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REVIEW ORIGINS OF LANGUAGE

What enables human language? A biocultural framework

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Editor's summary

For nearly as long as humans have had an understanding of language, we have been interested in understanding its origins. Although human language is unique in many ways, recent research has made clear that language per se is not unique to humans. Arnon *et al*. describe a framework for understanding language evolution that incorporates both culture and biological preparedness. The authors then demonstrate the value of this framework in case studies of three aspects of language evolution. —Sacha Vignieri

Structured Abstract

BACKGROUND

Explaining the origins of language is a key challenge in understanding ourselves as a species. We present an empirical framework that draws on synergies across scientific disciplines to facilitate robust studies of language evolution. The approach is multifaceted, seeing language emergence as dependent on convergence of multiple capacities, each with their own evolutionary trajectories. It is explicitly biocultural, recognizing and incorporating the importance of both biological preparedness and cultural transmission as well as interactions between them. Biocultural and multifaceted perspectives are increasingly appreciated, but there remains a need to integrate them within a unified framework and demonstrate how this advances understanding. We do so in this paper through three case studies examining the evolution of different facets of human language (vocal production learning, linguistic structure, and social underpinnings), each synthesizing the latest findings from multiple fields to generate valuable insights and setting a new agenda for future research.

ADVANCES

Case study 1 considers vocal production learning, an organism's capacity to enlarge and modify its repertoire of vocalizations based on auditory experience. This ability is crucial for learning spoken language and limited in nonhuman primates but has emerged in other branches of the evolutionary tree, including subsets of birds, bats, elephants, cetaceans, and pinnipeds. Bringing together data from molecular investigations of speech and language disorders, genetic manipulations in

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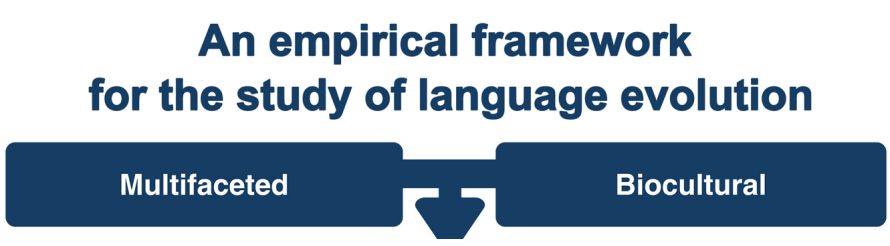
animal models, and studies of ancient DNA, this case study demonstrates how ancient genetic and neural infrastructures may have been modified and recombined to enable distinctive human capacities. Case study 2 examines the emergence of linguistic structure, a defining property of human language, using data from real-world cases of emergence (e.g., homesign and emerging sign languages); experiments recreating cultural evolution in the lab; and comparative studies of nonhuman animals, including songbirds and primates. This case study highlights the importance of transmission and interaction, suggesting that emergence of structure involves a combination of biological, cognitive, and cultural conditions: Although some (or all) traits are shared with other species, their combination may be specific to humans. Case study 3 focuses on the social underpinnings of communication across species. Social interaction contributes to language learning in humans and learned behaviors in other species with culturally transmitted communication systems, such as songbirds. But humans also demonstrate a strong internal drive to socially share information, which is rarely observed in nonhuman animals.

OUTLOOK

Drawing on diverse data, the case studies show how modification and recombination of abilities present in nonhumans, combined with intra- and intergenerational cultural transmission, may yield linguistic capacities in our own species. This perspective increases the range of species relevant for understanding language origins, as different abilities may be present across different branches of the evolutionary tree. The case studies also demonstrate the value of explicit biocultural framing, where both biological preparedness and cultural evolution shape language emergence. Language evolution is impacted by three distinct but interacting timescales: the individual (language learning), the community (cultural evolution), and the species (biological evolution). Understanding how the timescales interact and constrain one another requires synergies of data, methods, and fields. A recurring theme and avenue for future research is the role of biological reward systems in language evolution, including the motivation to communicate and endogenous and exogenous rewards for successful imitation and communication. Our integrative framework shows how research across disciplines and methods can advance understanding of a fundamental question in human evolution.



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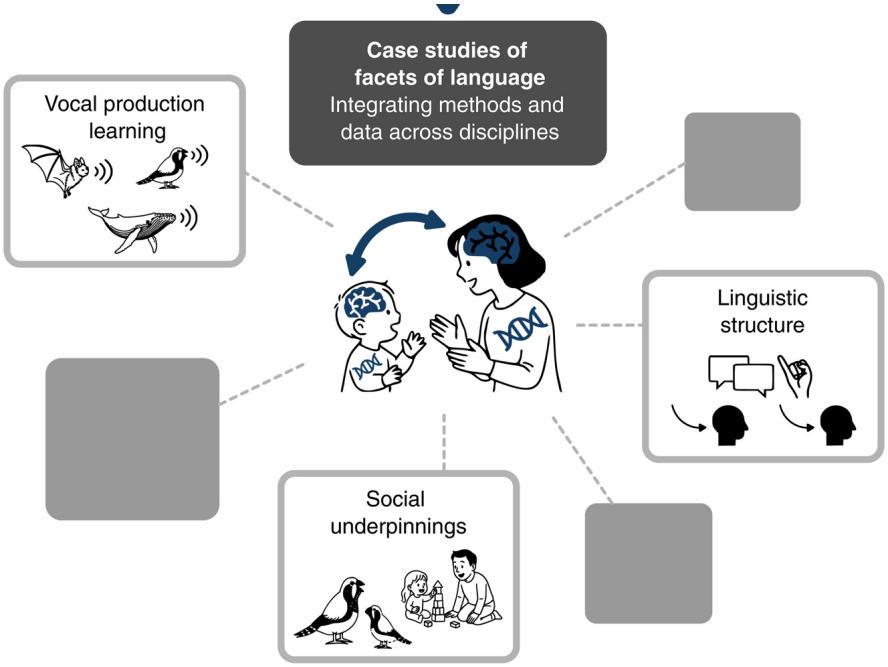

Our framework is both multifaceted and explicitly biocultural and is grounded in empirical investigations spanning a diverse array of fields and benefiting from major advances in methods, analyses, and theory.
We demonstrate the potential of this integrated framework through three example case studies, each focused on a different facet with its own distinctive evolutionary history (other facets relevant to language, not discussed in the present paper, could be similarly investigated under this framework; these facets are represented by the empty gray boxes). Drawing on data from multiple disciplines and several species, including humans, primates, and songbirds, the case studies highlight the importance of both biological preparedness and cultural processes, as well as the interactions between them, in the emergence of language.

Abstract

Explaining the origins of language is a key challenge in understanding ourselves as a species. We present an empirical framework that draws on synergies across fields to facilitate robust studies of language evolution. The approach is multifaceted, seeing language emergence as dependent on the convergence of multiple capacities, each with their own evolutionary trajectories. It is explicitly biocultural, recognizing and incorporating the importance of both biological preparedness and cultural transmission as well as interactions between them. We demonstrate this approach through three case studies that examine the evolution of different facets involved in human language (vocal production learning, linguistic structure, and social underpinnings).

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References and Notes

1 M. H. Christiansen, S. Kirby, "Language evolution: The Hardest Problem in Science?" in *Language Evolution*, M. H. Christiansen, S. Kirby, Eds. (OUP Oxford, 2003), pp. 1–15.

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2 W. T. Fitch, *The Evolution of Language* (Cambridge University Press, 2010).

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FEB. 19, 2026

From Multimodal Brain to Amodal Language

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More than 20 years after the field's last flagship paper published in *Science* (1), Arnon and colleagues set sail here to develop what they refer to as a biocultural framework for studying the evolution of language, including a set of open questions for future investigation (2). We believe that cognitive and comparative neuroscience can provide important answers to these questions about the origins of language. Here, we illustrate this by tentatively answering the authors' closing question, "[...] why language (unlike, say, birdsong) is flexible enough to be

conveyed by radically different sensory systems" (2).

Arnon et al.'s framework reminds the careful reader of Eric Lenneberg's pioneering approach (3) which as early as the 1960s recognised the biological and cultural contributions to language. While neuroscience was still in its infancy then, his perspective already recognised the fundamentally abstract nature of the way in which the human brain computes the relations expressed in sentences and their components. This amodal, key aspect of the human ability for language is what enables us to express language in different modalities, including sign, tactile sign, and speech. Such multimodal expression appears to be rare and differs from other communication systems, such as birdsong. Since Lenneberg, cognitive neuroscience has offered some insights with regard to where language processing takes place in the brain, and comparative neuroscience has provided a tentative answer as to why we observe striking similarities across modalities.

While language processing in communicative contexts recruits distributed bilateral networks

in the brain, a primarily left-hemispheric fronto-temporal network has emerged as an invariant neural system involved in language processing regardless of sensory-motor modality (e.g., speech, sign, but also tactile sign). This primarily left-hemispheric core network links the posterior portion of the inferior frontal gyrus (pIFG) to the posterior temporal cortex (pTC) via the arcuate fasciculus and is widely considered a universal substrate for human language (4-6). Evidence from deaf people who acquired a sign language already early in life demonstrates that this core language network is also robustly engaged during sign language comprehension and production, despite the reliance on the visuo-spatial modality and the absence of speech and auditory processing (7-9). Crucially, these brain regions appear sensitive to the processing of linguistic information that is imposed onto the signal, rather than perceptual features (10). They are particularly engaged in combinatorial processes where individual signs are integrated into sentences (11), similarly to what has been observed for the integration of words into sentences in spoken and written language (4-6). Tactile sign language also implicates a left-lateralized fronto-temporal network, though neuroimaging data are scarce (12). Moreover, developmental studies with hearing children using a spoken language, as well as case studies of language-deprived deaf individuals who grew up without access to a sign language (i.e., homesigners) illustrate that the structural development of the usually left-lateralized fronto-temporal language system is malleable to environmental factors because its typical development depends on the access to linguistic input (i.e., speech or sign) early in life (13,14). In sum, these findings suggest that the human brain's core language network is not bound to a particular modality and can flexibly interface with radically different sensory channels for production and perception.

Converging findings from the last two decades suggest that precursors of this left-hemispheric fronto-temporal language network exist in non-human primates (15-17). Recently, we identified a crucial component of this network: The left-lateralised connection of the arcuate fasciculus to the middle gyrus in pTC (18). With this final piece in place, the chimpanzee's neural infrastructure can be regarded as, in essence, human-like, though features specific to humans persist, such as the greater connectivity strength of this pathway. This naturally raises the question: Which cognitive functions does this neural system support in non-linguistic primates? Integrating structural and behavioural data is crucial to reducing uncertainty when determining whether shared traits reflect continuous evolution or convergent solutions—much like the independently evolved eyes of cephalopods and vertebrates, which have similar structure but different vision. For example, both the pIFG and a superior portion of pTC have been shown to support intentional vocalisations and communicative gestures in chimpanzees (19), as well as communicative gestures, as opposed to non-communicative actions, in both adults and developing baboons (20). This suggests that language might have evolved from a multimodal form of primate communication. Moreover, in line with Arnon et al.'s biocultural framework, it is increasingly recognised that interspecies brain variabilities need not only reflect phylogenetic distance but can also reflect socio-ecological differences (21-23). Emerging evidence suggests that this may also apply to the precursor of the language network in nonhuman primates: Captive and wild chimpanzees show differences in communication strategies (24), and training-induced changes in fronto-temporal connection lateralization have been observed in captive individuals (25). Our own data might confirm a socio-ecological effect on brain lateralisation, revealing possible differences in arcuate fasciculus lateralisation to the middle temporal gyrus between captive and wild chimpanzees. These findings indicate that the precursory brain basis for language is flexible and may have also been shaped by socio-ecological influences during evolution.

Taken together, we propose the following potential answer to Arnon et al.'s closing question: Contemporary neuroimaging work with humans suggests that the core network for language develops in an input-dependent manner and is recruited for computing abstract linguistic information independent of modality (speech, sign, or tactile sign). The evolutionary origin of this amodal system might be visible in present day primate communication which is inherently multimodal and enabled by a brain that processes different modalities in a flexible and potentially abstract—amodal—way. Departing from our last common ancestor with nonhuman primates, the language system in humans might have been exapted from an already flexible pre-existing system. Accordingly, even though a large proportion of modern day human communication is vocal, the key underlying brain infrastructure (still) operates in a flexible and amodal way. In other words, language is flexible because its neural basis is.

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