



Deepening Understanding of Frequency Effects in Exemplar Models of Language Change

Siddharth Chatteraj, Shahil Patel, Simon Todd

UC SANTA BARBARA

Motivation & Research Questions

- Exemplar models have been used to explain frequency effects in language change.
- Different modeling decisions have yielded different frequency effects in past work.
- The full relationship between modeling decisions & freq. effects is not yet understood, nor is the potential for freq. effects on how much words spread out from each other.
- We conduct simulations under a range of modeling decisions to ask:

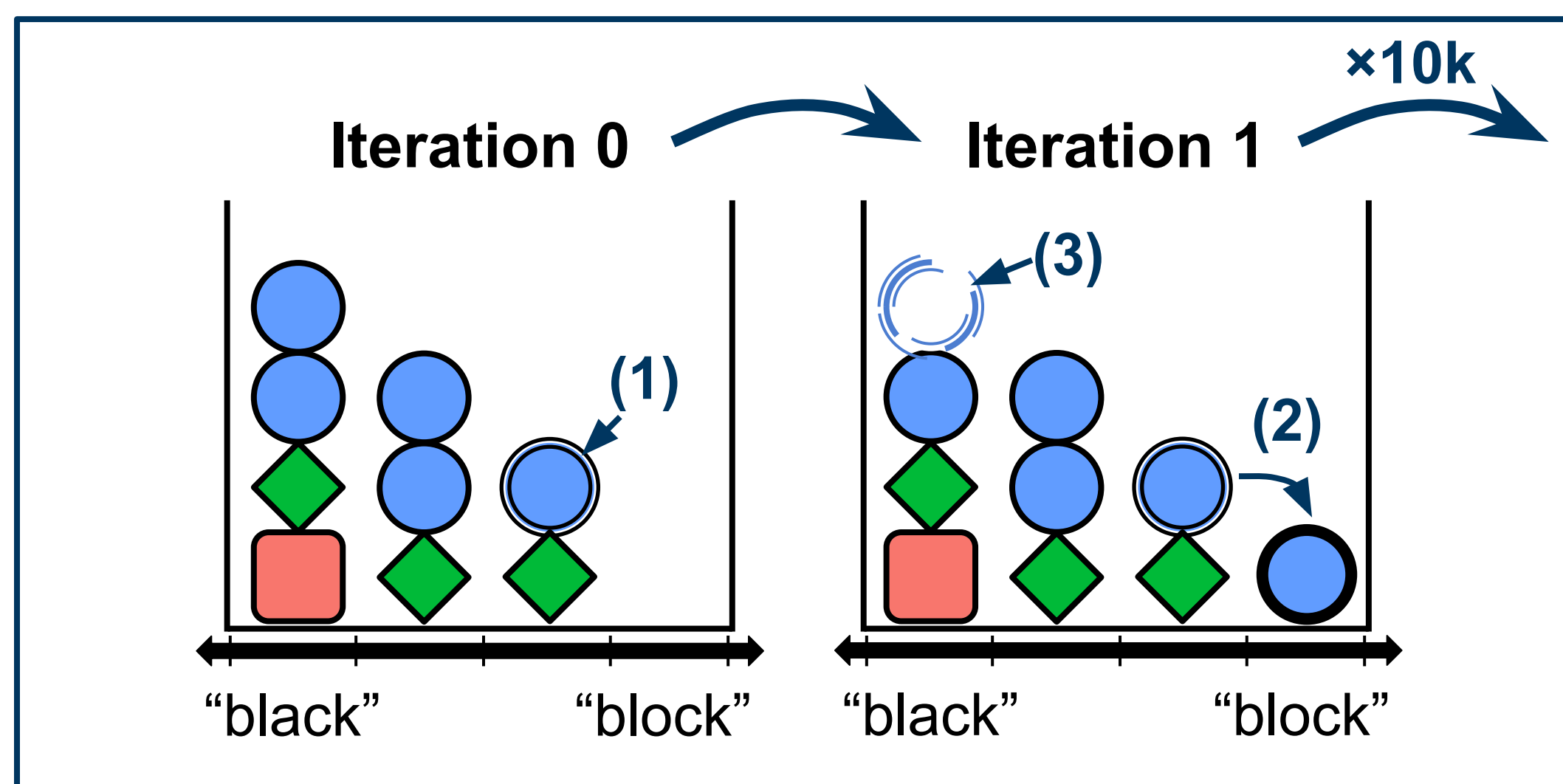
- Do freq. effects depend upon model architecture: **overwriting vs. decay**?
- Are they observed across different metrics: **values and variances**?
- How do they vary with parameters: **number / total strength of exemplars**?
- When they occur, what causes them?

Background & Key Ideas

- Exemplars are memory traces of produced / perceived words that collectively make up the mental lexicon (Goldinger, 1998).
- Language change can be modeled through a closed loop where exemplars are sampled from the mental lexicon, altered, and redeposited in it (Wedel, 2006).
- There are two architectures of memory turnover in this model: old exemplars can be randomly overwritten by new ones, or can gradually decay in strength over time.
- High freq. words have been observed to change faster than low-freq. words in a decay model (Pierrehumbert, 2001), but not an overwriting model (Todd et al., 2019).
- Todd et al. (2019) argue that decay models show freq. effects only when the word-level strength across all exemplars of a word is less than 1 on average.

Overwriting Model

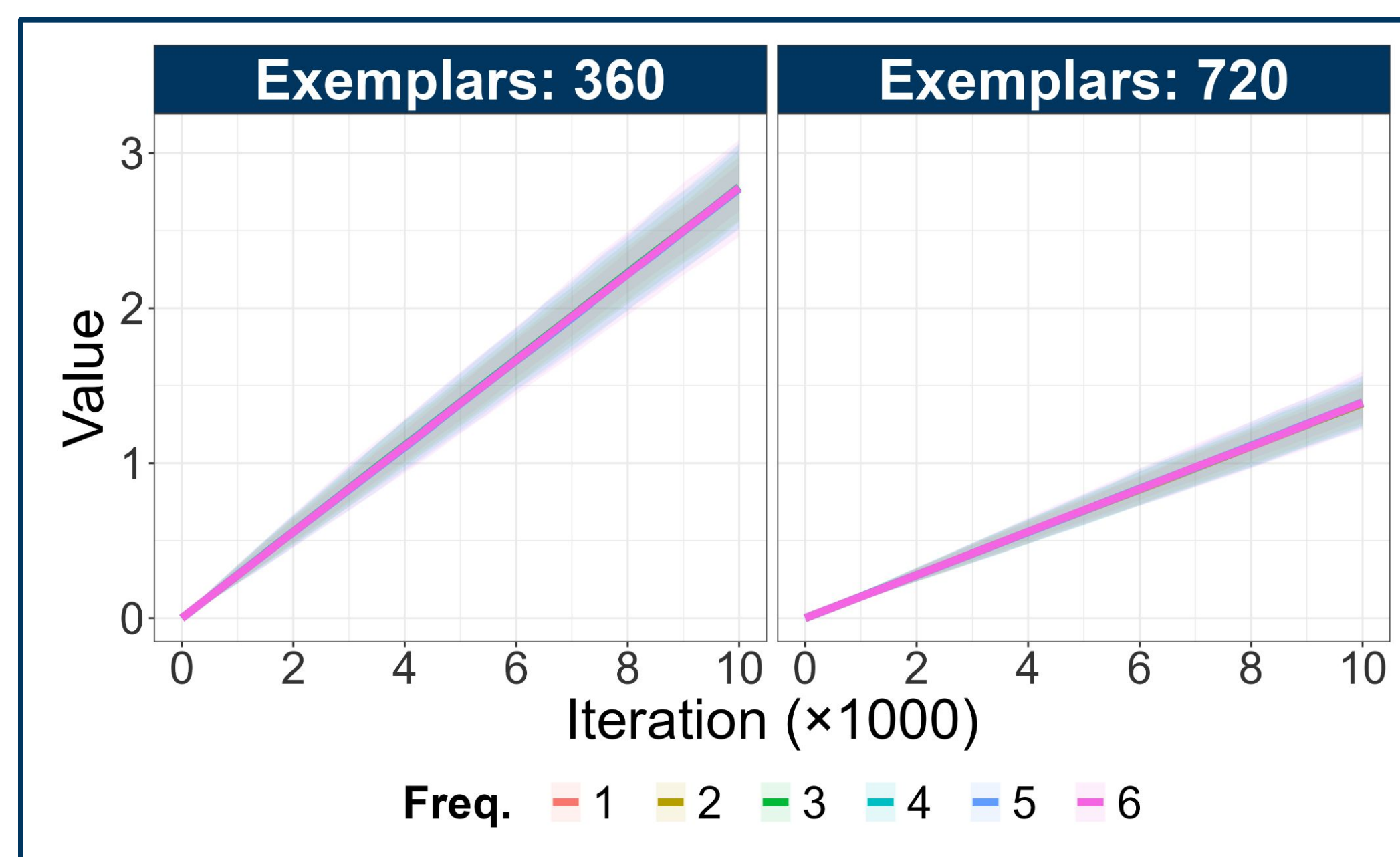
Method



Repeat for 10,000 iterations:

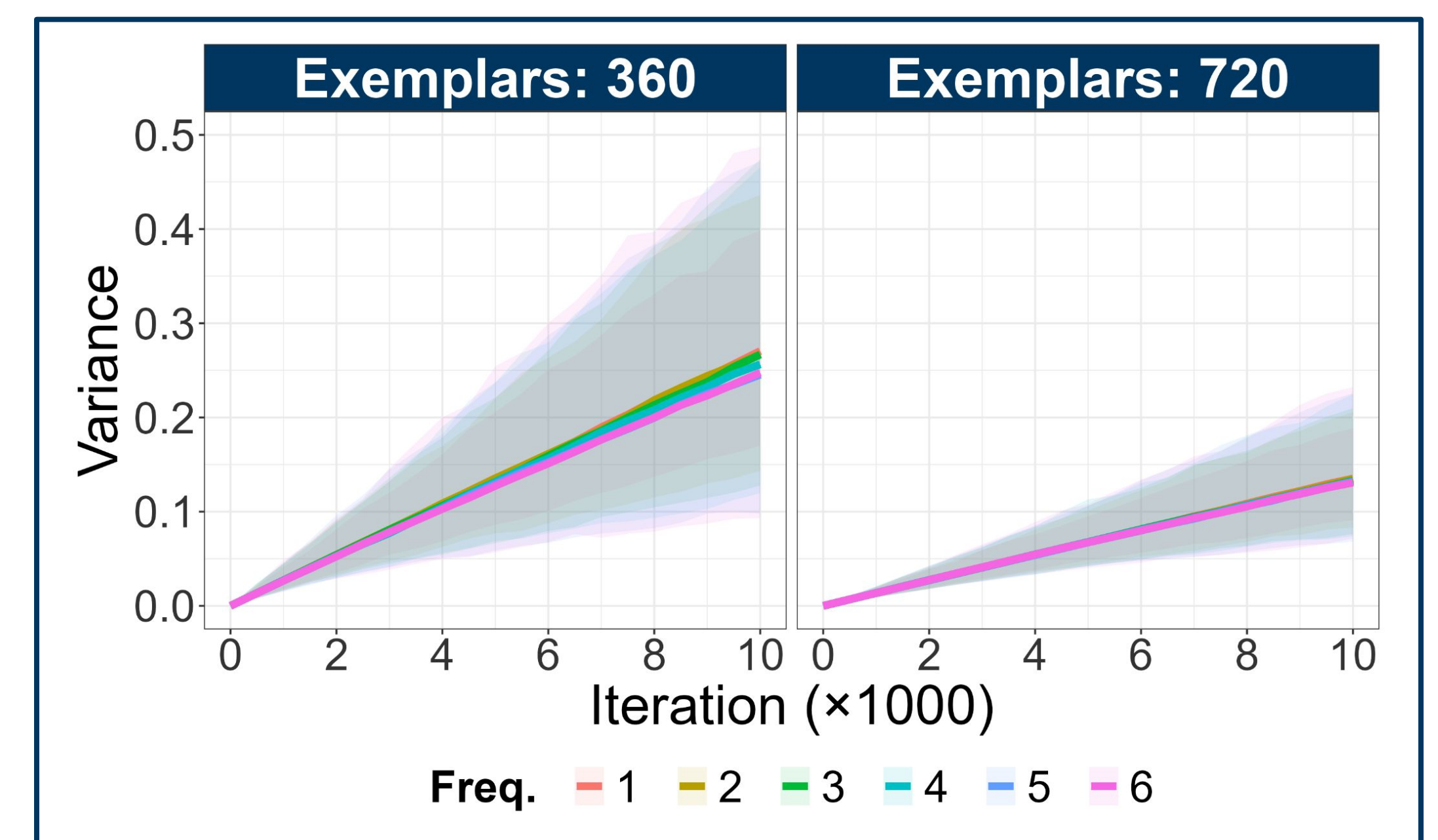
- Randomly pick word (~freq.) & exemplar (uniformly)
- Make a copy of target exemplar and advance it
- Randomly delete an old exemplar of target word

Evolution of values



- Words of all frequencies **change at the same rate**
- Regardless of parameter** for total number of exemplars

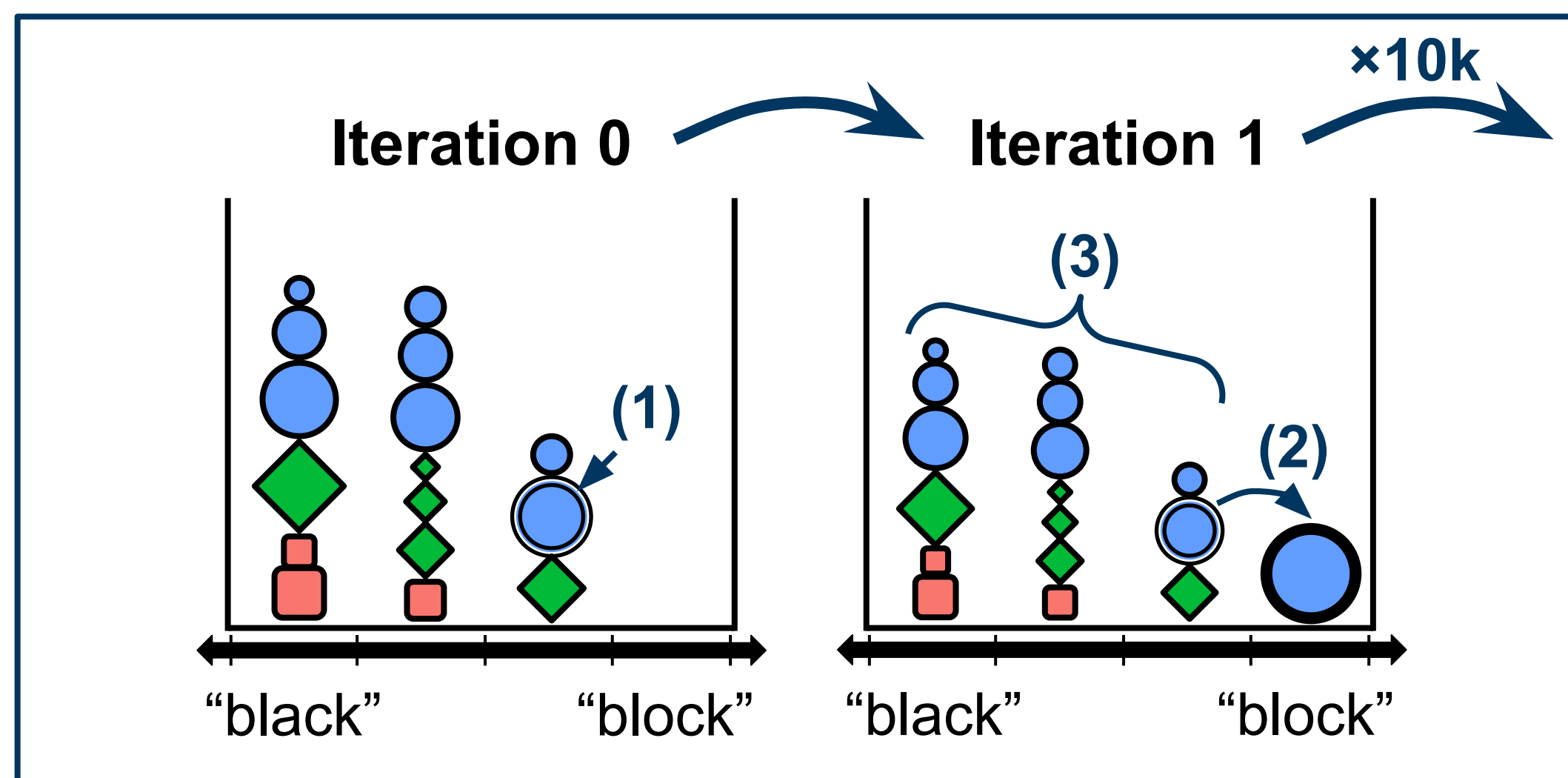
Evolution of variances



- Words of all frequencies **spread out at the same rate**
- Regardless of parameter** for total number of exemplars

Decay Model

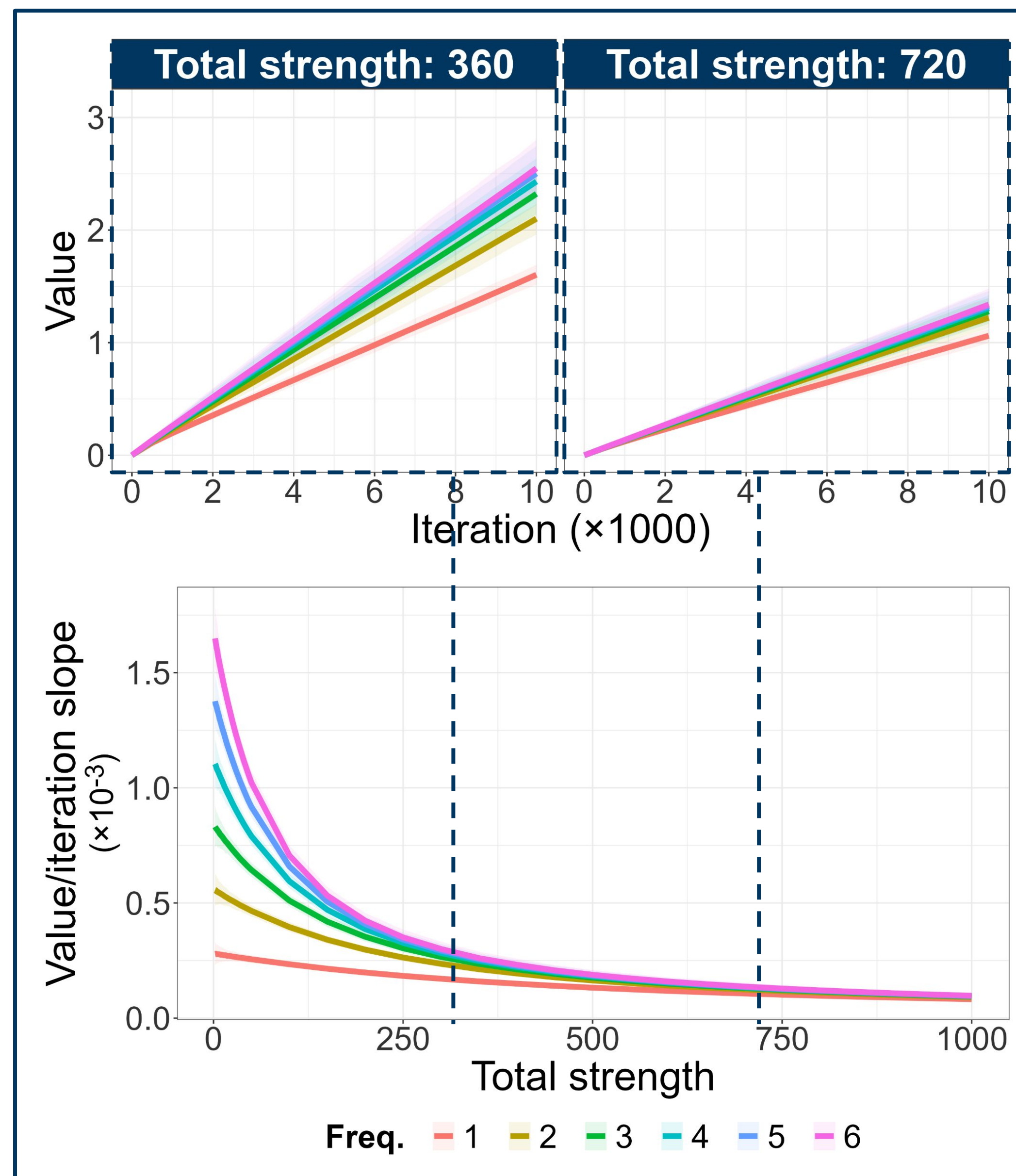
Method



Repeat for 10,000 iterations:

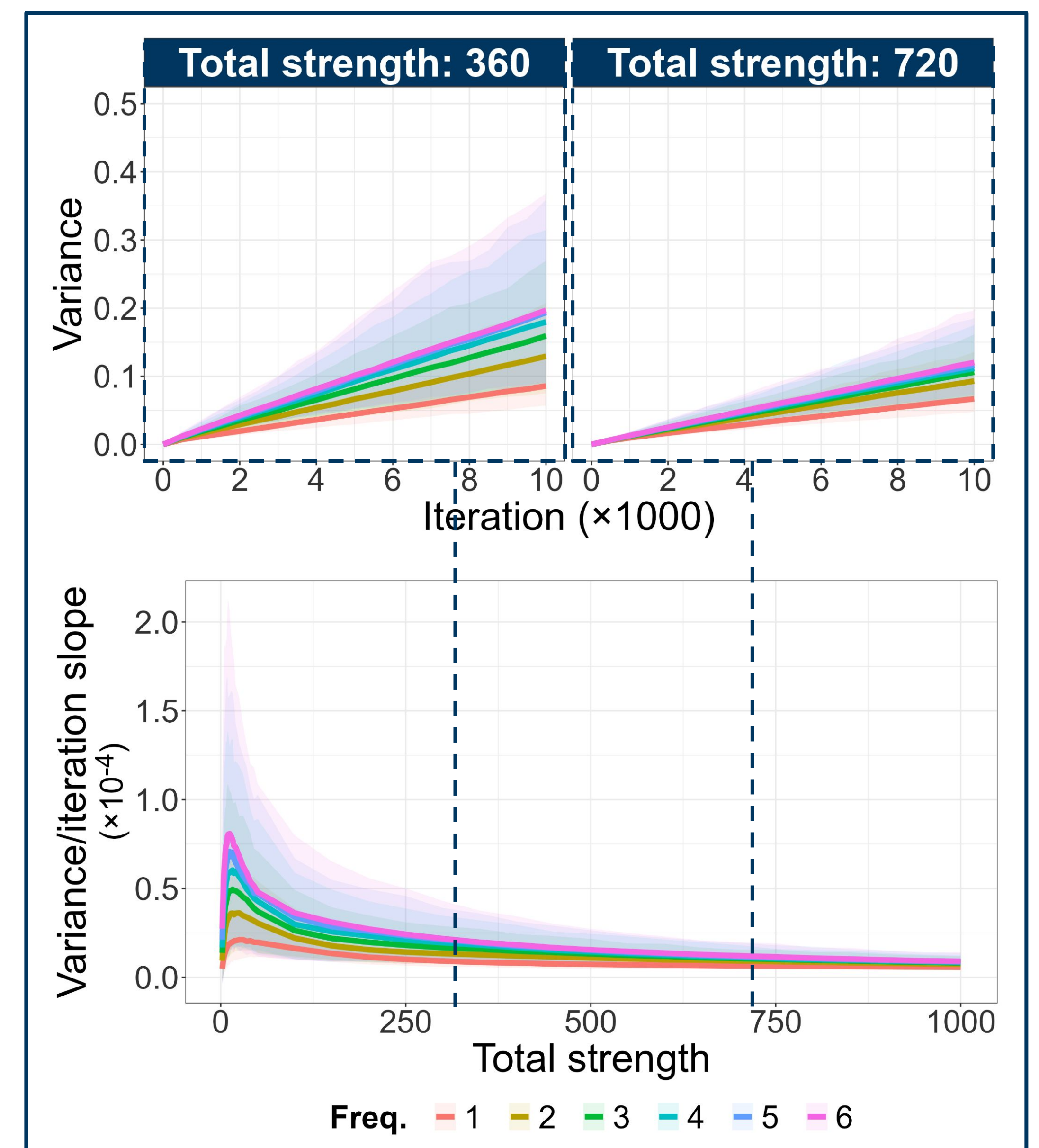
- Randomly pick word (by freq.) & exemplar (by strength)
- Make a copy of target exemplar and advance it
- Decay strengths of all old exemplars

Evolution of values



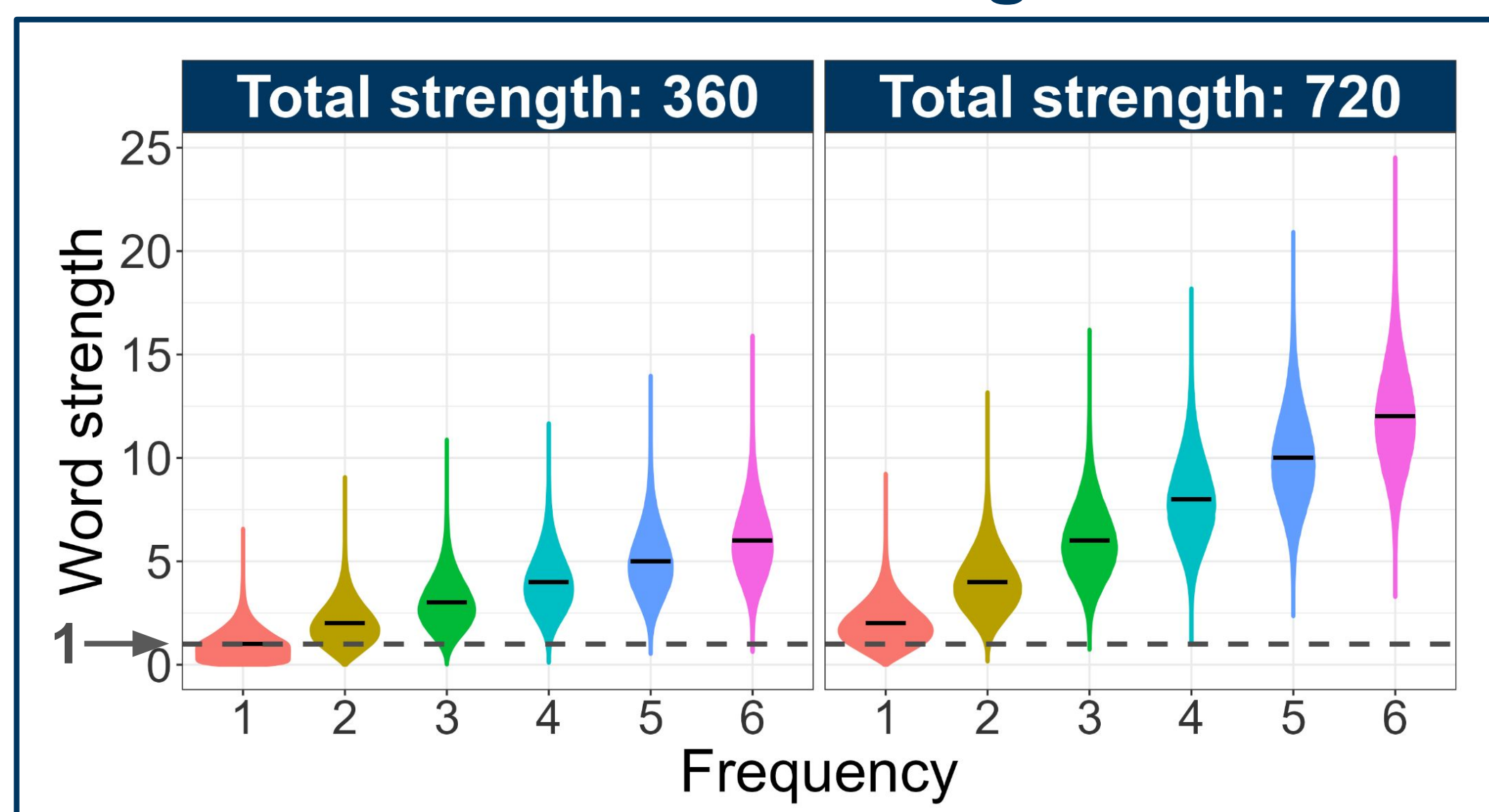
- Words can **change slower** than under overwriting
- Freq. effect:** LF words can change slower than HF
- Freq. effect **depends upon parameter** for total strength
- As total strength decreases, words **gradually peel off** to change at a slower rate than others in order of freq.
- For many params, freq. effect is **only in lowest freq.**

Evolution of variances



- Words can **spread out slower** than under overwriting
- Freq. effect:** LF words can spread out slower than HF
- Freq. effect **depends upon parameter** for total strength
- Same patterns with total strength as for values, except it is **counteracted** in the limit of very small total strength
- Freq. effect is **weak and variable** compared to values

Word-level strengths



- Freq. effects don't require **average** word strength < 1
- They emerge when **any** words have strength < 1

Conclusion

- Our results confirm that **modeling decisions play a large role** in determining frequency effects in exemplar models.
- Freq. effects in **rates of change and spreading out** can emerge in a **decay model, but not an overwriting model**.
- In a decay model, freq. effects only emerge if the **total exemplar strength parameter is sufficiently small**, because they are caused by **any word** having strength below 1 across all its exemplars when picked as target.
- When total strength is not small enough, freq. effects may be seen **only in the lowest-freq. words, or not at all**.
- It remains to be seen whether decisions informed by experiments actually account for freq. effects in language change.

References

Goldinger, S. D. (1998). Echoes of Echoes? An Episodic Theory of Lexical Access. *Psychological Review*, 105(2), 251–279. | Pierrehumbert, J. B. (2001). Exemplar dynamics: Word Frequency, Lenition and Contrast. In J. Bybee & P. Hopper (Eds.), *Frequency and the Emergence of Linguistic Structure* (pp. 137–157). John Benjamins. | Todd, S., Pierrehumbert, J. B., & Hay, J. (2019). Word Frequency Effects in Sound Change as a Consequence of Perceptual Asymmetries: An Exemplar-Based Model. *Cognition*, 185, 1–20. | Wedel, A. B. (2006). Exemplar models, evolution and language change. *Linguistic Review*, 23(3), 247–274.