What genes can’t learn about language

Robert C. Berwick1
Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, MA 02139

Human language has long been viewed as a product of both genes and individual external experience or culture, but the key puzzle has always been to assess the relative contribution of each. Is language more like fashion hemlines or more like the number of fingers on each hand? On the one hand, we know that all normal people, unlike any cats or fish, uniformly grow up speaking some language, just like having 5 fingers on each hand, so language must be part of what is unique to the human genome. However, if one is born in Beijing one winds up speaking a very different language than if one is born in Mumbai, so the number-of-fingers analogy is not quite correct. The right answer must therefore cut a fine line between sufficient genomic constraint guaranteeing that every child will successfully develop an adult language and sufficient liability guaranteeing that no matter where they are born each child will acquire the language of its caretakers. Now a new study in a recent issue of PNAS (1) promises to shed light on this fine balance between cultural experience and genetic entrenchment to language’s design, all within the context of biological evolution. It maintains that the linguistic particulars distinguishing Mandarin from Hindi cannot have arisen as genetically encoded and selected-for adaptations via at least one common route linking evolution and learning, the Baldwin–Simpson effect (2).

Deriving Minimal Genomes for Language

In the Baldwin–Simpson model, rather than direct selection for a trait, in this case a particular external behavior, there is selection for learning it. However, as is well known (2, 3), this entrenchment linking learning to genomic encoding works only if there is a close match between the pace of external change and genetic change, even though gene frequencies change only relatively slowly, plodding generation by generation. Applied to language evolution, the basic idea of Chater et al. (1) is to use computer simulations to show that in general the linguistic regularities learners must acquire, such as whether sentences get packaged into verb–object order, e.g., eat apples, as in Mandarin, or object–verb order, e.g., apples eat, as in Hindi, can fluctuate too rapidly across generations to be captured and then encoded by the human genome as some kind of specialized “language instinct.” This finding runs counter to one popular view that these properties of human language were explicitly selected for, as argued in refs. 4 and 5, instead pointing to human language as largely adventitious, an exaptation (6), with many, perhaps most, details driven by culture. If this finding is correct, then the portion of the human genome devoted to language alone becomes correspondingly greatly reduced. There is no need, and more critically no informational space, for the genome to blueprint some intricate set of highly-modular, interrelated components for language, just as the genome does not spell out the precise neuron-to-neuron wiring of the developing brain.

Cultural evolution can sweep through populations as quickly as viral infections.

Although such a result may prove surprising to Darwinian enthusiasts who see the hand of natural selection everywhere, perhaps more startling still is that Chater et al.’s report (1) also points to a rare convergence between the results from 2 quite different fields and methodologies that have often been at odds: the simulation-based, culturally-oriented approach of the PNAS study (1) and a recent, still controversial trend in one strand of modern theoretical linguistics (7–9). Both arrive at the same conclusion: a minimal human genome for language. The purely linguistic effort strips away all of the special properties of language, down to the bare-bones necessities distinguishing us from all other species, relegating such previously linguistic matters such as verb–object order vs. object–verb order to extralinguistic factors, such as a general nonhuman cognitive ability to process ordered sequences aligned like beads on a string. What remains? If this recent linguistic program is on the right track, there is in effect just one component left particular to human language, a special combinatorial competence: the ability to take individual items like 2 words, the and apple, and then “glue” them together, outputting a larger, structured whole, the apple, that itself can be manipulated as if it were a single object. This operation runs beyond mere concatenation, because the new object itself still has 2 parts, like water compounded from hydrogen and oxygen, along with the ability to participate in further chemical combinations. Thus this combinatorial operation can apply over and over again to its own output, recursively, yielding an infinity of ever more structurally complicated objects, ate the apple, John ate the apple. Mary knows John ate the apple, a property we immediately recognize as the hallmark of human language, an infinity of possible meaningful signs integrated with the human conceptual system, the algebraic closure of a recursive operator over our dictionary.

This open-ended quality is quite unlike the frozen 10- to 20-word vocalization repertoire that marks the maximum for any other animal species (9). If it is simply this combinatorial promiscuity that lies at the heart of human language, making “infinite use of finite means,” then Chater et al.’s (1) claim that human language is an exaptation rather than a selected-for adaptation becomes not only much more likely but very nearly inescapable.

What Models Can’t Tell Us About Language Evolution

However, one must bear in mind 2 important caveats regarding the scope of Chater et al.’s (1) findings. First, if it were indeed the case that language’s shape was entirely culturally driven, then one might expect to see all language features rise and fall like hemlines. To be sure, to some extent that is precisely what we do observe: after all, you say to-MAY-to, and I say to-MAH-to. Such variations can, and have, been analyzed as culturally driven by an earlier generation of modelers, sociolinguists, and population geneticists (10–12). However, there is a key distinction to be drawn here between the values of linguistic features and the kinds of features them-

Author contributions: R.C.B. wrote the paper.
The author declares no conflict of interest.
See companion article on page 1015 in issue 4 of vol- ume 106.
1E-mail: berwick@csail.mit.edu.
selves, with the latter being largely fixed, just as hemlines rise and fall but hem-
lines have always been with us. Indeed,
as far back as we can discern, human
languages have always been just as com-
plicated and fixed along certain dimen-
sions. Despite many controversies in the
field, most linguists agree on the follow-
ning basic properties regarding human
language, among many others: languages
have always been either verb-object or
object-verb; no language has ever used
counting, forming a passive sentence like
John was kissed by Mary by placing a
special marker word after, say, the
fourth position into the sentence, a re-
sult consistent with recent brain imaging
studies, along with analysis of the abili-
ties of linguistic savants (13, 14); all
human languages (quite unlike any com-
puter languages) permit the replace-
ment of phrases so that, e.g., in English
we can focus the topic of a sentence and
say, Mary, John kissed; all languages
draw from a fixed, finite inventory, a
basis set, of articulatory gestures, such
as whether or not to vibrate one’s vocal
cords, thus distinguishing a b from a l,
but not all languages distinguish b and l,
again a difference between permissible
language kinds and their values.

The Chater et al. report (1) therefore
pins down something valuable about
possible adaptive selection for the latter,
but stands mute on the former. Why?
Because there has been no obvious phe-
notypic or genotypic variation in the
kinds of core language properties as op-
posed to their values, it seems highly
unlikely that this invariant core can even
be a part of the Baldwin–Simpson simu-
lation explored in ref. 1, because no
variation means, mathematically, no evo-
olutionary alternatives to even model.
Indeed some of these properties, partic-
ularly promiscuous recursion harnessed
to our conceptual dictionary, are ar-
guably part of the very expatation Chater
et al. themselves endorse and so are be-
yond the scope of their present analysis.

Second, there remain inherent restric-
tions on our ability to ferret out biologi-
cal adaptation generally and see into the
past, more so than is sometimes gener-
ally acknowledged, simply because of
limits on what we can measure given the
signal-to-noise ratio of evolution by nat-
sional selection, and similarly constraining
what computer simulations like the one
in this issue of PNAS (1) can ever tell
us. Since the pioneering study in ref. 11
we know that cultural evolution can
swarm through populations as quickly as
viral infections. By comparison, evolu-
tion by natural selection is orders of
magnitude slower and weaker, its effects
on gene frequencies easily swamped by
the migration of even a few individuals
per generation (15). Practically, this
means that although we know without a
doubt that adaptive selection has been
involved in the shaping of certain traits,
language being one of them, the data to
establish this fact conclusively remains
methodologically out of reach simply
because it is infeasible to collect the
requisite experimental evidence. To take
a far more secure case than language,
although we have long known that hu-
mam blood group differences confer cer-
tain reproductive evolutionary advan-
tages, geneticists have estimated we
would require the complete age-specific
birth and death rate tables for on the
order of 50,000 individuals to confirm
what must certainly be true (16, 17).

Given the great costs coupled with the
relatively small benefits of confirming
what we already know, the pragmatic
nature of science wins out and there is
simply little enthusiasm in carrying for-
ward the exercise.

Consequently, it is probably safe to
say that neither this nor any other con-
firmaion of adaptive advantage for one
or another particular evolutionary story
line about human language, no matter
how compelling or how internally con-
sistent its computer simulation logic,
will be immediately forthcoming. To be
sure, computer simulations can still es-
ablish boundary conditions on evolv-
ability via the Baldwin–Simpson effect or
set directions for further inquiry, and
Chater et al. (1) succeed admirably.

Nonetheless, we should remain ever
alert that there are always restrictions
on restrictions, that neither this study
nor others like it can tell us how human
language actually evolved.

on biological adaptation in language evolution. Proc
(Lawrence, Kan.) 7:110–117.
Created Language (Harper–Collins, New York).
Cambridge, MA).
10. Labov W (1994) Principles of Linguistic Change (Black-
well, Oxford).
sion and Evolution: A Quantitative Approach (Prince-
ton Univ Press, Princeton).
Learning and Evolution (MIT Press, Cambridge, MA).
impossible: The acquisition of possible and impossi-
ble languages by a polyglot savant. Linguist 91:279–
347.
(Univ California Press, Berkeley).
troduction to Genetic Analysis. (Freeman, Phila-