Modeling Phonetic Neutralization in Exemplar Theory

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INTRODUCTION. Since the 1980s, numerous studies have shown that phonological neutralization can be phonetically incomplete[1][2], challenging classic generative theories that predict categorically identical phonetic targets for neutralized forms. In contrast, Exemplar models have been argued to account for such cases naturally.[3][4] This paper presents computational implementations of exemplar theory showing that, under core connectionist assumptions, exemplar theory does indeed predict phonetically *incomplete* neutralization. However, the same mechanisms that support this prediction prevent the theory from modeling *complete* neutralization.

NEUTRALIZATION. *Incomplete* neutralization occurs when underlyingly distinct segments become less distinct in specific contexts while maintaining consistent and measurable differences in their acoustic realizations. For example, in Japanese, short vowels lengthen in isolation to satisfy bimoraic minimality (e.g., [kii] 'tree'), neutralizing the contrast with underlying long vowels (/kii/ 'key') — yet derived long vowels remain measurably shorter than underlying long vowels.[2] In contrast, *complete* neutralization shows no such trace: for example, in Mankiyali, a vowel nasality contrast is fully neutralized before nasal suffixes, with no residual nasality differences.[5]

In connectionist exemplar models, no formal grammar exists. Instead, the lexicon comprises a vast network of phonetically detailed memories (exemplars) of individual words, in which the strength of connection between exemplars increases as semantic and phonetic similarity increases. The fundamental assumption that enables these models to account for incomplete neutralization is the interconnectedness of similar exemplars influencing future productions. For Japanese speakers, the short vowel in a word like [kimo] 'also tree' exerts a strong influence on the production of the vowel in [kii] 'tree' due to their shared morphology. This influence perturbs the lengthening of the vowel, resulting in incomplete neutralization.

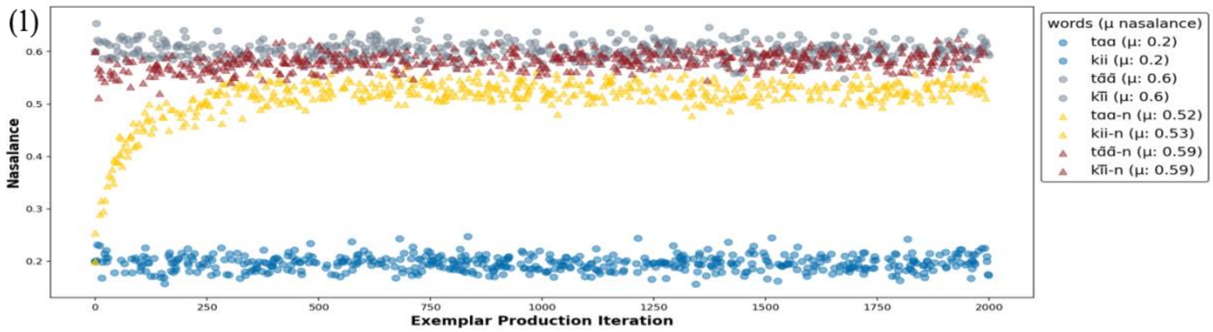
With that said, this same mechanism makes it difficult for exemplar models to account for complete neutralization. In a case like Mankiyali, for example, the oral vowel in [ɖɪɪ] 'giant' should influence [ɖɪ̃ɪ̃ɳ] 'of the giant', making the observed complete neutralization of nasality unexpected.

COMPUTATIONAL MODEL. To test whether connectionist models can capture both types of neutralization, I developed an algorithm that simulates the neutralization of vowel nasality before nasal suffixes through the accumulation of exemplars. The input to the model consists of four word categories: two base nominative categories (ORAL and NASAL) and two genitive categories with a nasal suffix (ORAL-N and NASAL-N), each starting with two word forms that contain a single exemplar. ORAL and ORAL-N forms begin with low nasalance (.2), while forms in the NASAL and NASAL-N conditions begin with high nasalance (.6), reflecting underlying orality and nasality.

During each iteration, a word form is selected based on pre-specified frequencies, and the mean nasalance of that form's current exemplars is used to generate a new exemplar. The value is optimized by scipy.optimize in Python to minimize an objective function composed of (i) a channel bias favoring nasalization before nasal consonants, (ii) a morphological bias penalizing deviation from a base form's nasalance, and (iii) a category bias that penalizes deviation from other forms within an inflectional category. Morphological and category penalties are scaled by the relative frequency of connected forms, simulating the stronger influence of high-frequency items. Random noise is then applied to the form to imitate natural phonetic variation, and the resulting nasalance value is added to the form's exemplar cloud. Repeating this process thousands of times causes each form's exemplar cloud to accumulate exemplars and evolve in response to a given form's usage frequency, morphological relationships, and category members.

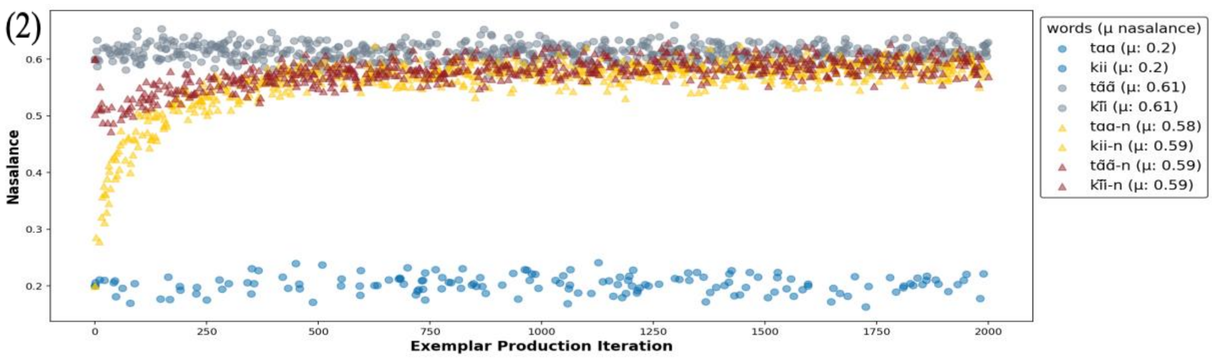
The plot in (1) shows nasalance over 2000 iterations for each category when all categories occur with equal frequency. Each point represents an exemplar, with nasalance on the y-axis and iteration on the x-axis. Genitive forms with underlying oral vowels (yellow) show rapid increases in nasalance early on in the simulation due to the combined influence of channel and category biases. However, their nasalance plateaus below that of underlying nasals because they are constrained by the influence of their base ORAL forms. The result is incomplete neutralization: ORAL-N vowels become more nasalized over time but remain measurably distinct from underlying nasal vowels.

(1)



Two strategies are possible to simulate complete neutralization. One is to increase the weight of the channel bias, further penalizing low-nasalance ORAL-N vowels. However, connectionist exemplar models lack a mechanism for adjusting bias weights directly. The only alternative within the model is to modulate influence through token frequency. Specifically, reducing the frequency of ORAL base forms weakens the morphological bias that penalizes nasalance in ORAL-N forms. In the simulation shown in (2), complete neutralization is achieved only when base ORAL forms are approximately four times less frequent than their genitive ORAL-N counterparts.

(2)



CONCLUSION. While such frequency asymmetries may arise for individual items, it is implausible to assume that nominative forms are systematically less frequent than their genitive counterparts across the lexicon. Without a separate mechanism to calibrate the strength of competing phonetic pressures, then, exemplar theory must rely on unnatural frequency manipulations to account for both types of neutralization. As such, I argue that a hybrid model is needed to model both types of neutralization — one that maintains the representational richness of exemplars while allowing for formal, grammar-like calibration of phonetic biases.

[1] Port, R. & M. O'Dell. (1985). Neutralization of syllable-final devoicing. *J. of Phonetics.* [2] Braver, A. (2019). Modeling neutralization with weight constraints. *Phonology*. [3] Bybee, J. (2001). *Phonology & Lang. Use.* [4] Pierrehumbert, J. (2002). *Word-specific phonetics.* [5] Paramore, J. (2025). *Phonetically complete neutralization in Mankiyali.*