Design Features of Language

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Synonyms

Characteristics of human language

Definition

Distinctive qualities of human language

Introduction

Some general conclusions apply to all communication among living organisms. Communication, even in nonhuman animals, has unexpected complexity; it is a form of cooperative behavior; it includes individual recognition and categorization; and it requires the development of associations and thus memory. Furthermore, noise in communication is inevitable. Critical terms, such as information, signal, and noise, require operational definitions (for more on these topics, see ▶ "Evolution of Communication").

These conclusions change basic assumptions about the relationship between nonhuman and human communication. Communication by nonhumans is more complex than expected and communication by humans, as presented in the following sections, perhaps less so. There is clearly a large difference in brain size, cognition, and communication between humans and most other animals. Nevertheless, overstating a difference hinders comprehension just as much as understating it.

For centuries people have sought objective criteria to separate humans from other animals, and language has often taken first place among these criteria. Once Darwin and the early ethologists made it clear that nonhuman animals also have elaborate communication, the focus has narrowed to the properties of language that distinguish humans. Each such proposal has spurred students of animal behavior to probe deeper for parallels among nonhuman animals. Some organization in this process came when Charles Hockett (1960) presented a set of 16 "design features," or distinctive properties, of human languages. Some of these features, such as a vocal-auditory channel (with its concomitants, broadcast transmission, directional reception, and rapid fading), interchangeability, and specialization are easily identified in diverse nonhuman animals. The remaining design features have more problematic parallels in nonhuman animals. Some of the issues they raise invite applications of the general conclusions listed above. The following discussion focuses on illustrative examples, rather than a general review, of these parallels.

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Cultural Transmission

Culture is widespread in species with persistent associations of parents and offspring, but it is also prevalent in many species with less complex social behavior. Culture develops when patterns of behavior are acquired by young individuals as a result of experience with older ones. Prevalent examples in nonhuman animals include migration routes, territory boundaries, mating preferences, food selection, and predator recognition. Cultural transmission in humans as well as in other animals includes relatively unconstrained learning. Possibilities for learning have broad scope within wide predispositions. Nevertheless, the study of nonhuman animals has revealed that even impressively open forms of learning have constraints that guide learning in adaptive ways. For rapid acquisition of complex traits within adaptive boundaries, learning within constraints is perhaps the optimal method. Such constraints (or predispositions) can for instance ensure that learning occurs within species, a particularly clear example of which is song learning by oscine birds. In this case, predispositions must affect responsiveness as well as production. Nevertheless, identifying predispositions for acquisition of human language remains contentious.

Animals other than humans rarely, if ever, appear to engage in teaching, in which an experienced individual directs the attention of an inexperienced audience to a task. Cultural transmission instead appears to result predominantly from observational learning by young individuals in the presence of adults performing routine activities (Matsuzawa 1999). A recent experiment with great tits reveals that observational learning can produce persistent cultural traditions in the feeding behavior of birds, even when the tradition is maladaptive (Aplin et al. 2015). In contrast, schools or apprenticeships are perhaps universal in human cultures. Nevertheless, it is possible that much, perhaps most, of human culture is instead transmitted by observational learning.

Cultural traditions in the songs of passerine songbirds, parrots, and hummingbirds illustrate one of the usual consequences of culture, the differentiation of dialects or traditions among nearby populations. All species of songbirds appear to learn at least some features of their songs. With few exceptions these species develop prominent geographical variation in their songs, whereas songs of other species vary only slightly, in line with variation in morphology. When the individuals of a species sing a single song pattern, all those in a limited geographical area often learn the same distinctive pattern. When individuals have repertoires of songs, dialects often intergrade as the frequencies of different acoustic patterns change progressively but incoherently with location (Marler and Slabbekoorn 2004; Kroodsma 2005; Podos and Warren 2007). When individuals sing only one pattern each, the formation of dialects is perhaps simplified. Nevertheless, distinct dialects in the vocalizations of some parrots and cetaceans include coherent repertoires of patterns.

Geographic differentiation of culture depends on the relationship between two periods in an individual’s life: when a young individual learns the relevant behavior and when and where it moves before it eventually settles. The formation of distinct dialects requires either that young birds usually settle within the area of their natal dialects or that learning after settling predominates over earlier learning. In the case of coastal populations of white-crowned sparrows in California, individuals usually sing only one pattern, and dialects occupy nearly distinct areas with irregular shapes 2-20 km across. It remains uncertain whether the songs a young sparrow eventually masters are influenced by experience predominantly before or after dispersal. Conversely, it is also unclear whether or not a young sparrow’s decision about where to settle is influenced by early experience.

Furthermore, it is also unclear whether or not dialects in birdsong are evolutionary adaptations (Podos and Warren 2007). Adaptation is a result of natural selection, the spread of alleles associated with advantages for individuals’ survival or reproduction. In one possible scenario, dialects might result from adaptations for efficient signal detection in different environments. Alternatively, dialects might promote local adaptations for survival or reproduction in general, by restricting gene flow to populations in distinctive environments. Another possibility is that dialects might arise as collateral effects of the evolution of learning, if, for instance, complex learning was in itself important for mate choice. Or dialects might arise as side effects (pleiotropy) of local adaptations for noncommunicative purposes in structures also used for communication, for instance, if the structure of birds' bills adapted to the characteristics of their food but also constrained the kinds of sounds they could produce. In the latter two situations, the formation of dialects would in itself have no influence on individuals' survival or reproduction. In any case, dialects might promote the genetic divergence of populations and ultimately contribute to the origin of separate species.

All of these issues about dialects apply to human cultures as well. The maintenance of human languages and dialects indicates that individuals learn from older individuals within their natal area and then predominantly settle nearby. The increasing frequency of exceptions in recent centuries is presumably changing the geography of human languages. Each individual's choices of mates and places to settle are no doubt to some extent influenced by their natal language. Important but infrequent exceptions are the abduction of individuals and the translocation of populations as a regular consequence of warfare between culturally distinct groups. No doubt the boundaries between languages are influenced by interactions across these boundaries, but differentiation of languages in turn influences the nature of these interactions.

In contrast to birdsong, human language is distinguished by two levels of geographic differentiation. At one level, there are mutually incomprehensible "languages," which in their geographic pattern resemble the distinct dialects of songbirds. At another level, human "dialects" within a language intergrade more or less progressively, like geographic variation in the frequencies of song patterns of birds that have repertoires. Perhaps more study of songbirds would also reveal multiple levels of geographic differentiation.

A related design feature, learnability, refers to the human ability to learn more than one language. In songbirds with vocal dialects, individuals usually respond to dialects other than their own, although sometimes less so to distant dialects (Searcy et al. 1997). Furthermore, just as children are adept at learning any human language, songbirds acquire any dialect of their species-specific song with apparently equal facility. Bilingual individuals also occur among songbirds. Although careful comparisons are lacking, bilingual proficiency is perhaps as frequent as it is in human populations. Bilingual competence is hard to confirm when individuals sing multiple patterns that vary incoherently with location. When dialects are distinct, on the other hand, persistent study often reveals the presence of bilingual individuals. Most white-crowned sparrows that settle near a dialect boundary sing only the pattern appropriate for their dialect, but some individuals near a boundary are indeed bilingual, with two song patterns, one matching each nearby dialect (Baptista 1977). To clarify these parallels between human and nonhuman cultures, the spatial and temporal properties of the transmission of signals and responses, in relation to the dispersal of individuals, need more attention, both in humans and nonhumans.

Despite these open questions about the process, geographical differentiation is one of the salient features of culture, both human and nonhuman. This differentiation requires errors in cultural transmission and thus reveals a crucial effect of noise in communication. Even if cultural traits have adapted to particular social or physical environments and even if migration of individuals introduces novelties in new areas, nevertheless errors must initiate the process of cultural change somewhere. Errors in cultural transmission are analogous to genetic mutations, insofar as both are transmitted to subsequent cohorts, although the rates of innovation and mutation can differ. Migration is similar in the two also, except that migrating individuals can abandon cultural traits but do not change genes (although the expression of genes might change). Cultural and natural selection, on the other hand, lack close analogy. The plasticity of individuals' traits, the rates of transmission, and the recipients all can differ markedly. Nevertheless, in the case of human languages, the stability and restricted acquisition of language might approach that of genetically canalized phenotypes. Close relatives usually play a predominant role in transmitting language. Language proficiency by humans requires years to develop and then, after the lapse of sensitive periods for acquiring some features of language, changes with great difficulty.

The transmission and innovation of culture depend on communication. Unless completely arbitrary, without advantages or disadvantages for signalers or receivers, this communication evolves by the same process of mutual optimization that applies to the evolution of all communication (see ▶ "Evolution of Communication"). The advantages for signalers depend on the behavior of receivers, and the advantages for receivers depend on the behavior of signalers. Errors, from multiple sources, are inevitable. Even perception evolves by optimization with errors. The crucial role of errors, in other words noise, in all communication and perception means that culture, in humans or other animals, cannot be understood without studying errors. In studying the evolution of birdsong, the variation in learning is as important as the norm. The same is true of all human culture, including language. Yet studies of culture have usually focused on the norms, to the exclusion of the errors. Understanding communication requires attention to exceptions as well as norms.

Semanticity, Displacement, Arbitrariness, and Discreteness

This set of Hockett's design features refers in one way or another to how signals are related to situations. Many animals use discrete signals. Discrete signals are likely to improve discrimination by receivers and thus could have advantages in noisy situations such as long-range communication. In line with this expectation, discrete articulation might be more pronounced in long-range speeches by humans than in close-range conversation. This variation in discreteness would exemplify the scaling of exaggeration in signals with the level of noise, as predicted for the evolution of all communication in noise (see ▶ "Evolution of Communication"). More study of variation in signals with contexts could clarify this issue.

Arbitrariness refers to separation of a signal from direct resemblance to or evocation by its referent. Warning calls, for instance, do not resemble the sounds of predators. On the other hand, the pitch or tonality of sounds in some cases directly reflects an individual signaler's overall physiological state, such as its tendency to flee, fight, or freeze (Morton 1977; Reby et al. 2005). Arbitrariness is intended to denote a signal's association with a more cognitive internal state, a specific neurophysiological state rather than a general physiological or emotive one. These alternatives, of course, are the ends of a spectrum of possibilities. Each case lies somewhere between a scream of fear and an abstract notion. Human speech conveys information about a speaker's general states, or emotions, in addition to and concurrently with specific states or abstractions. Any signal has some degree of arbitrariness and some degree of abstraction. No doubt human language includes more cognitive complexity than other animals' signals. An unanswered question though is whether or not it might also include more emotive complexity. This continuum between emotive and cognitive applies to the next two design features also.

Note in passing that arbitrary signals in discussions of sexual selection are defined differently. They have zero utility for receivers and, as argued elsewhere, seem highly unlikely in noisy communication (see ▶ "Sexual Selection" and ▶ "Evolution of Communication").

Semanticity and displacement are related to information in signals about the external environment. Some of the best examples of semanticity in nonhumans are warning calls and food calls. Semanticity applies to signals associated with external referents in contrast with those expressing the signaler's internal states. This distinction is just as untenable here as in the previous paragraph. Recall from previous sections that all of an individual's actions are influenced by both its internal and its external state, by both its current constitution and its impinging sensations. Rather than a distinction between signals that are emotive versus cognitive, there is instead a continuum from more emotive to more cognitive. The question is where particular instances of calls lie on this continuum from emotive to cognitive.

Playbacks show that individuals respond appropriately to alarm or food calls even in the absence of an actual predator or food. Furthermore, some birds and mammals have distinct calls for two or more predators that pose different threats, and playbacks of these calls evoke the appropriate responses. The associations with different predators are in some cases learned. Young vervet monkeys reliably produce the correct calls only after prolonged practice (Cheney and Seyfarth 1990). Many birds in contrast easily learn experimental associations of predator calls with various improbable objects. It is thus clear that some nonhuman animals can learn to produce, and to respond to, signals associated with specific external situations, and in some cases these associations are learned easily.

On the other hand, in normal circumstances these calls are produced and evoke responses, only in the presence of actual predators. Displacement, in contrast, refers to separation of a signal and its referent in space and time. This separation requires memory. With displacement, the cognitive rather than emotive associations of signals, and thus their semanticity, often seem clearer. Furthermore, relatively more cognition is suggested by two forms of noise in communication: unreliable and deceptive signals. Adult vervet monkeys, for instance, learn to ignore the unreliable calls of young individuals (or unreliable adults) (Cheney and Seyfarth 1990). Furthermore, some monkeys and birds produce predator warnings deceptively in the absence of a predator, as discussed further below. Errors in communication, the apparent exceptions, provide intimations of cognition.

Displacement is also attributed to the waggle dances of honeybees. These dances in a hive or a swarm indicate the location of food or potential nesting sites by means of two transpositions. The direction to the goal with respect to the sun becomes the direction of a waggle dance on a vertical surface with respect to gravity, and the total energy expended in flight to the goal becomes the instantaneous expenditure of energy in the dance. The levels of arbitrariness and semanticity are both low. The mapping of direction and distance onto the signaler's overall behavior and the limited memory remove this case from typical human cognition. Arbitrariness, semanticity, and displacement again contribute to a continuum between emotive and cognitive behavior. All are widespread in communication. All are disrupted by noise. Yet their use in noise sometimes reveals a degree of cognition.

Prevarication

Hockett's final design features are at the top of his proposals for human specializations. Nevertheless, there are reports of prevarication, or deceptive use of signals, in many birds and mammals. Predator calls, in particular, can serve to distract higher-ranking opponents so that low-ranking ones have a chance to obtain food or matings. Analysis of communication in noise shows that opportunities for such deception are expected in all forms of communication (see ► "Evolution of Communication").

Nevertheless, linguists often balk at attributing true prevarication to nonhuman animals, in the absence of evidence for the signalers' intention. Intention becomes one of the definientia of deception. Does the signaler expect or plan to deceive the receiver? How does a person expect or plan to take advantage of another person? Presumably the actor anticipates a personal advantage based on anticipation that the recipient is vulnerable. In the case of deceptive communication, the signaler thus anticipates that a particular receiver is likely to respond in a way that yields an advantage to the actor despite a disadvantage to the receiver. This anticipation is tantamount to mind-reading or having a "theory of mind." There is a circularity here: an actor has intentions provided it can read another's mind, and primary evidence that an actor can read a mind is provided by thoughts such as intentions.

Such circularity in discussions of mental phenomenon excludes not only nonhuman animals from a thinking person's mentality but also all other humans. An operational definition of deception, which avoids such circularity, is a system of signals directed specifically (nonrandomly) at receivers from which a response, on average, has advantages to the signaler but disadvantages for the receiver. Such signals require some preliminary strategy. Because responding to signals should evolve to increase a receiver's advantage in reproduction or survival, deceptive signals, which have the opposite effect, must in general occur infrequently. Consequently, deception often reveals evidence of a cognitive ability by signalers to adjust the frequency of attempted deceptions by itself and others. For instance, a deceptive signaler might anticipate a particular receiver's probable response; in effect it might read its mind, from the temporal context of signaling.

Reports of deception by nonhuman animals indicate that this behavior is, as expected, usually dependent on the circumstances of the audience. Signals that call attention to the presence or location of food often depend on whether the audience is likely to be a competitor or a partner. Recognition (categorization) of individuals, not just broad classes of individuals, is often critical. Anticipation of the state of the audience is of course widespread in nonhuman signaling, but this attribution applied to specific individuals matches the kind of behavior associated with intentions, as just defined. It presumably occurs in many sorts of social interactions, from anticipatory cooperation to strategic aggression (Cheney and Seyfarth 1990, 2007; Seyfarth and Cheney 2014). It applies to roosters advertising food to attract hens (Gyger and Marler 1988), to subordinate males courting females without drawing the attention of dominant males (Smith et al. 2011), and to territorial warblers challenging specifically those neighbors that have trespassed (Godard 1993). The complexity of an organism's "theory of mind" depends to a large degree on the complexity of its categorization of the individuals it interacts with. Furthermore, intentions in the form of signals adjusted to contexts, whether human or nonhuman, are subject to errors.

Duality of Patterning and Openness

These final, and most problematic, design features are closely related. Openness in human language, an ability to rearrange units of sound to produce new phrases, depends on duality, the organization of speech into at least two hierarchical layers. Elements of a lower layer, which in themselves have little or no meaning, are arranged to produce units of higher layers, which do have meaning. As previously suggested, the operational definition of the "meaning" of a signal, in a particular context, is the receiver's usual response, overt or covert, immediate or remembered. Language is often described with three layers, phonemes, morphemes, and phrases (sometimes with syllables of phonemes interposed), of which only phrases convey meaning. Duality of patterning requires two layers arranged so that recombined discrete components of one layer are nested within components of the other.

Many nonhuman animals have substantial repertoires of discrete signals (see ▶ "Evolution of Communication"). In those species that produce sequences of signals, some recombine signals into larger performances. Some songbirds use the same components in different sequential patterns of song, but some use different components in each sequential pattern. There is sparse evidence that the different sequential patterns in these repertoires convey different information, for instance, by association with different contexts or internal states, or evoke different kinds of response (Wiley et al. 1994). An absence of evidence is particularly inconclusive here, because finding significant associations with complex patterns of recombining elements becomes statistically challenging. Anthropologists have a big advantage in deciphering a previously unknown human language, as a result of their preconceptions about what humans are likely to talk about. Humans, in other words, have an anthropocentric theory of mind, one that provides much less help in deciphering communication of other species. Humans perhaps should not underestimate other animals.

Despite these possibilities for other species, human language no doubt has remarkable capability to recombine components of signals to convey a vast complexity of information. Nevertheless, components of language are not nearly so distinct in actual speech, in all its various contexts, as they are often presumed to be. Contextual and individual variation in phonemes and morphemes is well known. Furthermore, everyday conversation might depend heavily on phrases as units, learned for production and response as units, rather than as recombined components. All languages are beset with idioms and pat phrases, particularly for routine communication, phrases learned as units rather than by rules. In English, few people know the expressions "thin as a rail" or "what's up," for instance, as anything other than "thin-as-a-rail" or "whats-up," single units of expression, not recombining units. Another example is the instability of prepositions (and grammatical cases). Across and within languages, association of prepositions with contexts often defy consistent definition and instead become erratic or idiosyncratic. Most of these associations are presumably learned and deployed as units without parsing. Proficiency thus might often depend on mastering associations of these unitary phrases. Even when some parsing of recombined components is necessary, the associations of phrases can depend on common underlying metaphors (Lakoff and Johnson 1980). Indeed, morphemes raise the same questions. Many words are sequences of two or more syllables, which in combination evoke unitary associations. Etymological stems for syllables are rarely parsed. Even then underlying metaphoric associations dominate. Thorough study of the variability of human speech at all levels might reveal that duality of patterning requires a dose of grammatical fantasy.

The deployment of writing in itself changes communication. Writing allows much greater permanence than does neural memory alone, and this permanence allows a reader, as a receiver of signals, to examine and even to review the structures of phrases more carefully than is possible in conversation. With time available, humans can indulge their drive to categorize, by abstracting, cataloguing, and eventually prescribing patterns of usage. In reality both human and nonhuman communication are permeated with unexpected variation, as a result of errors in production, transmission, or reception of signals, but also just idiosyncrasies in usage by individuals or small groups of communicating individuals. The irregularities, idioms, idiosyncrasies, and errors are an inescapable part of language.

Openness is an abstraction or exaggeration of reality as well. Although linguists often claim infinite possibilities for language, the components of language are finite, the human brain is finite, and the practical possibilities for combinations are finite. Speaking humans do not produce stereotyped phonemes that recombine to form stereotyped morphemes and then phrases with unlimited possible meanings. The number of possible associations is no doubt large, but the number of associations humans make in using language might not exceed the number of associations they make in categorizing other humans (Wiley 2013). Errors also limit associations of attributes with other objects.

Furthermore, limited evidence is a temptation for simplification of nonhuman animals' behavior. For instance, songbirds are usually thought to have repertoires of distinct patterns of notes, from one to several hundred such patterns. Careful inspection, however, reveals much variation in details, little or none of which has any current explanation. Perhaps even greater complexity in sequences of sounds occurs in cetaceans. The difficulties of investigating complex signals include the impediment of lacking an appropriate theory of mind on which to base hypotheses. Nevertheless, much variation is no doubt meaningless, just as it presumably is in human speech.

A promising way to investigate variation consists of looking for dependence in recombinations of components. A simple example is provided by displays of the Carib grackle (Wiley 1975). Males perform conspicuous displays to females and other males. Each display involves raising wings, tail, and bill to varying degrees. Elevated wings show some association with displays toward females, elevated bills with those toward males. Because these displays are easily observed, a large number can be scored for each element. Analysis reveals that wing and tail elevation are independent of each other, so in this case this species has the potential to generate infinite gradations of wing and bill elevation, each presumably related to neural and mental states while interacting with females and other males. This example of insipient duality and openness indicates how difficult it can be to decide whether complex variation in signals is relevant, erroneous, or simply adventitious.

Hierarchical Organization

As awareness of the complexities of nonhuman communication has accumulated, attention has focused on hierarchical organization as the key to the relative openness of language. Although responses to “sign stimuli,” simple sensations, occur widely, especially in the initial responses of young organisms or in the quick avoidance of predators, nevertheless, responses to more complex stimulation are also widespread. For instance, many vertebrates, but not humans, have neurons that act as movement detectors, even at low levels of sensory processing. Recognizing patterns is not an unusual capability of many other animals. Although birds and mammals soon after hatching or birth have reflex (highly canalized) responses to simple stimulation associated with predators, they often quickly learn more complex associations. Object constancy, an ability to recognize (form associations with) a set of sensations as a unique object despite varying perspective and occultation, does not differ in principle from other forms of recognition, including recognition of individual conspecifics or recognition of verbal sequences. Recognition of patterns, spatial or temporal configurations of components, is thus a mental capability that occurs widely in animals as well as humans.

Much recognition is potentially hierarchical. Any particular instance of a set of sensations could be recognized as belonging to one or more progressively more inclusive and complexly embedded or overlapping categories. A territorial neighbor can be recognized, for instance, despite singing multiple different song patterns, at different locations and distances, under different environmental conditions. Furthermore, it might be recognized more specifically as one that had recently trespassed or one known from a previous year (Godard 1991, 1993; Wiley et al. 1994; Godard and Wiley 1995). Hierarchical categories are recognized by Aristotelian definition, with consistently defined features. Alternatively, categories might be recognized by family resemblance, with inconsistently shared features. In the first case, all members of a category would share an inclusive set of features, as in a phylogenetic tree. Membership in categories would be unambiguous. In the second, members of a category would each share some but not necessarily the same set of features with every other, as in an actual family. Ambiguity might occur.

Chomsky (2005) recognized the importance of categorization when he proposed that merging is the crucial cognitive operation of language. Merging, in the usual sense of simple combining, is nevertheless too simple for his examples, which require combining elements from two separate categories, subjects and predicates, in order to produce a phrase with meaning. In more physiological terms, Chomsky’s merging is not just association of perceptions but association of elements from two categories of perception. Associating perceptions from two categories is cognitively similar to associating individuals with different contexts. It is a matter of common experience that contexts affect recognition of individuals, presumably because objects such as individuals become associated with their contexts. Thus each context merges, in Chomsky’s sense, more easily with some individuals than with others, just as each verb merges more easily with some nouns than others. In this way, parsing social interactions might require cognitive abilities that could be coopted for language. Yet it is not clear whether the relevant categories are recognized by definition or by family resemblance. Furthermore, both in language and social interaction, associations might sometimes be recognized as units, without any parsing, in other words, without any analysis and merging of parts, at all.

Consequently it seems unlikely that either language or social interaction is organized entirely hierarchically. Nevertheless, this particular form of organization has received special attention as a possibly fundamental feature of language. Hierarchy connotes two distinct kinds of organization. Human institutions are hierarchical in the sense of a chain of command, with each individual overseeing a set of subordinates. The organization is like a multidimensional pyramid, with lower sets embedded (nested) within higher sets. In contrast, tennis players and perhaps society mavens are ranked unidimensionally, in a ladder. In nonhuman social organization, dominance hierarchies take the latter form. An example of such a pattern is (A>B>C>D) where A through D are individuals ranked on a single dimension. Embedding in this case consists of pairs of closely ranked individuals inserted between pairs of distantly related individuals, (A>(B>C)>D). Human language is also linearly ordered in time (speech) or space (writing), with similar nestings of components, where A through D are words (morphemes). Several experiments have suggested that birds can recognize sequences like (AABB) or (ABBA), although it is not clear that they can generalize such a pattern to new exemplars (Van Heijningen et al. 2009). The second sequence superficially matches a pattern of embedded phrases in language. On the other hand, the first, not the second, sequence matches complex dominance hierarchies that result when individuals' rankings are embedded within families' rankings or when dominants create coattails for familiar subordinates. There are indications that baboons and birds can "parse" a dominance hierarchy with embedded clusters (see ▶ "Evolution of Communication").

Embedding of phrases in language (often confusingly termed recursion) is more complicated than either diagram above. Each phrase consists of components with different roles, for instance, nouns and verbs, or more generally objects and attributes. The exact relationship of these two types of components in a phrase is marked either by their sequence or by tags (inflections), and the relationships of phrases are also marked by their sequence or by tags (conjunctions). A more accurate diagram of embedding in language is thus (A1(B1B2)A2), where A and B are phrases and 1 and 2 designate appropriate objects and attributes within each phrase (Corballis 2007). A human receiver associates A1 with A2 and B1 with B2. These associations are either temporal (for a listener) or spatial (for a reader). The cognitive issue is whether or not nonhuman organisms can respond reliably to (A1–A2) regardless of whether these two components are separated in time or space by analogous phrases, such as (B1B2).

Sensations evoking responses by animals are often (perhaps always) composed of multiple elements in particular arrangements. Thus it is not surprising to find that animals can master associations like (A1–A2) regardless of some interruptions. An ability to respond to the associated sensations despite interruption comes close to object constancy, discussed above. The experiments mentioned above, which show that birds fail to generalize such patterns (Van Heijningen et al. 2009), perhaps miss the point. Object constancy is probably not generalized either; instead each object is learned by family resemblance of its particular features, despite various interruptions, and eventually evokes a unitary response. Furthermore, as discussed above, it is not clear that using language requires parsing of components.

Embedding in language is even more complex, because in this simple case, (B1B2) modifies A1, so that (A1B1B2A2) becomes in effect ((A1(B1B2))A2). The phrase "The cat that the dog attacks hisses" does not merely merge two phrases "The cat hisses" plus "The dog attacks." Instead the inner phrase changes the meaning of the outer phrase; the conjunction makes the connection. Can some nonhuman animals recognize an association of two signals, each of which associates components from two categories, regardless of whether one signal is interposed between the components of the other signal? Perhaps.

As important as embedding is for human language, the relationship established by an action also seems critical, as in a phrase such as "The dog attacks the cat." The relationship between the "dog" and "cat" is in part specified by the action "attacks" but also by marks that indicate the relationship of each object to the action. This latter relationship is marked in English primarily by sequence: (A1 B1 A2). In Russian, and many other languages, the relationships are marked by modification of each noun (the case of each noun, either nominative or accusative): (A1n B1 A2a). In Russian, sequence has less salience (and determinatives are usually absent), so this inflected phrase would elicit a similar response in the sequence (A2a A1n B1) or in any other sequence. Can animals recognize a three-component signal in which the components have particular relationships specified either by arrangement in time or space or by at least one modifying (case) component. Despite the complexity, this challenge is nevertheless met by some nonhuman animals (Herman and Richards 1984; Marino et al. 2007).

Language as Criteria for Responses

The forgoing discussion has failed to identify a key to language. It has made little progress in isolating any qualitative requirement for the use of language that nonhuman animals do not already have, in some cases to a considerable degree. Yet it seems clear that no other species engages in communication approaching the complexity of human language. Nor have they achieved the levels of technological competence that language has catalyzed among humans. Before suggesting a solution to this paradox, this section first provides a different way to conceptualize the use of language. Recent thinking about language has usually started from the top, from idealizations by grammarians and linguists (Hauser et al. 2002; Chomsky 2005; Tomasello 2010; Fitch 2017; Seyfarth and Cheney 2017). The following starts from the bottom, from basic neural mechanisms for all communication.

Language consists of clusters of perceptions. Categorizing clusters of perceptions to form components of language is fundamentally the same as categorizing sensations to form primary perceptions. Sensations have inherent variability, as a result of variation introduced by their sources (including human signalers, speakers, writers, or signers), their receivers (including human listeners, readers, or sign readers), and the medium in between. This variability is noise in the perception of signals. All receivers of signals in noise make decisions to associate sensations with responses by means of criteria for response (Wiley 2015, 2017; see ▶ "Evolution of Communication"). These criteria associate particular sets of incident sensations with particular sets or levels of responses, either overt or covert, in action or memory. Classification of sensations is thus a result of their associations with responses. Initial perceptions are the first responses to sensations.

The criteria for each decision, like all other features of living organisms, develop in the course of each individual's life as a result of an interaction between its genetic constitution and its environmental conditions. At any moment these criteria depend on the individual's current physiological and anatomical state. The association of sensory input with response thus results from the individual's current state and the impinging sensations.

Classification of sensations is the preliminary stage in the eventual classification of perceptions into the components of language. Initial perceptions are the fundamentally meaningful categories of sensations. At each subsequent stage of categorization, the process of association divides perceptions into progressively more specific perceptions or other responses. At each stage, the criteria for categories might combine definitions and family resemblances, and the criteria might change, with developing familiarity, from sequential or inflectional parsing of relationships among components to immediate unitary detection. The inherent variation in sensations at the root of the process propagates into variation in perceptions at every higher stage. Noise permeates all stages in the processing of language. It requires neural decisions to recognize categories of sensations or perceptions at each stage. The variation and exceptions are as important as the norms.

This perspective of language does not preclude human cognitive criteria that quantitatively exceed those of nonhumans. Yet it has not identified a qualitative cognitive capability that nonhumans entirely lack. Combinations of associations in time and space admit great complexity. Increased complexity no doubt can lead to a "great leap forward." It is a truism that quantitative change can lead to qualitative change. Indeed humans have a nearly inexhaustible impulse to categorize, so any change, no matter how small, can invite categorization as a qualitative change. Yet it is not clear whether or not such a "leap" requires any innovations beyond one small step at a time on the same path. Nevertheless, something extraordinary happened when human language developed. It might not have required any advance in cognition.

From Nonhuman to Human Language

Chimpanzees, bonobos, bottlenose dolphins, grey parrots, and other nonhuman animals have demonstrated surprising capabilities (Savage-Rumbaugh and Lewin 1994; Marino et al. 2007; Pepperberg 2004). They easily master the use of abstract symbols, reference, displacement, and sequential recombinations. They can both produce and respond appropriately to symbols. They can use symbols to communicate with conspecifics to solve problems. They can to some extent acquire these capabilities from other conspecifics.

Despite some animals' language-like abilities, there is no clear evidence that these abilities are used for communication in natural situations. It is interaction with language-capable humans that reveals the inchoate capabilities for language in apes, parrots, and dolphins. This situation recalls a repeated result of all mathematical models for the evolution of communication. The initiation of communication, of whatever simplicity or complexity, must surmount a hurdle. Rare alleles associated with response to a new signal are unlikely to spread in the absence of individuals producing the signal. Conversely, rare alleles associated with producing a new signal are unlikely to spread in the absence of individuals responding to the signal. As seen in the models for the evolution of communication in noise and for the evolution of traits and preferences by sexual selection, the benefits of signaling depend on responses, and the benefits of responding depend on signals. The frequencies of signals and of responses must reach some threshold before the benefits of signaling and responding begin to spread (see ► "Evolution of Communication" and ► "Sexual Selection").

This conclusion invites application to these language-capable but language-deficient populations. Chimpanzees have evolved enough mental capabilities to provide the advantages of language, yet in natural situations language among chimpanzees is, by all evidence, absent. There could well be advantages for apes to have language to assist in coordinating cooperation within their groups and competition between groups. They appear to have enough of a start in mental competence. Perhaps, so far, neither the frequency of gestures nor responses have reached the necessary threshold. Who knows? Perhaps a fortunate coincidence, just one small group with by chance a few gesturers and a few responders, a few individuals with just the requisite predispositions, such as Kanzi seemed to have, and overnight a new kind of chimpanzee society based on new possibilities for communication would sprout. Subsequent natural selection would enhance these incipient predispositions for specialized learning.

After that leap forward, natural selection would result in evolution toward optimal signaling and responding. Perhaps it would evolve rapidly, accelerating as expected for sexual selection but also for any frequency-dependent selection of mutualism in communication. The increase in size and complexity of society with the introduction of agriculture might contribute to selection for greater complexity in language. The concurrent invention of writing would almost certainly increase the potential complexity, as a result of the greater storage and review of language. Then there would come printing and eventually the Internet and computers to assist with storage, search, translation, and associations of language. Perhaps even tools and fire might have affected the evolution of language, or, perhaps more likely, language affected them.

It is easy to imagine how increasing competence with language could improve thinking, which is after all internal communication. It presumably would require higher levels of association and memory. In contrast, a proposal that language-like thought might *precede* language for external communication with other individuals seems unlikely. Private language would lack the stability acquired from consilience in the process of communication with other individuals (Wiley 2015). Instead the evolution of language is likely to have promoted the evolution of thinking.

Conclusion

This scenario supposes that the advantages of complex hierarchical societies with some incipient forms of cooperation and monitoring of other individual's social relationships might have favored the initial evolution of advanced mental capabilities. The advantages of multiplicity and specificity in individual recognition might be enough to promote the evolution of complex associational learning. The requirements for criteria based on complicated family resemblances and for object constancy in challenging conditions might produce enough cognitive complexity. The ultimate form of cooperation, language, would then just need the impetus to get past the impasse of signalers without receivers and receivers without signalers. A boost in frequencies of signals and responses might come with a random perturbation during a bottleneck in population size. After crossing the initial hurdle, natural selection on the predispositions for language could take hold. Perhaps faster than so far imagined, the use of language would flourish.

Cross-References

- ► Evolution of Communication
- ► Evolution of Culture
- ► Sexual Selection

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