Phonetically Complete Neutralization of Vowel Nasality in Mankiyali

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1 Introduction

This chapter examines the neutralization of vowel nasality in Mankiyali, an endangered Indo-Aryan language spoken in northern Pakistan. To evaluate the extent of neutralization in the language, I report the results of two production experiments. The first experiment examines the realization of vowel nasality on the target vowels themselves using both airflow and acoustic measures. The second experiment explores whether traces of the underlying contrast persist in anticipatory coarticulatory nasalization on preceding segments. The results indicate that the neutralization of vowel nasality in Mankiyali is phonetically complete. Not only are underlying oral and nasal vowels indistinguishable in the neutralizing environment, but their coarticulatory effects are likewise statistically equivalent. These findings contribute a rare case of phonetically complete neutralization to the literature and provide further evidence that phonological neutralization can, in some circumstances, eliminate all measurable traces of an underlying contrast. More broadly, they raise important questions about how theories of speech production account for both complete and incomplete neutralization.

2 Mankiyali

Mankiyali is an endangered Indo-Aryan language spoken by about 500 people in two small villages, Danna and Dameka, located in Mansehra district, Khyber Pakhtunkhwa Province, Pakistan. As shown by the map in Figure 1, the villages are situated in the northwest region of Pakistan, located about 220 km north of the capital, Islamabad, on an isolated mountain. All Mankiyali speakers are at least trilingual, frequently using Hindko (Northwest Indo-Aryan) — the dominant language of Mansehra — and Urdu (Central Indo-Aryan) — the national language of Pakistan — in addition to Mankiyali. Many are also fluent in Pakistani Pashto (Eastern Iranian), and a small number of men speak English and/or Gojri (Central Indo-Aryan). While exhibiting many features common to Indo-Aryan languages, Mankiyali is mutually unintelligible with any other language in the region.

Figure 1: Map of Pakistan. The two Mankiyali-speaking villages, Danna and Dameka, are in the Khyber Pakhtunkhwa Province of Pakistan, the yellow region of the map.

Until recently, no formal writing system existed for Mankiyali, but most male speakers are fully literate in Urdu. As such, the Perso-Arabic script is typically used as a medium for informal written communication among the community.

The Mankiyali vowel inventory is provided in Figure 2. As is evident, five of the vowel qualities exhibit a nasality contrast in long vowels.

		Front			Central			Back		
		short	long	nasal	short	long	nasal	short	long	nasal
High	tense	i	iː	ĩː				u	uː	ũː
	lax	ɪ	ɪː	ɪ̃ː						
Mid	tense		eː						oː	õː
	lax							ʌ		
Low	tense									
	lax								ɑː	ɑ̃ː

Figure 2: The Mankiyali vowel inventory (Paramore, 2021; Paramore and Aurangzeb, 2025)

Examples of (near) minimal pairs of nouns in the unmarked nominative case contrasting in vowel nasality are provided in (1).

(1) Contrastive vowel nasality in Mankiyali

a. /ɖɪː/ 'giant.NOM' vs. /ɖɪ̃ː/ 'pine firewood.NOM'
b. /gɑː/ 'cow.NOM' vs. /gɑ̃ː/ 'village.NOM'
c. /suːʋiː/ 'big needle.NOM' vs. /tʃuʋ-ɪ̃ː/ 'squash-M.PL.NOM'

When followed by a nasal consonant suffix, this vowel nasality contrast is neutralized, as shown by the examples in (2), with the genitive feminine singular case marker, /-ɳ/. Native speaker consultants consistently judge vowels occurring before nasal consonant suffixes as categorically nasalized. This holds true regardless of whether the vowel is underlyingly oral or nasal. In what follows, I describe two experiments measuring vowel nasality patterns in Mankiylai. The results demonstrate that the neutralization of vowel nasality before nasal consonant suffixes is phonetically complete.

(2) Neutralization of vowel nasality contrasts in Mankiyali

a. /ɖɪː-ɳ/ → [ɖɪ̃ːɳ] 'giant-GEN.F.SG'
b. /ɖɪ̃ː-ɳ/ → [ɖɪ̃ːɳ] 'pine firewood-GEN.F.SG'
c. /gɑː-ɳ/ → [gɑ̃ːɳ] 'cow-GEN.F.SG'
d. /gɑ̃ː-ɳ/ → [gɑ̃ːɳ] 'village-GEN'
e. /suːʋɪː-ɳ/ → [suːʋɪ̃ːɳ] 'big needle-GEN.F.SG'
f. /tʃuʋ-ɪ̃ː-ɳ/ → [tʃuːʋɪ̃ːɳ] 'squash-M.PL-GEN.F.SG'

3 Experiment 1: target-segment neutralization

Experiment 1 aimed to compare the realization of vowel nasality on contrastive oral /Vː/ and nasal /Ṽː/ vowels when followed by a nasal consonant suffix. While nasalance is a primary correlate of nasality, Shosted (2015) and others have shown that vowel nasality sometimes covaries with other acoustic properties such as tongue height (F1 modulation) and breathiness. As such, three phonetic measures (nasalance, vowel breathiness, and F1 modulation) were extracted from the experimental data to examine the phonetic realization of vowel nasality for contrastive oral and nasal vowels in various contexts.

3.1 Participants

Twenty male native Mankiyali speakers participated in the experiment. Their mean age was 33 (sd = 12). All participants were born and have lived in Danna most of their lives. Every participant reported fluency in Hindko and Urdu in addition to Mankiyali, and many also speak Pakistani Pashto and Punjabi. A few participants reported fluency in English and/or Gojri as well. Due to cultural customs and low literacy rates among women in the region, only men were available to participate in the study.

3.2 Stimuli and Design

62 monosyllabic words sourced from five conditions were elicited. Two baseline conditions established the endpoints of the [NAS] feature contrast: contrastive contrastive /CVː/ and contrastive nasal /CṼː/. To avoid carryover coarticulation effects, items in the two baseline conditions contained no nasal consonants in any position. To test whether vowel nasality is phonetically neutralized before nasal suffixes, a subset of words from the contrastive oral and nasal conditions were produced with the feminine singular genitive nasal suffix /-ɳ/, yielding the critical conditions /CVː-N/ (neutralized oral) and /CṼː-N/ (neutralized nasal). A fifth condition comprised monomorphemic words with pre-N vowels (/CVːN/). In all three coda-nasal conditions, items with nasal onsets were excluded to avoid carryover coarticulation.

Table 1 summarizes the distribution of words and expected token counts across conditions; complete glosses are provided in Table 9 of the appendix. While an imbalance in token count and vowel qualities was present across the neutralized oral /CVː-N/ and neutralized nasal /CṼː-N/ forms, this is addressed in the analysis of the results.

Condition	# Words	Expected # lapel tokens	Expected # mask tokens
CVː	21	800	1,600
CṼː	19	760	1,520
CVː-N	4	160	320
CṼː-N	7	280	560
CVːN	11	440	880
Total	**62**	**2,440**	**4,880**

Table 1: Distribution of words, expected lapel tokens (20 speakers x 2 repetitions x # of words), and expected air pressure mask tokens (20 speakers x 4 repetitions x # of words) used in experiment 1, separated by condition.

3.3 Procedure

All recording sessions took place in a quiet home in the village of Danna. A native speaker consultant — Aurangzeb — with knowledge of the experimental goals presided over the experiment, interacting with participants only in Mankiyali.

A Glottal Enterprises dual-chamber oro-nasal air pressure mask equipped with a handle and connected to two separate transducers was used to measure air pressure from the nose and mouth separately at a sampling rate of 11,025 kHz. The silicone mask was constructed with a bifurcation to separate the oral and nasal chambers, allowing for simultaneous, time-aligned air-pressure measurements in each channel. These signals were used to compute changes in nasalance over time, defined as the ratio of nasal air pressure (A^n) to the total amount of oral (A^o) and nasal air pressure across both chambers: $\frac{A^n}{A^n+A^o}$.

In addition, an Audio-Technica AT831 cardioid condenser lapel microphone connected to a Zoom H5 Handy Recorder was attached to the upper collar of participants' shirts to obtain high-quality acoustic recordings along with the air pressure data obtained from the airflow mask.

Participants were presented with tokens in the Urdu script in a randomized order using a Python GUI. Each token was produced six times in the following order: twice without the mask to obtain clear acoustic recordings with the lapel microphone, twice slowly into the mask and twice using rapid speech into the mask to test whether speech rate impacted the degree of nasality on neutralized vowels (Solé, 1992, 1995).

3.4 Analysis

All recordings obtained from the nasal airflow mask were hand-annotated by three undergraduate research assistants; I reviewed all annotations to ensure consistency. A Praat script was then used to iterate through the files and convert the oral and nasal air pressure channels to intensity tracks, and subsequently extract nasalance values over 11 time-normalized windows for each segment.

While nasalance acts as a relatively straightforward primary correlate to vowel nasality, previous work has shown that the acoustic underpinnings highlighting the contrast between nasal and oral vowels are more dynamic than a simple linear correlation between velopharyngeal port opening and vowel type (Carignan, 2017; Shosted, 2015; Shosted et al., 2012).

As such, in addition to recording nasalance measures, formant values for each vowel were also analyzed. Formant values from the lapel microphone were extracted over 10 equidistant windows for each vowel.[1]

3.5 Vowel Nasality Neutralization is Phonetically Complete

3.5.1 Nasalance

Of the 4,880 potential tokens measured with the airflow mask in experiment 1, 31 low-quality trials were removed, resulting in a total of 4,849 tokens included in the analysis. Figure 3 shows generalized additive model (GAM) curve visualizations — grouped by condition — of the vowels tokens from experiment 1. Since vowel height has been shown to covary with nasality in both oral and nasal vowels (Bell-Berti, 1993), the data is partitioned into three separate plots for high, mid, and low vowels respectively.

The vowel qualities of tokens from the neutralized oral /CVː-N/ condition were all either low or mid vowels, whereas vowel qualities of tokens from the neutralized nasal /CṼː-N/ condition were all either mid or high vowels. While this unbalanced vowel quality is accounted for in the statistical analysis using linear mixed effects modeling (Baayen et al., 2008; Speelman et al., 2018), including the full range of vowel qualities in the plots distorts the reality of the similarities in nasalance traces across conditions, so the visualizations are partitioned by vowel quality to remedy this.

[1] Breathiness has also been found to be an acoustic correlate of nasality in some languages (Garellek et al., 2016), but no difference in breathiness (H1*-H2*) was found between contrastive oral /CVː/ and nasal /CṼː/ vowels in the Mankiyali data. As such, breathiness results were omitted. For more details see Paramore (2026, ch.4).

As shown by the plots, when vowel quality is controlled for, the contrast in nasality between underlying contrastive oral and nasal vowels qualitatively vanishes in the context of a nasal consonant suffix. Importantly, the two vowel types do not converge at a midpoint in nasalance between contrastive nasal and oral vowels. Instead, the neutralized oral /CVː-N/ vowel adopts a similar nasalance trajectory as underlying nasal /CṼː/ and /CṼː-N/ vowels across its entire span.

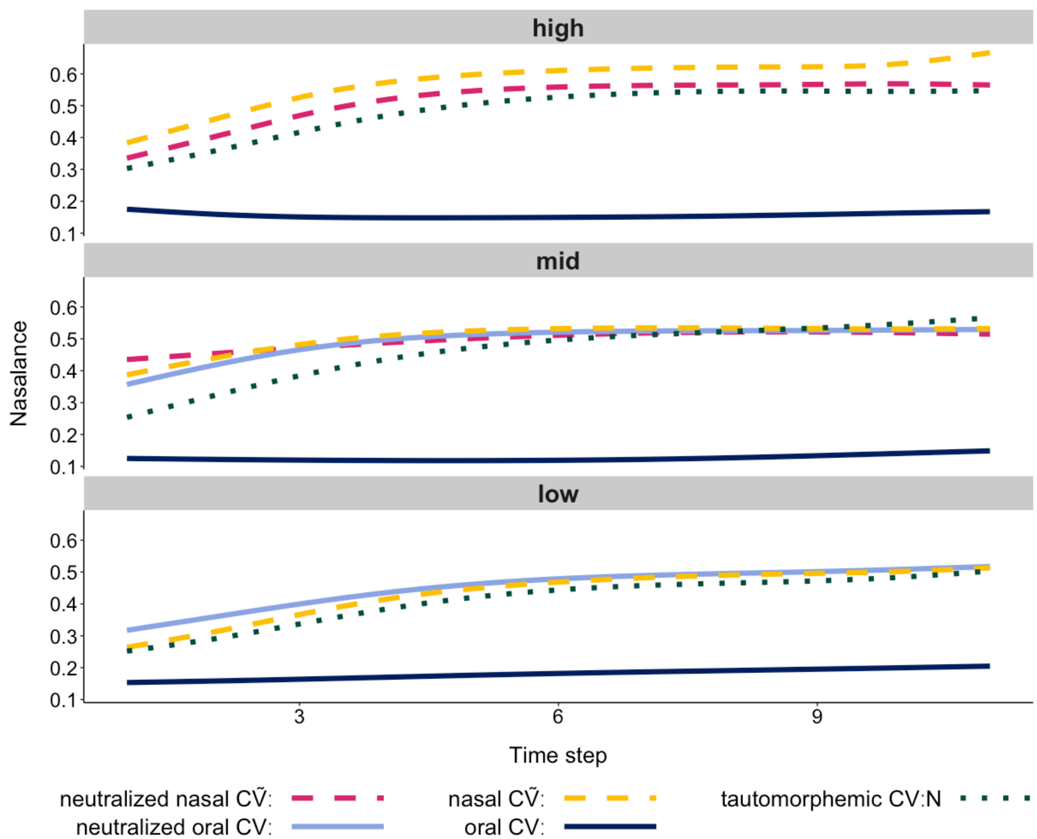

Figure 3: GAM curves separated by condition showing mean vowel nasalance across 11 normalized timesteps for all tokens in experiment 1, grouped by vowel height and condition. Underlyingly oral vowels are represented by the solid lines, underlyingly nasal vowels by the dashed lines, and vowels followed by a tautomorphemic nasal coda with a dotted line.

To quantitatively assess whether neutralized oral /CVː-N/ vowels undergo complete phonetic neutralization to [+NAS], I fit a linear mixed effects model to all tokens in the contrastive nasal /CṼː/ (n = 1520), neutralized nasal /CṼː-N/ (n = 541), and neutralized oral /CVː-N/ (n = 315) conditions. CONDITION, VOWEL QUALITY, TIMESTEP, and the CONDITION*TIMESTEP interaction were included as fixed effects. By-speaker random intercepts and random slopes for CONDITION were included as random effects. For the fixed effects, CONDITION was dummy (aka treatment) coded, while VOWEL QUALITY and TIMESTEP (operationalized as three temporal regions corresponding to the first, second, and final third of the vowel) were effect (aka sum) coded. Consequently, the model intercept (β_0) represents the mean vowel nasalance of contrastive nasal /CṼː/ vowels, averaged over the different levels of VOWEL QUALITY and TIMESTEP. The remaining fixed effect coefficients (β_1-β_{10}) capture the estimated deviation from baseline contrastive nasal /CṼː/ vowels for each predictor. Finally, the interaction terms (β_{11}-β_{13}) indicate how much neutralized oral /CVː-N/ vowels vary from the vowel nasalance of contrastive nasal /CṼː/ vowels at each specified time step, adding to the main effect size of vowel condition (β_1).

Results of the model (Table 2) show that the interaction terms between CONDITION and TIMESTEP are significant, indicating that nasalance trajectories across the span of the vowel differ between contrastive nasal /CṼː/ and neutralized oral /CVː-N/ vowels. Specifically, neutralized oral /CVː-N/ vowels are estimated to be slightly *more* nasalized at the onset of the vowel than contrastive nasal /CṼː/ vowels (.011). In the final 2/3 of the vowel, however, contrastive nasal /CṼː/ vowels are slightly more nasalized. Nevertheless, the interaction effect sizes are quite constrained, with 95% CIs remaining within $\pm$.021 nasalance across all time steps. Thus, it is safe to examine the main effect between the two vowels without interaction effects obscuring the results.

Rows 1-3, the portion of the model most relevant to the present discussion, show that neutralized oral /CV:-N/ vowels do not differ significantly from contrastive nasal /CṼː/ vowels. In contrast, the estimated nasalance of neutralized *nasal* /CṼː-N/ vowels in row 3 *were* significantly different, with a mean nasalance about .045 *less than* contrastive nasal /CṼː/ vowels. This suggests that, controlling for TIMESTEP and VOWEL QUALITY, neutralized oral /CVː-N/ vowels exhibit a slightly *higher* degree of nasalance than neutralized nasal /CṼː-N/ vowels.

Predictor	β	95% CI	t	p
Intercept (nasal CṼː)	.532	[.508, .557]	42.29	$<$ .001 ***
neutralized oral CVː-N	-.005	[-.049, .040]	-.20	.84
neutralized nasal CṼː-N	-.045	[-.078, -.013]	-2.74	.01 *
Beg	-.083	[-.085, -.081]	-79.87	$<$ .001 ***
Mid	.034	[.032, .036]	32.97	$<$ .001 ***
Fin	.049	[.046, .051]	38.59	$<$ .001 ***
uː	.036	[.008, .063]	2.53	.02 *
iː	.125	[.100, .151]	9.68	$<$ .001 ***
ɪː	-.050	[-.076, -.025]	-3.87	$<$ .001 ***
oː	-.018	[-.042, .007]	-1.44	.16
ɑː	-.093	[-.120, -.066]	-6.71	$<$ .001 ***
neut. oral CVː-N:Beg	.016	[.011, .021]	6.07	$<$ .001 ***
neut. oral CVː-N:Mid	-.007	[-.012, -.002]	-2.82	.005 **
neut. oral CVː-N:Fin	-.008	[-.015, -.002]	-2.66	.008 **

Table 2: LMER model summarizing the effects of CONDITION, (3 levels), TIMESTEP (3 levels), VOWEL QUALITY (5 levels), and the interaction between CONDITION and TIMESTEP on nasalance for all vowel tokens in experiment 1: lmer(nasalance∼CONDITION*TIMESTEP + VOWELQUALITY + (1 + CONDITION|speaker) + (1|word).

In order to examine the relationships between the two neutralized vowel conditions more closely, I extracted a pairwise comparison from the LMER model in Table 2, using the emmeans() package in R (Lenth, 2024), which provides estimated marginal means across conditions, adjusting for the other model predictors. As can be seen in Table 6, the pairwise comparison between the nasalance of neutralized oral /CVː-N/ vowels and neutralized nasal /CṼː-N/ vowels is insignificant.

Comparison	β	95% CI	t	p
(neut. oral CVː-N) — (neut. nasal CṼː-N)	.041	[-.024, .105]	1.51	.39

Table 3: Pairwise comparison showing the effect of vowel condition on nasalance: emmeans(lmer-exp1, ∼condition).

With that said, the absence of a statistically significant difference between neutralized oral /CVː-N/ vowels and nasal /CṼː/ and /CṼː-N/ vowels in experiment 1 does not entail that the vowel types are equivalent in their nasalance. Rather, it simply means that we lack evidence to conclude they are different. To formally establish equivalence — and thereby test for phonetically complete neutralization of vowel nasality — we can establish a ***R**egion **o**f **P**ractical **E**quivalence (-h to h)* for the nasalance of contrastive nasal vowels in Mankiyali (Bonett, 2021; Lakens et al., 2018; Wellek, 2010). Within this region, differences in mean nasalance can be treated as random variation within the same category. After defining the *RoPE*, the 95% confidence interval for differences in nasalance between neutralized oral and contrastive nasal vowels can be evaluated against it. If the CI falls entirely within the *RoPE*, we can conclude that the two vowel types are practically equivalent in terms of nasalance.

To define a *RoPE* for mean nasalance of nasal vowels in Mankiyali, I grouped all contrastive nasal /CṼː/ tokens from experiment 1 by speaker and vowel quality, then calculated the mean and standard deviation of each group. Computing by-speaker nasalance means separately for each vowel quality controls for inherent differences in nasalance across vowel heights. For each speaker, the mean nasalance and standard deviation was then averaged across vowel qualities to obtain by-speaker standard nasalance distributions. Using these measures, I defined the *RoPE* as the range covering 95% of nasal /CṼː/ nasalance values ($\pm$2 sd) for the speaker with the tightest clustering of nasalance values across tokens. Because all vowels in the contrastive nasal /CṼː/ condition are phonologically contrastive nasal vowels, any within-speaker variation in nasalance can be treated as random noise. Setting the *RoPE* equivalent to the speaker with the least variability's standard deviation thus provides a stringent threshold, within which variation can be interpreted as within-category random phonetic noise rather than a cross-category phonological distinction (see Paramore and Bennett 2025 for a similar approach in Punjabi). Figure 4 shows the mean nasalance and $\pm$2 sd of nasal /CṼː/ vowels for each speaker in experiment 1. Speaker SR0 exhibited the least amount of variation, with 2 sd of .078, so a conservative estimate of the *RoPE* in this experiment is $\pm$.078.

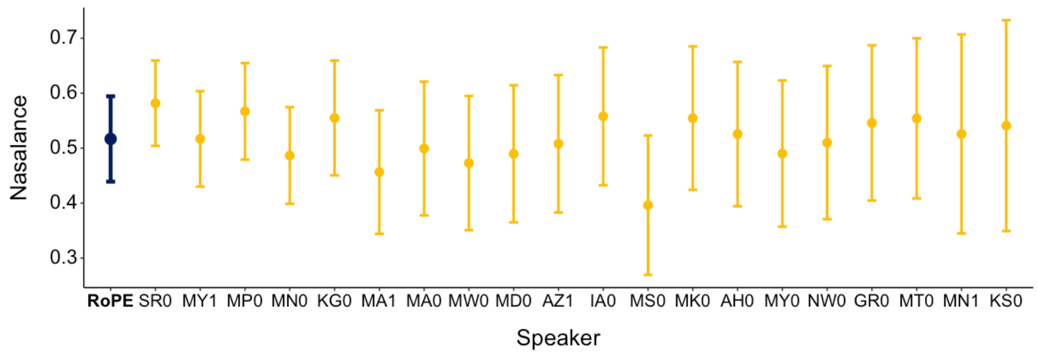

Figure 4: Dot and whisker plot showing mean nasalance of contrastive /CṼː/ vowels from experiment 1. Yellow dots indicate each speaker's mean /CṼː/ vowel nasalance, with whiskers showing ± 2 sd around that mean. Speakers are ordered from left to right by magnitude of sd. The blue dot marks the mean nasalance across all speakers, and its whiskers represent the proposed *RoPE* of $\pm .078$ for contrastive nasal /CṼː/ vowels, equivalent to the ± 2 sd range of the speaker with the narrowest nasalance distribution (SR0).

Reevaluating the 95% confidence interval for the estimated nasalance difference between contrastive nasal /CṼː/ vowels and neutralized oral /CVː-N/ vowels (row 2 in Table 2), it is clear that the entire interval of [-.049, .040] falls within the $\pm .078$ *RoPE*. Moreover, examining the 95% CI for the estimated difference in nasalance between neutralized oral /CVː-N/ vowels and neutralized nasal /CṼː-N/ vowels in Table 6, the upper bound of the 95% CI (.105) extends beyond the *RoPE*. This deviation reflects the possibility that neutralized nasal /CṼː-N/ vowels are, if anything, slightly *less* nasalized than neutralized oral /CVː-N/ vowels.[2] Taken together, these results support the conclusion that the neutralization of nasalance between oral and nasal vowels is phonetically complete on the vowels themselves.

[2]In discussing phonetic neutralization, Du and Durvasula (2025) note that cases of *over-neutralization* — in which the phonetic realization of the relevant feature in a neutralized segment is realized to a greater degree than in a segment that is underlyingly specified for that feature — have never been observed. While the results here are non-significant, it is nevertheless intriguing that the underlyingly oral vowels show, if anything, a greater degree of nasality than their nasal counterparts in the same context.

3.5.2 F1 Modulation

As Shosted (2015) observed, contrastive nasal vowels are not simply [+NAS] oral vowels, in that vowel nasality contrasts cannot be reduced to the lowering of the velum to couple the nasal tract with the oral tract during vowel production. Instead, other modifications of the vocal tract commonly covary with velum lowering and serve as secondary correlates to nasality. Indeed, previous work has shown that vowel nasality correlates with dynamic changes in F1 over the timecourse of a vowel (Carignan, 2017; Shosted et al., 2012). As such, in this section, I explore whether residual differences in tongue height (F1) persist between neutralized oral /CVː-N/ and contrastive nasal /CṼː/ and neutralized nasal /CṼː-N/ vowels.

Figure 5 shows the vowel space in the F1/F3 — F2/F3 plane, with the mean formant ratio values extracted from the midpoint of each token averaged by condition across all speakers in the study (dynamic changes in F1 are examined below). F1/F3 and F2/F3 ratios were used rather than mean F1 and F2 values alone because F3-normalized values have been shown to successfully remove cross-speaker variation (Monahan and Idsardi, 2010), thus providing an effective means of cross-speaker formant normalization. From a cursory inspection of the vowel space, contrastive nasal /Ṽː/ vowels (yellow) are generally pronounced with the tongue slightly lower and further back than their contrastive oral /Vː/ counterparts (dark blue). Crucially, the neutralized oral /CVː-N/ (light blue), neutralized nasal /CṼː-N/ (pink), and tautomorphemic /CVːN/ (green) vowels cluster with the contrastive nasal vowels in the vowel space.

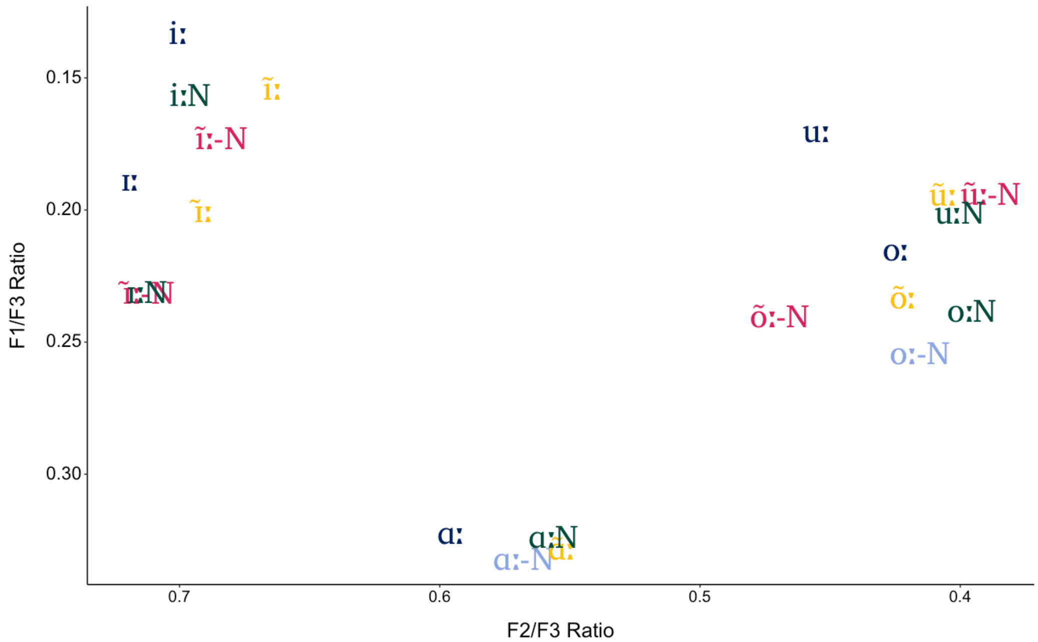

Figure 5: F1/F3 — F2/F3 vowel space showing the mean F1/F3 and F2/F3 ratio values calculated from the midpoint of all vowels, averaged across speakers, and separated by condition: oral /CVː/ (dark blue), nasal /CṼː/ (yellow), neutralized oral /CVː-N/ (light blue), neutralized nasal /CṼː-N/ (pink), and tautomorphemic /CVːN/ (green).

To evaluate the potential for dynamic changes in F1 over time, formant values were extracted from each /oː/ token at 10 normalized time windows across the length of each vowel. Because the mid back /oː/ vowel is the only vowel present in all four conditions, the analysis only compares formant differences for this vowel. In line with previous literature, the mid back /oː/ vowel showed no distinction in tongue backness (F2/F3 ratio), so the remainder of this section focuses on potential differences in tongue height (F1/F3 ratio).[3]

Figure 6 shows GAM curves fit to the 10 timepoints for all F1/F3 values for the contrastive oral and nasal, as well as the neutralized oral and nasal conditions.

[3]Interestingly, while the mid back /oː/ vowel showed no significant changes in F2/F3 ratio in relation to nasality, the vowel space in Figure 5 highlights that nasal vowels are produced with a lower F2/F3 ratio compared to oral vowels for most of the vowel qualities in Mankiyali. As such, future research exploring whether F2 modulation correlates with nasality in the language would be welcomed.

Comparing F1 trajectories of contrastive oral and nasal vowels (solid lines), the plot shows that, at the endpoints of the vowels, no tongue height distinction exists for mid back /oː/. However, contrastive nasal /õː/ exhibits a lower tongue height (larger F1/F3 ratio) compared to contrastive oral /oː/ throughout the middle portion of the vowel. This provides good evidence that F1 modulation is recruited as an additional correlate to nasality in Mankiyali, at least for mid back vowels.

Crucially, the F1 distinction is neutralized before the genitive suffix, /-ɳ/. Whereas contrastive oral /oː/ forms a clearly distinct trajectory, the trajectories of the remaining three conditions cluster closely together in the middle portion of the vowel, as can be seen by the substantial overlap in their confidence intervals. Of particular interest, neutralized oral /CVː-N/ patterns with the two nasal conditions rather than with contrastive oral /oː/, indicating that the lower F1 characteristic of oral vowels is lost in the neutralizing environment. The markedly raised F1/F3 values in the later portions of the vowel for the two neutralized conditions undoubtedly reflects the transition into the retroflex nasal consonant coda, /-ɳ/, since retroflexion significantly lowers F3 (Hamann, 2003).

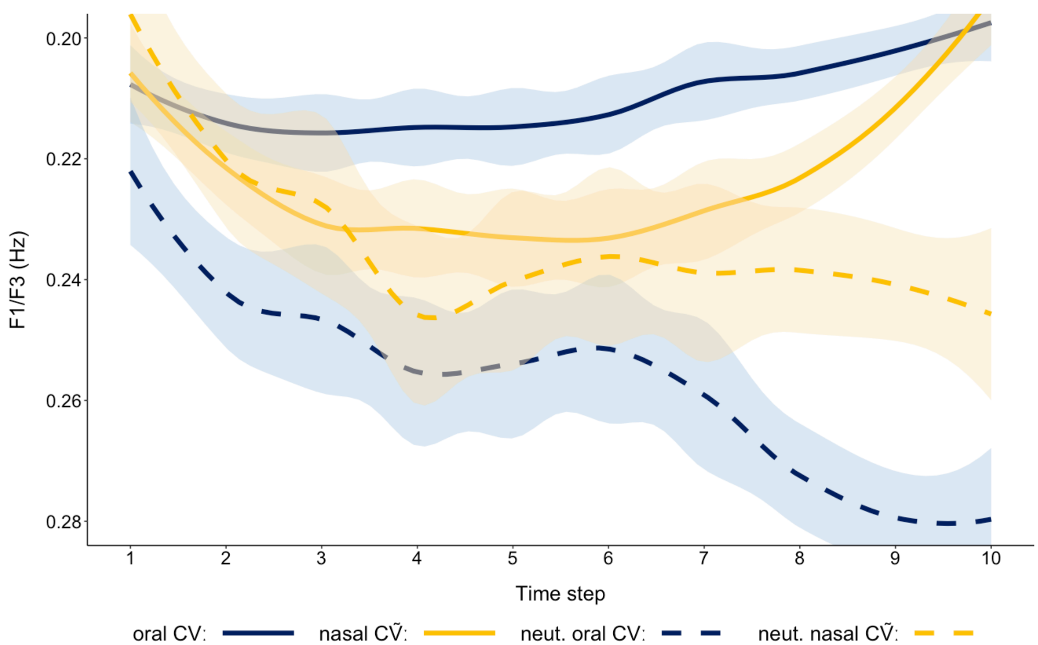

Figure 6: Generalized Additive Model (GAM) curves of mean F1/F3 ratio across 10 timesteps for tokens with the low back mid vowel /oː/ or /õː/ in Experiment 1.

Table 4 summarizes a linear mixed effects model fit to the F1/F3 ratio data, with CONDITION as the sole fixed effect. By-speaker random intercepts and random slopes for CONDITION were included as random effects. A likelihood ratio test comparing this model to one including TIMESTEP (steps 4-7) and its interaction with CONDITION as additional fixed effects did not significantly improve model fit ($\chi^2(9) = 4.08$, p = .91), so TIMESTEP was excluded from the analysis. The oral /CVː/ condition was also removed to allow for better assessment of potential differences between the other three conditions. As is evident from the results in Table 4, neither of the neutralized vowel conditions were found to exhibit significantly different F1/F3 ratio values.

Predictor	β	95% CI	t	p
Intercept (nasal Cõː)	.232	[.205, .259]	16.76	$<$ .001 ***
neut. oral Coː-N	.023	[-.005, .051]	1.6	.16
neut. nasal Cõː-N	.008	[-.027, .043]	.46	.67

Table 4: LMER model summarizing the effects of CONDITION, (3 levels) on F1/F3 ratio for all mid low back vowel tokens uttered by all 20 speakers in experiment 1: LMER(F1/F3∼CONDITION + (1 + CONDITION|speaker) + (1|word)).

To examine whether the neutralization of vowel height differences between oral and nasal vowels was phonetically complete in the neutralized oral /CVː-N/ condition, I established a *RoPE* for F1 in a manner parallel to that of section 3.5.1. For each speaker, I calculated the mean and standard deviation of the F1/F3 ratio for all nasal /õː/ vowels in the /CṼː/ condition. The *RoPE* was then defined using the speaker with the narrowest 2sd interval in F1/F3 ratio variation, which in this case was $\pm$.029.

Comparing this *RoPE* to the 95% CIs in Table 4, the upper bound of the 95% for the estimated difference of neutralized oral /CVː-N/ vowels from underlying nasal /CṼː/ vowels extends beyond the *RoPE*, while the lower bound falls within it. Thus, it is clear that, if anything, neutralized oral /CVː-N/ vowels are ‘over-neutralizing’ in tongue height.

Taken together, the analysis of changes in F1/F3 in this section and nasalance in section 3.5.1 provide evidence that the phonological neutralization of vowel nasality on oral vowels occurring before nasal suffixes is phonetically complete.

4 Experiment 2: coarticulatory neutralization

While the phonetic analysis in the previous section showed that vowel nasality is completely neutralized on the vowels themselves before nasal suffixes in Mankiyali, it does not provide sufficient evidence that the neutralization is phonetically complete in these words. In previous work demonstrating the incomplete neutralization of phonologically neutralized contrasts, residual surface differences revealing the underlying contrast have been discovered on adjacent segments, as in the classic example of phonetically incomplete neutralization of word-final devoicing in German (Port and O'Dell, 1985; Roettger et al., 2014).

It is well known that in many languages, segments preceding nasal consonants and vowels exhibit anticipatory nasalization, in which the velum is lowered well before the onset of a [+NAS] segment in anticipation of the production of the nasal sound (Beddor and Krakow, 1999). In some cases like English (Pouplier et al., 2023), anticipatory nasalization commences well before the [+NAS] segment, resulting in long-distance anticipatory nasal coarticulation. It is possible, then, that similar to the case of German word-final devoicing, the phonetic remnants revealing the lexical identity of the vowel nasality contrast in Mankiyali manifest, not on the vowels themselves, but on preceding segments exhibiting anticipatory nasalization. To explore this possibility in Mankiyali, experiment 2 examined nasalance on segments preceding oral and nasal vowels to see if any lingering phonetic effects hinting at the underlying nasality contrast were preserved.

4.1 Stimuli, Design, and Analysis

Sixteen additional male Mankiyali speakers who did not participate in experiment 1, took part in the second experiment (mean age = 40.3, sd = 9.1). All participants spoke Urdu and Hindko in addition to Mankiyali, and some also spoke Punjabi, Pakistani Pashto, English, and/or Arabic. All speakers were born in Danna and resided there at the time of the experiment.

Stimuli were sourced from four conditions: baseline oral /Vː/, baseline nasal /Ṽː/, neutralized oral /Vː-N/, and neutralized nasal /Ṽː-N/. Here however, all words were at least disyllabic, containing a vowel–glide–vowel (VːGVː) sequence in the final two syllables of the word. The penultimate pre-glide vowel in the /VːGVː/ sequence was always oral. The 38 word forms across the four condition are provided in Table 3.

(3) Mankiyali experiment 2 items and conditions

oral /Vː/ (11)		neutralized oral /Vː-N/ (11)	
sɑːʋuː	‘powerful’	sɑːʋuː-ɳ	‘powerful-GEN.F.SG’
bɪːʋɑː	‘marriage’	bɪːʋɑː-ɳ	‘marriage-GEN.F.SG’
pɑː-ʋiː	‘table leg-PL’	pɑː-ʋɪː-ɳ	‘table leg-PL-GEN.F.SG’
sɪːʋɑː	‘more’	sɪːʋɑː-ɳ	‘more-GEN.F.SG’
tʃiː-ʋeː	‘early birth-PL’	tʃiː-ʋɪː-ɳ	‘early birth-PL-GEN.F.SG
sɑː-ʋiː	‘green/blue-PL’	sɑː-ʋɪː-ɳ	‘green/blue-PL-GEN.F.SG’
buʋɑː	‘ploughing’	buʋɑː-ɳ	‘ploughing-GEN.F.SG’
suːʋiː	‘big needle’	suːʋɪː-ɳ	‘big needle-GEN.F.SG’
hʌʋɑː	‘air’	hʌʋɑː-ɳ	‘air-GEN.F.SG’
seːʋuː	‘apple’	seːʋuː-ɳ	‘apple-GEN.F.SG’
ʈɑːʋuː	‘competitor’	ʈɑːʋuː-ːn	‘competitor-GEN.F.SG’

nasal /Ṽː/ (8)		neutralized nasal /Ṽː-N/ (8)	
lɪː-ʋɑ̃ː	‘I mud’	lɪː-ʋɑ̃ː-ɳ	‘I will mud’
tɑː-ʋɑ̃ː	‘I heat up’	tɑː-ʋɑ̃ː-ɳ	‘I will heat up’
tʃu-ʋĩ̄ː	‘squash-PL’	tʃu-ʋɪ̃ː-ɳ	‘squash-PL-GEN.F.SG’
sɪː-ʋɑ̃ː	‘I make wet’	sɪː-ʋɑ̃ː-ɳ	‘I will make wet’
rɑː-ʋɑ̃ː	‘bean-PL’	rɑː-ʋɑ̃ː-ɳ	‘bean-PL-GEN.F.SG’
lɪː-ʋɪ̃ː	‘we mud’	lɪː-ʋɪ̃ː-ɳ	‘we will mud’
pɪː-jɑ̃ː	‘I sit’	pɪː-jɑ̃ː-ɳ	‘I will sit’
pʌndʒi-jõː	‘toe-PL’	pʌndʒi-jõː-ɳ	‘toe-PL-GEN.F.SG’

The primary focus of the experiment was to explore whether coarticulatory nasalization in the neutralized oral /Vː-N/ condition is phonetically distinct from the coarticulatory nasalance observed in the two conditions with underlying nasal vowels (nasal /Ṽː/ and neutralized nasal /Ṽː-N/). Section 4.2.1 replicates findings from experiment 1, showing that the neutralization of nasalance on the vowels themselves is phonetically complete. Section 4.2.2 then shows that the coarticulatory nasalization on segments preceding neutralized oral /Vː-N/ vowels is identical to that observed on segments preceding underlying nasal vowels.

4.2 Results

Of 2,432 possible tokens, 2,331 were included in the analysis; 101 tokens were excluded due to poor recording quality.

In Figure 7, GAM curves fit to 33 timesteps in the /VːGVː/ sequence show the mean nasalance over time for each condition.[4] As expected, nasalance across the

[4]Because nasalance measurements were taken at 11 equidistant timesteps for each segment,

entire /VːGVː/ sequence in the oral /Vː/ condition remains steady at about .2. By contrast, the two nasal conditions and the neutralized oral /Vː-N/ condition exhibit strikingly similar trajectories.

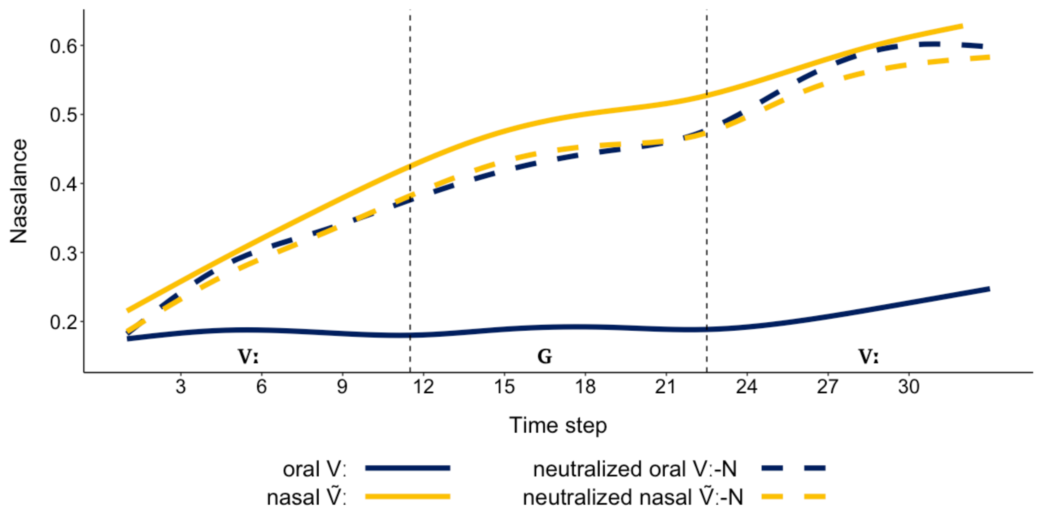

Figure 7: GAM curves separated by condition showing mean vowel nasalance at 33 normalized timesteps across the /VːGVː/ sequence for all tokens in experiment 2 produced by 16 speakers. Vertical dashed lines represent segment boundaries.

4.2.1 Neutralization on the target vowel

Table 5 summarizes the results of a linear mixed-effects model fit to the nasalance data of the final vowel of the contrastive nasal /Ṽː/, neutralized nasal /Ṽː-N/ and neutralized oral /Vː-N/ conditions. The interaction terms in the final three rows show a significant, but practically miminal (at most .017 difference in nasalance), effect at all three Timesteps of the final vowel.

Examining the main effect of vowel condition, while neutralized nasal /Ṽː-N/ approached significance in its nasalance difference with underlying nasal /Ṽː/, nasalance of neutralized oral /Vː-N/ was significantly different. These decreased nasalance values in the two nasalance conditions may be due to differing post-vowel contexts. That is, the final nasal /Ṽː/ vowels always occurred in an open

Figure 7 involves some distortion of time. For instance, glides were typically much shorter than either of the vowels in a given token, and so the timesteps during [G] in Figure 7 are not strictly comparable to those for the adjacent vowels [Vː].

syllable, with the immediate context being a pause. Speakers may have initiated oral occlusion toward the end of the vowel while velopharyngeal port closure lagged behind due to the independent timing of velic and lingual gestures (Byrd et al., 2009; Krakow, 1989, 1993). This would increase nasalance values relative to pre-N contexts at the end of phrase-final vowels.

Predictor	β	95% CI	t	p
Intercept (nasal /Ṽː/)	.636	[.581, .692]	22.51	$<$ .001 ***
neutralized nasal /Ṽː-N/	-.043	[-.087, .001]	-1.93	.06
neutralized oral /Vː-N/	-.066	[-.109, -.023]	-3.04	.006 **
Beg	-.040	[-.043, -.036]	-21.83	$<$ .001 ***
Mid	.006	[.002, .01]	3.06	.002 **
Fin	.034	[.030, .038]	15.63	$<$ .001 ***
uː	.096	[.053, .138]	4.4	$<$ .001 ***
iː	-.045	[-.073, -.016]	-3.11	.005 **
oː	-.005	[-.052, .042]	-.22	.83
ɑː	-.046	[-.071, -.02]	-3.52	.002 **
neutralized oral /Vː-N/.Beg	-.012	[-.017, -.008]	-5.32	$<$ .001 ***
neutralized oral /Vː-N/.Mid	.007	[.002, .011]	2.68	.007 **
neutralized oral /Vː-N/.Fin	.006	[0, .011]	2.09	.04 *

Table 5: LMER model summarizing the effects of CONDITION (3 levels), TIMESTEP (3 levels), VOWELQUALITY (4 levels), and the interaction between CONDITION and TIMESTEP on mean nasalance of the final stem vowel for all tokens uttered by 16 speakers in experiment 2: LMER(nasalance$\sim$CONDITION*TIMESTEP + VOWELQUALITY + (1 + CONDITION$|$speaker) + (1$|$word)).

To assess practical equivalence in nasalance for the final vowel between the two neutralized conditions (oral /Vː-N/ and nasal /Ṽː-N/), I defined a Region of Practical Equivalence (*RoPE*) following the procedure used in previous sections, using the final stem vowel in the baseline nasal /Ṽː/ condition; this yielded a *RoPE* of $\pm$.119.

I then extracted a pairwise comparison between the two neutralized vowel conditions using the emmeans() package in R (Lenth, 2024), as in the previous section. Table 6 summarizes the pairwise comparison between the nasalance of neutralized oral /Vː/-N vowels and neutralized nasal /Ṽː-N/ vowels, showing no significant difference in nasalance between the two vowel types.

Comparison	β	95% CI	*t*	*p*
(neut. oral Vː-N) – (neut. nasal Ṽː-N)	-.023	[-.076, .030],	-1.03	.91

Table 6: Pairwise comparison showing the effect of vowel condition on nasalance. Results were extracted using emmeans(), which averages over other predictors in the model: emmeans(lmer-exp2, ∼condition).

Comparing the 95% confidence interval from this pairwise comparison to the *RoPE*, the interval lies well within $\pm.119$, thus replicating the experiment 1 results that no practical difference in nasalance between the stem-final neutralized oral and neutralized nasal vowels exists.

4.2.2 Neutralization of anticipatory nasalization

To examine potential differences in anticipatory coarticulation between the neutralized oral /Vː-N/ and neutralized nasal /Ṽː-N/ conditions, I fit an additional lmer model to nasalance across the VːG sequence. The fixed- and random-effects structure matched that of the model summarized in Table 5, except that TIMESTEP was coded as a six-level factor (three bins for both the penultimate vowel and glide). The results — summarized in Table 7 — show no evidence for a difference in anticipatory coarticulation between the two neutralized vowel conditions.

Predictor	β	95% CI	t	p
Intercept (Neut. Oral /Vː-N/)	.359	[.278, .44]	8.7	$<$ .001 ***
Neut. Nas. /Ṽː-N/	.027	[-.045, .100]	.73	.47
penult Beg 1/3	-.083	[-.093, -.072]	-14.81	$<$ .001 ***
penult Mid 1/3	-.043	[-.053, -.032]	-8.22	$<$ .001 ***
penult Fin 1/3	-.002	[-.012, .008]	-.41	.68
glide Beg 1/3	.013	[.003, .023]	2.57	.01 *
glide Mid 1/3	.046	[.036, .056]	8.91	$<$ .001 ***
glide Fin 1/3	.068	[.058, .078]	13.55	$<$ .001 ***
uː	-.004	[-.013, .005]	-.96	.33
iː	.010	[-.003, .022]	1.48	.14
eː	-.060	[-.073, -.046]	-8.65	$<$ .001 ***
ə	.087	[.073, .101]	12.25	$<$ .001 ***
ɑː	-.039	[-.045, -.032]	-11.37	$<$ .001 ***
j	-.051	[-.075, -.028]	-4.24	$<$ .001 ***
ʋ	-.028	[-.052, -.004]	-2.30	.02 *
Neut. Nas. /Ṽː-N/:penult Beg 1/3	-.008	[-.019, .004]	-1.33	.18
Neut. Nas. /Ṽː-N/:penult Mid 1/3	-.008	[-.017, .001]	-1.82	.07
Neut. Nas. /Ṽː-N/:penult Fin 1/3	-.003	[-.011, .004]	-.84	.4
Neut. Nas. /Ṽː-N/:glide Beg 1/3	.009	[.002, .017]	2.42	.015 *
Neut. Nas. /Ṽː-N/:glide Mid 1/3	.010	[.002, .018]	2.38	.017 *
Neut. Nas. /Ṽː-N/:glide Fin 1/3	-.0004	[-.008, .007]	-.11	.91

Table 7: lmer model summarizing the effects of CONDITION (2 levels), TIMESTEP (6 levels), SEGMENT QUALITY (7 levels), and the interaction between CONDITION and TIMESTEP on mean nasalance of the VːG sequence for all tokens uttered by 16 speakers in experiment 2: LMER(nasalance$\sim$CONDITION*TIMESTEP + VOWEL QUALITY + (1 + CONDITION$|$speaker) + (1$|$word)).

To test for equivalence, I established six *RoPE*s using data from the underlying nasal Ṽː condition, one for each timestep included in the lmer model. For each *RoPE*, the speaker with the narrowest standard deviation for that given time bin set the threshold, yielding a conservative criterion for equivalence between conditions. Table 8 displays six pairwise comparisons between the two neutralized conditions — one per time bin — along with columns reporting the corresponding *RoPE* and whether the 95% confidence interval (CI) of the difference lies entirely within it. No comparison shows a significant nasalance difference between conditions. Moreover, the 95% CIs for four of the six comparisons fall within their respective *RoPE*s; only the first two time bins fail to meet the equivalence criterion. This likely reflects onset-related differences that affect the early trajectory of nasalance: in the neutralized nasal /Ṽː-N/ condition, 3 of the 8 onsets were liquids, whereas in the neutralized oral /Vː-N/ condition, all onsets were obstruents (cf. Pouplier et al. 2024).

/Vː-N/ – /Ṽː-N/	β	95% CI	*t*	*p*	*RoPE*	*Equivalent?*
penult Beg 1/3	-.020	[-.093, .054]	-.52	.60	±.082	No
penult Mid 1/3	-.019	[-.092, .054]	-.51	.61	±.083	No
penult Fin 1/3	-.024	[-.097, .049]	-.64	.52	±.196	Yes
glide Beg 1/3	-.036	[-.109, .036]	-.98	.33	±.173	Yes
glide Mid 1/3	-.037	[-.110, .036]	-1.00	.32	±.159	Yes
glide Fin 1/3	-.027	[-.099, .046]	-.72	.47	±.145	Yes

Table 8: Pairwise comparisons show the effect of vowel condition on F1/F3 ratio. Results were extracted using emmeans(), which averages over other predictors in the model: emmeans(nasalance∼CONDITION + (1 + CONDITION—SPEAKER) + (1|WORD)).

Regardless, the evidence presented here overwhelming suggests that the neutralization of vowel nasality on oral vowels is, by all measurable accounts, phonetically complete, both on the vowel itself and in its coarticulatory effects.

5 Discussion

The experiments presented above provide strong evidence for phonetically complete neutralization of vowel nasality in Mankiyali. While other comparable examples of phonetically complete neutralization have been reported in the literature, such cases remain relatively rare, in part because the evidential bar is higher. That is, it is not enough to show the absence of an effect, but rather statistical equivalence — established with the use of a statistical method like the *RoPE* approach used here — between all potential phonetic correlates of two underlyingly contrastive categories must also be established. This was the aim of the present experiments. Only a handful of other studies have reported complete neutralization, including the loss of a manner distinction between stops and fricatives in Korean (Kim and Jongman, 1996), a voicing contrast neutralization between word-initial stops in the Southern Bavarian variety of Tyrolean (Vietti et al., 2018), the neutralization of vowel length in open syllables in Dutch (Lahiri et al., 1987), pre-stop nasal consonant place assimilation in English (Ellis and Hardcastle, 2002), and pre-stop place assimilation of coronal stops in Korean (Kochetov and Pouplier, 2008).

By contrast, cases of incomplete neutralization are much more widely attested, since the evidential burden is lighter. Namely, it suffices to detect a residual difference between two underlyingly contrastive forms in any phonetic property. Well-known examples include word-final obstruent devoicing in German (Port and O'Dell, 1985), Catalan (Dinnsen and Charles-Luce, 1984), Dutch (Warner et al., 2004), and Russian (Matsui, 2015); Japanese vowel lengthening in monomoraic forms (Braver, 2013, 2019; Braver and Kawahara, 2016); flapping in American English (Braver, 2014); morphological tone in Cantonese (Yu, 2007); tone sandhi in Standard Mandarin (Zeng et al., 2025) and Huai'an Mandarin (Du and Durvasula, 2022, 2025); coda aspiration in Eastern Andalusian (Gerfen, 2002); and vowel nasality in Mixtec (Bennett and Eischens, 2026).

The presence of both complete and incomplete neutralization raises a broader question: which phonological theories can effectively account for both types of neutralization? In recent years, incomplete neutralization has often been treated as a poster child for usage-based approaches to linguistic representation (Díaz-Campos and Balasch, 2023). A few features of the theory make this true. First, under usage-based approaches, speech representations are conceived as networks of phonetically rich episodic memory traces (or exemplars) formed through language use, meaning that detailed traces of prior productions are always available at varying degrees of strength as influencers to future speech utterances (Bybee, 2023, p.14-15). Second, exemplars that are semantically and/or phonetically similar influence one another's representations and productions more strongly, leading to subtle carry-over effects across items in memory (Bybee, 2001, p.23). In line with this, grammar itself is said to *emerge* with repeated use across tokens and is not separate from the network of lexical representations (Bybee, 2001, p.3, 26-27). In other words, massive amounts of practiced repetition of patterns across words and individual speech creates an *entrenchment* effect, in which a pattern that is used repeatedly is reinforced. Over time, this reinforcement creates the effect of a systematic, rule-like, pattern without a formal grammar needed to enforce it. Finally, token frequency plays a central role: more frequent exemplars become strengthened in memory and therefore exert greater influence on production patterns than less frequent tokens (Bybee, 1985, pp. 119-123).

Taken together, these assumptions predict that phonetic traces of underlying contrasts will survive in the lexicon and resurface in production, yielding gradient cases of incomplete neutralization. The neutralization of word-final obstruent voicing in German provides a clear example. In German, voiced obstruents undergo devoicing in word-final position, causing minimal pairs like /bad/ 'bathroom' and /bat/ 'ask' to both surface as [bat]. However, Port and O'Dell (1985) demonstrated that this devoicing is phonetically incomplete: there is a small but reliable acoustic difference in the duration of preceding vowels depending on the underlying voicing of the obstruent. Specifically, the vowel in /bad/ $\rightarrow$ [bat] 'bathroom' is consistently longer than the vowel in /bat/ $\rightarrow$ [bat] 'ask'.

A usage-based approach explains this asymmetry through the highly associative structure of the lexicon. Semantically and phonetically similar forms, such as [bat] 'bathroom' and [badə] 'bathrooms', are closely linked in memory, allowing stored productions of the plural form to influence productions of the singular form. This association leaves subtle but systematic phonetic traces of the underlying voicing contrast in [bat] 'bathroom.' By contrast, [bat] 'ask' lacks semantically related forms that maintain voicing on the stop, so no comparable effects arise in its exemplars. The end result is incomplete neutralization: the voicing cues in [bat] 'bathroom' differ consistently, though subtly, from those in [bat] 'ask'.

In contrast to usage-based theories, incomplete neutralization has been viewed as a thorn in the side of generative theories that maintain static symbolic representations and a modular separation between phonology and phonetics. In classic generative approaches (Chomsky and Halle, 1968), symbolic representations serve as the input to the phonological grammar, and if two distinct representations are neutralized by the grammar, their output from the phonological grammar will be identical. Under a strictly modular interpretation of this architecture, the phonetics component operates over these neutralized outputs rather than directly over lexical representations themselves. As a result, the persistence of systematic phonetic differences between neutralized forms is surprising. In the German word-final devoicing example, then, when the phonological grammar neutralizes the obstruent voicing contrast between /bat/ 'ask' and /bad/ 'bathroom', both forms are mapped onto the same surface representation [bat]. The existence of consistent phonetic differences between these outputs therefore raises the question of how information about the underlying contrast continues to influence phonetic realization despite phonological neutralization.

In sum, incomplete neutralization is relatively straightforward to explain in usage-based models and has engendered concerns over the classic feed-forward mechanism of generative phonology.

In comparison to the rich literature on the role of incomplete neutralization in understanding the speech production process, phonetically *complete* neutralization has received little attention.

Phonetically complete neutralization follows naturally in a classic generative framework. For example, the contrasting vowels in the two Mankiyali forms, /dɪː-ɳ/ 'giant-GEN.F.SG' and /dĩː-ɳ/ 'pine firewood-GEN.F.SG' undergo phonological neutralization of vowel nasality when filtered through the phonological grammar. Though they originate from distinct URs, a phonological process requiring vowels to be [+NAS] before a nasal consonant yields identical SRs: [dĩːɳ]. Assuming no other factors play a significant role (e.g., phonological planning effects (Du and Durvasula, 2025) or cascading activation (Zeng et al., 2025)), these SRs should be indistinguishable to the phonetic system and should therefore produce indistinguishable productions (i.e., phonetically complete neutralization) precisely as observed in the experiments reported here.

As noted above, one of the benefits of usage-based models is their ability to account for cases of incomplete neutralization. Much less attention, however, has been given to whether usage-based models can also account for phonetically complete neutralization. Crucially, the very mechanisms leveraged by usage-based models to predict incomplete neutralization could make it difficult to capture complete neutralization. In Mankiyali, for instance, the present study found that the vowel nasality contrast is fully neutralized before nasal suffixes, with no residual differences between underlying oral and nasal vowels. Given the semantic and phonetic ties between forms such as oral [ɖɪː] 'giant' and neutralized oral [ɖĩːɳ] 'giant-GEN.F.SG', an eliminativist usage-based approach may incorrectly predict carry-over influences from the oral form, making the observed complete neutralization of vowel nasality in the genitive form unexpected.

More broadly, an adequate theory of speech production should be capable of explaining both phonetically complete and incomplete neutralization. While incomplete neutralization has received considerably more attention in the literature, complete neutralization poses an equally important challenge for theories of representation and production. Usage-based approaches, for example, may be able to account for complete neutralization under particular assumptions (see Paramore (2026, ch. 5) for recent usage-based computational simulations of neutralization). The central question is therefore not whether a given framework can explain one type of neutralization or the other, but rather what mechanisms give rise to complete versus incomplete neutralization and what predictions those mechanisms make.

6 Appendix: Experiment 1 Tokens

Oral Vː		Nasal Ṽː		Neutralized Oral Vː-ɳ		Neutralized Nasal Ṽː-ɳ		1-Morpheme VːN	
ziːb	'tongue'	zĩː	'louse'			zĩː-ɳ	'louse-GEN.F.SG'		
kiː	'some, few'	kĩː	'insect'			kĩː-ɳ	'insect-GEN.F.SG'		
siːd	'straight'	sĩː	'needle'					siːn	'Indus River'
piː	'fear'							piːŋg	'swing'
iː	'he'	ĩː	'Eid'						
kɪː	'that'	kɪ̃ː	'that which'					kɪːɳ	'blind women'
ʒɪː	'then'	ʒɪ̃ː	'which'			ʒɪ̃ː-ɳ	'which-GEN.F.SG'		
ɖɪː	'giant'	ɖɪ̃ː	'firewood'					ɖɪːm	'water dam'
		bɪ̃ː	'arm.F.PL'			bɪ̃ː-ɳ	'arms-GEN.F.SG'		
pɪːɖ	'food'							pɪːɳ	'sister'
guːr	'brown'	gũː	'feces'			gũː-ɳ	'feces-GEN.F.SG'		
duː	'two'	tũː	'smoke'			tũː-ɳ	'smoke-GEN.F.SG'		
		jõː	'they.ERG'			jõː-ɳ	'they-GEN.F.SG'		
luː	'heatwave'							luːɳ	'salt'
puː	'drink.IMP'	pũː	'farting'					puːɳ	'to filter'
koː	'who'	kõː	'why'					koːm	'nation'
kjoː	'cook oil'	gjõː	'wheat'	kjoː-ɳ	'cook oil-GEN.F.SG'				
poː	'soil'	põːts	'to reach'	poː-ɳ	'soil-GEN.F.SG'				
gɑː	'cow'	gɑ̃ː	'village'					gɑːm	'long stride'
bɑː	'disease'	bɑ̃ː	'arm.F.SG'	bɑː-ɳ	'disease-GEN.F.SG'				
tɑː	'fever'	tɑ̃ː	'thread'					tɑːɳ	'tautness'
sɑː	'purlin'			sɑː-ɳ	'purlin-GEN.F.SG'				
bɑːɣ	'garden'	bɑ̃ːɣ	'prayer call'					bɑːnd	'clear'

Table 9: Experiment 1 tokens, consisting of 62 monosyllabic words separated into five conditions. Rows are grouped by (near-)minimal pairs across conditions.

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