Behavioral (interference / facilitation) ≠ (competitive / non-competitive) lexical selection mechanisms

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A longstanding debate has focused on the computational logical of lexical selection in language production: is it competitive (e.g., a relative threshold: it becomes slower in the presence of multiple strong options) or non-competitive (e.g., an absolute threshold: it depends only on the accessibility of the most active word)? Arguments on both sides have focused on empirical observations of interference and/or facilitation from semantically related alternatives in picture naming tasks. In blocked cyclic naming, taxonomic relations (e.g., cow/bear) consistently elicit RT interference, but thematic relations (cow/milk) have elicited less consistent results. Interference from thematic relations has been interpreted as evidence for a competitive selection mechanism (e.g., Abdel Rahman & Melinger, 2007), while the absence of interference (or even facilitation) has been claimed as evidence for a non-competitive mechanism (e.g., de Zubicaray et al, 2014). Because there is a close rhetorical association between RT patterns and selection mechanisms, this empirical inconsistency poses a problem for theories of language production, leading to two questions:

The empirical question:

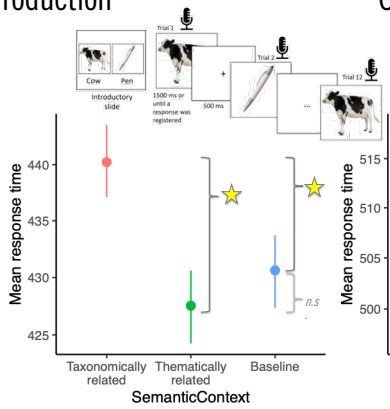
Do taxonomic and thematic relations elicit equivalent interference? (McDonagh et al., 2020)

Methods:

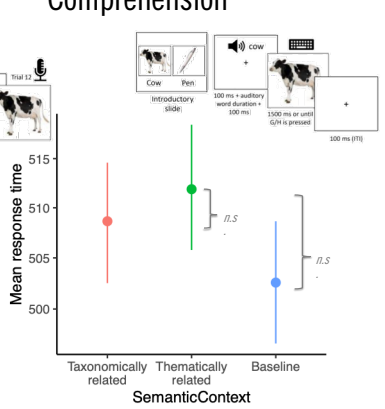
Orthogonal manipulation of taxonomic similarity, thematic similarity, and production vs. comprehension

- Two groups of 60 native-English-speaking Carnegie Mellon University Psychology undergraduates (120 total)
- 24 color photographs depicting common objects/entities
- A streamlined adaptation of the blocked cyclic naming paradigm (see Nozari et al., 2016), to allow PWI-like pairwise control
  - Pairs orthogonally manipulated:
    - Taxonomic similarity, via WordNet-based Resnik scores
    - Thematic similarity, via SUBTLEX-US-based PMI and log-likelihood
  - Pairs controlled for frequency, AoA, word length, phonological overlap
  - Each block contained 6 pseudo-randomly ordered repetitions of two items
- Production used voicekey-based RTs
- Comprehension used bi-manual RTs for word-picture matching

Production



Comprehension



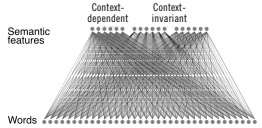
In production, thematic relations elicit less interference than taxonomic relations

The theoretical question:

Do RT interference and facilitation require distinct lexical selection mechanisms?

The base model

(adapted from Oppenheim et al.'s, 2010, incremental learning model of cumulative semantic interference)



- Feed-forward connections only
- 100 pre-training epochs
  - Delta rule learning followed each trial in training and testing.
- Tested on blocked cyclic naming as implemented in the production experiment on the left.

Selection mechanisms

(following Eq. 11-12 from Oppenheim et al., 2010; cf. Krajbich & Rangel, 2011; Nozari & Hepner, 2019)

Words accumulate activation until a clear winner emerges; the time of selection is determined by either an absolute (non-competitive) or relative (competitive) threshold.

Non-competitive (absolute threshold)

$$t_{selection} = \log_\beta\left(\frac{\tau}{a_{t\,t_1}}\right)$$

Competitive (relative threshold)

$$t_{selection} = \log_\beta\left(\frac{\tau}{a_{t\,t_1} - a_{strongest\ competitor\ t_1}}\right)$$

Representational assumptions

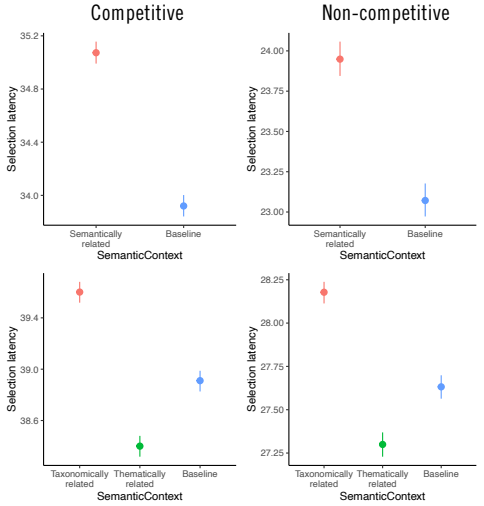
1. Words are activated by the intersection of semantic features
2. Features vary in scope, and therefore in their dependence on broader contextual relevance
   - Features that describe individual concepts must activate and de-activate quickly, on the timescale of individual words; those that describe relations between concepts must activate and deactivate slowly, on the timescale of multi-concept phrases.
   - Context-dependency might be implemented as a parametric change in activation/decay rates, or as a mechanism-neutral IFF statement; both approaches yield similar results.
3. Thematic associations may tend to be represented as context-dependent features

When targets share context-invariant features, simulations produce robust interference regardless of the selection mechanism

- As in Oppenheim et al. (2010), this interference is primarily caused by error-based incremental learning, which continually re-optimizes the production system to prioritize the words that have been most useful most recently. The 'dark side' of this re-optimization is that alternatives are de-prioritized, becoming harder to access.
- The presence or absence of competition in the selection mechanism makes no discernable difference

When targets share context-dependent features, simulations produce robust facilitation regardless of the selection mechanism

- This facilitation emerges because the supporting context provides an additional retrieval cue. That additional cue is also subject to cumulative semantic interference, but nonetheless provides a net benefit (as semantic features must, in any fluent production system).
- The presence or absence of competition in the selection mechanism again makes no discernable difference



Taxonomic interference and thematic facilitation are similarly compatible with competitive and non-competitive selection mechanisms

Conclusions

- The empirical contrast between taxonomic interference and thematic facilitation is real, but the contrasting effects do not imply specific or contrasting selection algorithms
- Overlap in context-invariant features produces semantic *interference*
  - Incremental learning includes unlearning
- Representing themes as context-dependent features produces theme-based *facilitation*
  - Theme-relevant contexts provide additional retrieval cues
- Neither effect is noticeably modulated by the presence or absence of competition in the selection algorithm

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References

Abdel Rahman, R., & Melinger, A. (2007). When bees hamper the production of honey: lexical interference from associates in speech production. Journal of Experimental Psychology: Learning, Memory, and Cognition, 33(3), 604–614.
de Zubicaray, G. I., Johnson, K., Howard, D., & McMahon, K. (2014). A perfusion fMRI investigation of thematic and categorical context effects in the spoken production of object names. Cortex, 54(1), 135–149.
Krajbich, I., & Rangel, A. (2011). Multialternative drift-diffusion model predicts the relationship between visual fixations and choice in value-based decisions. Proceedings of the National Academy of Sciences of the United States of America, 108(33), 13852–13857.
McDonagh, D. C., Fisher, A. V., & Nozari, N. (2020). Do Taxonomic and Associative Relations Affect Word Production in the Same Way? Proceedings of the 42nd Annual Conference of the Cognitive Science Society, May.
Nozari, N., Freund, M., Breining, B. L., Rapp, B., & Gordon, B. (2016). Cognitive control during selection and repair in word production. Language, Cognition and Neuroscience, 31(7), 886–903.
Nozari, N., & Hepner, C. R. (2019). To select or to wait? The importance of criterion setting in debates of competitive lexical selection. Cognitive Neuropsychology, 36(5–6), 193–207.
Oppenheim, G. M., Dell, G. S., & Schwartz, M. F. (2010). The dark side of incremental learning: a model of cumulative semantic interference during lexical access in speech production. Cognition, 114(2), 227–252.