Modeling Neutralization in Exemplar Theory

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What is Neutralization?

- When a phonological contrast in a language is lost in certain contexts.
- Example cases of neutralization:
  - Obstruent Voicing in Russian (Matsui, 2015)
  - Vowel length in Japanese (Braver, 2019)
  - Vowel nasality in Mankiyali (Paramore, 2025)
  - Manner of articulation in Korean (Kim & Jongman, 1996).
- The phonetic realization of phonological neutralization can be **complete** or **incomplete**.

Phonetically Incomplete Neutralization

- Residual phonetic traces of the underlying phonological contrast persist in the acoustic record.

i.	/ki-mo/	→	[kimo]	tree-PART	μ duration of [i]: 50 ms
ii.	/kiː/	→	[kiː]	key	μ duration of [iː]: 157 ms
iii.	/ki/	→	[kiː]	tree	μ duration of [iː]: 125 ms

Table 1: *Vowel Lengthening in Japanese.* *(Braver, 2019)*

Phonetically Complete Neutralization

- No measurable surface differences in the neutralized contrast.

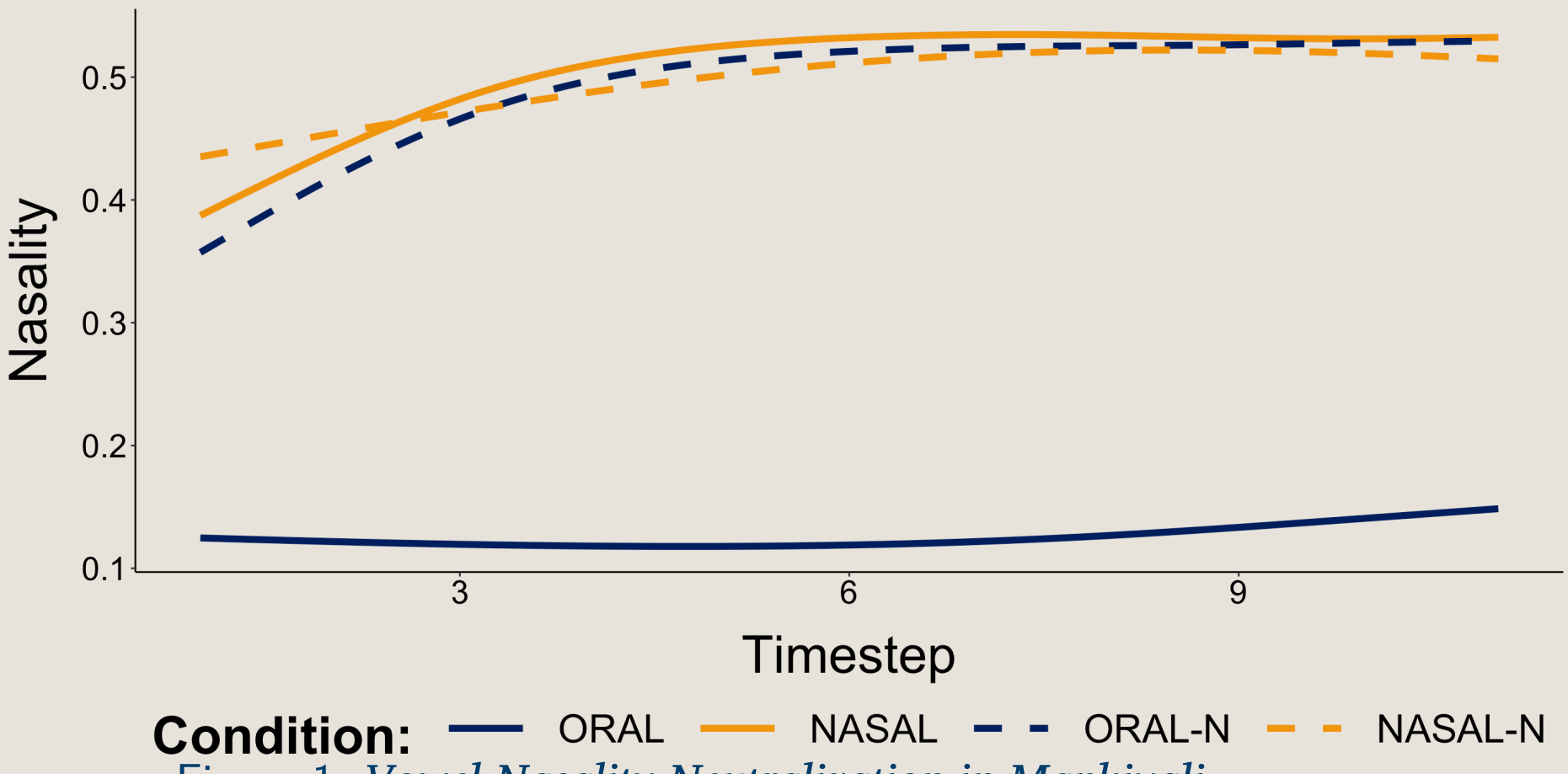


Figure 1: *Vowel Nasality Neutralization in Mankiyali.* *(Paramore, 2025)*

This Paper

- **Research Question**:
  - Within an eliminativist exemplar-theoretic framework, is it predicted that we should observe both types of neutralization?
- **Computational model of exemplar accumulations**:
  - Naturally predicts either incomplete or complete neutralization.
  - Barring unnatural token frequency effects, both types of neutralization are difficult to generate.

What is Exemplar Theory?

- A cluster of theories with the common view that language use is the main driver of linguistic cognition (Bybee, 2001; Goldinger, 1998; Goldrick & Cole, 2023; Johnson, 1996, 2006; Kaplan, 2015; Nosofsky, 1986; Pierrehumbert, 2001, 2016).
- The assumptions followed here are based closely on Bybee (2001), Pierrehumbert (2001), and Kaplan (2015).

Core Assumptions of Exemplar Theories

1. Speech representations are networks of phonetically rich memories/*exemplars* formed through use (Bybee, 2023, p.14-15).
2. Grammar *emerges* with repeated use and is not separate from lexical representations (Bybee, 2001, p.3, 26–27).
3. Semantically or phonetically *similar* exemplars are strongly linked in memory and influence one another (Bybee, 2001, p.21-23).
   - The base member of a paradigm asymmetrically influences other forms (Albright, 2002; Kaplan, 2015).
4. Token *frequency* impacts representation. More frequent exemplars are strengthened in memory (Bybee, 1985, p.119-123).
5. *Production biases* can shift exemplar categories over time (Pierrehumbert, 2001, p.146-148).

Modeling Neutralization

- *Model Overview*: Simulation of vowel nasality neutralization over time for an individual speaker.
- *Model components*:
  - **input**: four categories consisting of lexical items with pre-specified frequencies.
  - **exemplar accumulation**: iteratively creates new optimized exemplars based on eliminativist exemplar principles.
  - **output**: plot showing evolution of the four categories' nasality values over 1,000 iterations.

Model Input

- Four categories with two lexical items each.
  1. **ORAL**: [taɑ], [kii]
  2. **NASAL**: [tãɑ̃], [kĩĩ]
  3. **ORAL-N**: [taɑ-n], [kii-n]
  4. **NASAL-N**: [tãɑ̃-n], [kĩĩ-n]

- Each lexical item seeded with a single exemplar.
  - Content corresponds to vowel nasality
  - Nasality of ORAL and ORAL-N vowels ~ 0.2 (sd $= .015$)
  - Nasality of NASAL and NASAL-N vowels ~ 0.6 (sd $= .015$)

- Frequencies of each category in relation to other categories.

Exemplar Accumulation

Step 1: selection
Randomly select 1 of the 8 lexical items

↓

Step 2: entrenchment
Set nasality to mean of item's cloud

↓

Step 3: optimization
Optimize nasality based on examplar biases

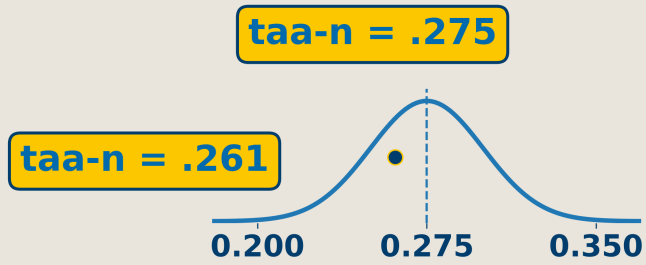
↓

Step 4: noise
Add random noise to the nasality value

↓

Step 5: storage
Store the new exemplar

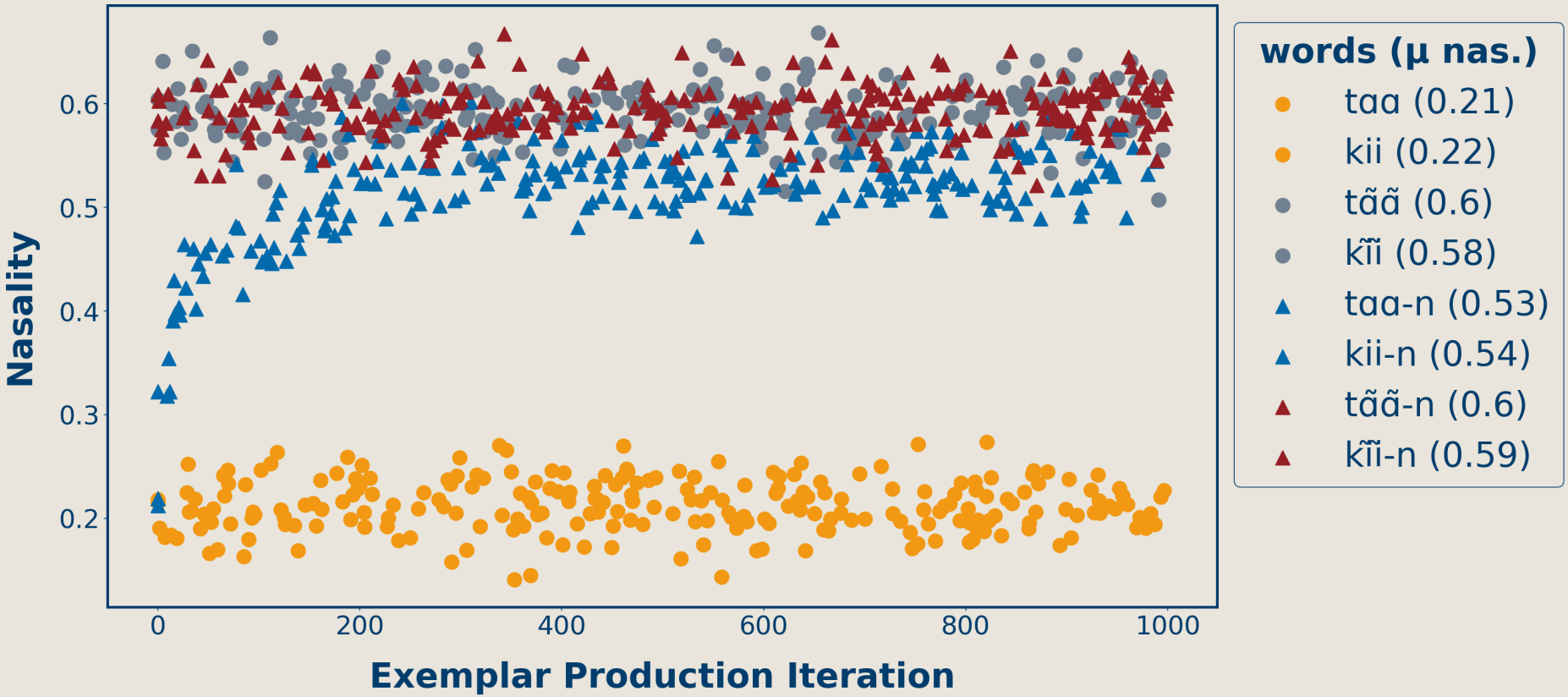
1. pre-N production bias: $5 \times (\text{NASAL} - \text{taa-n})^2$
2. morphological bias: $\text{FREQ} \times (\text{ORAL} - \text{taa-n})^2$



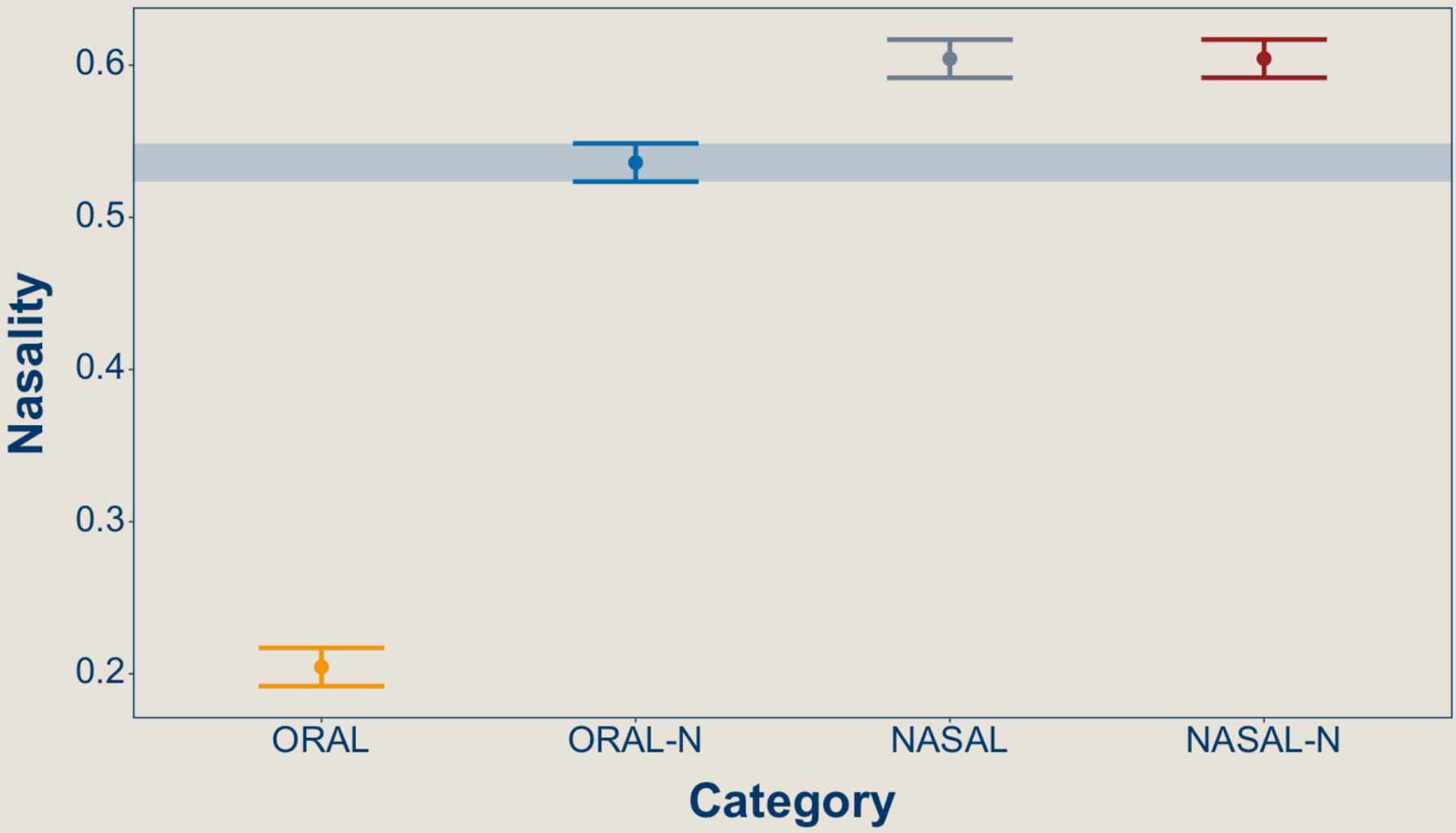
taa-n : [.18, .22, .261]

Modeling Incomplete Neutralization

Exemplar Changes in Nasality Over Time, Simulation 1



Estimates over 100 Simulations



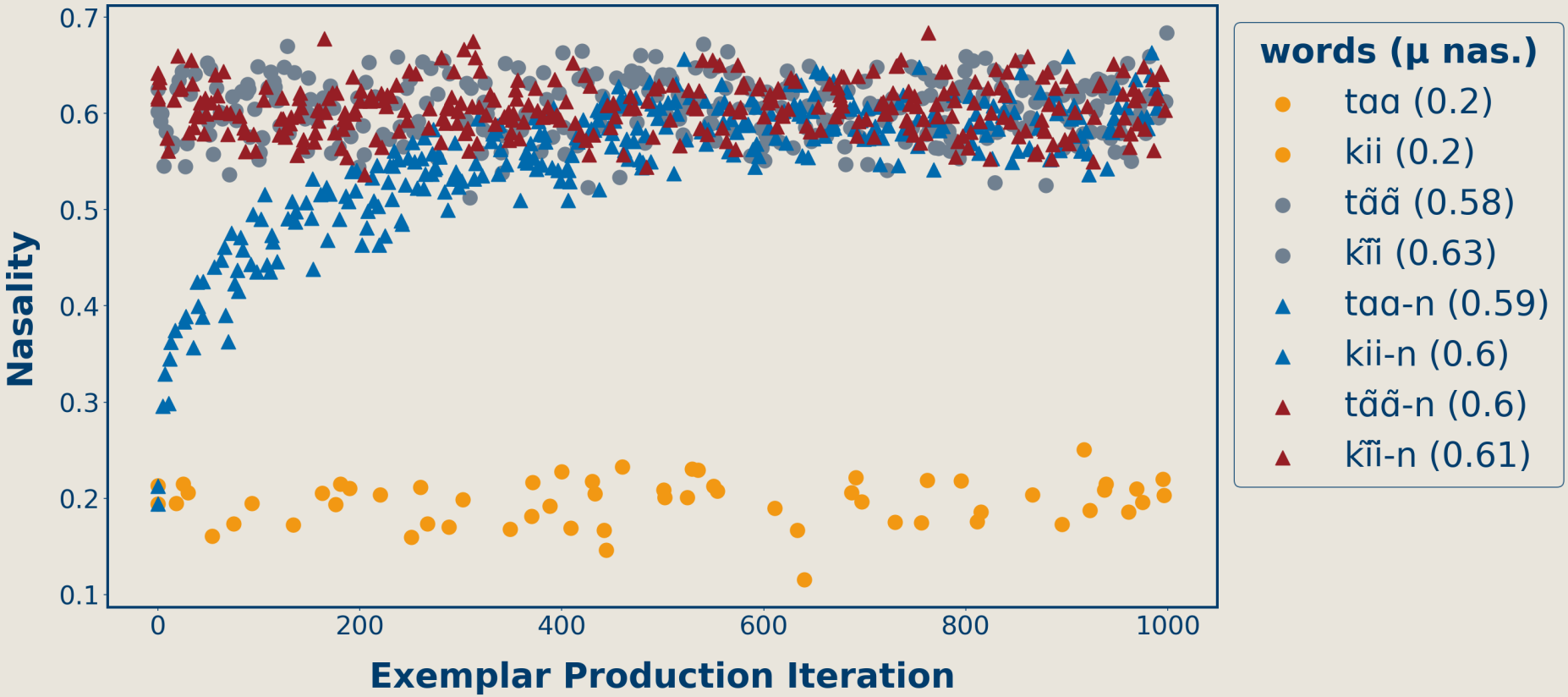
Frequency-Driven Complete Neutralization

- Lowering the token frequency of base ORAL forms.
  - Morphological similarity becomes increasingly less important.
  - Only requires changes to the exemplar space.

$$FREQ \times (BASE - exemplar)^2$$

Frequency-Driven Complete Neutralization

Exemplar Changes in Nasality Over Time, Simulation 1



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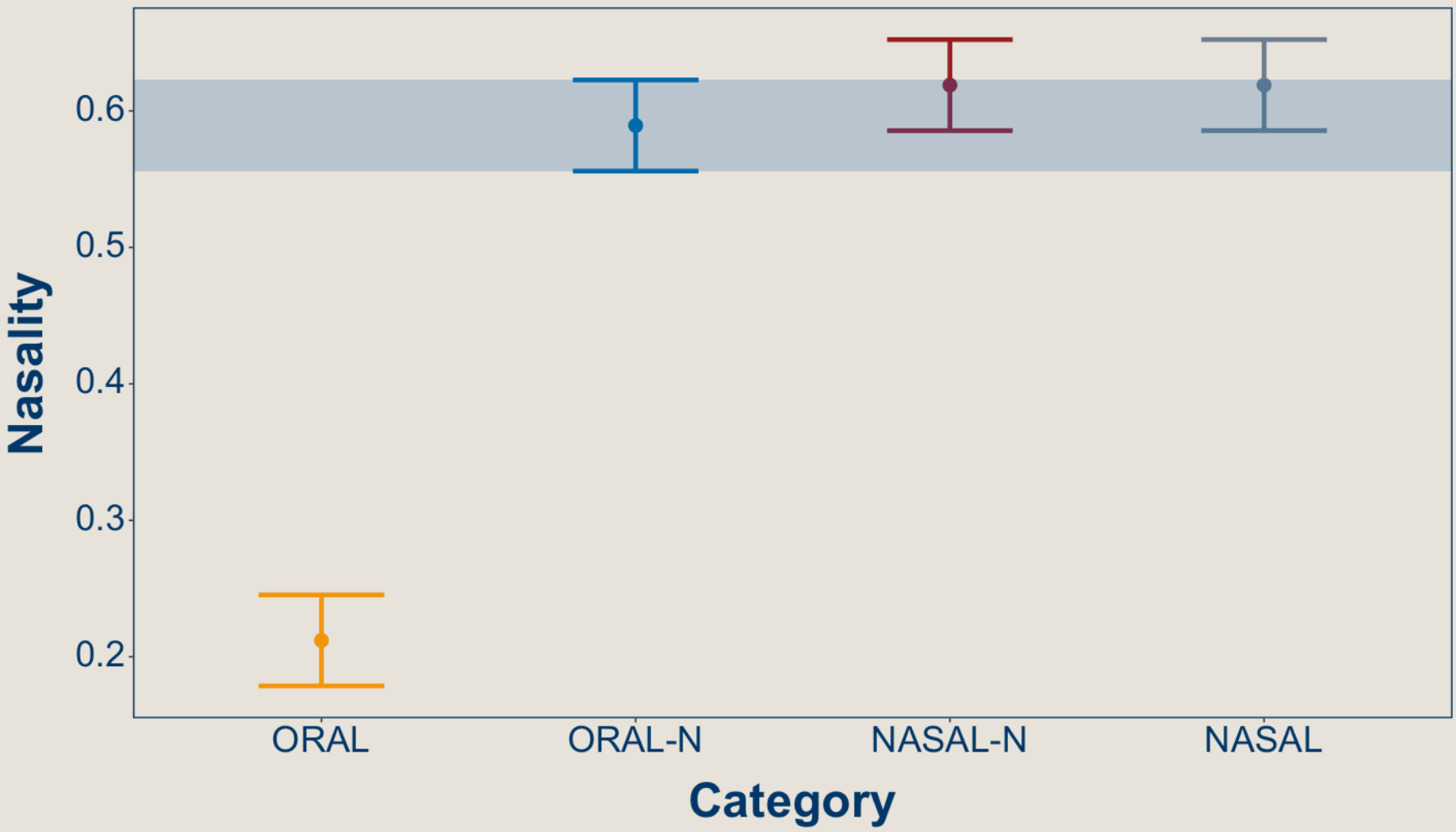


Frequency-Driven Complete Neutralization

- Manipulating base token frequency may not be empirically justified.
  - Not likely that BASE forms are systematically less frequent than paradigmatically related forms in a language.
- One (potentially) questionable prediction of this approach:
  - All languages that exhibit complete neutralization have relatively low-frequency BASE forms.
  - All languages that exhibit incomplete neutralization have relatively high-frequency BASE forms.

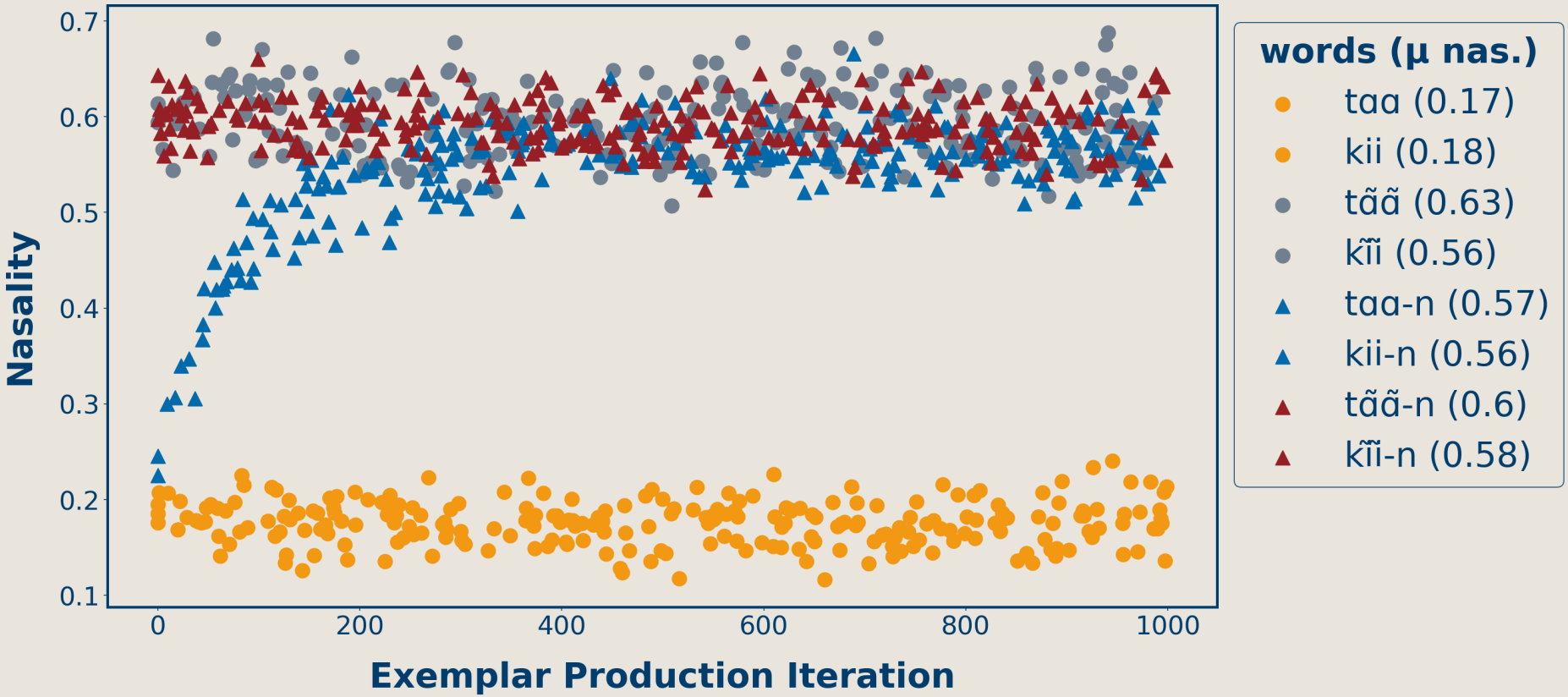
Modeling Complete Neutralization

- **My Proposal**:
  - Variation in planned output targets leads to distinct neutralization patterns.
  - Coarticulatory reanalysis leads a speaker to change the *planned* degree of nasality on ORAL-N forms (Beddor, 2009; Ohala, 1993).
- Can be implemented by changing the scalar of the pre-N nasality production bias.

$$\mathbf{5} \times (NASAL - exemplar)^2$$

Nasality Bias: $\mathbf{15} \times (NASAL - exemplar)^2$

Exemplar Changes in Nasality Over Time, Simulation 1



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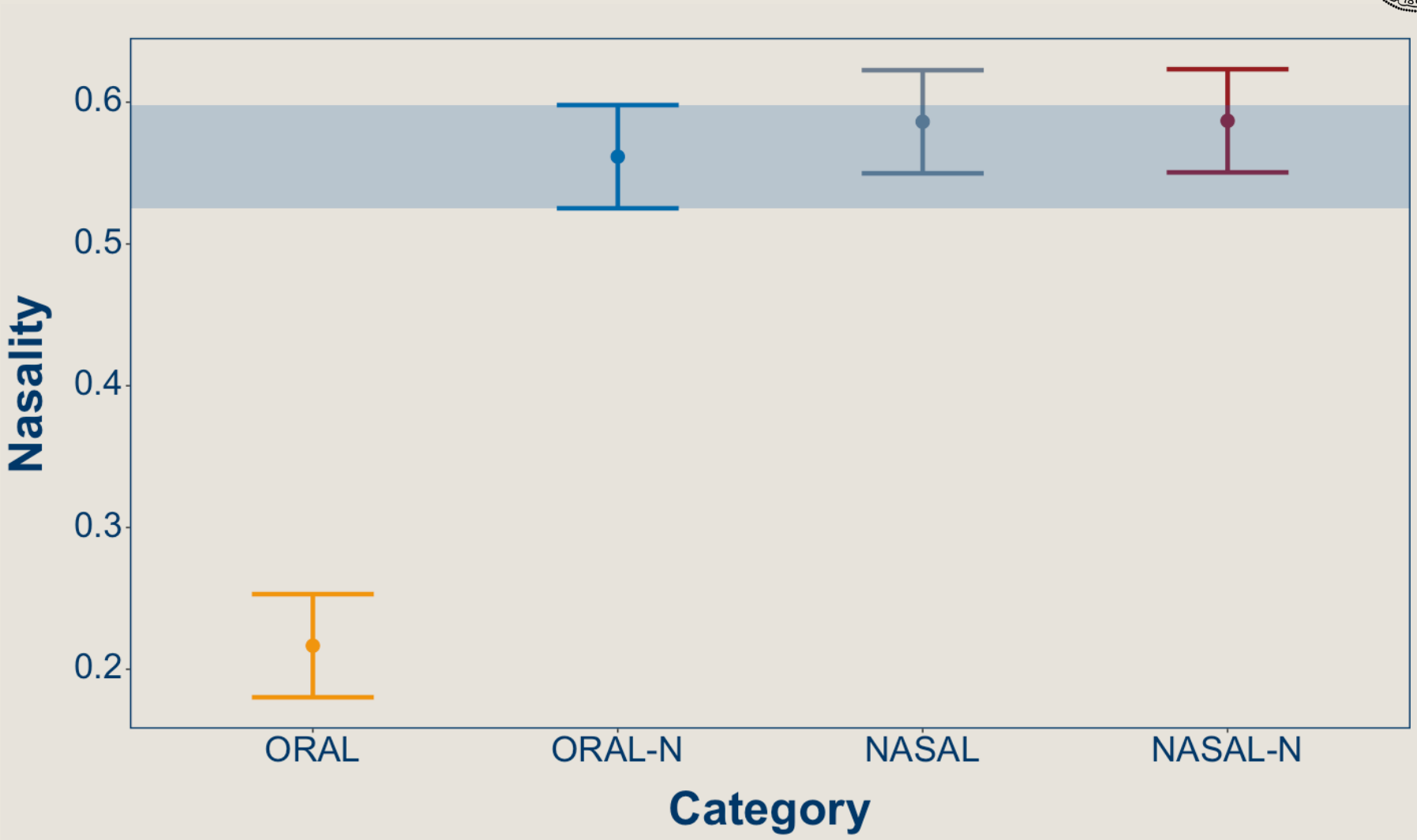


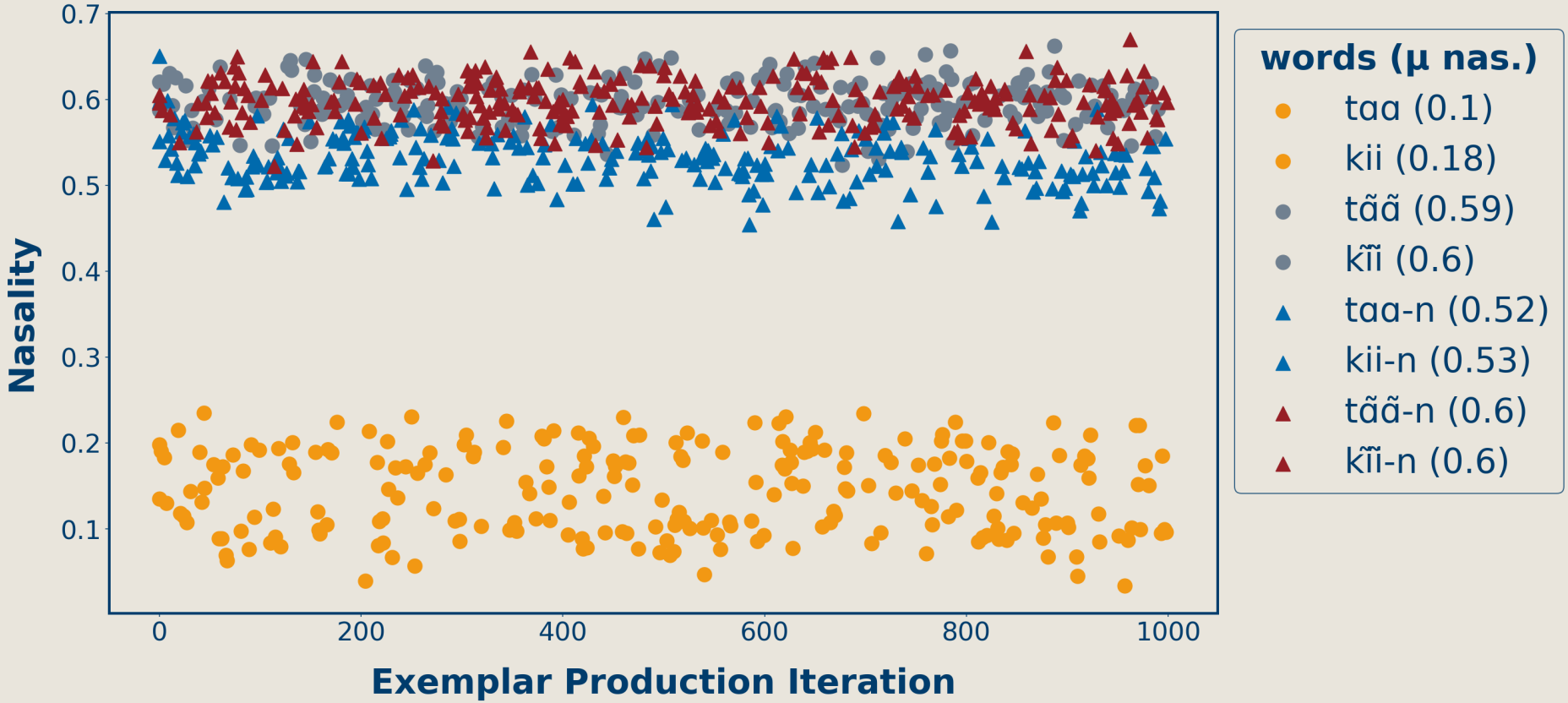
Discussion

- Barring unnatural frequency effects, changes in exemplar patterns struggle to capture both types of neutralization.
- Analyzing variation as differences in planned target outputs provides a possible solution.
  - This requires planned linguistic knowledge.
  - Changes in exemplar values alone do not change the endpoint of optimization.

Nasality Bias: $\mathbf{5} \times (NASAL - exemplar)^2$

- **tɑɑ-n** and **kii-n** initialized at 0.6

Exemplar Changes in Nasality Over Time, Simulation 1



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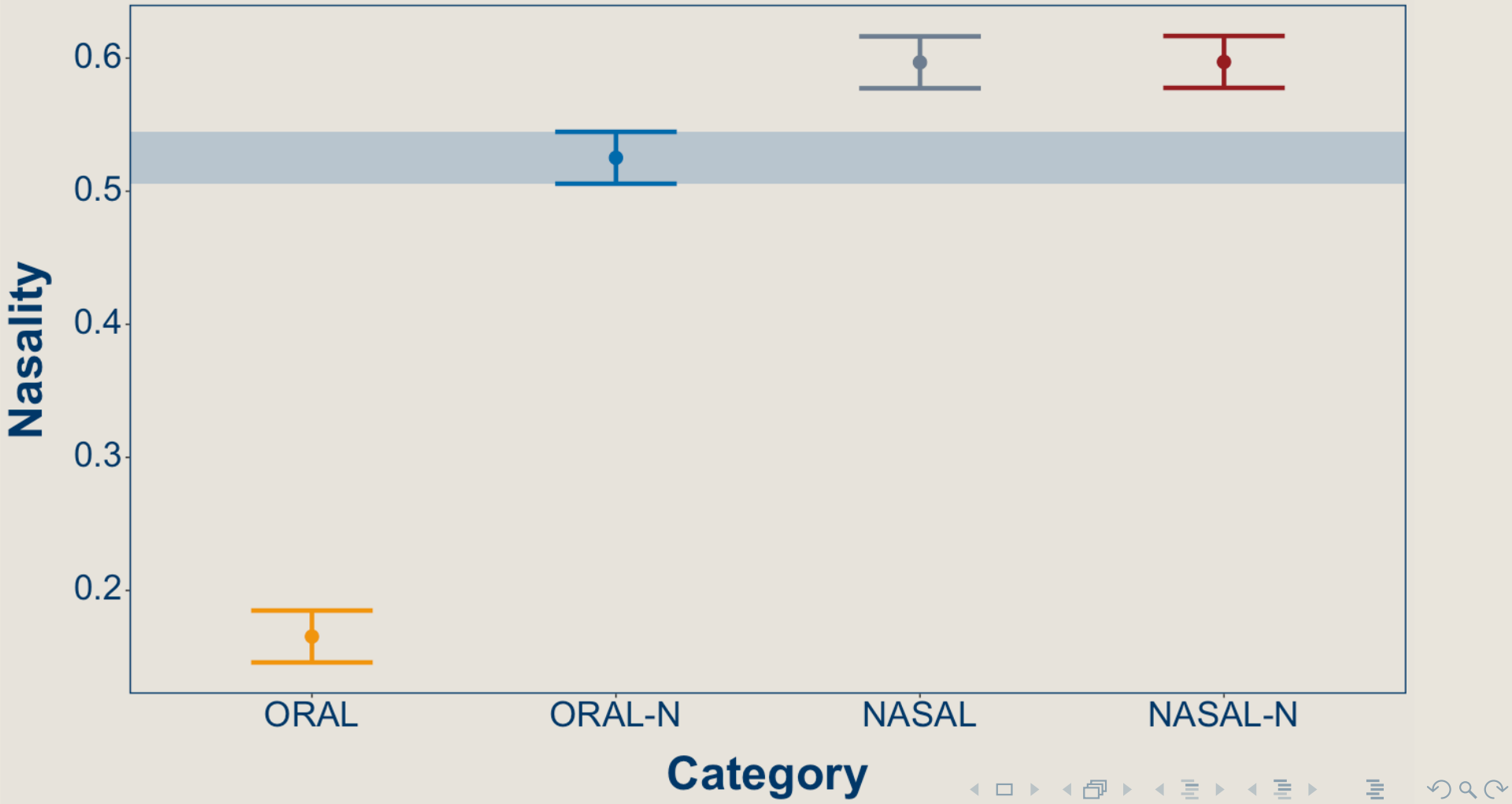

Future Directions

- The model presented here only considers production exemplars.
  - It's well-known that production and perception are linked and both play roles in shaping the lexicon.
  - Future updates to the model should incorporate perception exemplars (Beddor et al., 2018).
- The model weights all exemplars equally.
  - Social status, recency, etc. may result in certain exemplars having a stronger influence than others on future productions.

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