

Simulating Bilingual Naming in Laterally-Connected Self-Organizing Maps

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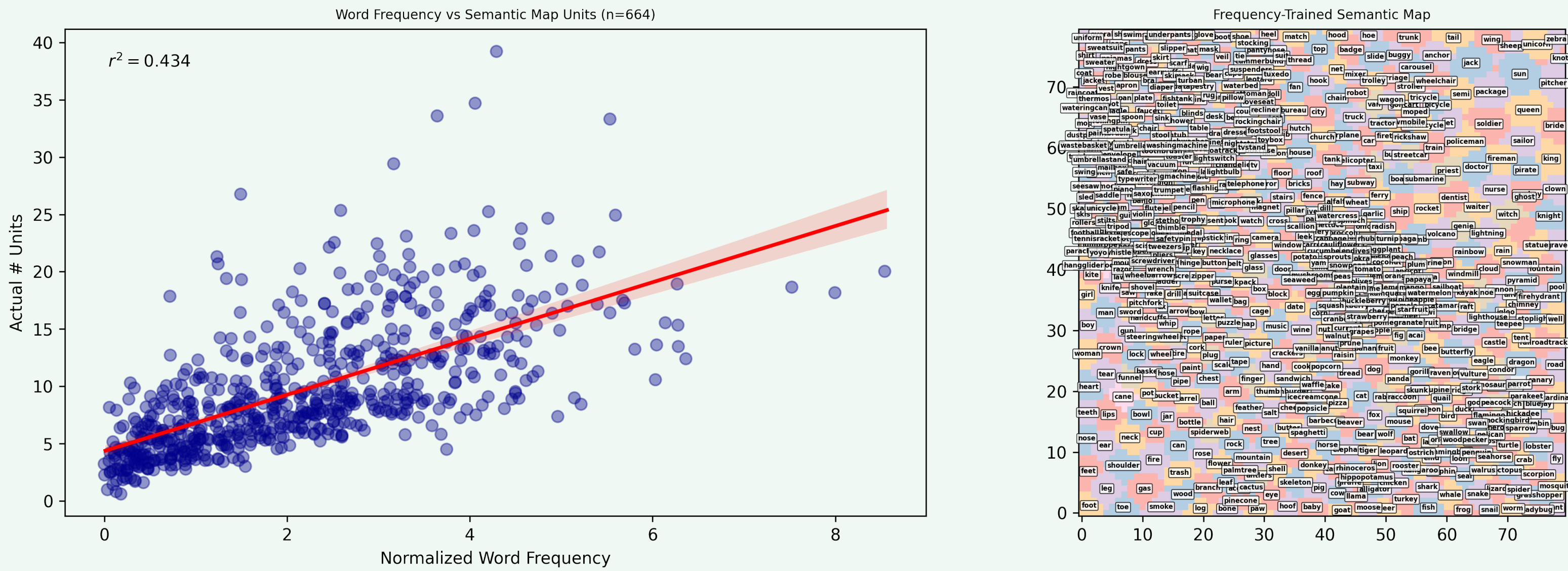


Abstract

- The BiLex model simulates the bilingual lexical system using laterally-connected self-organizing maps (SOMs), trained with short-range excitation and long-range inhibition
- Semantic and lexical mechanisms model detailed semantic effects such as word familiarity, typicality, and specificity
- BiLex performs with approximately 70% accuracy in English and Spanish naming tasks with word familiarity effects
- Biologically-plausible model: naming errors produced were human-like errors, not random failures**

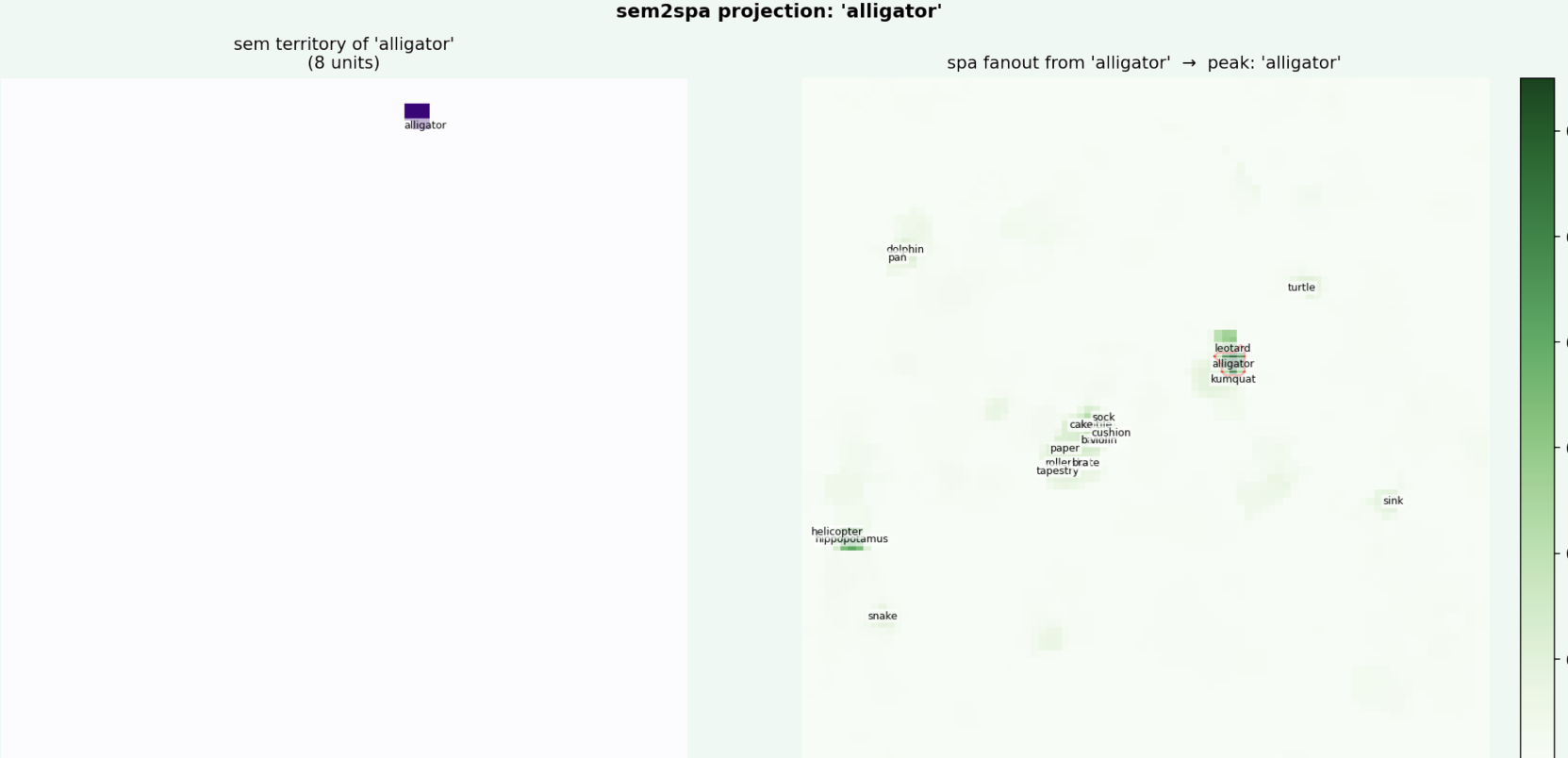
Word Familiarity Training

All SOMs trained with word-frequency sampling, resulting in greater map representation for higher-frequency words

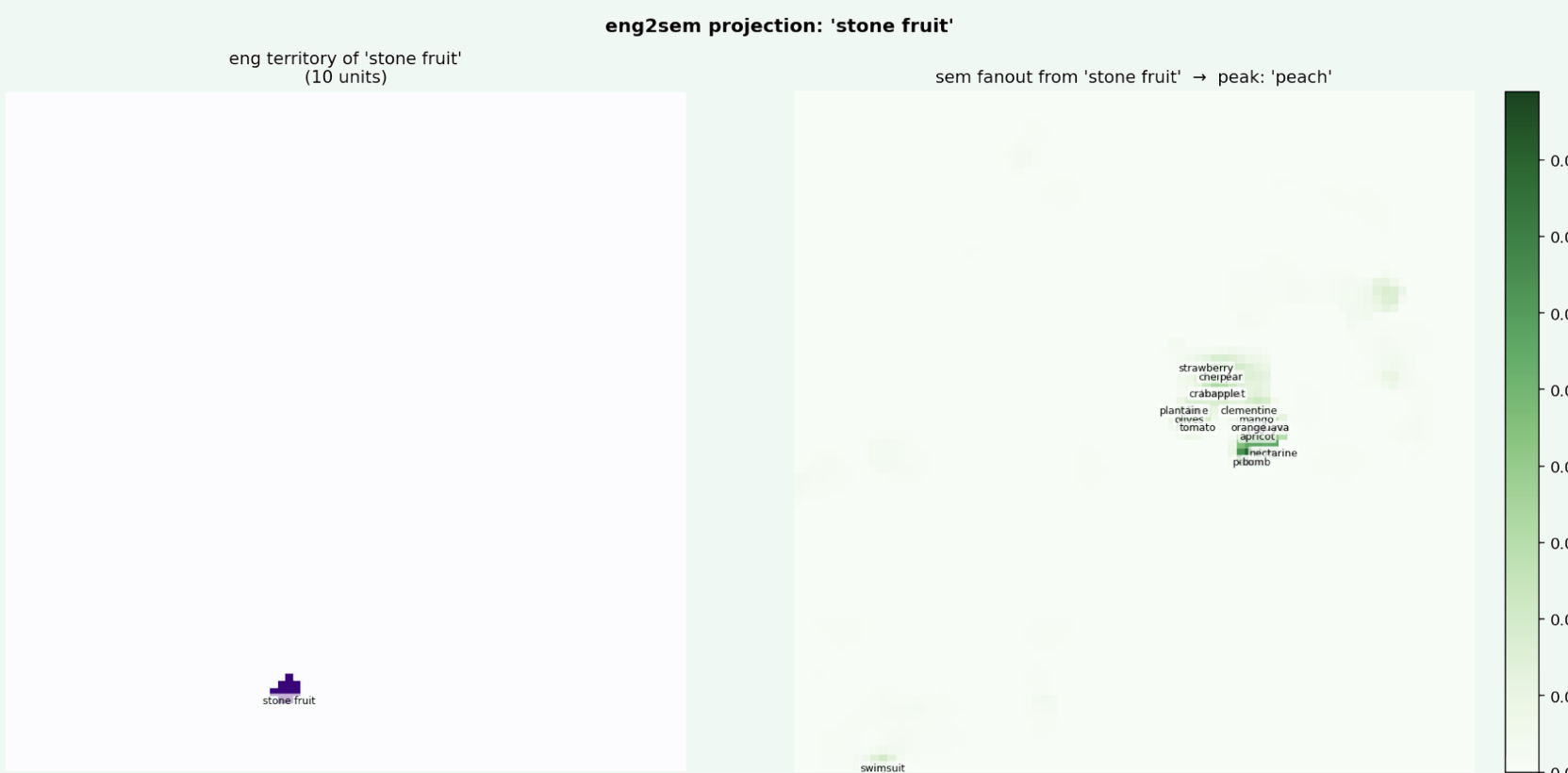


Modeling Word Specificity

Learned associative connections between subordinate words



Superordinate (category) words represented through associative connections with subordinate category members on the semantic map



Bilingual Naming Simulation

- 664 vocabulary words tested
- Naming simulations conducted in English and Spanish
- Time steps to lexical output indicate response speed

$$a_{t+1,i} = \alpha a_{t,i} + \beta \sum_j a_{t,j} (w_{ij}^+ - w_{ij}^-)$$

Lateral interactions update map activations over time steps

$$L(c, t) = \sum_{i \in M_c} a_{i,t}$$

“Dog”

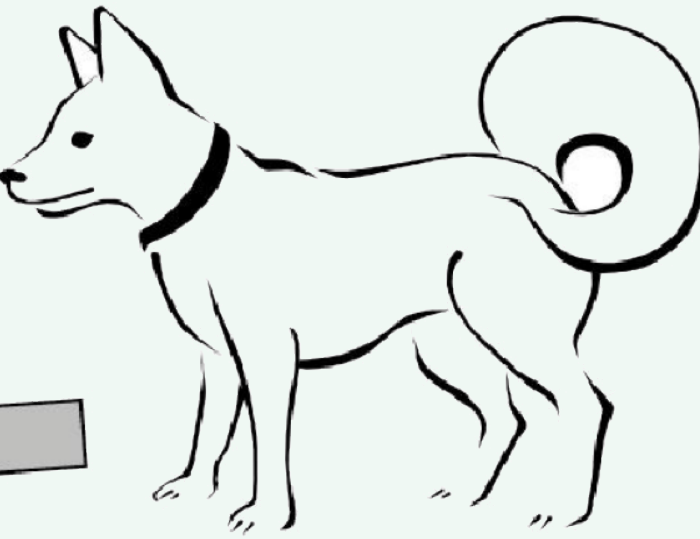
Target language map names the response when model certainty reaches the threshold

English phonetic map

$$a_{0,i} = \text{softmax}\left(\frac{|u_i - c|^2}{C_m T}\right)$$

Semantic map

Present naming item to the semantic map

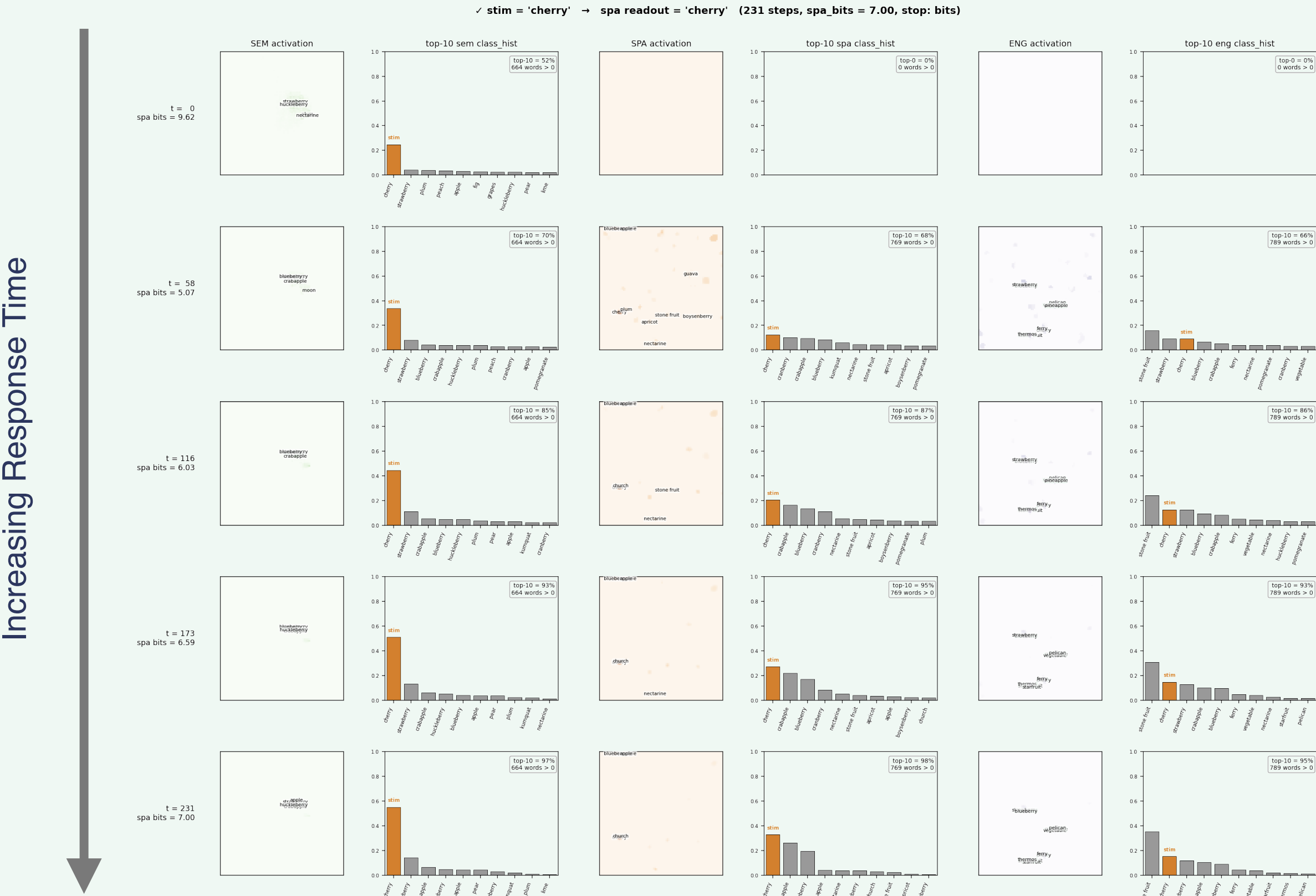


Associative connections transfer activation between maps

$$a_{t,j} = a_{t,j} + \gamma \sum_i a_{t,i} w_{ij}$$

Spanish phonetic map

Example Map Activation and Model Response Over Time

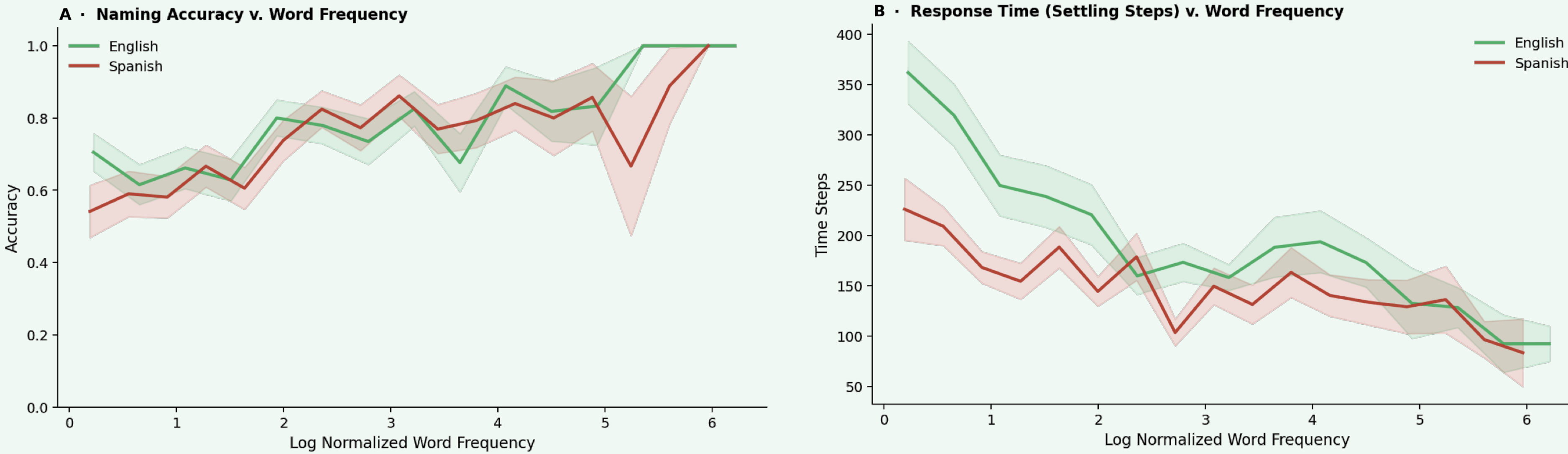


When “cherry” is presented to the semantic map, the Spanish map correctly names “cherry” as a response, while the English map produces the semantic superordinate error of “stone fruit”.

English and Spanish Naming Accuracy and Response Time

Finding: the laterally-connected BiLex model produces word familiarity effects in bilingual naming

Naming Results — English and Spanish



Naming accuracy in both English and Spanish indicate higher naming accuracy correlated with higher-frequency words (English $r_s(664) = .157$, Spanish $r_s(664) = .225$; all $p < 0.001$).

Time steps to naming was negatively correlated with word frequency, indicating higher-frequency words had faster response times (English $r_s(664) = -.261$, Spanish $r_s = -.180$; all $p < 0.001$).

The BiLex Model Produces Human-like Errors

Coordinate:
Tiger -> Lion

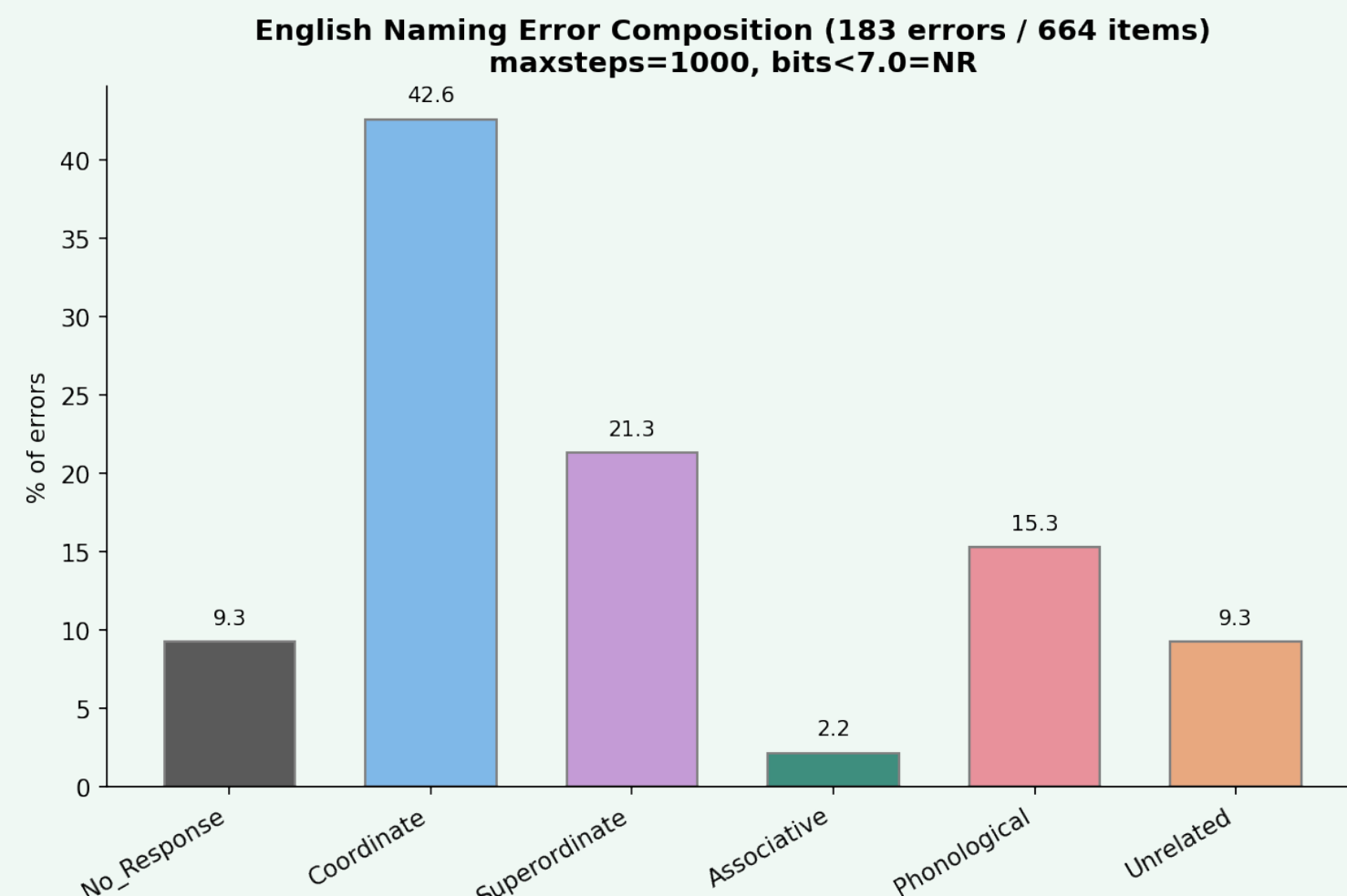
Superordinate:
Earring -> Jewelry

Associative:
Dill -> Condiment

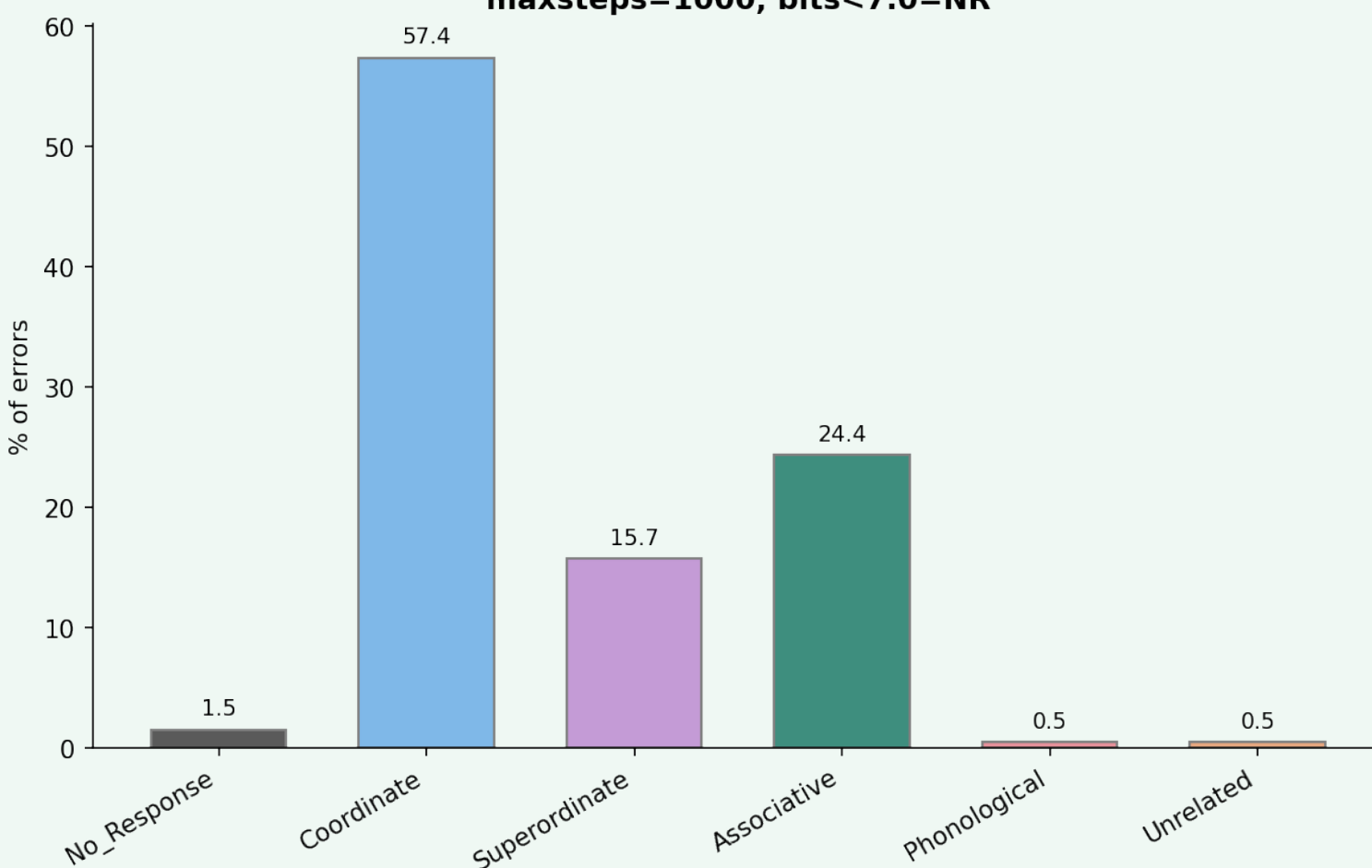
Phonological:
Crown -> Clown

Unrelated:
Stilts -> Fish

No response:
Failure to reach map certainty by maximum time step threshold



Spanish Naming Error Composition (197 errors / 664 items)
maxsteps=1000, bits<7.0=NR



Conclusions

- The BiLex model with lateral connections successfully simulates bilingual naming with structured errors
- Lateral connections enable response time modeling, with faster responses for higher word familiarity

Future Work: Modeling language decline and treatments with detailed semantic effects (familiarity, typicality, and specificity) in bilingual dementia patients

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References

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