

Cognitive Critique



IS HUMAN LANGUAGE UNIQUE?

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ABSTRACT

Questions about non-human animal language are intriguing, and finding an animal communication system complex enough to challenge human language's unique status would be a significant milestone in linguistic and psychological research. In this paper I investigate the claim that the dance system of honey bees, one of the most complex animal communication systems known, displays a complexity and versatility that rivals human language and therefore should be considered 'language'. I evaluate this claim based on both the features of honey bee dance and previous research into the features that characterize human language, and conclude that bee dance does not have enough of the significant features of human language to rival its unique status among systems of communication. In addition I argue against the claim that the label of 'language' is meaningful when describing an animal communication system. The aim of this paper is to inform future research into human and non-human communication systems both by arguing against the traditional 'language/non-language' dichotomy and by arguing that human language nevertheless remains unique among animal communication systems based on several significant features.

INTRODUCTION

The question of whether non-human animals have language is frequently asked but rarely comprehensively investigated from an informed perspective. The issues that such a question brings up are clearly of great interest, not only to animal psychologists and linguists but also to the fields of psychology, cognitive science, and philosophy. At first glance the lack of consensus on the topic is puzzling. After all, in a general sense everyone knows what language is, and identifying whether any particular animal species has it seems like a trivial investigation. Nevertheless, investigating animals' language requires delving into many background questions and assumptions, the main one being the definition of 'language'. Answering this question may seem like an esoteric exercise in the philosophy of language, but clearly a definition for the term must be agreed upon before it even makes sense to ask whether animals have language.

It is clear that questions about animal language are highly intriguing and have inspired much research (see, among many others, Savage-Rumbaugh 1986; Patterson 1978; Gardner and Gardner 1969 for ape language experiments; Herman et al. 1984 for dolphins). In general, experiments about animals' language use involve a highly evolved animal such as an ape or a dolphin which is taught a (signed) human language or an artificial language system. Experiments done with this *modus operandi* clearly advance our knowledge of symbolic and communicative capacities in human and non-human minds.

However, I wish to point out a distinction between the questions that these experiments try to answer and the question I address in this paper. An animal's ability to understand and use human language is different from its use of its own native system in the ecological context to which it is adapted. It is this native ability that is of interest when the question being asked is not about mental capacities *per se* but about the nature of language: it is not how an animal *can* use a language system in an experimental situation, but the properties and function of the code that it *does* use in its own environment, that bear on the question of whether human language is unique or whether, alternately, other animals' communication systems may be comparable to human language in crucial ways.

Eileen Crist, in her 2004 paper "Can An Insect Speak?", claims that the dance communication system of honey bees has what she ar-

gues are the crucial elements of human language, and that bee dance should therefore be considered language. As such, Crist (2004) offers a useful starting point for asking whether human language is unique or whether other communication systems exist which rival it in function and complexity. The present paper is not meant to be a critique of Crist (2004) specifically but to use that article as an especially lucid example of the kind of arguments made about animal communication systems in general. However, three features of Crist (2004) make it particularly useful. One is that it studies the bees' own system rather than their ability to communicate in a taught language, which as previously mentioned is an important distinction. The second is that her position in favor of bee language is very clear: to demonstrate that bees have language is Crist's stated aim rather than an incidental assumption made in the pursuit of another research goal. The third is that bee language is one of the most complex animal communication systems known. If any system is likely to challenge human language's unique status, it is the bee dance. Therefore the comparison between human language and bee dance has the greatest chance to provide insight about whether human language is unique. As such her paper is a particularly abundant source for specific discussion points.

A POOR WAY OF FRAMING THE QUESTION: 'LANGUAGE' OR NOT 'LANGUAGE'?

It is important, before delving too deeply into ideas about animal language, to be aware of what is being asked in formal terms. Crist (2004) frames the problem well by noting that

...[t]he question of language in the animal world is tricky in requiring comparison with human language. The problem is that if the yardstick of human language is too strict then language may be excluded, from the outset, from other species. On the other hand, if the defining features abstracted from human language are too general, there is a danger of attenuating the notion of language, such that all sorts of signals (for example, alarm calls or mating calls) could count as linguistic. So the question becomes whether criteria can be abstracted that are general enough to include other species, yet robust enough to exclude all manner of gestures from becoming 'language' (p.12).

The way Crist uses the term 'language' in this passage is problematic. While an everyday definition of 'language' undoubtedly exists, with connotations of both complexity and prestige, such a definition is not technical enough to support any rigorous claims. The combination of a common intuitive meaning but no formal, precise technical definition in this context of the term 'language' makes an easy one to use casually, and can confound (as it does in Crist's article) any claims made about any given system.

If we were to take seriously the semantic endeavor of attaching a technical definition to the term 'language' while maintaining its prestigious connotation, we would go about it as follows: While in everyday usage there are many things that people refer to with the word 'language', it seems clear that the prototypical and undisputed example of this category is human language, as exemplified both by individual languages such as Swahili and American Sign Language, and the general human capacity to acquire these individual languages. Unless it is accompanied by specific claims such as those discussed here, the term 'language' is used to describe non-human-language systems only metaphorically, by calling attention to a way in which they resemble, more or less abstractly, human language in form and function: computer programming languages, mathematics, body language, 'the language of dance', and so on.

We could therefore require 'language' candidates to have all of the features of human language, the only undisputed member of the category. Alternately, we could identify a set of features that communication systems might have and select a subset of them as necessary for 'language'. Thereby it would be possible to include the more complex of animal systems in the category 'language' while keeping out systems not possessing some arbitrary level of complexity.

It should be noted that prestige appears to be the main justification for making any categorical 'language/not language' distinction among communication systems. However, such a binary distinction is not scientifically useful. Whether bee dance is 'language' or not does not matter much to the bee, and should not dampen our appreciation for its elegance and efficiency or our ability to describe the system's features and function--or even the role that the system might play in furthering our understanding of human language. Nevertheless, as Crist (2004) demonstrates, the lure of the title of 'language' persists in the popular imagination and even in scientific but non-linguistic circles. In discussing a claim such as Crist's, it is

only fair to acknowledge this motivation even as we dissect it and ultimately set it aside.

Thus, the question of whether a given system is ‘language’, in the naïve sense in which Crist poses it for bee dance, is meaningless. However, terminological issues need not derail the investigation entirely. It is possible to address the question in the spirit in which it is asked, and the remainder of this paper will endeavor to do so.

A BETTER WAY OF FRAMING THE QUESTION: HOW ‘LANGUAGE-LIKE’ IS IT?

Crist (2004) in fact provides an opening for this very task when she asks “whether criteria can be abstracted [for the definition of ‘language’] that are general enough to include other species, yet robust enough to exclude all manner of gestures from becoming ‘language’” (p.12). Without concerning ourselves with the final yes-or-no answer, which as discussed above is not a useful distinction to make, we can nevertheless use this criteria-based approach to try to determine what, if any, are the key properties that divide human language and bee dance or, alternately, what key properties the two may have in common.

Of course, there is no definitively accepted list of criteria for evaluating the ‘languagehood’ of a given system; if there were, there would be no need to ask the questions currently under discussion. Attempts to list the characteristic features of language, usually referred to as ‘design features’, have in fact been made, notably by Hockett and Altmann (Hockett 1977; Hockett and Altmann 1968) and Hauser et al. (2002). Hauser et al. (2002) suggest that recursion, a structural property of a system that allows infinite embedding of new structures within an existing structure, is the one feature that is both unique to humans and unique to language.

The importance of other criteria discussed is debatable. For example, Hockett (1977) lists the vocal-auditory modality as universal to language when we now know that it is not even universal among human languages, which include many examples of signed languages using a visual-gestural modality. However, some key elements are generally considered to be the most significant: recursion; productivity or creativity, which is the system’s ability to encode and transmit messages never before created; displacement, which is a system’s ability to encode and transmit messages referring to items removed from the place and time of the message’s creation; and duality of patterning, which says that a system consists of two levels

of units, one meaningless (in spoken human languages, sounds) and one meaningful (words).

In the present paper I do not intend to propose a new analysis of the question of whether or not bees have ‘language’. Rather, using Crist’s claims as a starting point, I will discuss both whether the bee dance displays each of the features she identifies and whether each of those features is significant when comparing bee dance to human language.

BEE DANCE IS NOT HUMAN LANGUAGE

Crist makes four claims about bee dance that she argues qualify it as language. These claims are that it is “rule-governed”; “both structurally stable and contextually flexible”; “symbolic in representing states of affairs distant in space and time”; and “performative” (pp.8-9). As mentioned above, there are two implicit parts to each of these claims: one is that bee dance exhibits the characteristic in question, and the other is that the characteristic is necessary for a system to qualify as a language. First, let us begin by testing each of Crist’s claims about the bee dance system against linguistic criteria.

IS BEE DANCE RULE-GOVERNED?

Crist’s first claim is that “[t]he dance is grasped as a rule-governed activity, in that fairly reliable rules can be formulated for how, when, and why dances are performed” (p.13). The descriptions of the ‘rules’ that Crist sets forth are no doubt accurate; however, strictly speaking this is not the type of rule set that linguists use in describing the ‘rules’ of human languages.

The problem here is once again one of vague terminology. The word ‘rule’ is used here for two significantly different things: to indicate that a phenomenon or behavior is systematic, and to suggest an element of the cognitive process behind the behavior. Rules such as “Dance at the designated place in the hive” and “Never dance alone” (Crist 2004, pp.13-14) are the first, descriptive type of ‘rule’, in that they are simply descriptions of a systematic behavior on the bee’s part. Indeed, presumably any animal behavior could be described with rules such as these, since animal behavior is not random but emerges under certain circumstances: animals feed when they are hungry, sleep when they are tired, call when they are threat-

ened, and so forth. Clearly a 'rule' that an animal should feed when it is hungry is simply a description of a habitual behavior.

This is not to say that behavior and communication are two different things: Communication is a behavior that, like any other, emerges in certain predictable circumstances. However, to ascribe linguistic significance to bee dance simply because it can be systematically described is short-sighted.

A more linguistically rigorous use of the term 'rule' is in hypothesizing the use of a rule in generating the behavior, in this case the communicative signal. Consider the case of linguistic rules such as the one used to generate the past tense of verbs in English. The basic form of the past tense morpheme is [d], placed at the end of the verb. This form has two systematic variants: it emerges as [t] when the last sound in the word is voiceless, and as [əd] when the final sound is another alveolar stop. Native English speakers choose the appropriate form of the past tense morpheme automatically, and experimental evidence indicates that speakers correctly form the past tense of even made-up words (Berko 1958). From this evidence it is claimed (Pinker and Prince 1988) that English speakers have a rule that governs past tense usage (but cf. Rumelhart and McClelland 1987).

Another example is the set of rules used to generate sentences in a given language. It is difficult to explain how native speakers of English can share the intuition that *John sing* is poorly formed but that *John sings* is well formed without positing that English competence includes a rule about subject-verb agreement that, on some level, the generator of the sentence must deploy in forming the sentence. A rule of this kind thus has not only descriptive but also explanatory power in an account of the system and its use.

To what extent does a system's being 'rule-governed' in the powerful, explanatory sense bear on bee dance's capacity to challenge human language's unique status? The commonly posited linguistic features of semanticity and arbitrariness both require a type of explanatory rule, so let us examine each of them in turn.

Semanticity, basically defined, is the quality of having meaning. Communication systems are by definition semantic, and thus there must be a rule that relates each signal to its meaning. The bee dance is clearly semantic; it is clear that a certain type of dance indicates the presence of food at a corresponding location. Therefore there must be rules that relate the elements of the signal to the relevant elements of the real world. Crist lumps the structure of the bee

dance into one directive, “In dancing, follow the standard template that conveys direction, distance, and desirability” (p.13). This standard template must be governed by some kind of rules represented in the bee’s mind¹. For example, there must be rules that map the direction, distance, and desirability of the food source to specific features of the dance, including using an orientation with respect to gravity that imitates the food’s orientation with respect to the sun and a more intense waggle part of the dance to convey that the food is intensely desirable. As such, the requirement that the system be rule-governed must hold in some sense, but does not do so simply because the system adheres to predictable patterns.

The quality of arbitrariness, being a sub-feature of semanticity, also relies on rules. Semanticity can be described along a scale running from iconic to arbitrary, or in other words the degree to which the signal bears a physical or conceptual resemblance to its referent. In both fully iconic and fully arbitrary cases (and of course those somewhere in between) there must be some kind of rule relating the signal and its meaning, but in iconic systems the rule could be as simple as, for example, ‘the signal means whatever it resembles’, with the criteria for resemblance being situation-specific. In an arbitrary system, however, the rules are much more important in that each individual signal or signal unit must rely on a rule for its interpretation; absent the simple heuristic of resemblance, there can be no way to relate the signals of an arbitrary system to their meanings without a rule deployed in the process of encoding and decoding the message.

Whether bee dance is iconic or arbitrary is debatable, and the debate will be taken up again somewhat later in the discussion of whether the dance is symbolic. Returning to the discussion of whether being ‘rule-governed’ is a necessary language feature: in short, yes it is, but trivially so. Any communication system must be semantic, and any semantic system must be rule-governed to a greater or lesser extent, and therefore every communication system will be rule-governed by its nature even aside from the question of whether or not it is a language. Thus, the criterion of being ‘rule-governed’ fails to distinguish bee dance from any other communication system.

IS BEE DANCE ‘STRUCTURALLY STABLE YET CONTEXTUALLY FLEXIBLE’?

Crist’s next claim is that “[w]hile its form is structurally invariant, in application the dance is responsive to environmental conditions and hive requirements. The direction, distance, and desirability markers are immutable, but the sources sought and danced about are not rigidly fixed” (p.14). She goes on to say that “[i]ts form is always recognizably the same, but it accommodates different purposes, shifting circumstances, urgent needs, and unprecedented events; while structurally identical every time, it is also contextually flexible” (p.15), with this contextual flexibility taking two forms: “local context” and “social reality” (p.16).

The claim of structural stability is easily supported by the evidence. The dance appears to have three parameters: distance to a location, direction of the location with respect to the sun, and richness of the source found there. These are coded as speed, angle with respect to gravity, and liveliness of the dance respectively. Dances essentially transmit a value for each of these parameters. Outside of this variation in parameter settings, the dance is always performed in the same way.

Is structural stability necessary for a language? Here again the answer is a trivial yes: this feature is necessary for any communication system. A system without structural stability would be one in which the relation of signal to meaning is constantly in flux; such a system (if it could even be so called) would be cumbersome at best and could only be useful in a context in which the sender and receiver of a message were able to synchronize their signal-to-meaning encoding outside of the system’s structure—for example the case of a military cipher in which the senders and receivers changed their encrypting and decrypting keys based on the date or some other mutually known factor. Of course, in such a case, the synchronization ability would count as part of the system, and were that to be unstable yet a third order of coordination would have to be posited, and so on infinitely; at some point a useable system would have to have a structurally stable layer.

There is not enough evidence to back up a claim of contextual flexibility, however. The dance can be used when the hive needs nectar, or pollen, or water, or plant resins; or when a swarm is searching for a new nesting site. However, in each case the dance is the same. This is not a case of contextual flexibility, but rather of underspecification. Moreover, there is no way within the dance

system for a bee to specify what it is dancing for: it cannot say that the specified location has, for example, nectar as opposed to water. As such, the dance is not really flexible but merely applicable to a number of different situations.

Any given instance of the dance is, of course, different from any other, in that the parameters of direction, distance, and desirability will be set to indicate the exact location of the resource being danced about. However, to call this contextual flexibility would also be a stretch because if 'context' is defined as something separate from the content of the message, then these parameter settings would be involved in the content itself.

Contextual flexibility itself is not generally cited as a linguistic design feature, but the feature variously called openness, productivity, or creativity seems to present the same idea: users can create and understand new messages, either by rearranging existing elements such as words and affixes, or by assigning new meanings to the elements or sequences of elements of the language. For example, in English, a word such as *reunderdetermine* and a sentence such as *parrots have been shown to understand calculus* can be understood even if they have never before been encountered, because the combination of the units' meanings (that of *re*, *under*, *determine*, *parrot*, *s*, etc.) and the way in which they are combined are enough for their message to be decoded. In addition, existing words and morphemes can acquire new meanings and can be used metaphorically: *text* now has as one of its meanings 'send a text message' and can be comprehended in one-time context-dependent usages such as a hypothetical caption writer saying *I finished texting all the photographs* (*text*: 'to append a text to').

Bee dance does display productivity, shown by bees' ability to indicate novel locations: to encode the location of a source never before visited, the bee will perform a dance never before performed. However, the bee has no way to create a message that does not refer to a location in space, and because of this the productivity of the dance system is severely limited. In principle the elements of the dance could be assigned additional semantic content so that a particular dance could refer to either a location in space or some other message, but there is no evidence that bees do this. In addition, because the three pieces of information coded in the dance are all coded on separate dimensions, the idea of rearranging the parts to form a new message does not even apply to the bee dance system.

IS BEE DANCE SYMBOLIC?

The next claim is that the bee dance “symbolically represents states of affairs in the world” and in particular that it “refers to subjects distant in time and space” (Gould and Gould 1995, pp.59-60, cited in Crist 2004, p.19). While the first part of the claim is true, the second cannot be substantiated.

The field of semiotics has devised terms for several types of signs, namely *indices*, *icons*, and *symbols* (Peirce 1955, p.102). According to Peirce, a symbol is a sign that is related to its object by an abstract, conventional linking, whereas an icon bears at least some physical resemblance to its object. The words of human language are considered symbols; with the exception of a minority of onomatopoeic words, there is no physical relationship between the word and its object. However, it is not clear that the elements of the bee dance reach this level of abstraction. The mapping of the sun angle with the gravity angle is arbitrary, but the angle of the dance with respect to gravity corresponds directly to the angle of the food source with respect to the sun once that initial linking has been established. The liveliness of the dance might also be considered an icon of the food’s richness, although admittedly less directly. The duration, or number of waggles, of the dance, which encodes the distance to the food source, seems to be its only abstractly symbolic element, and even so it arguably might be considered iconic in that the duration of the dance and the duration of the journey to the danced-about location are related.

The idea that bee dance can refer to things distant in space and time is also problematic. This feature, known in linguistic circles as displacement, is posited, along with productivity, to be a defining feature of human language, and what separates it from all other known systems of animal communication. Strictly speaking, bee dance shows displacement. Bee dances do refer to locations that are not immediately present in the dancer’s environment; that is, after all, their purpose. However, they do not truly show displacement in the same way that human language does, because they are constrained in having to refer to a distant place with respect to the dancer’s immediate location. This forced deixis--the necessity of incorporating contextual information into an interpretation of an utterance’s meaning--prevents the bees from truly referring to any location, or by extension any entity at all, in an entirely abstract sense. To put it another way, a bee dance ‘statement’ may whimsically be interpreted as saying that there is food at A distance and B

angle from *here*², but a bee could not go on to say that, for example, another food source could be found at C distance and D direction from *there*, or refer to any entity without reference to a location at all. That is, there is no equivalent in bee dance to a human language sentence such as *Clover has purple flowers* or even *We need water to cool the hive*, sentences that have no mention of any physical place.

Similarly, the only displacement in time that is apparent in the bee dance system has to do with the time it takes for a bee to fly to the food source in question. This too is a misreading of the idea of referring to things distant in time. There is in fact no evidence that bees take time into account at all within their messages. The source being danced about is a source of some desideratum now, and if bees stop dancing about it some hours or days later it will only be because it is no longer a useful source in a future present moment. Bee dance messages are unspecified for the time displacement that human languages encode with features such as tense and aspect or semantic content such as *yesterday*, *March 3rd*, *evening*, *summer*, etc. That is, continuing the example above, that the bee has no way of saying that a flower patch was rich yesterday or that it will be tomorrow, or that a worker should wait for a period of time before flying to the indicated source.

IS BEE DANCE PERFORMATIVE?

Another possible criterion for comparison between human language and bee dance is the quality of being “performative” (Austin 1975). Austin’s claim is that language can be used not only to comment or describe but actually to ‘do things with words’: to perform acts with language in the same way that they might perform any other act to accomplish their real-world goals. An utterance such as *I name this child Mary Elizabeth* or *I apologize for my behavior* accomplishes, by virtue of being uttered, the act of naming or apologizing. Stating, commanding, questioning, announcing, and many other acts are accomplished simply by an actor’s uttering a relevant sentence in human language.

Crist claims that bees “do things with dancing” (p.20) in the same way that Austin meant when he discussed ‘doing things with words’. Crist’s evidence for this is that bee dances both accomplish something in the real world for the bees’ direct benefit, and that they can be paraphrased with human language interpretations in the form of statements and commands. Crist explains that “the dance

is described as an invitation, a summons, a recall to action, or a recruitment; it is said to announce, report, or guide” (p.20). In addition, she observes the shorthand translations into human language used by researchers such as Von Frisch, who provided glosses for bee dance acts such as this: “The message brought by a bee as she performed the round dance seemed to be a very simple one, one that carried the meaning ‘Fly out and seek in the neighborhood of the hive!’” (Von Frisch 1950, p.57). In discussing such human-language paraphrases, Crist claims that “...however tongue-in-cheek translations of the dance may be, they are also dead serious in two ways. First, translations function as *realistic* vehicles for clarifying the meaning and function of the dance. Second, translations simply make explicit performatives that are *already* ubiquitous in the honeybee literature” (pp.21-22).

The idea that bee dances accomplish something for the bees’ benefit is self-evident. Indeed, because of the process of natural selection, the behaviors of any species have emerged because they provide some benefit to the individual or to its group. Once again, this trivially fulfills the criterion that a performative quality is necessary for a system to be a language used for communication.

Crist’s observation that the bee dance can be paraphrased with human language performative utterances such as reporting and commanding does not take into account the human tendency to project human intentions and states of mind onto both human and non-human entities. That is to say that the tendency for humans to label behavior as intentional does not mean that the behavior really is so; these performative glosses provided by human observers can be misleading to an objective examination of what bees do.

It is easy to believe that humans’ ability to use language for performative acts is somehow a sign of human language’s sophistication, and that the significance of finding performatives in bee dance lies in co-opting that sophistication for bees as well. However, the only real significance of the possibility of translating bee dances into performative utterances in human language (English, and of course in Von Frisch’s case, German) is that this shows that our communication and theirs serve the same basic function. That is, a human would speak (or sign) to accomplish his goal of finding food or causing others to fetch it, and a bee would dance to accomplish the same end. As such, the criterion of performativity does not appear to be meaningful to the question of whether bee dance poses a challenge to human language’s uniqueness.

CONCLUSION

Having said all this, we come back to the original question: whether bees have language. Once again, here is Crist's view on the topic:

...[t]he question of language in the animal world is tricky in requiring comparison with human language. The problem is that if the yardstick of human language is too strict then language may be excluded, from the outset, from other species. On the other hand, if the defining features abstracted from human language are too general, there is a danger of attenuating the notion of language, such that all sorts of signals (for example, alarm calls or mating calls) could count as linguistic. So the question becomes whether criteria can be abstracted that are general enough to include other species, yet robust enough to exclude all manner of gestures from becoming 'language' (p.12).

Clearly this is an enormous question and not one that can be tackled in the limited context of this paper. However, we are in a position to decide, based on the evidence presented here, whether bee dance deserves to cross the traditional schism between human language and all other biological communication systems. The answer appears to be no. Bee dance lacks enough of the features of human language that does not offer a genuine challenge to the idea that human language is unique among animal communication systems.

Thus, Crist's (2004) goal of getting bee dance recognized as a language fails in two ways: because she fails to define criteria for 'language', and because bee dance does not have the complexity of the default standard, human language. While this analysis has used Crist's paper as an anchor point for a broader discussion, she is certainly not unique in espousing ideas about animal communication and the nature of language that do not hold up under scrutiny.

The idea that animals may have systems of communication similar in sophistication to those of humans is seductive, and it is certainly clear that bees are capable of much more than has traditionally been their due. It is also true that, with no definitive criteria for a system to bear the title of 'language', a claim can be made for the 'languagehood' of any particular system in good faith and with the admirable idea that humans have no a priori claim on linguistic uniqueness.

Nevertheless, the multiple, significant, and qualitative differences between bee dance and human language make it difficult to justify placing bee dance on the human side of the ‘language divide’.

ENDNOTES

1. The question of what, exactly, a bee’s mind consists of, as well as the question of how a rule is represented in a mind, are topics for a different paper.
2. I do not mean this example as a claim that a bee is actually ‘*saying*’ anything.

REFERENCES

- Austin JL (1975) How to do things with words. 2nd ed. Harvard University Press, Cambridge MA
- Berko J (1958) The child's learning of English morphology. *Word* 14:150-177
- Crist E (2004) Can an insect speak? The case of the honeybee dance language. *Social Studies of Science*. SSS and Sage Publications. 34:7-43
- Gardner RA, Gardner BT (1969) Teaching sign language to a chimpanzee. *Science* 165:664-672
- Gould J, Gould C (1995) The honey bee. Scientific American Library, New York
- Hauser MD, Chomsky N, Fitch T (2002) The faculty of language: what is it, who has it, and how did it evolve? *Science* 298:1569-1579
- Herman LM, Richards DG, Wolz JP (1984) Comprehension of sentences by bottlenosed dolphins. *Cognition* 16:129–219
- Hockett CF (1977) The view from language: selected essays, 1948-1974. University of Georgia Press, Athens GA, pp 125-186
- Hockett CF, Altmann SA (1968) A note on design features. In: Sebeok TA (ed) *Animal communication*. Indiana University Press, Bloomington IN, pp 61-72

- Patterson F (1978) Linguistic capabilities of a lowland gorilla. In: Peng F (ed) Sign language and language acquisition in man and ape. Westview Press, Boulder CO, pp 161–201
- Peirce CS (1955) Philosophical writings of Peirce. Dover, New York
- Pinker S, Prince A (1988) On language and connectionism: analysis of a parallel distributed processing model of language acquisition. *Cognition* 28:73-194
- Rumelhart DE, McClelland JL (1987) Learning the past tenses of English verbs: implicit rules or parallel distributed processing? In: MacWhinney B (ed) Mechanisms of language acquisition. Erlbaum, Hillsdale NJ
- Savage-Rumbaugh ES (1986) Ape language: from conditioned response to symbol. Columbia University Press, New York
- von Frisch K (1950) Bees: their vision, chemical senses, and language. Cornell University Press, Ithaca NY