How did we get from there to here in the evolution of language?

Willem Zuidema
Language Evolution and Computation Research Unit
School of Philosophy, Psychology and Language Sciences
and Institute of Animal, Cell and Population Biology
University of Edinburgh
40 George Square, Edinburgh EH8 9LL, United Kingdom
jelle@ling.ed.ac.uk

Bart de Boer
Artificial Intelligence Lab
Vrije Universiteit Brussel
Pleinlaan 2, B-1050 Brussels, Belgium
bartb@arti.vub.ac.be

http://www.ling.ac.uk/ $\sim$ jelle
http://arti.vub.ac.be/ $\sim$ bartb

Abstract

There has been a vigourous debate in the evolution of language literature on whether the human capacity for language evolved gradually or with an abrupt "big bang". One of the arguments in favor of the latter position has been that human language is an all or nothing phenomenon that is of no value when only part of its apparatus is in place. From a developmental perspective this has always been a peculiar argument, seemingly at odds with the gradual development of phonological, syntactic and semantic skills of infants. In the context of the evolution of language, the argument was eloquently refuted in a seminal paper by Pinker & Bloom (1990). However, Pinker & Bloom did not go much further than stating that a gradual evolution of Universal Grammar was possible. They did not explore the consequences of such a view for linguistic theory, and their approach was critized by both orthodox generativists and their long-term opponents.

Jackendoff (2002) has now gone one step further. If linguistic theory is incompatible with gradual evolution and development, perhaps linguistic theory needs to be revised. Jackendoff has written a powerful book around the thesis that the language capacity is a collection of skills ("a toolbox"). Some of these skills are language-specific, some not, and each of them is functional even without all or some of the other skills present. From his decomposition of linguistic skills follow a number of hypotheses on plausible intermediate stages in the evolution of language, that fit in neatly with many other theories, models and findings in this field.

Jackendoff's book therefore presents a significant departure from the generative, "formalist" tradition, where the evolution of language has received little attention. In this tradition, the structure of human language has often been viewed as accidental rather than as adapted to the functions that

language fulfills in life. Chomsky and others have been dismissive about attempts reconstruct the evolution of language, which they regard as unscientific speculation. Chomsky famously observed that "we know very little about what happens when 10^{10} neurons are crammed into something the size of a basketball" (Chomsky, 1975).

In contrast, Jackendoff presents the different tools from the "toolbox" as adaptations for better communication. Moreover, he gives a rather complete scenario of successive, incremental adaptations that is consistent with his view on how modern language works, and how it can be decomposed. Interestingly, he argues that present-day languages show "fossils" of each of the earlier stages: expressions and constructions that do not exploit the full combinatorial apparatus of modern language. Jackendoff's book is therefore a major contribution towards a more rigourous, scientific theory of the evolution of language, in part because it leads to some testable predictions, but more importantly because it is theoretically constrained by a testable theory of modern language.

However, Jackendoff does not really recognize that, in addition, evolutionary theory brings stringent theoretical constraints (Barton & Partridge, 2000). Good evolutionary explanations specify the assumptions on genotypic and phenotypic variation and selection pressures, of which the consequences can be worked out in mathematical and computational models. For instance, Nowak *et al.* (2001) derive a "coherence threshold" for the evolution of language, which poses a strict constraint on the accuracy of both genetic and cultural transmission of language for linguistic coherence in a population to be possible. In this type of work, one often finds that "adaptive explanations" that seem so obvious in a verbal treatment such as Jackendoff's are in fact insufficient.

Cavalli-Sforza & Feldman (1983) studied a "conformism constraint" that arises from the *positive frequency dependency* of language evolution: linguistic innovations are not advantageous in a population where that innovation is very infrequent. Imagine, for instance, a population that is in the second state of Jackendoff's scenario. I.e., individuals can use a large vocabulary of learned signals in a non-situation-specific manner, but their language is not compositional: signals can not be analyzed as consisting of meaningful parts. Suppose that a child is born with a genetic mutation that makes her more inclined to analyze sentences compositionally, i.e. a mutation that would take her into a next phase in Jackendoff's scenario, that of "concatenation of symbols". Would this child profit significantly from this mutation, even if the language of the population she is born into is not at all compositional? If not – and it takes some creativity to come up with reasons why she would – evolutionary theory predicts that the new gene will disappear through negative selection or random drift (Fisher, 1922).

That is not to say that language did not evolve according to Jackendoff's scenario, but just to emphasize that each of the transitions between the phases he proposes is a challenge in itself. The evolution of language is not, as is sometimes suggested, a domain for just-so stories. Rather, it turns out that it is very difficult to find even a single plausible scenario for the evolutionary path from primate-like communication to the sophisticated toolbox of human language that will survive close scrutiny from mathematical and computational modeling. Recently, this insight has led to a surge in the interest in "explorative", computational models (see Steels, 1997; Kirby, 2002b, for reviews). They have yielded intriguing ideas on adaptive and non-adaptive explanations for the emergence of shared, symbolic vocabularies, combinatorial phonology, compositionality and recursive phrase-structure.

For instance, the suggestion of Kirby (2000) – referred to but not discussed in Jackendoff's book – is that a process of cultural evolution might facilitate the emergence of compositionality. If a language is transmitted culturally from generation to generation, signals might frequently get lost through a bottleneck effect (that arises from the finite number of learning opportunities for the child). Signals that can be inferred from others signals in the language, because they follow some or other systematicity, have an inherent advantage over other signals that compete for transmission through the bottleneck.

With some sort of generalization mechanism in place (not necessarily adapted for language), one always expects a language to become more compositional (Kirby, 2000), and, more generally, better adapted to the idiosyncracies of the individual learning skills (Zuidema, 2003).

We can give a similar analysis of the problems in explaining the transition to a combinatorial phonology, and the possible solutions from cultural evolution under the natural constraints of acoustics and articulation (de Boer, 2000; Oudeyer, 2002). Similarily, the evolution of recursive phrase-structure could be facilitated by a cultural process under semantic constraints (Kirby, 2002a; Batali, 2002).

Throughout his book, Jackendoff uses metaphors and terminology from computer science. Terms like processing, working memory, and interface make it sometimes appear as if he is describing a computer rather than processes in the human brain. However, nowhere do his descriptions become sufficiently formal and exact to make them really implementable as a computer program. In this light, his criticism of neural network model of language acquisition and his mentioning only in passing of computational model of the evolution of language is unsatisfactory. Jackendoff's challenges for connectionists are interesting and to the point, but it is equally necessary for theories such as Jackendoff's, especially their implications for development and evolution, to be made more precise and to be extended in computational and mathematical models.

In sum, in the effort to find a plausible scenario for the evolution of human language, a book like Jackendoff's, based on a broad and thorough review of linguistic theory and facts, is extremely welcome. But as explorative computational models such as the ones discussed have been very fruitful in showing new opportunities and constraints for evolutionary explanations of human language, we hope that Jackendoff's lead will be followed by intensive cooperation between linguistic theorists and evolutionary modellers.

References

BARTON, N. & PARTRIDGE, L. (2000). Limits to natural selection. *BioEssays* **22**, 1075–1084.

BATALI, J. (2002). The negotiation and acquisition of recursive grammars as a result of competition among exemplars. In: Briscoe (2002).

DE BOER, B. (2000). Self organization in vowel systems. *Journal of Phonetics* **28**, 441–465.

BRISCOE, T., ed. (2002). *Linguistic evolution through language acquisition: formal and computational models*. Cambridge University Press.

CAVALLI-SFORZA, L. & FELDMAN, M. (1983). Paradox of the evolution of communication and of social interactivity. *Proc. Nat. Acad. Sci. USA* **80**, 2017–2021.

CHOMSKY, N. (1975). *Reflections on Language*. New York: Pantheon.

FISHER, R. (1922). On the dominance ratio. *Proc Roy Soc Edin* **42**, 321–431.

JACKENDOFF, R. (2002). *Foundations of Language*. Oxford, UK: Oxford University Press.

KIRBY, S. (2000). Syntax without natural selection: How compositionality emerges from vocabulary in a population of learners. In: *The Evolutionary Emergence of Language: Social function and the origins of linguistic form* (Knight, C., Hurford, J. & Studdert-Kennedy, M., eds.). Cambridge, UK: Cambridge University Press.

KIRBY, S. (2002a). Learning, bottlenecks and the evolution of recursive syntax. In: Briscoe (2002).

KIRBY, S. (2002b). Natural language from artificial life. *Artificial Life* **8**, 185–215.

NOWAK, M. A., KOMAROVA, N. & NIYOGI, P. (2001). Evolution of universal grammar. *Science* **291**, 114–118.

OUDEYER, P.-Y. (2002). A unified model for the origins of phonemically coded syllable systems. In: *Proceedings of the 24th Annual Conference of the Cognitive Science Society* (Bel, B. & Marlien, I., eds.). Mahwah, NJ: Laurence Erlbaum Associates.

PINKER, S. & BLOOM, P. (1990). Natural language and natural selection. *Behavioral and brain sciences* **13**, 707–784.

STEELS, L. (1997). The synthetic modeling of language origins. *Evolution of Communication* **1**, 1–35.

ZUIDEMA, W. (2003). How the poverty of the stimulus solves the poverty of the stimulus. In: *Advances in Neural Information Processing Systems 15 (Proceedings of NIPS'02)* (Becker, S., Thrun, S. & Obermayer, K., eds.). Cambridge, MA: MIT Press. (forthcoming).