The Relative Role of Biological and Linguistic Adaptation in Language Evolution: A Computational Approach.

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A crucial issue in understanding the evolution of language is to determine the relative contribution of linguistic and biological adaptation in the emergence of grammatical structure. A rapidly growing body of work focuses in the role of learning and cultural transmission in the evolution of linguistic communication, suggesting a key role for linguistic adaptation in the process of syntax emergence.

Using computational simulations, we here explore the hypothesis that linguistic rather that biological adaptation is the primary force in language evolution. We base our simulations on the assumption that when language emerged it would have had to "piggy-back" on pre-existing learning mechanisms (also suggested by Pinker & Bloom, 1990). Specifically, we focus on the role of pre-existing sequential learning mechanisms in language evolution, suggesting that early hominids evolved complex hierarchical learning mechanisms, which subsequently were utilized for the evolution of language. The question remains whether the process of subsequent language evolution would be characterized by biological or linguistic adaptation.

Our simulations involved generations of 9 differently initialized Simple Recurrent Networks (Elman, 1990). To simulate the emergence of hierarchical learning we first trained the networks on a complex sequential learning task. We allowed the networks to evolve "biologically" by choosing the best network in each generation, permuting its initial weights slightly to create 8 offspring, and then train this new generation on the sequential learning task. After 500 generations the error on sequential learning was reduced considerably, and we introduced language into the population. Thus, the networks were now trained on both sequential learning and language. Crucially, both networks and language were able to change, allowing us to pitch biological and linguistic adaptation against each other. At each generation, we selected the networks that performed best at language learning but only considering networks that maintained their earlier evolved ability for sequential learning (on the assumption that this type of learning would still be as important for survival as it was prior to language). At the same time, linguistic adaptation was implemented by selecting the best learned language as the basis for the next generation of languages. After another 500 generations, language learnability had improved considerably due to linguistic adaptation as indicated by a comparison of network performance on the initial and final languages (keeping networks constant; Fig. 1, right). Biological adaptation, on the other hand, produced very little change in performance, when comparing the initial generation networks with the networks from the last generation (keeping language constant, Fig. 1, left).

These results suggest that if languages and learners (networks) evolve simultaneously (while maintaining a pressure toward sequential learning), linguistic adaptation overpowers biological adaptation. This further highlights the important role of cultural transmission in the process of language evolution.

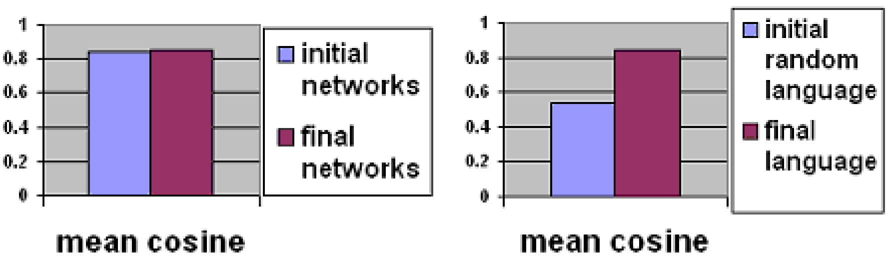

Fig 1: Right chart: language comparisons (networks constant). Left chart: network comparisons (languages constant).