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Authors

Chater, Nick
Christiansen, Morten H.
Griffiths, Thomas
et al.

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Cultural Evolution of Language: Implications for Cognitive Science

Moderator: **Morten H. Christiansen** (christiansen@cornell.edu)
Department of Psychology, Cornell University & Santa Fe Institute

Nick Chater (n.chater@ucl.ac.uk)
Division of Psychology and Language Sciences, University College London

Thomas L. Griffiths (tom_griffiths@berkeley.edu)
Department of Psychology, University of California, Berkeley

Simon Kirby (simon@ling.ed.ac.uk)
School of Philosophy, Psychology and Language Sciences, University of Edinburgh

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Introduction

The past couple of decades have seen an explosion of research on language evolution, initially fueled by Pinker and Bloom's (1990) groundbreaking article arguing for the natural selection of biological structures dedicated to language. The new millennium has seen a shift toward explaining language evolution in terms of cultural evolution rather than biological adaptation. Indeed, theoretical and computational considerations indicate that there are substantial restrictions on what linguistic properties can evolve through natural selection (Chater, Reali & Christiansen, 2009; Christiansen & Chater, 2008). In contrast, cultural evolution is now emerging as a key paradigm for understanding the evolution of language.

A rapidly growing bulk of work has begun to show how nonlinguistic inductive biases amplified by cultural transmission across generations may help explain many facets of linguistic structure observable in today's languages (see Brighton, Smith & Kirby, 2005, for a review). The basic insight from this work has been that wherever there is imperfect transmission from one agent to another, the transmission process becomes an *adaptive system*. Put simply, the inevitable product of cultural transmission is a system of behavior that appears to be designed to optimize transmissibility. In the case of language, computer simulations suggest that many key features of syntactic and phonological structure arise as adaptations to constraints like stimulus poverty, noise, processing constraints, etc.

Crucially, this research has many important implications for cognitive science, not only in terms of the nature of the biases to consider in language acquisition but also for cognition, more generally. So far, however, little of this work has surfaced at this conference or in the *Cognitive Science* journal. In this symposium, we therefore take stock of current work on the cultural evolution of language, highlighting key implications of this work for cognitive scientists from different perspectives, ranging from philosophical considerations (Chater) and Bayesian analyses

(Griffiths) to evolutionary psycholinguistics (Kirby) and molecular genetics (Christiansen).

The participants in this symposium have all worked extensively on both language evolution and cognitive science, more generally. Chater has been exploring the interaction of language acquisition and evolution, especially using formal analyses. Griffiths has been using mathematical analyses and laboratory experiments to explore how inductive biases influence the outcome of cultural evolution. Kirby has used multi-agent simulation modeling to understand the adaptive dynamics of the cultural transmission of language, and more recently has constructed close analogs of these simulations in laboratory experiments. Christiansen has conducted both agent-based simulations and artificial language learning experiments to explore cultural evolution of linguistic structure, and is currently using molecular genetics to investigate the innate preconditions for the cultural transmission of language. Together, the participants have published nearly 100 papers relating to language evolution, including in high-quality journals such as *Behavioral & Brain Sciences*, *Proceedings of the National Academy of Sciences*, *Proceedings of the Royal Society*, and *Trends in Cognitive Sciences*.

Chater: Cultural Induction and Language Acquisition

There are two very different types of inductive inference problems. In induction about the natural world, data is generated by some external source, and the learner attempts to predict how it continues. In cultural induction, by contrast, the objective is to make the *same* predictions as other learners. Thus, in language acquisition, children receive partial linguistic input, and must generalize to many new linguistic structures—but the standard of correctness is to generalize in the same way as other learners. To the extent that learners have the same biases and prior experience, this dramatically simplifies the learning problem, because their generalizations will typically agree. More generally, language evolution itself can be viewed as the accretion of successive generalizations upon which learners converge. This perspective radically reshapes the

problem of language acquisition, and other aspects of cognitive development concerned with learning culturally agreed patterns (Chater & Christiansen, submitted).

Griffiths: Uncovering Inductive Biases through Cultural Evolution

Understanding the influence of language acquisition on language evolution requires analyzing the relationship between the inductive biases of individual learners and the outcome of cultural evolution. Modeling learning as Bayesian inference provides the opportunity to explore this relationship, making the inductive biases of learners transparent through a prior distribution. Analyses of simple models of the transmission of languages and concepts along chains of Bayesian learners suggest that inductive biases should have a strong influence on the outcome of cultural evolution (Griffiths, Kalish & Lewandowsky, 2008). Laboratory experiments with human learners confirm these predictions (Kalish, Griffiths & Lewandowsky, 2007). These results provide insight into how cultural transmission can take some of the burden of explaining the structure of languages from biological evolution. In addition, they suggest that simulating cultural evolution in the laboratory may be an effective method for exploring human inductive biases.

Kirby: Language Evolution through Iterated Learning

Early work on the cultural evolution of language used computational simulation to explore how population-level behaviors like language can emerge out of *iterated learning*, the repeated cycle of production of specific behaviors and the perception/learning of those behaviors by another agent (e.g., Kirby, Dowman & Griffiths, 2007). A key question is whether a similar adaptive process can be observed in real human learners. By placing the artificial language learning paradigm within a cultural transmission framework, we can observe the evolution of languages in the laboratory (Kirby, Cornish & Smith, 2008). Results from these experiments show that linguistic structure does indeed emerge from initially random systems, and furthermore that this process is non-intentional. In other words, this cultural process provides “design without a designer” just as biological evolution does. This has important implications for where to look when seeking an explanatory mechanism for adaptive complexity in any culturally transmitted behavior, particularly one that has previously been assumed to require biologically evolved innate constraints (Pinker & Bloom, 1990).

Christiansen: Genetic Constraints on the Cultural Evolution of Language

Research on the cultural evolution of language also provides a new perspective on the study of the genetic bases of language, highlighting the importance of domain-general mechanisms (Christiansen & Chater, 2008). For example,

sequential learning and language both involve the extraction and further processing of discrete elements occurring in complex temporal sequences. Past simulation work combining biological evolution of sequential learning abilities with cultural evolution of language in a population of connectionist agents showed that constraints on sequential learning can shape the evolution of linguistic structure (Reali & Christiansen, 2009). A subsequent molecular genetic study showed that common allelic variations in the *FOXP2* gene are associated with differences in sequential learning (as measured by a serial-response time task) and language (Tomblin et al., 2007). These results suggest that *FOXP2* influences systems that are important to the development of both sequential learning and language, supporting the hypothesis that language may have been shaped through cultural evolution constrained by underlying mechanisms for sequential learning.

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