.5(u) −0.75(i)	−0.5(u)	−0.5(u)		−1	−1		−26
c. ∅ə	−0.5(u) −0.75(i)	−0.5(u) −0.75(i)	−0.5(u)			−1		−27
d. u∅	−0.75(i)	−0.75(i)	−0.75(i)	−1	−1	−1		−33
e. ∅i	−0.5(u)	−0.5(u)	−0.5(u)	−1	−1	−1		−27

In (18), candidates (a), (d), and (e) all contain at least one fully preserved vowel and therefore incur violations of all *UNSTRESSEDV markedness constraints; candidate (a) additionally violates *VV. Due to the low input activities of both vowels, the penalties incurred by these violations are greater than the penalties that would be incurred by violations of the MAX constraints if these vowels were realized unfaithfully. In candidates (b) and (c), input /u/ is deleted while input /i/ is reduced to some degree. The reduced input activity of /i/ is low enough for the violation of MAX[Height] by the mapping to [ɛ] to be tolerated in optimal candidate (b), but not enough for the violation of both MAX[Height] and MAX[Backness] by the mapping to [ə] to be tolerated in candidate (c). Candidate (e), in which the input /i/ is faithfully preserved, incurs an extra violation of *UNSTRESSEDV[Height] not incurred by winning candidate (b), while the violation of MAX[Height] by (b) is reduced by /i/'s lower input activity.

In the tableau in (19), both vowels' input activity values are lower still, below the 0.625 value established in (8) as the threshold below which reduction to schwa takes place. We illustrate with vowels with input activities of 0.4 and 0.6, respectively.

(19) *Activity of both vowels below 0.875; more active vowel's activity between 0.375 and 0.625: Vowel deletion and reduction to schwa optimal*

Input: /$u_{0.4}i_{0.6}$/	MAX[Ht] w=8	MAX[Bk] w=8	MAXV w=8	*UNSTV[Ht] w=7	*UNSTV[Bk] w=5	*UNSTV w=3	*VV w=6	H
a. ui				−2	−2	−2	−1	−36
b. ∅ɛ	−0.4(u) −0.6(i)	−0.4(u)	−0.4(u)		−1	−1		−22.4
☞c. ∅ə	−0.4(u) −0.6(i)	−0.4(u) −0.6(i)	−0.4(u)			−1		−22.2
d. u∅	−0.6(i)	−0.6(i)	−0.6(i)	−1	−1	−1		−29.4
e. ∅i	−0.4(u)	−0.4(u)	−0.4(u)	−1	−1	−1		−24.6

The violation profiles of the candidates in (19) are identical to those in (18), but due to the lower input activities of /u/ and /i/, the penalties of the three faithfulness constraints are reduced. As a result, candidate (c), in which /u/ is deleted and /i/ is reduced to [ə], is now the optimal candidate. Its additional violation of MAX[Backness] relative to candidate (b) is now tolerated due to the lower input activity of /i/.

In this section, we have shown how the analysis of Palauan's idiosyncratic single vowel reduction pattern presented in section 3.2 can be extended to the idiosyncratic reduction and deletion of vowels in hiatus contexts as well. All that is necessary is the addition of a single constraint against hiatus, *VV.

4 Alternatives

While numerous analyses of idiosyncrasy have been proposed in generative phonology, they can be broadly categorized into two main approaches. First, a number of analyses generate idiosyncratic patterns using *lexical diacritics*. Under this approach, the presence of a morpheme with a particular diacritic imposes some effect on the evaluation of constraint penalties. This characterizes analyses that use indexed constraints (Pater, 2000), lexical constraint scaling (Coetzee & Kawahara, 2013; Linzen et al., 2013; Coetzee & Pater, 2011), and constraint reweighting (Sande et al., 2020). A second approach to phonological idiosyncrasy employs *covert structural contrasts*, in which the idiosyncratic patterning of particular structures results from a difference in the content of their input representations. This includes analyses that rely on contrasts in featural underspecification (Kiparsky, 1993), contrasts in gestural strength (Smith, 2018), and contrasts in gradient activity (Smolensky & Goldrick, 2016).

While all of these proposals can generate idiosyncrasy across stems with respect to the patterning of single vowels,[5] only approaches that employ covert structural contrasts can generate the idiosyncratic patterning of tautomorphemic /VV/ sequences in Palauan without relying on additional ad hoc mechanisms or constraints. We illustrate this below with a hypothetical alternative analysis using lexical constraint scaling.

We restrict our attention here to the idiosyncratic contrast between forms that preserve the stem vowel (violating *UNSTRESSEDV) versus deleting it (violating MAX). In this approach, individual morphemes may

[5] The full Palauan pattern is challenging for an account in terms of featural underspecification alone. This approach cannot generate idiosyncrasy in vowel deletion versus non-deletion, because the process cannot be analyzed in terms of feature-filling (Inkelas, 2015).

be associated with distinct scaling factors that adjust the penalties assigned by one or more constraints. In the tableaux in (20) and (21), each stem has a different scaling factor applied to MAX, implemented here as the addition of a scaling factor value s to each weighted constraint violation ($H = w + s$). Here, idiosyncrasy in single vowel deletion can be captured by proposing differences in scaling factors across stems, such that deletion is optimal for some unstressed stem vowels and not others.

(20) *Scaling factor s = 0: faithful surfacing optimal*

Input: /ðiŋa-ɛl/	MAX w=8, $s_{/ðiŋa/}$=0	*UNSTRV w=3	H
☞a. [ðiŋá-l]		−1	−3
b. [θŋá-l]	−1		−8 = −1×(8−0)

(21) *Scaling factor s = −6: faithful surfacing optimal*

Input: /ðik-ɛl/	MAX w=8, $s_{/ðik/}$=−6	*UNSTRV w=3	H
a. [ðik-ɛ́l]		−1	−3
☞b. [θk-ɛ́l]	−1		−2 = −1×(8−6)

In (20), the scaling factor s on MAX is set to 0 for the stem /ðiŋa/, resulting in no adjustment to the high weight of MAX. As a result, deletion candidate (b) is highly penalized and the faithful candidate (a), violating lower-weighted *UNSTRESSEDV, is optimal. However, in (21), MAX's scaling factor s is set to −6 for the stem /ðik/. Consequently, deletion candidate (b)'s violation of this constraint incurs a lower penalty, making it the optimal candidate. Idiosyncrasy in the patterning of individual stems is thus captured by indexing between stems and constraint scaling factors.

However, such an analysis cannot be extended to account for the idiosyncratic patterning of tautomorphemic VV sequences. This is illustrated by the tableaux in (22) and (23) for two input stems containing the sequence /oɛ/.

(22) *Scaling factor s = 0: both vowels surface*

Input: /...oɛ.../	MAX w=8, $s_{/...oɛ.../}$=0	*UNSTRV w=3	H
☞a. ...oɛ...		−2	−6 = −2×3
b. ...o∅...	−1	−1	−11 = −1×(8−0) + (−1×3)
c. ...∅ɛ...	−1	−1	−11 = −1×(8−0) + (−1×3)
d. ...∅...	−2		−16 = −2×(8−0)

(23) *Scaling factor s = −6: neither vowel surfaces*

Input: /...oɛ.../	MAX w=8, $s_{/...oɛ.../}$=−6	*UNSTRV w=3	H
a. ...oɛ...		−2	−6 = −2×3
b. ...o...	−1	−1	−5 = −1×(8−6) + (−1×3)
c. ...ɛ...	−1	−1	−5 = −1×(8−6) + (−1×3)
☞d. ...∅...	−2		−4 = −2×(8−6)

In (22), a stem containing the vowel sequence /oɛ/ has a scaling factor s of 0. The MAX penalties incurred by the deletion of one or more vowels in (b), (c), and (d) exceeds the *UNSTRESSEDV penalties incurred by the surfacing of each vowel. The faithful candidate (a) is thus optimal. In (23), another stem containing the sequence /oɛ/ is indexed to the scaling factor s of −6. This results in a sufficiently large reduction of the penalties incurred by violations of MAX, such that candidate (d), in which both vowels are deleted, is selected as optimal. Crucially, there is no setting of the scaling factor s that favors candidates (b) and (c), in which only one of the stem vowels is deleted, over candidates (a) and (d). Furthermore, there is no way to account for a pattern in which candidate (b) is chosen for one stem input while candidate (c) is chosen for another, as the two always tie with respect to the constraints included here, regardless of the setting of the scaling factor *s*.

The lexical constraint scaling analysis struggles here because idiosyncratic patterning is analyzed as a *morpheme-level* property in this and other diacritic approaches; all vowels within a morpheme are predicted to be equally penalized or protected. Given this constraint set, one can only generate optimal candidates in which both vowels are preserved, or both vowels are deleted. In a morpheme-level diacritic approach, the contrast between stems in which the first vowel deletes versus stems in which the second vowel deletes can only be generated by a proliferation of scaled constraints. For instance, one could posit a higher scaled penalty of a markedness constraint *[o] for /bəroɛl/ 'spears' than /boɛs/ 'gun.' In contrast, such ad hoc constraints are not required in our proposed analysis situated within Gradient Harmonic Grammar.

5 Conclusion

In this paper, we have shown that Gradient Harmonic Grammar can account for two complex types of phonological idiosyncrasy, exemplified by vowel reduction in Palauan. First, the language's multiple degrees of idiosyncratic reduction are readily generated by the numerically continuous nature of input activity assumed within the framework. Each pair of conflicting markedness and faithfulness constraints potentially establishes a threshold activity value that delineates two input activity ranges with distinct output optima. A large number of input activity thresholds, and consequently a large number of input activity ranges, can be established from a fairly limited set of weighted constraints. Second, in Gradient Harmonic Grammar input activity specifications are associated with individual structures, including segments, rather than whole morphemes. This permits a straightforward account of unpredictable hiatus resolution among tautomorphemic vowel sequences, in contrast with alternative approaches that rely on morpheme-level diacritics. An elegant solution to some of the major analytical challenges posed by phonological idiosyncrasy, then, arises from a single departure from categorical Harmonic Grammar: the adoption of gradient input activity.

References

Coetzee, Andries & Shigeto Kawahara (2013). Frequency biases in phonological variation. *Natural Language and Linguistic Theory* 31:1, 47–89.

Coetzee, Andries & Joe Pater (2011). The place of variation in phonological theory. Goldsmith, John A., Jason Riggle & Alan C. L. Yu (eds.), *The Handbook of Phonological Theory, 2nd edition*, 401–434.

Flora, Marie (1974). *Palauan phonology and morphology*. Ph.D. thesis, University of California San Diego.

Hsu, Brian (2019). Exceptional prosodification effects revisited in Gradient Harmonic Grammar. *Phonology* 36:2, 225–263.

Hsu, Brian (2022). Gradient symbolic representations in Harmonic Grammar. *Language and Linguistics Compass* 16.

Inkelas, Sharon (2015). Confidence scales : a new approach to derived environment effects. Hsiao, Yuchau E. & Lian-Hee Wee (eds.), *Capturing Phonological Shades*, Cambridge Scholars Publishing, Newcastle upon Tyne, 45–65.

Josephs, Lewis (1975). *Palauan Reference Grammar*. University of Hawai'i Press, Honolulu.

Josephs, Lewis (1990). *New Palauan-English Dictionary*. University of Hawai'i Press, Honolulu.

Kiparsky, Paul (1993). Blocking in non-derived environments. Hargus, Sharon & Ellen Kaisse (eds.), *Studies in Lexical Phonology (Phonetics and Phonology 4)*, Academic Press, San Diego, 277–313.

Legendre, Géraldine, Yoshiro Miyata & Paul Smolensky (1990). Can connectionism contribute to syntax?: Harmonic Grammar, with an application. Deaton, Karen, Manuela Noske & Michael Ziolkowski (eds.), *Proceedings of the 26th regional meeting of the Chicago Linguistic Society*, Chicago Linguistic Society, Chicago, 237–252.

Linzen, Tal, Sofya Kasyanenko & Maria Gouskova (2013). Lexical and phonological variation in Russian prepositions. *Phonology* 30, 453–515.

Pater, Joe (2000). Non-uniformity in English secondary stress: the role of ranked and lexically specific constraints. *Phonology* 17, 237–274.

Revithiadou, Anthi & Giorgos Markopoulos (2021). A Gradient Harmonic Grammar account of nasals in extended phonological words. *Catalan Journal of Linguistics* 20, 57–75.

Rosen, Eric (2016). Predicting the unpredictable: Capturing the apparent semi-regularity of rendaku voicing in Japanese through Harmonic Grammar. Clem, Emily, Geoff Bacon, Andrew Chang, Virginia Dawson, Erik Hans Maier, Alice Shen & Amalia Horan Skilton (eds.), *Proceedings of the 42nd Annual Meeting of the Berkeley Linguistics Society*, Berkeley Linguistics Society, Berkeley, 235–250.

Rosen, Eric (2018). Predicting semi-regular patterns in morphologically complex words. *Linguistics Vanguard* 4:1, 1–15.

Sande, Hannah, Peter Jenks & Sharon Inkelas (2020). Cophonologies by Ph(r)ase. *Natural Language and Linguistic Theory* 38:4, 1211–1261.

Smith, Caitlin (2018). *Harmony in Gestural Phonology*. Ph.D. thesis, University of Southern California.

Smolensky, Paul & Matthew Goldrick (2016). Gradient Symbolic Representations in Grammar: The case of French Liaison. Unpublished ms., Johns Hopkins University and Northwestern University.

Smolensky, Paul & Géraldine Legendre (2006). *The harmonic mind: from neural computation to optimality-theoretic grammar*. MIT Press, Cambridge, MA.

Wilson, Helen (1972). *The phonology and syntax of Palauan verb affixes*. Ph.D. thesis, University of Hawaii.

Zimmermann, Eva (2019). Gradient Symbolic Representations in the Output: A case study from Moses Columbian Salishan stress. *Proceedings of the 48th Annual Meeting of the North East Linguistic Society*.

Zuraw, Kie (2003). Vowel Reduction in Palauan Reduplicants. *Proceedings of the 8th Annual Meeting of the Austronesian Formal Linguistics Association*, 385–398.