A computational model of individual differences children's vocabulary growth: Are differences in phonological working memory capacity necessary and sufficient?

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Although most children build a large and varied lexicon, there are substantial individual differences in the rate of their vocabulary growth and ultimate vocabulary size. One theory is that these differences emerge from variation in children's phonological working memory (WM) capacity (Gathercole & Baddeley, 1993; Gathercole et al., 1999). This account predicts that storing more information in WM concurrently will help children build their vocabulary faster. Across three studies, we ran simulations with the CIPAL cognitive architecture (Jessop et al. 2025) to test whether variance in WM capacity is necessary and sufficient to explain individual differences in vocabulary development. In Study 1, we trained CIPAL with different volumes of English child-directed speech (10k, 30k, or 50k utterances), while WM capacity was held constant (4 chunks). In Study 2, we manipulated the number of chunks CIPAL could simultaneously hold in WM (2, 4, or 6 chunks), while input quantity was held constant (30,000 utterances). Consistent with earlier work using the EPAM-VOC model (Jones et al., 2007), Study 1 found that variation in WM was not necessary to explain individual differences in vocabulary growth. Instead, the well-documented differences in children's language experience (Huttenlocher et al., 1991) could account for these diverging developmental trajectories (Figure 1). In Study 2, we found that a smaller WM capacity in CIPAL resulted in a larger vocabulary size when input volume was held constant (Figure 2), contrary to the predictions of the WM theories. This is because CIPAL learns from the input as each utterance is presented in real-time (phoneme-by-phoneme). When learning occurs incrementally, WM acts as an attentional spotlight – it determines how much of the input the model can perceive concurrently, but it does not limit the model's total access to the input. To accommodate a smaller WM capacity, CIPAL learns a larger quantity of chunks to help compress the input, which results in the model learning more words. To confirm this spotlight effect, we repeated Study 2 with a batch chunking model that processes and learns from the contents of each utterance in parallel, rather than attempting to learn from the material as the input unfolds one phoneme at a time. In this third study, we found that increasing WM capacity in the batch chunking model led to an increase in the model's ultimate vocabulary size (Figure 3); in particular, there was large boost in vocabulary size when the model's WM capacity was extended from two to four chunks. However, we argue that this assumption of batch learning is incompatible with developmental research; for instance, statistical learning experiments have demonstrated that children have online and incremental processing and learning abilities (Saffran et al., 1996). On this basis, we suggest that individual differences in vocabulary development are affected by variation in language experience but not by intrinsic differences in phonological WM capacity.

References

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Figures

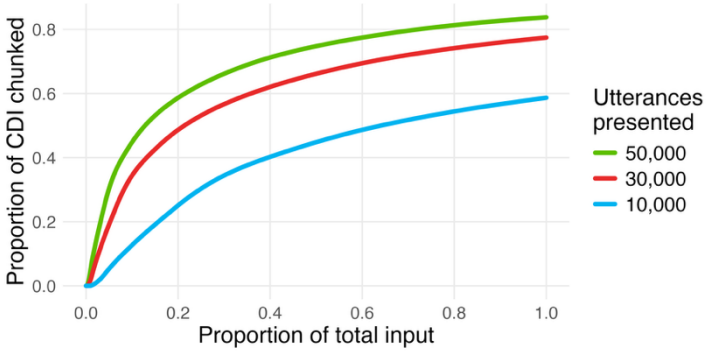

Figure 1. The results of Study 1.
The model was trained with three different levels of input with a constant WM capacity (4 chunks). We ran 1000 simulations per level.

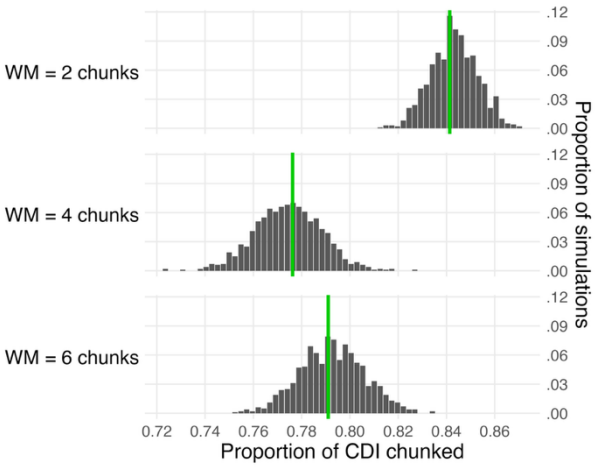

Figure 2. The results of Study 2.
The green line represents the mean. CIPAL was trained with 30,000 utterances of child-directed input with three different WM capacities (2, 4, or 6 chunks). We ran 1000 simulations per level.

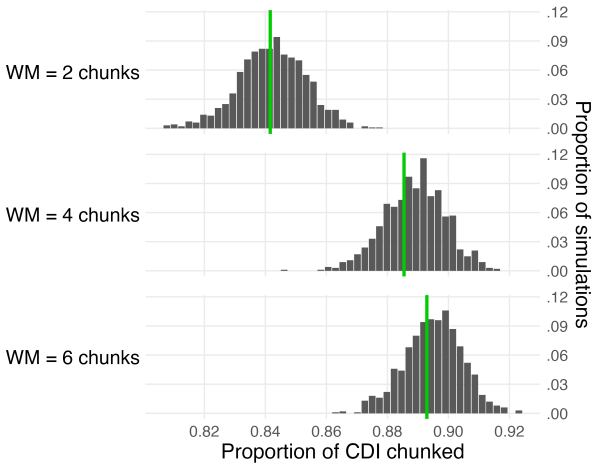

Figure 3. The results of Study 3.
The green line represents the mean. The batch chunking model was trained with 30,000 utterances of child-directed input with three different WM capacities (2, 4, or 6 chunks). We ran 1000 simulations per level.