Opinion

Language evolution as cultural evolution: how language is shaped by the brain

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This paper reviews arguments against the evolutionary plausibility of a traditional genetically specified universal grammar. We argue that no such universal grammar could have evolved, either by a process of natural selection or by other evolutionary mechanisms. Instead, we propose that the close fit between languages and language learners, which make language acquisition possible, arises not because humans possess a specialized biological adaptation for language, but because language has been shaped to fit the brain, a process of cultural evolution. On this account, many aspects of the structure of human languages may be explained as cultural adaptations to the human brain. *WIREs Cogn Sci* 2010 1 623–628

Perhaps the most fundamental question to be addressed in considering language evolution is: What has evolved? Is language to be treated as a *cultural* product, analogous to music, art, or religion, which has been shaped through processes of collective invention, and transmission from person to person and generation to generation? Or, by contrast, should language rather be viewed as a *biological* adaptation, such that the overt patterns of human language are viewed as generated by a language organ, language module, language acquisition device or universal grammar (UG), a putative genetically determined biological structure, embodying abstract principles of grammatical structure?

The first perspective has, historically, been dominant. For example, theorists such as von Humboldt,[1] and other 19th-century philologists (e.g., Franz Bopp and August Schleicher) viewed language as a cultural and historical phenomenon, and saw the variety of the world's languages as arising through gradual processes of splitting and change. Indeed, attempts to understand the 'tree' from which the world's languages could be derived by philological analysis, gave Darwin a possible model for the patterns of biological evolution. Thus, Darwin[2] drew explicit parallels between the process of biological evolution observed in the natural world, and the process of apparent cultural evolution revealed in the history of the world's languages.

In the latter half of the 20th century, an astonishing about-face occurred. The field of linguistics, and by extension related fields concerning language acquisition and language evolution, became dominated by the assumption that human language is generated by a special-purpose cognitive endowment, which provides a blueprint for universal patterns of language structure, and which is innately specified rather than acquired through learning from the cultural milieu. This orthodoxy stems in large part from Chomsky's[3,4] astonishingly bold claim that the problem of language acquisition given the evidence available to the child is so difficult that its solution must depend on the presence of a great deal of prior linguistic structure; and that this prior linguistic structure, or UG, cannot itself be learned, but must instead be innately specified. From this perspective, linguistics is a part of biology; and, by extension, providing an explanation of the evolution of language becomes primarily a matter of explaining the evolutionary processes that gave rise to a particular piece of biological machinery: UG.

Yet providing a credible account of how a UG might have evolved proves to be surprisingly difficult. Indeed, we shall review arguments that appear to rule out the evolution of a genetically based UG on evolutionary grounds. These arguments therefore

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cast doubt on the viability of the standard nativist perspective on language and language acquisition.

If UG is discarded, what alternative theoretical synthesis is possible? We argue for a return to the pre-Chomskyan viewpoint that the evolution of language is a process of cultural evolution—a process in which some of the most powerful selectional pressures concern the degree to which specific linguistic forms are easy to learn, easy to use, and communicatively useful. Accordingly, aspects of language which are easy to learn and process, and which have communicative utility, will be 'stamped in' and amplified over successive generations of language use, while linguistic patterns which are awkward to learn or process, or which have little value to language users, will be 'stamped out.' Thus, the close fit between languages and language users arises not because language users have special-purpose language processing machinery, but because language has been shaped by the brain, through cultural evolution.

We develop this argument in three steps. First, in *the logical problem of language evolution*, we explore the fundamental difficulties that arise for attempting to tell an evolutionary story about the origin of a biological language faculty or UG. Second, in *language as shaped by the brain*, we argue that language is primarily a product of cultural evolution, guided by selectional pressures determined by learning, processing, and communication. Third, in *language acquisition meets language evolution*, we argue that this perspective dramatically simplifies the problem that the child faces in acquiring a language, because language itself has evolved to match the inductive biases of previous generations of language learners.

THE LOGICAL PROBLEM OF LANGUAGE EVOLUTION

Starting from Chomsky's assumption that language is fundamentally a biological structure, there are two broad styles of accounts concerning how such a structure might have evolved. One style of explanation is adaptationist: UG is presumed to have arisen because it contributed to the inclusive fitness of early humans, and therefore was selected for by natural selection.[5] The other, nonadaptationist, style of account sees a more limited role for natural selection for linguistic ability, possibly allowing that language arose as a side effect of biological systems that have been subjected to natural selection for other purposes.[6] On further analyses, however, we find that neither approach can provide a satisfactory evolutionary explanation for a putative, language-specific UG.

The adaptationist account runs into difficulties because of the assumption that the principles of UG cannot be understood from a purely functional point of view, e.g., as arising from constraints on learning, processing, memory, or communication. That is, according to traditional conceptions,[4,7] it is crucial that UG represents *arbitrary* constraints on the space of possible languages. According to the classic UG picture, there are an infinite number of possible communication systems that would be just as effective as human natural language. Yet, it is argued, the world's languages exhibit intricate formal regularities, such as island constraints, subjacency, or binding constraints, hypothesized not to be explicable by functional explanation (but see Ref 8, for an argument against language universals from the viewpoint of language typology). Indeed, the very arbitrariness of these putative universal patterns is viewed as providing an important line of evidence that these constraints must be innate. But the claim that such arbitrary patterns became genetically embedded through processes of natural selection faces three difficulties, concerning the dispersion of human populations, language change, and the question of what is genetically encoded.

The first problem is that, across a wide range of different perspectives on the dispersion of human populations, it seems inevitable that divergent and mutually isolated populations of language users must have arisen. But if so, each such distinct group would adapt only to its own local linguistic environment. Thus, just as Darwin famously observed with populations of finches that became separated on different islands of the Galapagos, we should expect natural selection to result in biologically distinct forms—i.e., divergent 'UGs'—each adapted to local conditions. Hence, the putative 'universality' of UG across the human population becomes deeply problematic.

Second, note that, at least as observed in modern populations, linguistic conventions change far more rapidly than biological forms. Indeed, the whole of the Indo-European language family, from Bengali to Icelandic has arisen in less than 10,000 years,[9] implying that the linguistic environment provides a fast-moving target that genetic change may be unable to follow. Computer simulations have indicated that, while arbitrary features of language may become genetically encoded through natural selection, if the linguistic environment is static or changes extremely slowly, even modest rates of linguistic change eliminate such genetic assimilation.[10]

The third and final puzzle also concerns the tendency of natural selection to adapt to local conditions. It is hard to understand why highly *abstract* linguistic principles could have become favored by natural selection occurring in the context of a single linguistic environment, without the *superficial* properties, such as word order, or the inventory of speech sounds, being encoded.

These arguments do not rule out the possibility that natural selection has played a role in the evolution of human language, but they do underscore that such selection could have not been for arbitrary features of language. Instead, functional features of language, facilitating language learning, processing, and communicative expressiveness, might indeed be sufficiently constant across the world's languages to provide a stable target for natural selection.[11] Thus it remains possible, e.g., that a bias to expect languages to be compositional, or to have both phonological and syntactic structure, might have arisen through natural selection.

Can a nonadaptationist evolutionary account of UG fare better? Again the arbitrary, idiosyncratic aspects of UG are problematic. To the degree that the principles of language structure can be seen as natural outgrowths of general processing and learning mechanisms, such an account would be viable. But advocates of classical UG, such as the government and binding framework[12] have typically argued that the reverse is the case: that the constraints governing natural language form an intricate, interlocking system defined over highly abstract and specifically linguistic categories, containing binding principles, theta theory, and so on. Chancing upon a novel and fully functioning biological system through nonadaptive processes would require a truly spectacular coincidence. Modern evolutionary-developmental biology has, it is true, shown how small genetic changes can lead to dramatic phenotypic consequences, but not how a completely new biological system, such as a putative language module or language organ, could arise *de novo*.

While still highly influential in linguistics, the classical nativist meta-theory in linguistics was developed against the backdrop of 'mid-period' Chomskyan generative grammar. How far have recent technical and theoretical developments in the generative program, and in particular the minimalist program, changed this picture? Hauser et al.[13] suggest that UG (now termed 'narrow faculty of language'), far from consisting of a rich repertoire of language-specific principles, may consist of no more than recursion, and might even be empty. If so, then presumably most of the intricate structure of language must be shaped by general cognitive principles, combined with constraints of communication, in line with the approach developed below, although this perspective does not seem to be standard in current linguistic theory.[6]

LANGUAGE AS SHAPED BY THE BRAIN

If the brain is not shaped around language through natural selection, then how did language evolve? And what explains the close alignment between language and language learners, which makes language acquisition possible? Our starting point is that language should be viewed as a collective cultural system, built up piecemeal by countless generations of language users.

From this point of view, the evolution of language should be understood in terms of gradual processes of change operating on linguistic forms across generations of language users, a process by which new learners and speakers continually introduce novel patterns of variation; and in which the linguistic forms that are most readily propagated within a population of speakers and across generations of language learners become dominant. It is to return, in short, to the conception of language evolution as a process of continual variation and selection of linguistic forms, which inspired Darwin's theory of evolution by natural selection of biological forms.

In this picture, the patterns of historical language change studied in diachronic linguistics should exhibit the process of language evolution in microcosm, and hence the study of the forces that have shaped language change during historical times can provide crucial insights into how language may have evolved. One broad pattern of particular interest is *grammaticalization*,[14] by which forms with an initially narrow linguistic function is used more and more broadly, becoming bleached of meaning and ultimately signaling only general syntactic properties. For example, the construction 'be going to,' which originally only indicated movement in space (as in 'I'm going to Jaisalmer') now is used as a future or intention marker when followed by a verb (e.g., 'I'm going to like this'). Over generations such grammaticalized forms frequently become eroded (e.g., 'going to' becomes 'gonna'), typically for ease or speed of articulation, and often yielding an increasingly irregular morphology. Such erosion can be so severe that, in time, a new content word is hijacked for the purpose of clearly signaling the grammatical distinction, and the cycle begins again.

Some theorists see the processes of language change as fairly independent of biological factors.[15] And clearly, factors specific to the cultural transmission process itself (e.g., speech community size, how many people an individual can learn from, etc.) may significantly influence how quickly linguistic patterns can spread in a population. However, we see the nature of our neural and cognitive machinery as critical to explaining why some linguistic forms are readily transmitted from generation to generation, and why others are rapidly stamped out. Just as biological systems are shaped by the environment that determines their reproductive success, languages are shaped by the systems that transmit them through successive generations of speakers: language is shaped by the brain. Thus, similar to the proposed cultural recycling of prior cortical maps for recent human innovations such as reading and arithmetic,[16] we suggest that language likewise is piggy-backing on preexisting neural substrates, inheriting their structural constraints, which become amplified and embedded in language through cultural transmission.

Christiansen and Chater[17] highlighted four overlapping sets of such neural constraints on language evolution, deriving from thought, pragmatics, perceptuo-motor factors, and cognition. Perhaps the most fundamental constraint from *thought* is the apparently limitless set of thoughts, which must somehow be transmitted using a finite set of communicative building blocks. This appears to require language to have a compositional semantics, at least to some degree, which allows the content of a sentence to be derived from the meanings of the words and other morphemes from which it is composed. The richness of human *pragmatic* inference may determine linguistic structure in a different way. Prior to the convergence upon specific linguist conventions, the pragmatic system rapidly establishes differences in emphasis and nuance, which can then be fossilized, by processes akin to grammaticalization, into the grammar of the language. For example, Levinson[18] explores how pragmatic factors underpinning regularities in 'discourse' anaphora, which are closely analogous to patterns of 'syntactic' anaphora, can provide the starting point for a theory of anaphora and binding very different from that of standard syntactic theory. *Perceptuo-motor factors* require, among other things, that language be transmitted over a limited serial channel. This, combined with severe limits on human memory capacity, demand that language can be interpreted incrementally—i.e., that messages can be decoded piece-by-piece as they are encountered. Such factors may explain, in part, the organization of language into strings of phonemes, themselves composed into strings of words, rather than, e.g., using an analog code or a 'block code' as is typically found in engineered communication systems. Similarly, the *cognitive* mechanisms of learning and information processing which must be co-opted to support language are likely to have substantially influenced language structure. One example comes from our abilities for extracting and processing information from sequences of events occurring in rapid succession across time. Computer simulations have indicated that constraints on this kind of sequential learning may help explain statistical patterns of word order regularity across languages.[19]

We do not see these four sets of constraints as independent of one another; neither are they the only factors involved in language evolution. Rather, we expect that most aspects of language will have been shaped by the interaction of a wide range of constraints deriving from the operation of neural machinery not dedicated for language. Crucially, though, this absence of language-specific constraints does not entail a lack of species-specific constraints on language evolution. Indeed, it is likely that a number of human-specific biological adaptations were necessary before language could emerge by way of cultural evolution. For example, the development of sophisticated machinery for socio-pragmatic interpretations of the behavior of others and complex sequential learning abilities are possible candidates for such 'preadaptations' for language. Thus, our approach does not deny that there are substantial genetic constraints on language acquisition and processing, but suggests that these primarily relate to neural mechanisms not specific to, and which predate, language.

But what about language itself? What implications about language follow from the assumption that it is shaped by the brain? From our perspective, individual languages can be seen as local solutions to pressures from the neural constraints combined with cultural and historical factors. If our account is correct, then we would expect a tremendous amount of diversity to be observed across the languages of the world. Of course, some recurring crosslinguistic patterns would also be likely because of similarity in constraints as well as shared culture and history, but these patterns would be expected to be probabilistic in nature and thus unlike the rigid language universals associated with UG. And this is exactly the kind of family resemblance patterns that Evans and Levinson[9] argue best characterize the patterns of commonalities across the world's languages. Thus, the adaptation of language to our pre-linguistic neural and cognitive constraints is not only consistent with the notion that language is fundamentally variable but, as we describe next, it also has important implications for language acquisition.

LANGUAGE ACQUISITION MEETS LANGUAGE EVOLUTION

If language has been shaped by the brain, then the problem of language acquisition is dramatically simplified. Language acquisition is typically viewed as a special case of the general problem of scientific induction: the child is a scientist confronted with a source of data generated by the speakers who surround her/him. We shall call this type of problem N-induction, referring to typical problems of finding structure in the natural world from a sample of data. But notice that the child's situation is very different—because the goal is not to uncover regularities generated by an arbitrary structure in the natural world, but rather to converge on regularities created by past generations of learners. The latter type of learning problem is far easier: Whatever biases the child possesses, and which lead her/him to choose particular patterns of generalization from partial data, will automatically tend to be the right biases for language acquisition, because the language has been built up by previous generations of learners, with the same biases. We call problems in which learners must learn to converge on a particular cultural form, which has itself been shaped by previous generations of learners, problems of C- or cultural induction.[20]

To see the difference in learnability between problems of N-induction and problems of C-induction, consider the following cases. On the one hand, suppose that we have received a sample of data from a distant star, a paradigm example of N-induction, which exhibit the sequence 1, 2, 4, 8. If we know little of the underlying process generating these data, we can have little certainty concerning how it will continue; continuations such as 16, 32, . . ., a repeating cycle 1, 2, 4, . . ., oscillation 4, 2, 1, and many more seem equally plausible.

But suppose, on the other hand, that the same data arise in the context of C-induction: that is, our goal is to choose the continuation that most other people choose, and hence to agree with each other, rather than with some externally defined standard. Then it is clear that 16, 32, 64, . . ., will be the right continuation, at least given that we all have the same background knowledge about numbers, because we know this is the most cognitively natural generalization. In short, we have little guarantee that our inductive biases will happen to give good predictions when we attempt to understand the natural world; but we have every reason to believe that our inductive biases are likely to prove to be almost inevitably correct when each person's goal is merely to align with everyone else.

If language has been shaped by processes of cultural revolution, then we should expect that language will reflect the interaction of an extremely rich set of constraints, from the motor processes involved in speech production, and the perceptual processes involved in speech comprehension, to constraints on human learning, perhaps especially constraints on processing of sequential material, to the nature of thought, and the pragmatics and social context of communication.[17] If language emerges as a compromise between such interacting, and often conflicting, constraints then we should expect the structure of the language to be complex, subject to partial and often incompatible regularities, at a range of levels of abstraction. The resulting complexity appears to present insuperable challenges to the learner, from the point of view of N-induction, thus leading to puzzles concerning the poverty of the stimulus,[4] and apparent 'logical' problems of language acquisition.[21] But from the point of view of C-induction, it is the very richness of these constraints that makes language learning possible, because the success of each generation of learners is subject to the same constraints as the previous generations of learners; and thus these constraints will guide each new generation of learners to appropriate inductive generalizations about the structure of language, from relatively sparse data.

CONCLUSION

The problem of understanding language evolution is frequently framed as a problem for biology. We have argued instead that language evolution is the result of long processes of cultural, not biological, variation and selection, and that the structure of human languages has therefore been shaped by the properties of the system that selects among language variants across the generations, i.e., the human brain. If language is shaped by the brain, then the problem of human language acquisition is dramatically simplified. Each generation of learners are faced with the same problem of C-induction: they must align with the inductions of other learners, rather than attempting to capture the properties of some aspect of the external world (which we termed N-induction). And because learners share a common biological basis, their inductive leaps automatically tend to converge (a process we termed C-induction), when given sufficiently similar samples of linguistic input, sparse or not, as a starting point. More broadly, if language is shaped by the brain, then the study of neural and cognitive processes, human sequential learning, patterns of language change over historical time, and models and experiments concerning the transmission of information across generations, may be combined to provide not merely a richer picture of language evolution, but a revised theory of the nature of language acquisition, language processing, and the structure of language itself.

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