Alignment of phonetic and phonotactic evidence for the dual nasal hypothesis

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Abstract. This investigation demonstrates for the first time, phonetic evidence for a sonority-based split in the nasal natural class through case studies of Manam, Swahili, and Spanish. Previous studies on sonority have shown that phonotactic patterns as well as relative (minimum) intensity measurements indicate that nasals have lower sonority than liquids cross-linguistically. However, Kramer & Zec (2020) proposed the "Dual Nasal Hypothesis" citing new phonotactic evidence that many languages' nasal consonants are actually more sonorant than their liquids. The current investigation used relative intensity to investigate this claim phonetically. Acoustic analyses revealed that relative intensity of nasals in Manam and Swahili, were indeed significantly greater than those of the [l]s. This relationship is the opposite from what was found in the control low-sonority nasal language, Spanish. These findings coincide with the phonotactic patterns of all three languages thus supporting the Dual Nasal Hypothesis.

Keywords. Sonority, Nasals, Acoustic Phonetics, Swahili, Manam

1. Introduction. In the dominant understanding of the sonority hierarchy today, nasals are fitted broadly between obstruents and liquids. In fact, this placement of nasals has remained largely uncontested (despite other controversies surrounding the sonority hierarchy) with Parker (2002) suggesting that the minimal sonority hierarchy for all languages agreed upon by linguists is: vowels > liquids > nasals > obstruents. There has been abundant phonotactic and phonetic evidence that robustly supported this hierarchy and its universalism until more recently.

1.1. PHONOTACTIC EVIDENCE OF THE SONORITY HIERARCHY. Typologically, languages have a preference for organizing sounds into syllable units which in turn also have common structures and constraints. The constraints restricting phonemes within and across syllable boundaries are language-specific phonotactic rules. The patterns found cross-linguistically concerning these constraints have given way to several highly cited phonotactic principles that both rely on and give evidence for what we know as sonority. Unlike some other constraints in phonotactics such as restrictions on place of articulation between adjacent phonemes that concern distance in any direction (Katarzyna Dziubalska-Kołaczyk 2014), the sonority principles function broadly based on the concept of continuous sonority cycling. This can be seen in Figure 1. These principles dictate that syllables should each have one peak in sonority (the syllable nucleus) (Blevins 1995), and that syllables are more 'well-formed' if they have maximal sonority difference between each internal segment (Clements 1990; Steriade 1982) and between syllable boundaries (Gouskova 2004). These are known as the Sonority Sequencing Principle, Sonority Dispersion Principle, minimum sonority distance restrictions, and the Syllable Contact Law respectively. These principles explain why all languages permit vowels (the most sonorous category) in nucleus position, some allow very sonorant consonants in the nucleus (ex. Batibo, 2002), and very few allow less

* I would like to thank Mohammad Hossein Behboudi, Dr. Anya Hogoboom and Dr. Kate Harrigan for their help in this work along with Dr. Mandy Maguire, the members of the UTD Developmental Neurolinguistics Lab, and the William & Mary research meeting for their support and feedback. I would also like to thank the anonymous Manam, Swahili, and Spanish Speakers who provided the language samples used. Author: Rowan S. Levick, The University of Texas at Dallas (Rowan.Levick@utdallas.edu)

sonorant consonants in the nucleus (Ridouane 2014). Instead, the least sonorant sounds are more preferred in the troughs of the sonority cycles, the onsets. The moderately sonorant sounds often appear in between these two, such as second consonants in onset clusters and as codas. Therefore, where specific phonemes appear in syllables can demonstrate how sonorous they are.

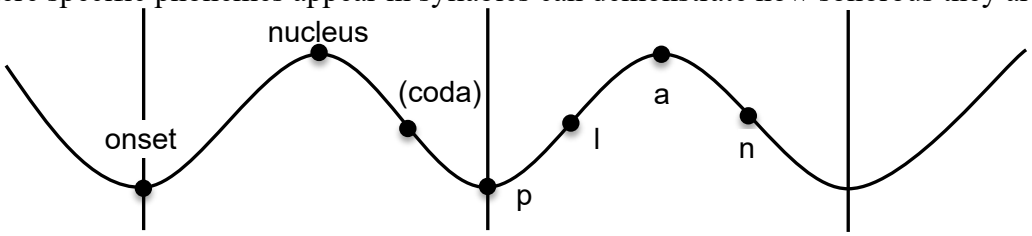

Figure 1: Sonority Wave

For an example concerning nasals, in Spanish, the onset cluster /pl/ is permitted while /pn/ is not (Shepherd 2003). This contrast between tolerance of /l/ versus /n/ in this position occurs due to their differing sonority levels along with Spanish's minimum sonority distance restriction derived from the cross-linguistic preference for greater sonority difference between adjacent segments. The cluster /pn/ violates the minimum sonority distance restriction in Spanish because /n/ is too close to /p/ in sonority. However, /l/ has high enough sonority to create an acceptable distance from /p/. Therefore, this pattern demonstrates that /n/ has lower sonority than /l/ in Spanish. This example is one of many phonotactic observations that have supported the minimal sonority hierarchy, and more specifically, the universality of the liquid > nasal ranking within it.

1.2. PHONETIC EVIDENCE OF THE SONORITY HIERARCHY. From a phonetic perspective as well, the minimal sonority hierarchy has gone unquestioned. The exact phonetic correlates of sonority are still somewhat debated with past research having investigated a wide variety of ideas, such as jaw aperture, resonance, clarity, and duration, through a variety of methods including perception, acoustic, and articulatory studies (review in Parker 2002). While it is not necessarily the sole acoustic correlate of sonority, intensity is seemingly the most studied measure with data collected from a wide variety of languages showing consistent and robust alignment with the minimal sonority hierarchy (Parker 2008; Jany et al. 2007; Schröer 2020). These findings suggest that acoustic intensity is correlated with the phonological concept of the sonority feature and that this relationship and hierarchy are applicable across languages.

Concerning acoustic correlates specifically, duration has also been shown to have an inverse relationship with sonority (Parker 2002). However, in that study, this duration relationship was less consistent than that of intensity with speakers demonstrating some reversals of the expected sonority rankings. Schröer (2020) also concludes that mean and minimum intensity correlate well with sonority, though he reports that duration too has a meaningful involvement that can be accounted for using a measure of periodic energy. Periodic energy is a similar measure to intensity though is more complex and specific to perceptible variation. For this reason, along with its strong alignment with the sonority hierarchy and phonotactic behavior, models using this measure have been popularized more in recent years (ex. Albert & Nicenboim 2022). Beyond giving further evidence for the sonority hierarchy and phonotactic restrictions based on it, these periodic energy findings also importantly serve to connect the strong intensity-sonority relationship with actual effects on perception.

1.3. THE DUAL NASAL HYPOTHESIS. Though previous phonetic and phonotactic evidence had yielded a consistent conclusion about the relative sonority ranking of nasals and liquids, a more recent cross-linguistic survey of phonotactics calls the universality of the nasal sonority ranking

into question (Krämer & Zec 2020). This study revealed that nasals follow two distinct patterns, which, given the discussed sonority principles, indicate the existence of both a low-sonority and a high-sonority nasal. The former is the previously documented class of nasals which are less sonorous than liquids, and the latter demonstrates plain nasals patterning as more sonorous than liquids. For example, a language with low-sonority nasals may only allow obstruents and nasals, but no liquids, in onset position, while a language with high-sonority nasals may in theory allow only obstruents and liquids as onsets, but no nasals (recall that lower sonority is preferred in onsets). Krämer & Zec (2020) also discuss languages that demonstrate both nasal types in complementary (usually by syllable position), and contrastive distribution. There are many possible language-specific phonotactic restrictions that would indicate a language's nasal typology. Even some other phonological clues could perhaps aid determining nasal typology as previous research has shown cases of assimilation where nasals align with either obstruents or very sonorant groups like vowels (Botma 2004, Durvasula 2009).

1.4. CURRENT STUDY AIMS. Importantly, these phonotactic findings are inconsistent with prior assumptions of the universality of the liquid > nasal ordering in the classical sonority hierarchy and prior phonetic studies of that ordering. While phonotactic evidence to support an alternative dual nasal model is provided in Krämer & Zec's (2020) study, it includes no phonetic evidence. There being measurable physical differences is important to rule out alternative explanations of this phonotactic discrepancy and to further understand what drives the sonority difference between nasal types. Phonetic evidence is also important as some linguists in the past have taken issue with the cyclical logic of sonority and phonotactic principles alone (ex. Ohala 1990a). For these reasons, it is the task of the current study to initiate an exploration into phonetic evidence as it relates to this high-sonority nasal hypothesis. The findings will serve as the first phonetic investigation for the hypothesis and ensure that our understanding of the phonetic correlates of sonority is sound universally, including in languages with the high-sonority nasal phonotactic behaviors. Toward this goal, the current study compares intensity (and duration) between lateral liquids and plain nasals in languages whose phonotactics indicate high-sonority nasal typology.

> HYPOTHESIS: If it is true 1) that there is a sonority-based split in the nasal natural class and 2) that intensity correlates with sonority, then languages theorized to contain high-sonority nasals should demonstrate higher relative intensity in nasals than in their lateral liquids. This relationship should be the inverse in a control language previously shown to have nasals of lower sonority (and intensity) than lateral liquids.

2. Methods. Two languages were chosen to represent high-sonority nasal languages: Manam and Swahili. Both languages were selected based on the following criteria:

1. Fulfilling the phonotactic requirements for having high-sonority nasals[1] and not also showing evidence of low-sonority nasals
2. Presence of the lateral liquid [l] in the language's inventory
3. Both nasals and [l]s present in onset position
4. High percentage of CV(V) syllables

[1] For Manam, the satisfactory high-sonority nasal patterning is discussed at length in Krämer & Zec (2020) where only nasals can occur in coda position (Lichtenberk, 1983). For Swahili, Batibo (2002) and Mwangi (2010) note that nasals are the only consonant permitted in the nucleus of a syllable, which is an acceptable indication of high-sonority nasals according to Krämer and Zec (2020).

5. Lack of a tonal system that may affect intensity (Chen 2005)

An additional language, Spanish, was selected to serve as a control, demonstrating low-sonority nasals. Spanish has already been shown to meet the phonotactic criteria for low-sonority nasals (Shepherd 2003) as well as demonstrate phonetic corroboration (Parker 2008).

Existing field recordings of one speaker of each language were used to collect nasal and [l] tokens (Global Recording Network: Manam, Mexican Spanish; Word Project: Swahili). All speakers were perceived to be adult males (unknown ages) with 100% consistency between five raters. Other speaker information was not available. Praat (Boersma & Weenink 2025) hand-segmentation was performed to isolate tokens of nasals including [m], [n], [ɲ], and [ŋ], as well as of the lateral liquid [l]. Token boundaries were determined via visual inspection of the spectrogram and oscillogram. Auditory determinations were also used as needed to supplement. 0.001s timesteps of intensity were used to identify mean and minimum intensity from each token as well as maximum intensity measure of the following vowel to identify a 'syllable maximum'. There were 286 nasal and 105 [l] tokens collected from Manam, 221 nasal and 175 [l] tokens collected from Swahili, and 322 nasal and 79 [l] tokens collected from Spanish. For nasals, this is further broken down as 166 [m]s, 96 [n]s and 30 [ŋ] in Manam, 78 [m]s, 125 [n], and 28 [ɲ]s in Swahili, and 174 [m]s, 132 [n]s, and 16 [ɲ]s in Spanish. All tokens were collected from stressed, intervocalic positions.

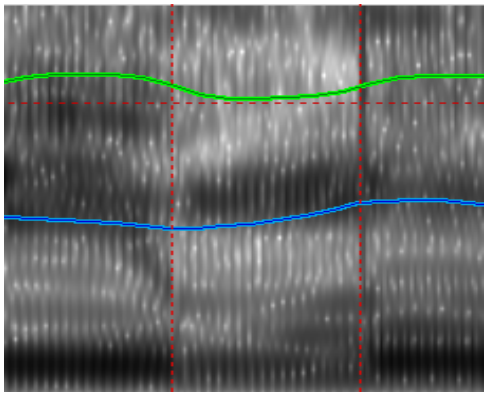

Image 1: Example of [m] token in Swahili

Additionally, mean and minimum for each token was relativized based on the syllable maximum (syl max). This method is similar to Parker's (2008) for Spanish where values were adjusted based on a specific [a] token in each phrase. However, syllable relativization is more suited to the phrase variability of the more naturalistic data used here. The value of {token minimum - syl max} instead of raw minimum (or mean) across tokens represents the dip (or range) in intensity between the consonant and following vowel across tokens. This method helps account for any individual variation between the syllables where measures were taken from.

3. Intensity Analyses.

3.1. INTENSITY BY LANGUAGE AND TOKEN TYPE. Two-way ANOVAs were performed in R to evaluate the main and interaction effects of TOKEN TYPE (nasal vs [l] status) and LANGUAGE on RELATIVE MINIMUM INTENSITY (token minimum - syl max) and RELATIVE MEAN INTENSITY (token mean - syl max) while controlling for HEIGHT of following vowel. Then, estimated marginal means were calculated and pairwise contrasts were run for nasal and [l] tokens in each language.

The interaction of TOKEN TYPE and LANGUAGE: SPANISH was significant ($p < .0001$) compared to both the other languages for both intensity measures. There was no significant interaction for TOKEN TYPE and LANGUAGE: SWAHILI compared to LANGUAGE: MANAM for either intensity measure ($p > .05$). The summaries of these individual between-language analyses for RELATIVE MINIMUM INTENSITY (R MIN) are shown in Table 1. The inverted token type effect on intensity in Spanish compared to the other two languages can also be observed through the within-language pairwise contrasts. The pairwise contrasts for R MIN are listed in Tables 2 and 3. Spanish demonstrates significantly greater [l] than nasal intensity ($p < .0001$) while Manam and Swahili oppositely demonstrate significantly lower [l] than nasal intensity ($p < .0001$). The model-adjusted mean differences in R MIN between nasals and [l]s for Manam, Swahili, and Spanish were 1.96dB, 2.11dB, and -3.64dB respectively. For R MEAN, these values were 1.78dB, 2.04dB, and -4.28dB respectively. Intensity results are visualized in Figures 2 and 3. Outputs for other intensity measure models including R MEAN, and raw intensities can be found here.

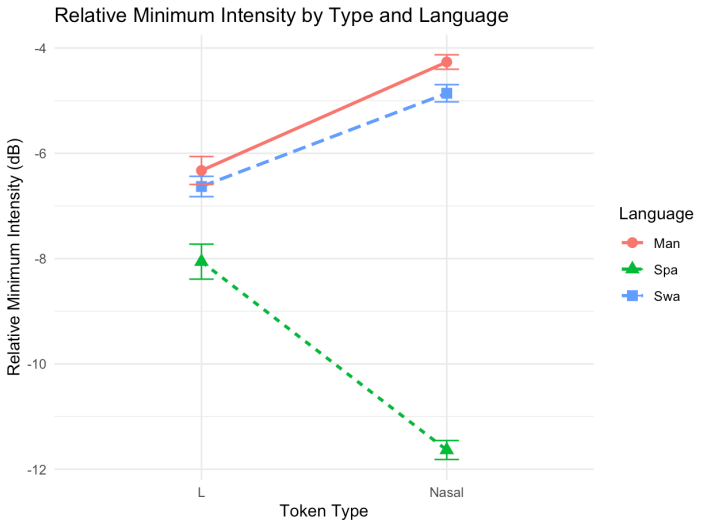

Figure 2: RELATIVE MINIMUM INTENSITY by TOKEN TYPE and LANGUAGE

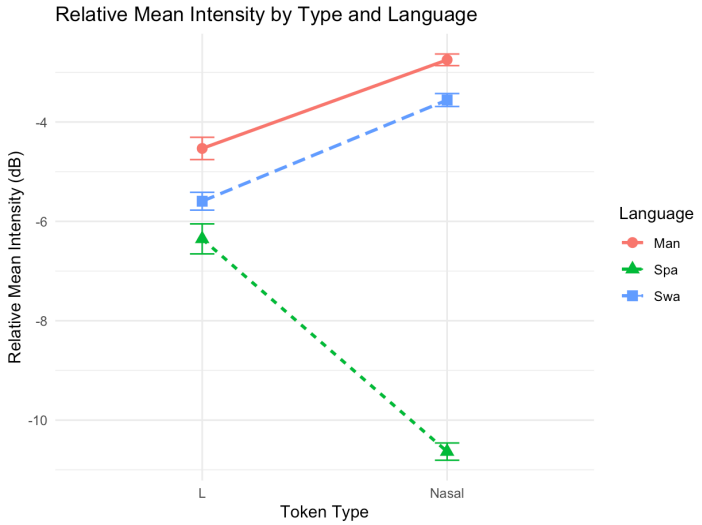

Figure 3: RELATIVE MEAN INTENSITY by TOKEN TYPE and LANGUAGE

Model	Effect	DF	Sum Sq	Mean Sq	F value	Pr(>F)
Manam - Spanish	Type: Language	1	1091	1091	140.47	< 2e-16 ***
Spanish - Swahili	Type: Language	1	1267	1267	159.82	< 2e-16 ***
Manam - Swahili	Type: Language	1	0	0.5	0.078	0.77998

Table 1: TOKEN TYPE-LANGUAGE interaction effects: RELATIVE MIN INTENSITY

Language	contrast	esti-mate	SE	df	t.ratio	p.value
Manam	L - Nasal	-1.96	0.310	1200	-6.389	<.0001 ***
Swahili	L - Nasal	-2.11	0.278	1200	-7.580	<.0001 ***
Spanish	L - Nasal	3.64	0.340	1200	10.712	<.0001 ***

Table 2: Within language pairwise contrasts: RELATIVE MIN INTENSITY

Token Type	contrast	estimate	SE	df	t.ratio	p.value
Type: L	Manam - Spanish	1.841	0.402	1200	4.574	0.0001 ***
	Manam - Swahili	0.703	0.341	1200	2.061	0.0986
	Spanish - Swahili	-1.138	0.370	1200	-3.073	0.0004 ***
Type: Nasal	Manam - Spanish	7.442	0.219	1200	34.020	<.0001 ***
	Manam - Swahili	0.558	0.238	1200	2.348	0.0498 *
	Spanish - Swahili	-6.884	0.234	1200	-29.449	<.0001 ***

Table 3: Between language pairwise contrasts by TOKEN TYPE: RELATIVE MIN INTENSITY

Though relative intensity values control for syllable difference, models with the non-relativized mean and minimum intensity values (raw measures) also showed all the same within language significant effects from token type as their relativized counterparts. With these raw values, there was no significant main effect of vowel height, so it was not added as a covariate.

4. Duration Analysis. Duration for each token was also collected, and a two-way ANOVA was performed in R to evaluate the main and interaction effects of TOKEN TYPE and LANGUAGE on DURATION. Additionally, estimated marginal means were calculated and pairwise contrasts were run for DURATION of both nasal and [l] tokens in each language. Within Swahili, there was no significant effect of TOKEN TYPE on DURATION. Spanish did demonstrate an individual significant effect of TOKEN TYPE on duration ($p < .05$) with the model adjusted mean increase from [l] to nasal tokens being 5.489ms. Manam also showed a significant effect ($p < .001$) in the same direction with the model adjusted mean increase from [l] to nasal tokens being 12.028ms. There were also significant TYPE - LANGUAGE interaction effects between Manam and Swahili and between Manam and Spanish ($p < .05$) demonstrating that the [l] - nasal duration relationship was significantly different in Manam than the other languages but not between Spanish and Swahili. Additionally, [l]s and nasals had significantly different durations between languages ($p < .0001$). The summaries of these analyses are listed in Tables 4-6 and visualized in Figure 4.

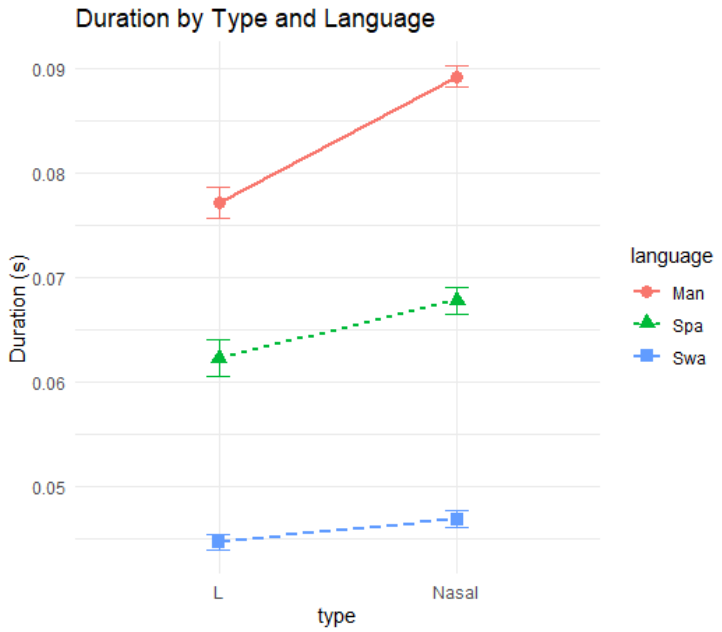

Figure 4: DURATION by TYPE and LANGUAGE

Model	Effect	DF	Sum Sq	Mean Sq	F value	Pr(>F)
Manam - Swahili	Type: Language	1	0.00426	0.00426	20.14	8.25e-06 ***
Manam - Spanish	Type: Language	1	0.00149	0.00149	3.903	0.0485 *
Spanish - Swahili	Type: Language	1	0.00043	0.00043	1.432	0.232

Table 1: TOKEN TYPE-LANGUAGE interaction effects: DURATION

Language	contrast	estimate	SE	df	t.ratio	p.value
Manam	L - Nasal	-0.01203	0.00196	1201	-6.149	<.0001 ***
Swahili	L - Nasal	-0.00216	0.00173	1201	-1.250	.2114
Spanish	L - Nasal	-0.00549	0.00217	1201	-2.533	.0114 *

Table 2: Within language pairwise contrasts: DURATION

Token Type	contrast	estimate	SE	df	t.ratio	p.value
Type: L	Manam - Spanish	0.0149	0.00257	1201	5.810	<.0001 ***
	Manam - Swahili	0.0325	0.00212	1201	15.318	<.0001 ***
	Spanish - Swahili	0.0176	0.00234	1201	7.538	<.0001 ***
Type: Nasal	Manam - Spanish	0.0214	0.00139	1201	15.390	<.0001 ***
	Manam - Swahili	0.0424	0.00152	1201	27.959	<.0001 ***
	Spanish - Swahili	0.0210	0.00149	1201	14.104	<.0001 ***

Table 3: Between language pairwise contrasts by TOKEN TYPE: DURATION

5. Discussion and Limitations.

5.1. INTENSITY. All three languages displayed the intensity relationship between [l] and nasal tokens that was predicted by their phonologically determined sonority rankings. Manam and Swahili demonstrated higher relativized and raw mean and minimum intensity for nasals than for [l]s indicating the presence of high-sonority nasals. Spanish was significantly different demonstrating the opposite pattern: nasals having lower relative and raw mean and minimum intensity than [l]s on average. The decibel difference in Spanish between nasals' and [l]s' relative minimum intensity was similar to Parker's (2008) report of a 3.3dB difference between the groups (the current study reports a 3.64dB difference). The combination of the findings from these three languages is consistent with the Dual Nasal Hypothesis which proposes that different high- and low-sonority nasals exist cross-linguistically (Krämer & Zec 2020).

It is, however, important to note patterns in the intensity data that are not predicted by nasal sonority type differences. First, while the relationship between type and intensity was not significantly different between Manam and Swahili, overall intensity of both token types was significantly different in the majority of intensity comparisons between all languages. Manam consistently had the highest intensity, and Spanish consistently had the lowest. This is likely due to individual speaker differences such as volume or distance from the microphone. Because the interaction of language and token type on intensity was not significantly different between Manam and Swahili, only between Spanish and the other two, this does not pose an issue to the stated conclusions. It would, however, be helpful for future work to include more speakers and normalize levels between recordings to ensure there are no other factors at play here.

5.2. DURATION. Even though duration has been shown to be related to sonority (Parker 2002; Schröer 2020) the split pattern in nasal sonority does not emerge for duration like it does with intensity. Instead, nasals have a greater duration across languages, though there is much variation between languages. It is possible that the main effect of language on duration is the result of speech rate variation between speakers or languages (Coupé et al. 2019). It is also likely that this main effect impacts the interaction effect as there is less room for raw duration variation by token type when all segments are shorter. Given this, a proportional rather than raw duration analysis of interaction effect of language and token type would be helpful in future work, or an analysis that maps tokens by multiple variables such as intensity and duration simultaneously. This could reveal if duration is still related to sonority and the relationship is actually being masked in the current analysis by a feature that affects duration more strongly than sonority. Therefore, even though the duration findings appear inconsistent with the intensity and phonotactic evidence for the Dual Nasal Hypothesis, more research is needed to understand these results. However, even if further investigation does not yield duration findings consistent with intensity and phonotactics, it is more likely that duration is not truly correlated with sonority instead of intensity given the robust history of alignment between intensity and phonological sonority, including in the current study. Additionally, as previously mentioned, some research isolating duration has found it to be less consistent than other measures like intensity, especially with more sonorous phones (Parker 2002). It's possible that the duration - sonority association in past literature was mediated by another variable and likely that the duration findings from the current data and analysis do not truly reflect sonority.

5.3. OTHER TOKEN INTENSITY VARIATION. As the data was collected from existing recordings, not controlled laboratory elicitations, even though tokens all came from stressed intervocalic environments, there were other elements of the phonological environment that varied between

tokens. These factors include phrase/word level prosody, following vowel, token place of articulation, and word-mediality (in Spanish and Manam). Using relativized intensity measures helps control for overall intensity variation such as what may be caused by prosodic variation. In this case, the process of obtaining relativized measures relied on the following vowel, thus introducing the risk for further effects from following vowel variation in the data. Therefore, [+/- high] status of the following vowel was controlled for in the relative intensity models since high vowels are reported to have lower intensity and sonority than low vowels (Parker 2008). When examining the main effects of vowel height, [+high] tokens yielded significantly greater (less negative) relative mean in all three languages as well as relative minimum in Spanish. This indicates that [+high] vowels are closer in intensity to the consonants than [-high] vowels, an unsurprising result considering Parker's (2008) findings. The effect showing up most prominently in relative mean intensity is also unsurprising given the nature of means including values at segment boundaries, which are values more likely to be influenced by the surrounding segments. However, the variation between languages, especially in the case of relative minimums, suggests that further analysis of the behavior of each language's vowels is necessary in order to know how to properly control for vowel features in the relative intensity analyses. Although all three languages use a five vowel /a,e,i,o,u/ system, it is possible that vowels are not identical or that they demonstrate different variation between languages especially in the post-nasal position.

For nasal place of articulation, Manam was the only language to display a significant effect. However, a higher percentage of [m] tokens in Manam than other nasal subtypes were followed by a [-high] vowel. Because there was also a significant positive effect of height on intensity in Manam, it is likely that this was confounding the results. An additional model using raw intensity values instead of relative showed no significant main effect of subtype [m]. With this finding, it would seem that overall, place of articulation, specifically for nasals, does not significantly impact intensity and thus sonority. Therefore, nasal place of articulation was not controlled for in the intensity models from section 3.

In the current study also, collection of onset vs coda and word-medial status is only controlled for in Swahili with strictly word-medial onsets being collected. Status of these variables for each token was recorded in Spanish (25 word-final nasals and 20 word-final [l]s, 119 word-initial [n]s and 27 word-initial [l]s) but that information was not available for Manam. There were no main effects found from this variation in Spanish. Therefore, these tokens were included the final dataset as they were still intervocalic and much research, including with Spanish, suggests that intervocalic word-final codas are resyllabified as onsets (ex. Colina 2009a). In lieu of being able to obtain a transcript for Manam recordings, Spanish findings were extrapolated to assume any possible effects of token syllable position in Manam unlikely to be significant, at least in regard to interaction with the main effect of token type. However, given other differences between the nasals of both languages, this assumption should be checked in future work.

5.4. LIMITATIONS. While there were significant results from this study that supported the hypothesis, and even though phonological environment factors were controlled in the data and analysis, there are significant limitations to this preliminary acoustic investigation of high-sonority nasals. As mentioned above, inconsistency concerning vowel feature effects warrants further testing as do differences in overall token intensity measures between languages. Because at least the latter of these inconsistencies, is possibly the result of individual speaker variation, this finding exemplifies the need to expand this investigation beyond case studies and include multiple speakers as is more standard in phonetics literature. It is also possible that there are other less apparent effects on the data and results due to this issue. Similarly, it will benefit the data and

ease of analysis to use tokens collected during a controlled elicitation. This will ensure that phonological and phrase environment, as well as recording environment and equipment are all controlled for. It is perhaps unlikely that something such as recording environment coincidentally influenced the data for all languages to be in exact alignment with their phonotactic predictions, especially since Spanish token decibel differences were very similar to what was found in past research (Parker 2008), though there is still a need for this possibility to be eliminated. The final limitation of note is the lack of articulatory or perceptual acoustic measures in this study. Further research with the data from this study and future studies should elect to also include periodic energy. Intensity may correlate with sonority, though it alone is not a variable used in human speech processing (Albert & Nicenboim 2022). Of course, for children acquiring languages that have both nasal types contrastively, there must be a perceptible difference distinguishing them. So, comparisons using periodic energy in the future are quite important for expanding this research into auditory (and acoustic-articulatory correlate) investigations.

Lastly, as this study does not investigate articulation and only uses intervocalic tokens, it does not provide support for the part of the Dual-Nasal Hypothesis which asserts that the sonority difference between the nasal types is due to a specification or lack of specification of the continuant feature (Krämer & Zec, 2020). It is also unclear how this difference in specification of the continuant feature would be predicted to affect articulation in such a way that would yield the present intensity contrasts between intervocalic nasals cross-linguistically. It is worth investigating other possible featural differences too that could exist between the two types of nasals investigated in this study or alternatively acknowledging sonority as an independent feature that is affected by other features incidentally through some common articulatory correlate. Investigations that include tokens from other syllable environments may be helpful toward clarifying the scope of phonetic variation. Overall, evidence to support a specific featural difference or articulatory correlate is beyond the ability of the current study.

6. Conclusion and Future Directions. The study discussed here demonstrates for the first time phonetic evidence for a sonority-based split in the nasal natural class. By comparing intensity measures of nasal and liquid tokens between Manam, Swahili, and Spanish, clear patterns of high and low nasal sonority emerged. Thus far, these are only single-speaker case studies and have notable limitations to the data, though measures are being taken to address these in future studies. Regardless, these findings still provide support for Krämer & Zec's (2020) Dual Nasal Hypothesis, challenge the universality of the liquid > nasal sonority ranking, and generally, further exemplify the need for always expanding typology and phonetics research to include more underrepresented languages. The findings from this study also provide increased evidence of the sonority-intensity association and pose possible concerns for the sonority-duration one.

This study should also pave the way for future work to further solidify acoustic findings and explore nasal sonority with different methodologies. In particular, investigating acoustic periodic energy, articulatory measures, and perceptive differentiability of nasals would be helpful for expanding on this nasal sonority research. Additionally, there are many more languages which merit investigation as their phonotactics predict them to have high-sonority nasals in a variety of capacities. It should also be possible to use acoustic methods such as those from the current study or other future phonetic studies to investigate nasal typology in languages with lesser documentation or opaque phonotactics. Hopefully increased phonetic exploration on this topic can also provide clues for the underlying cause of this sonority and intensity difference between the two proposed nasal classes.

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