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REVIEW ESSAY

The evolution of communication and language in the voices of nature

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Abstract
To better understand the knowledge of language we study how it interacts with other kinds of knowledge in the performance of different abilities and their corresponding knowledge structures, for example in reading and writing or in comparing prose and singing. The more difficult study is to gain a better understanding of how language emerged in our species. Comparative research with other species focused on communication, especially when expression is vocal and reception is auditory, may help us to formulate the right questions. In the comparisons in which the mechanisms of communication and aspects of the underlying knowledge are learned, another dimension of the research program presents itself. A recent survey of the field by Nicolas Mathevon maps out some of the main results of this research in *The Voices of Nature: How and Why Animals Communicate* (2023). The following review essay will be selective, as the survey is wide-ranging and covers related topics that will take us too far, even though they are, ultimately, related.

Keywords Bological systems · Song and language · Natural selection · Domain specific · Domain general

Introduction: voice in communication and in language

In this review we ask how communication evolved, its onset and time-course in the different lineages of vertebrates in particular, about the mechanisms that account for performance and how the underlying competencies develop across the lifespan. How do the individuals of the same species come to identify each other acoustically, use the information carried by the signal for mating, defending a territory, signal the presence of a predator, source of food and for social interaction generally? On the last

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point, *Voices of Nature* (henceforth *Voices*) describes compelling examples of how, for example, parents and offspring communicate with each other, sometimes under special, acoustically exceptional, circumstances.

The investigation of animal communication attempts to explain how the forces of natural selection and sexual selection participated in the emergence across time of the different communication systems. Then we ask how the communicative competencies unfold developmentally, again a biological question related to the evolutionary question. A hard-wired innate process (e.g. young songbirds will typically only acquire the song of their species) can be compared to an acquisition process, also guided by innate constraints. As we would expect, a good portion of the Mathevon study, Chaps. 1, 3, 10, 11, and 12, is focused on vocal expression and learning in birds. The innate constraints on acquisition, e.g. of birdsong, are a good example of how these processes in nature are also channeled by genetic endowment, what in cognitive science is related to the idea of "poverty of stimulus" in development.

Among the scientific questions raised in the book, as we can already see, one stands out among the others: vocal communication, expression and comprehension, in the animal species where it is (and has been) acquired/learned by the young from auditory input captured from their parents. In this field of study, "comprehension" encompasses a broad category (in reference to a more general sense of "meaningful"), that of: information that can be processed cognitively (experienced) in a way that is apprehensible, sensible/discernible, and in a way that is typically species-specific. It is with this idea in mind that we will consider both language and music in humans and the evolutionary precursors of both language and music among our recent ancestors. The former, human language, is the provocative topic with which the book concludes (Chap. 18: "Words…words"). In this regard it is noteworthy that *Voices* makes reference to both non-musical communicative expression and song. Charles Darwin's hypothesis—presented parenthetically, in passing—about the common origin of linguistic and musical competence (1981[1871]) is directly relevant to the theme that this review will take the liberty of emphasizing.

From the point of view of linguistic science (the study of language in the narrow sense, specific to humans), there are two approaches when considering the findings from non-human animal communication: (1) that specifically linguistic competence in modern humans, consisting in the grammar and the knowledge of words, is not directly informed by the study communication systems in other animals, and (2) that it is, depending on the comparison in question, relevant in different ways from an evolutionary point of view.

Fortunately for our discussion, from the perspective of both proposals (1) and (2), linguists generally accept that human *communicative ability* is a broader category of which linguistic competence (in Fig. 1, labelled "Language") is only a part. Thus "Communication" in the diagram encompasses the two domains on the left, as some communication is not linguistic. "Language," for its part, is of course largely communicative, and provisionally again we can accept that one of the uses of language is not communicative: for introspection and the organization and processing of thought—what is often termed "inner speech" (Vygotsky 1962[1934]). "Inner speech" corresponds to the right-hand side domain in Fig. 1.

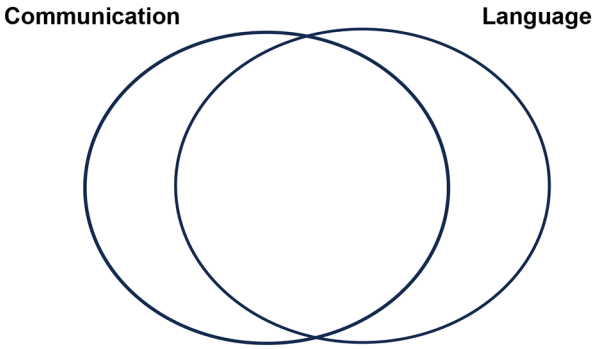

Fig. 1 Proposal for how human language and communication are related

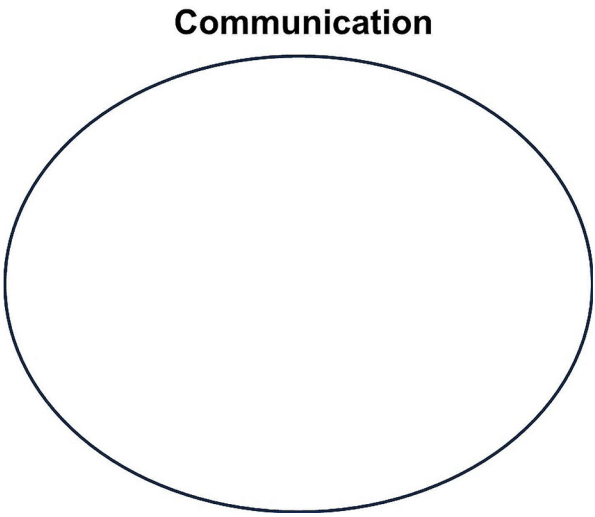

Fig. 2 Prelinguistic communicative ability prior to the emergence of language

From one point of view, the study of analogous communicative competencies of birds and non-human mammals, for example, may provide relevant comparison. Are there analogies or parallels of some kind across the evolutionary emergence of the competencies of communication and language that are worthy of comparative study? Might research on the underlying structures reveal interesting parallels or antecedents? At the same time we should be able to agree that the emergence of human language and communicative ability has vastly surpassed ("incomparably") in its complexity, creative potential, information processing capability and expressive power all other systems. With this assumption in mind, the review of the research will ask if there are any potential parallels in regard to complex vocalization,[1] and in regard to learning/acquisition.

One argument will present the following: Aside from the value of comparative animal research in its own right, there is the possible application to better understanding the evolution and development of communication and language specifically in humans. It accepts, tentatively, a version of (2) above, that our modern communicative abilities cannot be set apart completely in every way. While not explicitly stated, an underlying theme of *Voices* is that, along these lines, the idea of a sharp break

in relatedness is not justified by the findings of research in bioacoustics and animal communication.[2] At least, "sharp break" shouldn't be the default assumption.

The opposing argument (1) presents a model of language that focuses on its central faculty within linguistic competence. From the point of view of possible antecedents in evolution, this core grammar would be without a true precursor in the sense of being sui generis or singular, with an underlying cognitive structure of unique properties. Even though in the end we will have to accept that both (1) and (2) are plausible, contrasting the two hypotheses will be of great value for reflecting on one of the interesting claims in *Voices* and for better understanding the larger research program on language and communication from an evolutionary perspective.

Bird-brain communication

In the study of the evolution of complex vocalization, in which learning is required for full development, the distinction between analogy and homology is important. *Voices* calls special attention to the former, in particular in the chapters on birds and mammalian species for whom learning has been demonstrated. Simplifying greatly, analogous features emerge in converging evolution (e.g., dorsal fin in sharks and dolphins, flight in birds and bats), while in contrast homologous features can be traced to a common ancestor. See Scott-Phillips and Heintz (2023) for examples from non-human communication. We can consider the two categories in turn, taking up the latter in more detail in the next section.

The remarkable parallel between song in birds and language/music in humans has been the focus of much informed observation and experimental study.[3] The parallel involving whale and dolphin vocalization we know less about. Contrary to an idea of coincidence of little scientific interest, Mathevon, following the example of a number of researchers in the different fields, takes the possibility of antecedent as an important empirical question. The different kinds of parallel in each case should be considered, even as the problem of evidence is a difficult one. In "biological systems, the same problem (learning and producing song) [is related to] "the same solution (specialized brain nuclei for these functions)…[example of] structural and functional convergence" (p. 168). Returning to the relationship between the communicative competencies and linguistic competence in Fig. 1, at least for the former (learned communication by vocalization), the examples of convergence deserve our close attention. The question is one of better understanding the evolutionary analogy, the parallel selection processes that we can infer in the observation of acquisition/learning. Spoiler alert: regarding a different comparison, we will not be able to ignore the question of *homology* in regard to the emergence of both communicative competencies *and* linguistic knowledge in humans either, in this case, for obvious reasons, not involving songbirds and marine mammals.

Chapter 12, half-way through the book, represents a turning point in the discussion of animal communication as it presents interesting parallels across the species. As researchers have suggested, musical cognition consists of a network of various components, or modules, with different evolutionary histories. Fitch (2006) outlines the cross-species comparisons. These are relevant to our topic as we are accepting pre-

liminarily the possibility of a common emergence in humans of music and language (Mithen 2009), view that is compatible with the comparative approach of biomusicology that Fitch favors: "…music has better analogs in the natural word" (p. 175) than language. For example, vocal learning in humans and birds, with no common ancestral feature, nevertheless provides evidence for adaptation. To reemphasize, the object of study is that of analogy, as humans are the only primate in which "complex learned vocalization" (song/speech) has evolved (p. 182). Here, the focus on the subcomponents, or modules, of music and language, allows us to better evaluate the evidence.

Birdsong (in the avian species that sing) should be distinguished from "calls," which are not learned; song is marked by its complexity, with its development dependent on the relevant input from parents. Also following Darwin, the importance of the comparison to birdsong for the study of language/music capability in humans resides in its possible adaptive functions (p. 187)—territorial defense, mating and communication with offspring. Analogously (*in respect to birds*), the adaptive function for the emergence of a (hypothetical) integrated musical-linguistic precursor among archaic hominids might have been related to an advantage accruing to individuals with more effective socialization/communicative ability. An example has been proposed, speculating on the variation in survivability among archaic hominids (e.g. from predation and other dangers) related to infant response to maternal lullaby-type vocalization (Mehr and Krasnow 2017). The more general hypothesis makes reference to selection for the ability to understand complex information, provide relevant feedback, and so forth. We have to take note here, again getting ahead of ourselves: for some hypotheses of language evolution (so-called, of *discontinuity*) the hypothetical comparison in this case between archaic hominids and modern humans might perhaps be one of analogy. For so-called hypotheses of *continuity*, they would be one of homology.

In regard to possible parallel (analogous) cognitive mechanisms, another interesting example is the developing variation resulting in dialects: "non-native" variants are acquired by experimentally adapted sparrows provided that the chicks are young enough and have not begun to sing.[4] The "foreign" song, learned from loudspeaker input in the wild, was passed on to the next generation. The parallel in question refers to the *critical period* phenomenon in early acquisition, demonstrated in birds and today definitively in humans.[5] Denial of usable input to the chick (in some bird species, so called "closed-ended learners"), or human infant, results in generally irremediably abnormal development in this domain, and subsequently in related cognitive domains. In songbirds, analogously to human child language acquisition, development passes through stages of experimentation and approximation (narrowing) toward the parent bird target proficiency. Learned song patterns are combinatorial (especially noteworthy when improvising and *inventing new song*) as the creative constructions of young birds are "rule-governed" (p. 190), i.e. systematic. The song that corresponds to a bird's species is the one that is "selected" for acquisition/learning from competing input among adults of different species (Mathevon 2023: 158—165). Parallel to dialect drift in speech communities, the gradual accumulation of new forms from "imperfect" learning ("copying error") lead to divergence between isolated populations, and forgetting (i.e. replacement)—shift to another "vocal cul-

ture" (pp. 171—173). Before proceeding, especially in light of the comparison here between songbirds and human children regarding the phenomenon of critical period, readers will find it useful to study the first section of the Scott-Phillips and Heintz (2023: 93—96) paper on the distinction between analogy and homology.

Comparison and contrast across evolutionary time

By the end, *Voices* sets out an approach to studying non-human communication systems that potentially should inform our study of human language. Taking the example, in particular, of learned vocalization, there is reason for engaging in this research (on bird and marine mammal song for example) as a case of analogy/convergent evolution. How do selective pressures converge on parallel cognitive structures? The question of what accounts for the analogy in evolution is an interesting scientific problem in its own right, and future results of fieldwork and laboratory experiment will undoubtedly present us with important findings about the biological foundations of the kinds of cognitive process (revealed in behavior) described by scientists. We have to say, from these descriptions, that what has been revealed so far should be surprising, motive for pause and reflection. Reflecting on this phenomenon, we could say that convergent evolution applies, without much controversy, to the non-linguistic aspects of the communicative competencies mentioned earlier.

The debate, now, presents itself more clearly. The concluding chapter of *Voices* poses the question of *continuities* and *discontinuities*, the previous chapters having prepared readers for it. "Do [non-human animals] have a language of the same type as [human] spoken language, with rules that allow us to exchange information as we do, through sequences of words and sentences?' Is non-human communication "comparable" regarding the "combination of units," for example human language differing significantly, making it admittedly "unique," in its degree of complexity (p. 281)? Thus, in the way the question is presented, *Voices* favors a *continuity* hypothesis, one belonging to the larger family of continuity hypotheses.

Within the category of the communicative competencies, the continuity would go beyond analogy, to consider the possibility of shared inheritance—homology. In fact, the general idea of continuity (in the way we are taking the liberty of using the term) now goes beyond the domain of non-linguistic communicative capability to consider homologous features in language itself–actual linguistic competence. There are a number of continuity-discontinuity discussions in the literature—for brevity and for introductory purposes we can take up the one cited in Chap. 18, the concluding presentation on this topic (p. 282). It also happens to be timely and appropriate as it is representative of the discontinuity hypotheses (Hauser et al. 2002). The 2002 paper was updated by Hauser et al. (2014). Representing a strong claim by prominent theorists in cognitive science, it is associated theoretically with the Minimalist Program in linguistics. In this case, the modular core of linguistic competence, the Faculty of Language in the Narrow sense (FLN), considered as specific only to humans and unique to language, is conceived of as not evolving from precursor faculties that served communication. The FLN consists of the core syntax, with even phonology forming part of a periphery of the broader faculties—the Faculty of

Language-Broad (FLB), with which FLN competence interfaces. Conceptual structure (semantics) would be a clear example of a separate cognitive faculty with which FLN interacts, a view also shared by linguists outside of the Minimalist Program. There would be neither analogs of any scientific interest to FLN in other animals, nor homologs among ancestral, extinct, primate species. There are no directly relevant parallels in regard to the core of linguistic competence in the narrow sense, none that would inform understanding of the underlying biological capacity in question (p. 1). The core syntax of the FLN centers on the property of recursion; and all non-human communication systems appear to lack any analog, much less homolog, to this defining aspect of linguistic competence.[6]

Supporting the hypothesis of discontinuity are the results from the ambitious studies of non-human primate language teaching. Taking as subjects our closest surviving primate cousins, all attempts have failed, after intensive training, to even approximate the spontaneous and automatic language acquisition attainment of human preschoolers. In the famous experiments, the instruction provided to non-human primates revealed no vocal learning, critical period, developmental stages such as babbling, or the development of grammar knowledge involving the merging of constituents to form language-like phrases and sentences. In contrast, young children acquire a fully formed syntax without instruction of any kind, requiring only "simple immersion." Mastery of the "core grammar" of the narrow language faculty is uniform across culture, ethnicity and socio-economic status, as well as being unaffected by seeming grammatical complexity that appears to differ from one first language (mother tongue) to another. At the same time, while recognizing the stark contrast in regard to human grammatical knowledge, objective assessment of the teaching experiments prompts us to credit the *communicative abilities*, associated with limited vocabulary learning, of the non-human subjects as impressive and surprising. The reference in *Voices*, in Chap. 12, to the primate teaching experiments generally concurs with this overall assessment.

As a rough estimate, as all speculation on this question is rough, linguistic competence (the FLN) emerged recently according to the discontinuity proposal, after the divergence of *H. sapiens* and *H. neanderthalensis*. The hypothesis for the recent emergence, *not gradual evolution*, of language, the authors categorize as non-adaptive. Non-adaptive hypotheses question the evidence for, or assumption of, "higher biological fitness for more proficient [language] learners" (Hauser et al. 2014; p. 8).

Interestingly, a counterposing continuity hypothesis may be the most prominent reply, coming from within a similar theoretical framework of Universal Grammar (UG). According to Pinker (2013), the modern Faculty of Language (FL), also viewed as uniquely human and domain-specific (specific to language, i.e., autonomous from Conceptual Structure), should be studied as a product of gradual evolution, emerging from ancestral precursor capabilities. In our attempt to better understand it, both analogy and homology come into play, in different ways. According to this view, the FL is "a complex biological adaptation that evolved…for communication in a knowledge-using, socially interdependent lifestyle" (p. 16). Similar to all other UG proposals (including the Minimalist Program), the grammar is not one undifferentiated domain, but is a system consisting of combinatorial sub-systems that interface, internally, within the linguistic domain and beyond with the broader non-linguistic domains

of cognition. Unlike cultural learning, language should be thought of as "part of the standard human phenotype a trait whose genetic basis was shaped by natural selection" (p. 22). The learning mechanisms would have come to be adapted in such a way so that they are domain-specific, specialized for language. The language faculty is internally diverse, of complex network interaction among its different components, or modules. The evolutionary force that gave rise to this kind of complex design would have involved pressure to fulfill functional requirements corresponding to a complex adaptive design, according to this view. Such a system, because of its complexity, had to have been evolvable, over evolutionary time (Dawkins 2006; Kinsella 2009).

On the important results from non-human primate language teaching experiments, continuity proposals (UG-motivated, at least) will be in agreement with the observations of discontinuity. The communicative ability attained by subjects does not offer support for homology. However, Pinker calls our attention to the fact that from within the hominid lineage only a small contingent has accompanied modern humans to the present. Among archaic human populations there could have evolved many lineages that have not been identified, with language emerging in only one that has *survived*. But in the hundreds of thousands of generations after the chimp-human split, a number of homologous structures subserving approximations to modern language could have evolved in species that have since gone extinct. The possibility of the evolution of primitive-ancestral protolanguage among *H. neanderthalensis, Denisovans* and even *H. erectus*, based on archaeological findings showing evolution of general cognitive abilities, should not be dismissed. See the discussion in Mithen (2009) of the "musilanguage" hypothesis, following Darwin (1981[1871]). The adaptation (what language and approximations toward language favored) served the distinctive emerging traits of our ancestors and the conditions in which their offspring were able to survive: hyper-sociability, interdependence and the need to share complex information, for example about causes and effects. Grammar and an extensive vocabulary co-evolved with a higher-order general cognition (p. 29). Incremental inherited advances in these domains, gradually over time, favored survival and reproduction.

An important clarification here is necessary to make. No attempt should be assumed in the discussion of this debate to assimilate the evidence of cross-species communicative parallels in Mathevon's study toward the UG-related adaptationist hypothesis. The comparison, made above, is strictly one of pointing out that the perspective put forward in *Voices* on the comparative research belongs to the larger family of continuity hypotheses. Strong non-UG proposals on the evolution of language, and on language ability in general, also belong to this family. For example, the widely cited language evolution account of Everett (2017) rests on assumptions that completely dispenses with the domain-specificity of linguistic competence or the concept of UG. According to this view, there is no reason to posit a genetic endowment that is specialized for language acquisition. The discussion of the different points of view in Francis (2017) outlines the relevant similarities and differences. Everett's hypothesis also proposes a protracted, gradual and incremental, evolution of language with the necessary emergence of shared ancestral features in our recent lineage. In this case the target of natural selection would be domain-general cognitive ability, as opposed to a domain-specific FL.

Considering Everett's view, an important current of theorizing from within a cross-disciplinary discussion of language evolution focuses on the domain-general capacities (not necessarily making reference to them with this term). Fortunate this is for Usage-based hypotheses, such as Everett's, *and* UG-oriented proposals that do not reject the participation of general learning processes in the evolution of language competence (or developmentally), even for some components of the core grammar. This provisional common ground[7] now allows us to benefit from the above mentioned inter-discipline cognitive science discussion of the evolutionary antecedents of fully formed language ability as attained, ultimately, by modern humans. It can start with (the different, if they really are, variants of) the "pragmatics first" hypothesis, that communicative abilities are independent of language (Bar-On and Moore 2017). They are prior to and foundational for language. In a way, also by hypothesis, "concepts first" could be a more general statement of this proposal, as conceptual structure would also be independent and prior to language. The ability to share information gradually advanced, forming the seeds, precursors, of pragmatic competence that came to be biologized by natural selection (Moore 2018). The controversial idea here is that these kinds of domain-general capability, and others, might have in fact evolved in this way—that they actually, materially, formed part of the evolving human cognitive architecture. Among our recent ancestors, there emerged the perception of intention in expressive communication, the beginnings of mind-reading, thinking about others' mental state. Full-fledged Theory of Mind (ToM) then would have been attained in parallel with the emergence of fully formed linguistic competence. These were apparently the defining features of only one surviving lineage from which emerged modern humans.

At this point readers will take note that no aspect of the commonality among the different continuity hypotheses confers upon them a decisive advantage. The contrasting Minimalist Program "saltation" proposal could in the end show them all to be on the wrong track. In addition, the Hauser et al. proposal in no way minimizes the scientific value of the research on non-human animal communication systems. It simply questions the relevance of its findings to the problem of language emergence in modern humans and the nature of linguistic competence (knowledge of language in the narrow sense). Finally, readers should set aside the bias that appears in this concluding section toward the continuity/language-as-adaptation hypotheses, such appearance resulting from the greater degree of abstractness in the presentation of the Minimalist Program non-selectionist proposal in the literature. That it appears as less intuitive, of course, in no way stands as an argument to its disfavor.

Returning to Fig. 1, we can now consider an earlier period that preceded the evolution of language, in the strict, or narrow, sense: before a fully formed linguistic competence emerged consisting of a lexicon, grammar and phonology. Communicative ability among our earliest hominid ancestors was non-linguistic in this sense.

Early archaic humans possessed an ability to communicate. Linguistic competence emerged in one lineage of humans—early modern humans, *H. sapiens*.

Figure 2 can serve to recap the discussion and conclude this review. Based on the summary of the discontinuity and continuity hypotheses, there are two scenarios that we have been considering for the emergence of a fully formed linguistic competence—"Language" in Fig. 1:

1) Core language knowledge emerged separately, in recent evolutionary time, and rapidly, for reasons other than communication—discontinuity.
2) Core linguistic knowledge evolved primarily to serve communication, linguistic competencies evolving from communicative competencies; adaptations acted upon protolanguage precursors gradually, over evolutionary time. Natural selection was the mechanism—continuity.

In scenario (2), there exist possible relationships of homology between modern language and precursor protolanguage in extinct human ancestors. In (1), modern language (the core linguistic knowledge) probably cannot be traced back to protolanguage homologs.

To be clear, the discontinuity hypothesis of the Minimalist Program does not exclude the possibility that the modern human communicative competencies of FL-broad, falling outside of FL-narrow, can be traced to homologous communicative competencies of archaic hominids. Plausibly, some aspects of these underlying knowledge structures are shared between modern humans and living non-human animals (Hauser et al. 2002). It is the core of language, the FLN, that cannot, via natural selection, be traced back in this way. Thus, the discontinuity applies only to FLN, the Minimalist Program accepting a possible continuity in other domains. Another informative comparison of the two language emergence scenarios is that between the papers by Hauser et al. (2002, 2014) and the discussion of continuity hypotheses related to the concept of protolanguage, for example, in Tallerman (2007).

In the speculation regarding protolanguage, researchers have pointed to the evidence for increased social complexity and technical skills, among other cultural inheritances. Effective cultural transmittal suggests that teaching and learning evolved, the increasingly high-fidelity transmission improving incrementally (Sterelny 2016). Along with mental rehearsal and cooperative activity, ToM evolves (p. 177). The incremental nature of these advances implies that they began to appear prior to even the most incipient approximations toward protolanguage, at least prior to "voice-based" protolanguage. On this idea (of gradual, over evolutionary time, emergence of language-related competencies), Sterelny argues that even our common ancestor *H. heidelbergensis* (who we share with Neanderthals), despite their evolved social and technological capabilities, only approached an incipient language-like system. That is, *sapiens* may not have inherited a late-stage evolving protolanguage from *this* ancestor (p. 178–179). The gradualist view presented here is consistent with the "concepts first" or "communicative ability (pragmatics) first" hypothesis. Along the same lines, in regard to another, related, research problem of continuity between modern human communication and ancestral communication, Scott-Phillips and Heintz (2023) suggest that "meaning and grammar have different etiologies" (p. 15).

An earlier appearance of protolanguage, assuming the same "very [slow] and [gradual]" (p. 212) evolution, is proposed by Planer (2017). An incipient and limited ToM, the ability to construct mental models, and to imitate, formed the necessary cognitive underpinning. As the beginnings of a lexicon expand, a rudimentary syntax eventually presents itself. Even if what was in place was the most primitive "apprentice learning system" for tool making, involving basic "demonstration and error correction," interpersonal communication with a vocabulary generated a simple

grammar for making reference in face-to-face cooperation to activities and states of being (p. 215). For example, there is "evidence showing that early Pleistocene [2.5 mya – 800 kya] hominins made long journeys…to procure raw materials for stone tools" (p. 217).

There exist other proposals for thinking about the relationship between language emergence and non-human communication that this review has not taken up that deserve attention now with the backdrop of *The Voices of Nature* and continuing investigation in the field of ethology. If a recommendation for a second edition is in order, it would propose a more thorough concluding discussion in Chap. 18 on the question of continuity and discontinuity, specifically in relation to human language. It was the (interesting) passing reference, citing the Hauser et al. (2002) paper, that prompted this review.

The same kinds of question about the relationship between language and non-human-communication, and kinds of question that are different, apply to the comparative research on communicative ability within and across other lineages. The problems of language ability and the evolution of its neurological underpinning in humans would not have to come up. For good reason, this research is not always about us.

Notes.

1. The emergence of sign language historically, or evolutionarily, and its development in children and older learners, is an important related research question. The interesting discussion specifically on evolutionary antecedents (Corballis 2002) needs to be deferred for now.
2. One example of a possible archaic precursor of an aspect of modern human communicative ability has been proposed by evolutionary theory. Prior to the emergence of language, therefore of *H. sapiens*, it bears on the narrative competencies. Among both recently extinct ancestors, and surviving mammalian cousins, there appears evidence that they possessed, and the latter possess, the capability to process memory representations of event structure of varying degrees of complexity, and can access them purposefully, "coherently." See the discussion in Fletcher (2023) of examples.
3. Only three groups of birds learn signing: oscines, parakeets and parrots, and hummingbirds—nevertheless accounting for over half of currently living species, approximately 4700, 350 and 330 species, respectively (Mathevon 2023 p. 160).
4. During the beginning of the *critical period* of song acquisition (e.g., in the male zebra finch 20 days after hatching) the chick begins to "babble" (producing a "subsong"), then to gradually, but spontaneously, converge on the adult-like target ability. More so than the example of a convergence on a genetically programmed critical period in development, the most provoking biological parallel may come from the research on analogous neural structures, circuits dedicated to birdsong, and circuits dedicated to language in humans (Zhang et al. 2023).
5. In humans, the findings of age of acquisition effect for first language in the Nicaragua Sign Language (NSL) study (Senghas et al. 2004) were decisive, as a clear effect of late exposure, beyond the critical period, was able to be compared to

normal timely language input. The comparison was made possible in this project because two distinct cohorts of children presented themselves in the same quasi-experimental setting: late-acquirers (older children) and young children still within the critical period. The latter *creolized* the limited sign language input that they received, creating a fully formed sign language (NSL); the former, despite demonstrated progress, did not.

6. Considering this aspect of discontinuity in relation to the core property of narrow syntax (recursion): "[the] FLN may have evolved for reasons other than language hence comparative studies might look for evidence of such computations *outside of the domain of communication*" [emphasis added] (Hauser et al. 2002; p. 1569).
7. Here it is useful to recall the title of Bates and McWhinney's (1990) commentary on Pinker and Bloom's (1990) target article on language and natural selection in *Behavioral and Brain Sciences*: "Welcome to functionalism," heading that can be understood in two ways (in this review, "welcomed" favorably as an invitation).

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