Defusing the Childhood Vocabulary Explosion

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Between birth and adulthood, children learn about 60,000 words, on average, 8 to 10 words per day. Studies consistently reveal that, during the second postnatal year, word learning accelerates dramatically (*1*). Although the acceleration is continuous and not stagelike (*2*, *3*), this so-called vocabulary explosion is a foundational phenomenon that theories of language acquisition must address.

Common explanations posit specialized mechanisms that build on the first words to better acquire new words. Early words may force changes, like the naming insight, or reorganize conceptual structures. Processes like syntactic bootstrapping and mutual exclusivity may also leverage known words to acquire new ones (*4*, *5*).

This paper demonstrates computationally that specialized processes are unnecessary to explain the vocabulary explosion. Acceleration is guaranteed in any system in which (i) words are acquired in parallel, that is, the system builds representations for multiple words simultaneously, and (ii) the difficulty of learning words is distributed such that there are few words that can be acquired quickly and a greater number that take longer. This distribution of difficulty derives from many factors, including frequency, phonology, syntax, the child's capabilities, and the contexts where words appear.

Such a system was simulated by generating a Gaussian distribution of time to acquisition for 10,000 words. Figure 1A shows the number of words at each difficulty level. Most are acquired at 4000 time steps, whereas a few are easier. To simulate learning, at each time step each word accrues a point. When a word crosses its time-to-acquisition threshold, it is learned. This model exhibits the characteristic pattern of slow learning followed by acceleration (Fig. 1B, black line). Deceleration is seen at the end of acquisition, something that has been hypothesized (*3*) but not examined empirically [Supporting Online Material (SOM) text S2].

Further simulations examined mechanisms that leverage initial words to facilitate learning. As each word was acquired, a benefit was added to unlearned words (SOM text S3), accelerating learning (Fig. 1B, blue line). However, acquisition also accelerated when each learned word incurred a cost (red line).

Analytically, the number of words acquired by the model within a given time window is the integral of the ease-of-acquisition distribution over that window. In a Gaussian distribution, the first quarter (e.g., 0 to 2000 time steps) has a smaller integral than the second (2000 to 4000). Hence, the rate of acquisition will appear to accelerate at the later time points (Fig. 1A). Acceleration should thus be observed in any distribution in which the number of words at a given difficulty level correlates positively with difficulty, that is, if there are fewer easy words than moderate or difficult ones (SOM text S4). Additionally, the central limit theorem suggests that, because many factors contribute to time to acquisition, their individual distributions sum to a Gaussian (assuming reasonable independence).

Given this generality, a time-to-acquisition distribution was developed from real language. Word frequency was used as a proxy for difficulty by linearly scaling the log frequency of the 2000 most frequent words of English in adult- and child-directed speech (SOM text S5). This model showed acceleration (Fig. 1C). Interestingly, child-directed speech yielded faster early learning, whereas adult-directed speech was faster later—the optimal distribution may change with age. Acceleration was also seen in a fixed-threshold model where each word had the same threshold, but at each time step only one (randomly chosen from a distribution based on the same log-frequencies) received a point. Thus, acceleration in vocabulary growth could arise from occurrence statistics alone.

The vocabulary explosion is a by-product of parallel learning and variation in the time to learn words. Although words accumulate evidence at a constant rate, the outcome accelerates. The ease-of-acquisition distribution provides a framework for integrating linguistic, psychological, and statistical factors in word learning. These mundane structural features of the organism-environment complex, not specialized learning processes, determine the form of growth. Specialized processes are not causally necessary to explain acceleration; such processes may, in fact, arise in response to acceleration, or they may offset other processes that slow learning (*6*). Moreover, the model's generality suggests that any parallel learning system (e.g., motor patterns and concepts) should behave similarly. Acceleration is an unavoidable by-product of variation in difficulty. It should not be misconstrued as evidence for specialized learning.

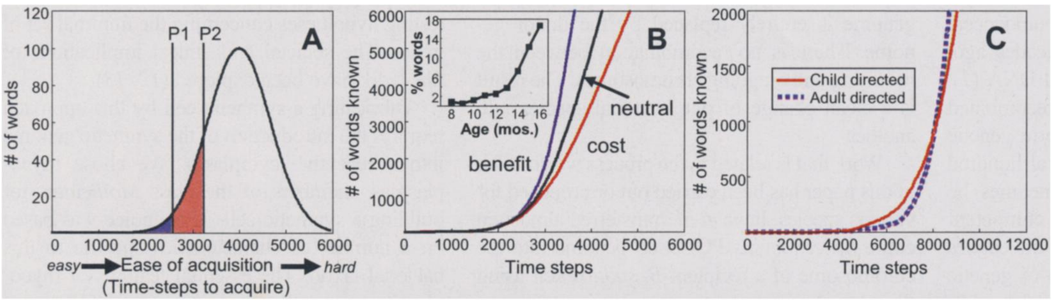

Fig. 1. (**A**) A Gaussian distribution of time to acquisition. Between 0 and 2600 time steps (P1), 1481 words are acquired. An additional 3966 are acquired in the next 600 (P2). (**B**) Vocabulary size as a function of time in initial simulations, and when learning a word offers a cost or benefit to future learning. (Inset) Percentage of words on MacArthur Communicative Development Inventory produced by children as a function of age (SOM text S1). (**C**) Acquisition in simulations based on word frequency.

References and Notes

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7. The author thanks R. Aslin, P. Bloom, J. Freeman, P. Gupta, J. Horst, K. McGregor, and especially L. Samuelson and M. Blumberg for helpful comments on earlier drafts of this manuscript; C. Manson for assistance with the figure; and G. Oden for suggesting the central limit theorem. This research was supported by NIH grant DC008089-01.

Supporting Online Material
www.sciencemag.org/cgi/content/full/317/5838/631/DC1
SOM Text
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20 April 2007; accepted 14 June 2007
10.1126/science.1144073

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