1 Theoretical and Methodological Tools for Comparison and Evolutionary Modeling of Communication Systems

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The Need for Framework Development in the Study of Evolution of Communication Systems

The study of communication and its origins has an illustrious and varied history. The inspiration for the effort has often been focused upon the possibility of illuminating the evolution of language in humans (Condillac, 1756; Locke, 1690; Aarsleff, 1976). But in the last few decades, there has been remarkable growth of understanding regarding communication systems of other species (see, e.g., review in Hauser, 1996). A comparative enterprise now holds the promise of richly clarifying both the similarities and the differences between our own communicative capabilities and those of other species.

To pursue the comparative enterprise effectively, a genuinely interdisciplinary effort is required. One of the primary needs is to formulate a lasting framework of *properties and principles* that can be understood across disciplines, and that can be used as a set of standards for comparison among species.

Hockett's Model

Groundwork toward this goal was laid in the pioneering effort of Charles Hockett and his colleagues (Hockett, 1960; Hockett and Altmann, 1968). However, it is clear the framework of "design features" for communication systems that was provided by Hockett needs drastic revision. The definitions of features within the framework formed a shaky foundation for comparison, perhaps in part because their formulation preceded much of the fundamental work that has illustrated communicative capabilities of nonhumans. The features were formulated with an eye always directed toward human language, and ignored many aspects of communication that are now evident from work with nonhumans. The features were characterized as binary properties, even though the authors acknowledged that they would at some point have to be reformulated as dimensions with many potential values. Binarity imposes unacceptable limits on description of both human and nonhuman systems of communication.

Perhaps the most fundamental problem with the Hockett framework is that it was formulated as a flat list of design features. Hockett understood that the concepts embodied in the model were actually related in many ways, and that in some cases the design features seemed to presuppose each other. Such relations among the features could, it appears, after restructuring and reformulation, reveal a hierarchical system indicating paths of potential evolution for communication systems. Lower levels of the hierarchy could be

expected to occur early in evolution and to form the foundation for elaboration toward higher levels of the hierarchy. The flat list of design features stood in the way of this more evolutionarily rich potential characterization of communication systems. Ultimately, it has become clear that many of the features formulated by Hockett were simply ill-defined, yielding unnecessary and confusing overlap among features, lack of clarity regarding boundaries implied by the definitions, and a failure to account for hierarchical relationships among features.

The inadequacies of the Hockett framework are illustrated with disturbing clarity by the fact that, based on a review of recent empirical evidence, comparisons within the framework have not proven to be unambiguously capable of discriminating human language from nonhuman primate communication systems. Nonhuman primates can be portrayed as illustrating all of the Hockett features, given the way they are defined (see Snowdon, chapter 8 in this volume). Not a single Hockett feature appears to be unique to human language. This is surely not what Hockett intended. And it does not lay the sort of foundation that is needed for evolutionary speculations about communication systems.

A New Look at Frameworks and Empirical Accomplishments in Evolution of Communication Systems

This volume is the product of a splendidly fruitful interchange among researchers from Europe and North America who are dedicated to addressing the evolution of communication and to the hope of contributing to a more lasting framework for description and comparison across species. Language in humans is clearly a topic of enormous interest to the contributors to this volume, but it is also clear that the authors have taken the burgeoning literature in animal communication extremely seriously. Some of them have made major contributions to that animal literature, and their empirical work is reflected here. In addition, the volume reflects interactions among philosophers of language, linguists, developmental psychologists, evolutionary biologists, and specialists in the development of new technologies for the study of evolution and communicative systems.

The chapters are organized in parts, but there is considerable overlap among the goals and focuses of authors across the parts. The following overview is intended to prepare the reader for a journey along new paths in communicative evolution.

Philosophical Framework Needs

In Part II, “Philosophical Issues: Conceptions and Foundations,” three chapters address critical matters regarding the evolution of signals and symbols, and all of them seek to develop a model that will characterize steps of evolution, the sorts of logically necessary steps that could provide an important update to the modeling work of Hockett.

The three chapters have much in common in terms of the subject of interest, and all arrive at a generally similar conclusion: In primitive animal communication, two aspects of the representation (or the signal) are *coupled.* These two aspects are those which can be interpreted as referring (to entities or events, or to concepts about entities or events) and those which can be interpreted as influencing responses in the receiver. And for all three of the authors, the decoupling of these elements of communication is taken to constitute a major necessary step in the direction of creating more complex and powerful representational and communicative devices.

Ruth Garrett Millikan's contribution extends her previous "functional semantics" work on the essential character of representation and meaning, formulating the idea of the "pushmi-pullyu representation" (PPR), a primitive representational form where both "what is the case" and "what to do about it" are transmitted simultaneously. PPRs in this treatment are representations that are said to face in both directions at once, toward indication and responsive action, "in one undifferentiated breath." Even reflexes, in this formulation, can be thought of as PPRs. Millikan then outlines possible steps toward complex and "articulate" communication (for example, in human language), where the indicative face of representation is no longer held fast to influences on the receiver.

William F. Harms addresses a similar issue. He asks whether animal signals such as warning calls provide indicative information or commands to action. He points out that the answer might be "both or neither." The two aspects of the signal are bound together, but their messages are not easily translated into human language, he argues. Such signals possess what he calls "primitive content," and he draws attention to the power of "functional semantics" (referring to Millikan's line of research) in making it possible to bring primitive content into the domain of what has traditionally been called meaning. He presents a six-layer scheme in which primitive content can be seen to emerge from even simpler nonmeaningful representations or acts. The inherent coupling of extension (reference) and intension (procedural specification) in primitive content is undone at the higher levels of evolution for meaningful acts that Harms outlines.

D. Kimbrough Oller offers a sketch of an "infrastructural" alternative to Hockett. He outlines steps of a "natural logic" indicating how foundations can be laid in primitive communicative systems, and how elaborations can be evolved to higher levels of complexity. The hierarchical scheme offers description in terms of many layers of communicative "properties" (which can be taken to be roughly equivalent to Hockett's design features) for both signal complexity ("infraphonology") and value/functional complexity ("infrasemiotics"). Like Millikan and Harms, Oller emphasizes coupling in primitive systems, noting that signals are permanently coupled to their values (functions, meanings, etc.) in primitive communications (such as the fixed signals exemplified by monkey alarm calls or distress cries), but that more intelligent animals often learn new pairings of signals

and functions. He also illustrates another way of looking at the indicative/procedural coupling in primitive representations that Millikan and Harms discuss, interpreting the procedural side of representations in terms of Austin's notion of illocutionary force (Austin, 1962).

Not surprisingly, the issues of coupling and decoupling raised by the three chapters in part II are treated from additional perspectives later in the volume, especially in chapter 12, by Chris Sinha, and chapter 13, by Peter Gärdenfors. From a variety of disciplines, then, it is clear that new approaches are being developed to characterize the essential qualities of more primitive and more elaborate forms of communication such that lasting comparative work can be pursued.

Methodological and Theoretical Developments

The study of the evolution of communication systems is being enriched enormously by new developments in tools of investigation. In the areas of artificial intelligence, connectionist modeling, neural network development, and pattern detection, growth of technology is extraordinary. The efforts are laying the groundwork for broad new methods to test theoretical approaches to evolution of learning systems. The simplest such systems merely acquire the ability to detect patterns, but work is underway to test artificial systems that, it is hoped, will one day be capable of learning human language. The work on these new methodologies clearly is not just tool development, however. The endeavor has been driven in many instances by fundamental new theoretical assumptions and by the desire to create ways to illustrate and simulate their implications.

Luc Steels presents a review of dynamic new developments in robotics and accompanying software that have provided a new foundation for the study of language. The work, to which he personally has contributed substantially, implements a theoretical perspective on the learning of and evolution of language, a perspective that assumes self-organization plays a significant role. Social and cultural interrelations are prominent in his simulation approach, which offers tests of game-theory models implemented in robotic and computer simulations.

The workshop that inspired this volume did not include a presentation in a particular area of interest to the participants: connectionist modeling. Consequently, Morten H. Christiansen and Rick Dale were invited to provide a contribution even though they had not been present at the workshop. The efforts they review represent an exciting field of computer-based connectionist simulation that is offering new perspectives on learning and its role in language and the evolution of communication. The authors contend that much of language evolution may have been shaped, in fact, by development. Self-organizing systems, acting within simulated social contexts, can acquire information and structure of remarkable complexity. By using computer simulation models of neural networks, the

authors review information and present two new simulations to support their view of the evolution of language.

In the final methodological article, Magnus S. Magnusson outlines a pattern detection scheme that promises to provide a powerful new method for discovering the organization of temporally systematic information. In particular, the algorithms implemented in the Theme software make it possible to determine the existence of hidden patterns in sequential data, patterns that are quite obvious when located but that can remain entirely hidden without the aid of the software tool. The algorithm is capable of locating even infrequent patterns in reasonably sized data sets. And perhaps most important, it can locate patterns of hierarchical character. Magnusson argues for the application of this sort of technique to a wide variety of problems in the area of communication and language, as well as to fields such as DNA sequencing.

These new methodological tools form part of a rapidly growing trend in the study of the evolution of communication systems. High technology is offering whole new approaches to study based upon simulations that can test existence hypotheses and compare various possibilities in game-theory and neural network modeling of evolutionary possibilities.

Animal Communication Systems

As suggested above, there has been rapid progress in the development of new information about animal communication systems in recent years. While the present volume can provide only a sampling of those developments, it is an intriguing sampling indeed.

Charles T. Snowdon provides a fascinating glimpse into the world of nonhuman primates and the relations between vocal communications found there and in human language. His approach offers a perspective on what the early environmental conditions may have been that led to the hominid communicative explosion. In particular, Snowdon points out that while apes and monkeys in the Old World tend to be relatively silent creatures, the New World is home to monkeys, such as tamarins and marmosets, that vocalize more frequently, that show more richness of development and learning in their vocal patterns, and that appear to transmit more information with the sounds they produce than do any of the Old World primates. A key reason, he suggests, is cooperative breeding, which is found in the New World animals to a much greater extent than in the Old World monkeys and apes. The New World primates that he is studying live in circumstances where engaging in rich communicative exchange is advantageous, because parents (and alloparents) engage in cooperative rearing and need to communicate about it. This, Snowdon suggests, may have been a critical factor that differentiated the early hominids from their ape cousins.

Donald H. Owings and Debra M. Zeifman take the ethologist's point of view when they study the human infant, just as they do in the study of other species. In particular, the authors look at the human infant cry from the perspective of assessment/management theory, a framework developed by Owings and his colleague Eugene Morton (Owings and Morton, 1998). This is an insightful approach, because it avoids the temptation to create inappropriately anthropomorphic comparisons between humans and nonhumans. The human infant's cry has much in common with the vocal communications of other primates, in fact much more in common than does speech, even the speech of little children. Owings and Zeifman indicate enlightening parallels with nonhuman communication in illustrating how the human infant "manages" and the parent "assesses" in the context of crying.

Irene M. Pepperberg provides a perspective on the remarkable minds of the members of the African Grey parrot species. By utilizing a specially designed training technique based on "model/rival" observation by the learner, she has been able to illustrate that these parrots can learn aspects of language that deserve substantial scrutiny, especially by those who might presume that only mammals have rich learning capabilities and communicative prowess. From the perspective of evolution of communication systems, the remarkable accomplishments of the parrot trainees include substantial vocabularies of intelligible words that are used in semantically creative ways. Further, the parrots show the apparent ability to use learned words to transmit multiple illocutionary forces (at least "identification" and "request"), a pattern that suggests the sort of decoupling (of different aspects of communicative function) that is so much the focus of articles in part II of this volume.

In the final chapter on animal communication, Jennifer A. Mather surveys work on the skin communication systems of the cephalopods, especially certain species of squid. These animals are able to create detailed patterns on their skin with extraordinary speed, flickering at rates that challenge the flicker-fusion rate of the human eye. Their skin patterns are used both for extremely effective camouflage and to communicate with conspecifics, especially in the domains of courtship and aggression. A general theory of evolution of communication systems will need to account for a broad range of modes and styles of communication, and the cephalopods offer an important expansion of our viewpoint about possible ways that communication systems can play out, because their system is visual, whereas the focus in most research in communication evolution is on acoustic systems. Taken together, the articles on animal communication put much of what the rest of the book considers in a concrete perspective.

Primitive Communication and Language

The remaining contributed chapters of the volume are dedicated to direct consideration of the relations between animal communication systems, beginning with very primitive ones,

and human language. The focus of the chapters is also upon the conditions (both ecological and physiological) that may be required for a linguistic system to emerge in evolution from a less complex communicative background.

In the first of these chapters, Chris Sinha outlines a proposal in which the more primitive signal systems of nonhumans are contrasted with human language in terms of a distinction between "signals" and "symbols." His view incorporates self-organizational principles and his own notion of "epigenetic naturalism." He argues that environment is "constructive" in its relation to self-organization and learning. As in the chapters by Millikan, Harms, and Oller, Sinha focuses on the growth of higher-order communicative structures from the primitive "signal" background seen in much of animal communication, but his view offers suggestions, based on epigenesis, about how the process of "elaboration" to higher-order "symbolic" structures occurs. He notes that two emergent properties are the product of symbolic elaboration: reference and construal. The former term requires joint attention by sender and receiver, and the latter, a more elaborate form of representation advocated by Langacker (1987).

Peter Gärdenfors refers to Sinha's work and modeling as he develops the idea that human language may have depended upon a strong tendency in the hominid line to plan into the future. This tendency to look forward, and to cooperate in social groups that look forward, may have been critical, in Gärdenfors's view, to the emergence of language. No other animal shows nearly the degree of planfulness as humans, and this, he argues is the crux of the language need and a critical foundation for it. The chapter provides a review of relevant animal literature, and notes in particular that "cued" representations (where communications are grounded in the here and now), which appear to be common in nonhumans, are less powerful and elaborate (and less capable of supporting planful behavior) than "detached" representations (where communications can refer to the present, the past, the future, the absent, or the imaginary). He exemplifies his approach with an outline of the underpinnings for names, nouns, and adjectives.

The chapter by R. I. M. Dunbar elaborates upon his widely cited hypothesis that the evolution of human language was dependent upon an increase in group size of ancient hominids in comparison with their ape relatives. As social groups became larger, means of maintaining bonds had to be extended beyond those available to other apes. Because grooming could no longer do the job (there was not enough time in the day to groom so many group members), another mechanism had to take over, and that mechanism was vocal in nature. The use of vocalization as a bonding and affiliative device jump-started language, according to Dunbar's hypothesis. His chapter in this volume reviews that hypothesis and offers the suggestion that both music and laughter may have played crucial roles in the early steps of the process by which hominids came to be vocally different from their ape cousins. Both music and laughter may have offered key social bonding devices,

with physiological rewards to maintain them. He reviews preliminary empirical evidence supporting the idea that physiological effects may be involved.

In W. Tecumseh Fitch's chapter the idea that social conditions may have spawned human language is formulated in the context of the Hamiltonian idea of inclusive fitness. The idea is that hominid societies may have offered circumstances where "cheap honest communication" could be advantageous because kin selection was able to drive evolution in the highly social hominid environment. Kin selection offers, in Fitch's view, an escape from "the evolutionary traps of constant Machiavellian deceit, or wasteful Zahavian handicaps." In this way, his proposal dovetails with other proposals in this volume, in particular with Dunbar's notion that change in group size may have created a special environment that was conducive to the effects of kin selection for vocal communication, with Snowdon's idea that cooperative breeding may have played a special role in language emergence, and with Gärdenfors's idea that cooperation for future planning was the driving force in the origin of human language.

The last two contributed chapters in the volume constitute a debate. James R. Hurford, one of the workshop participants, provides a critique of the "mirror neuron" concept and its applicability to the evolution of language. He communicated with Michael A. Arbib, a primary author of the mirror neuron work, and their discussions resulted in the written interchange published here. Both contributions were peer reviewed, and then rewritten by the authors. Arbib was not a participant in the workshop, but the questions evaluated in the debate regarding possible neural underpinnings for language were too engaging to ignore, and so he was invited to offer his response to Hurford's critique for back-to-back publication.

The articles in the final part offer a sampling of directions that the study of language evolution is taking. Both from the standpoint of social conditions and from the standpoint of physiological requirements, we are clearly entering a new era in research on the origin of complex natural communication systems.

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Communication models are authentic outcomes of systematic study of various aspects of communication. A model of communication gives a wholesome understanding of a system or structure by which people can understand similar systems or structure. Consider the following important points related to the importance of communication models âˆ’. Communication models help identify and understand the components and relationship of the communication process being studied. Models represent new ideas and thought on various aspects of communication which helps us to plan for effective communication system. The Communication is very important. It is a key to understanding between people. Through the years, communication has evolved. The way people communicate with each other today is entirely different from the prehistoric era. Before, communicating is limited to interpersonal interaction â€“ person to person. Until it evolved to alphabets, signs and symbols, letters, and telephone.Â The oldest form of symbols used for communication is cave paintings. According to theorists, cave paintings were created to mark a territory or to record events. The oldest cave painting was discovered inside Chauvet Cave in France around 30,000 B.C. Other earliest cave paintings were found in South Sulawesi, Indonesia and Coliboaia Cave in Romania. Mobile wireless communication system has gone through several evolution stages in the past few decades after the introduction of the first generation mobile network in early 1980s. Due to huge demand for more connections worldwide, mobile communication standards advanced rapidly to support more users. Letâ€™s take a look on the evolution stages of wireless technologies for mobile communication. History of wireless technology. Marconi, an Italian inventor, transmitted Morse code signals using radio waves wirelessly to a distance of 3.2 KMs in 1895.