
Symbolic Communication Between Two Chimpanzees (Pan troglodytes)

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mental is difficult to mask perceptually (*16*). The bottom two panels of column 2 show that the energy in the noise masker is confined to the band surrounding the 365-Hz fundamental, but does not overlap any of the components of the complex stimulus.

The effects of noise on FFR to the two stimuli are seen in the FFR wave forms and spectra of columns 3 and 4. In the presence of masking noise, the amplitude of averaged FFR to the pure tone is reduced by a mean value of 8.04 dB. The same masker was effective in reducing FFR to the missing fundamental by a mean value of only 1.04 dB. Comparison of these mean masking decrements shows the FFR to the pure tone to be significantly masked [$t(1,6) = 2.26$, $P < .05$], while FFR to the complex tone is not [$t(1,6) = 0.44$] (*17*). These results support the hypothesis that the pitch of the missing fundamental (residue pitch) is based on the period of a stimulus wave rather than its spectral content.

Our observation that band-limited masking noise affected FFR to a pure tone, but failed to affect a similar FFR derived from the residue of a complex tone, argues against the hypothesis that the missing fundamental arises from distortions that excite the apical 365-Hz region of the cochlear partition. Were this the case, the noise masker should have had a significant attenuating effect on FFR to the complex tone, as it did on FFR. The masking results further suggest that the pitch of the pure tone is carried by elements most sensitive to low frequencies, whereas the pitch of the missing fundamental is mediated by elements sensitive to frequencies other than those within the band of the masking noise.

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References and Notes

1. A. Seebeck, *Ann. Phys. Chem.* **60**, 449 (1843).
2. G. S. Ohm, *ibid.* **59**, 513 (1843); E. de Boer, in *Handbook of Sensory Physiology*, W. D. Keidel and W. D. Neff, Eds. (Springer Verlag, Berlin, 1976), pp. 481-583.
3. H. Fletcher, *Speech and Hearing* (Macmillan, London, 1929).
4. J. F. Schouten, *Proc. K. Ned. Akad. Wet.* **43**, 991 (1940).
5. J. C. R. Licklider, *J. Acoust. Soc. Am.* **26**, 945 (1954).
6. J. L. Goldstein and N. Y.-S. Kiang, *Proc. Inst. Electr. Eng.* **56**, 981 (1968); G. F. Smoorenburg *et al.*, *J. Acoust. Soc. Am.* **59**, 949 (1976); J. E. Hind, *Audiology* **11**, 42 (1972).
7. E. G. Wever [*Theory of Hearing* (Wiley, New York, 1949)] reasoned that a population of neurons could phase-lock to frequencies above those at which it is possible for a single neuron to fire on every cycle of a stimulus wave. The principle by which pitch information might be transmitted by a number of neurons firing in rotation at integral multiples of the stimulus period has come to be known as the "volley principle." It is evident that although Wever structured his theory around only sinusoidal stimuli, the principle can extend to any periodic stimulus.
8. S. B. Holstein, J. S. Buchwald, J. A. Schwafel, *Brain Res.* **15**, 483 (1969).
9. G. Moushegian, A. L. Rupert, R. D. Stillman, *Electroencephalogr. Clin. Neurophysiol.* **35**, 665 (1973); J. T. Marsh, W. S. Brown, J. C. Smith, *ibid.* **38**, 113 (1975); A. Lev and H. Sohmer, *Arch. Klin. Exp. Ohren- Nasen- Kehlkopfheilkd.* **201**, 79 (1972); H. Davis, *Ann. Otol. Rhinol. Laryngol.* **85** (Suppl. 28), 5 (1976).
10. J. T. Marsh, J. C. Smith, F. G. Worden, *Electroencephalogr. Clin. Neurophysiol.* **32**, 63 (1972).
11. S. C. Bledsoe, A. L. Rupert, J. S. Gidda, *J. Acoust. Soc. Am.* **62** (Suppl. 1), S36 (1977).
12. C. Tsuchitani and J. C. Boudreau, *J. Neurophysiol.* **27**, 814 (1964).
13. J. T. Marsh and F. G. Worden, *Laryngoscope* **78**, 1149 (1968).
14. The brainstem evoked response (BSER) [D. Jewett, H. N. Romano, J. S. Williston, *Science* **167**, 1517 (1970)] is a wave complex associated with stimulus onset, which can obscure the first 10 msec of FFR. High-pass filtering the incoming electroencephalographic signal with a 200-Hz cutoff before analog-to-digital conversion effectively removes BSER activity without significantly distorting the FFR.
15. In six subjects, a sample size of 2000 was used. In one subject, the signal-to-noise ratio was so low that a sample size of 3000 was required in order to produce a reliable averaged FFR. When responses from this subject were entered into the composite waves shown in column 3 of Fig. 1, they were reduced in amplitude by 1/3 in order to preserve scale consistency.
16. J. C. R. Licklider, *J. Acoust. Soc. Am.* **26**, 945 (1954); W. Thurlow and A. Small, *ibid.* **27**, 132 (1955).
17. Both analog spectral analysis and digital filter analysis of the composite FFR records, combined across seven subjects, show the decrement in pure-tone response to be approximately 11 dB in the presence of the noise masker (Fig. 1, column 4). When the attenuation of each subject's responses were measured separately, their mean was −8.04 dB as reported. The 3-dB discrepancy is attributable to accumulated small FFR phase differences between subjects.
18. This research was supported by NIMH grants MH 03831 and MH 00021.

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Symbolic Communication Between Two Chimpanzees (*Pan troglodytes*)

Abstract. *Through use of learned symbols, two chimpanzees accurately specified 11 foods by name to one another when the food item's identity was known by only one. They could not do this when denied use of the symbols. The chimpanzees then spontaneously requested specific foods of one another by name. Requests resulted in cooperative and reciprocal symbolically mediated food exchange.*

Following the Gardners' (*1*) report of the chimpanzee Washoe's use of signs (Ameslan) with human beings, the question of whether or not chimpanzees might be able to use learned symbols to enhance their communication with one another has often been raised (*2*). Fouts (*3*) reported that Ameslan-tutored chimpanzees occasionally sign "tickle" and "gimme fruit" in the presence of one another; however, wild chimpanzees also request tickling and food through nonverbal vocalizations and gestures (*4*). Additionally, Menzel (*5*) has demonstrated that untutored chimpanzees can, by means of vocalizations, gestures, and purposive locomotion, communicate whether they are traveling toward a food or nonfood substance. Clearly then, because of the chimpanzee's extant nonverbal communicative ability, any report of interanimal communication that purports to depend on symbolic or language-like skills must show that the communications did not and could not occur through nonverbal modes already available to the animal.

This report presents what is, to our knowledge, the first instance of such symbolic communication between nonhuman primates. The communication system is described in detail elsewhere (*6*). In brief, the chimpanzees use a graphic system of geometric symbols, or lexigrams, in which each symbol is intended to represent an English word (*7*). Words are expressed by depressing keys embossed with their respective lexigrams. Each key depression results in the reproduction of a facsimile of that lexigram on projectors above a keyboard. The experimenter can also communicate with the animal through these projectors on a separate keyboard outside the animal's room to eliminate cueing. All output is monitored and recorded by a computer (PDP8E) (Fig. 1).

The two chimpanzees of the present study were Sherman (4½ years old) and Austin (3½), both born in the laboratory. Both had received previous language training with the computer-based system; details of their original learning of the food names used during the communication task will be described (*8*). Following acquisition of food names, two additional stages of training provided them with the skills prerequisite to the specific type of communication reported here.

First the animals were asked to name, on their keyboards, various foods in response to the projector-posed question, "What this?" They could not request or eat the foods during the task—only name them. If they were correct, they received social praise or the opportunity to request a different food from the machine (*9*). The animals accurately named all the foods once they learned, through

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training with samples of two foods, that there need not be a correspondence between the named food and the food they might later request and eat. This training, which required 102 trials for Sherman and 201 trials for Austin, enabled the chimpanzees to distinguish between the use of a food name as its name and the use of that name as a request for food. On the first occasion when the animals were asked to name those foods not used during naming training per se, both animals were correct on 17 of 18 trials. Each of the other nine foods were presented twice in a random order (*10*).

The animals were then asked to decode symbolic information about food not in view. This was done by stating to the animal that a sealed container held one of a variety of foods. If the animal could decode this statement (made on the projectors) and request the correct food, we replied "Yes" and gave him the container. It required only five trials before they could work accurately with highly preferred foods, but practice continued for several days so that both Sherman and Austin worked without error with all foods, including those of relatively low preference such as monkey chow and beancake.

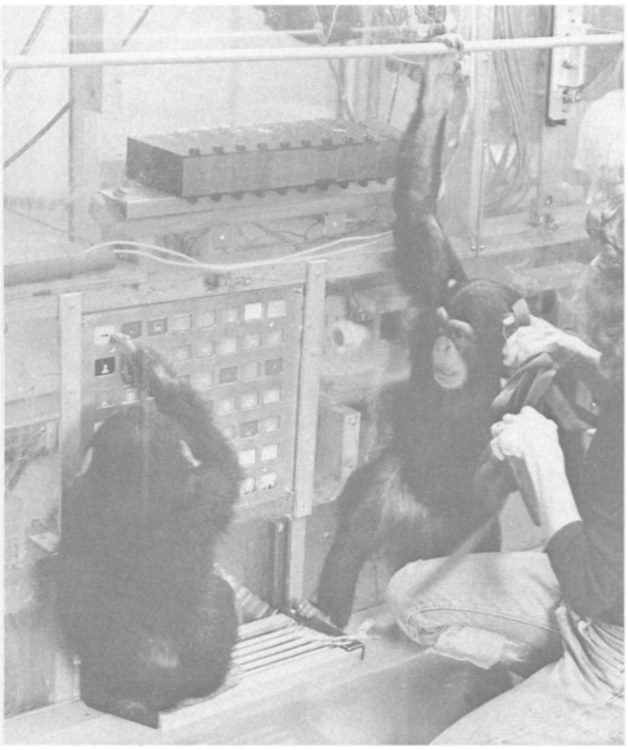

Fig. 1. Austin (left) uses the keyboard to declare the container's contents. Sherman (right) watches. Facsimiles of the lexigrams on the keys depressed are produced on the projectors above the keyboard.

Following this training, a test of the animals' ability to communicate symbolically with one another began. Before this test, the animals were not taught to (i) identify foods which they had seen in the other room, (ii) remember food names over a delay, (iii) attend to one another's statements at the keyboard, (iv) request food being eaten or conversed about by another animal, or (v) identify photos corresponding to food names. During the initial test both animals used a common keyboard. Each chimpanzee, on alternate trials, was led to an adjacent room where it observed the baiting and sealing of a container with one of 11 foods and drinks (beancake, banana, chow, milk, orange drink, juice, cola, orange fruit, sweet potato, bread, or candy). The contents of the container had to be remembered for approximetely 1 minute as each chimpanzee was led (with the container) back to the keyboard, where we then asked him about the container's content.

The second (observer) chimpanzee, who had not seen the baiting process, was then given access to the keyboard and allowed to request the food. If he correctly decoded the answer provided by the informer and through the use of that information correctly requested the food, the container was opened. Only if both animals were correct were they given the food or drink. If either the observer or the informer was incorrect, nothing was given to either. The animals were allowed to observe the container so they could see that they had been in error.

The animals were successful in accurately transmitting this information (Table 1, row 1) even when the experimenter was unaware of the condition (Table 1, row 2). A variety of control conditions were included to ascertain that the animals were not being cued and that they did indeed comprehend the nature of the information they were transmitting.

The roles of the animals were reversed on each trial and the food or drink to be baited was randomly determined. During

Table 1. Correct performance under different experimental conditions. Differing numbers of trials reflect the animals' differing interest in this task from day to day. Tests were terminated when animals began to refuse to name the food and request instead to be tickled, to go out of the room, and so forth. The proportions correct reflect the combined performance of both animals. Both the informer and the observer had to be correct on a given trial for that trial to be scored as correct. Additionally, when the observing animal was asked to point to a photograph of food (row 5), this information had to coincide with the name given by the informer and the symbolic request made by observing animal. Therefore, on any given trial, there were three opportunities for error.

Experimental condition	Trials (correct/total)	Proportion correct
Interanimal test		
Animals use single keyboard. Experimenter knowledgeable. (Vocabulary size = 36)	33/35	.9
Control conditions		
Animals use single keyboard. Experimenters blind. (Vocabulary size = 36)	60/62	1.0
Animals use single keyboard but view only projected response of informed animal. Experimenters blind. (Vocabulary size = 40)	24/26	.9
Animals use separate keyboards, observe one another through window. Experimenters blind. (Vocabulary size = 40)	36/40	.9
Animals use single keyboard, observing animal points to photograph of food following his request. Experimenters blind. (Vocabulary size = 40)	27/30	.9
Knowledgeable animal prevented from using keys		
Informed animal denied use of keyboard to describe contents of sealed container. Experimenters blind. (Vocabulary size = 40)	4/26	.2

the first test of interanimal communication, the experimenter who accompanied the animal during the baiting process had been aware of the container's contents during the communication task. However, during all remaining tests, the baiting was done by another experimenter so that no person in the test room with the animals had knowledge of the container's contents. This control had not been used at the outset because we expected that the animals would need some tutoring on this task. They did not. All trials given under all conditions of interanimal communication are reported. No training trials on this task preceded or intervened between either the original test or any of the controls presented in Table 1. The animals exploited and expanded upon previously acquired skills in the successful communication achieved here, and the transmission of information regarding the contents of the container was between two chimpanzees, unmediated by any human being.

Following these initial tests, four additional conditions were run with no further training. The first two (Table 1, rows 3 and 4) eliminated any possibility that the animals were using position of the key, as opposed to the symbol per se, to communicate. Therefore, in the first condition, the animals were not allowed to see one another name the contents of the container at the keyboard; rather, they were allowed to see only the informer's answer as it was displayed on the projectors above the keyboard (Table 1, row 3). In the second, a window was installed between two test rooms, and each animal used its own keyboard to inform the other animal of the container's contents. The observer chimpanzee watched the informer through the window, then used his own keyboard to request the food. Since none of the word keys were in the same exact or relative location on the boards, the observer chimpanzee had to ignore the positions of keys used by the informer to find the same words on his keyboard. The high level of accuracy on all 40 trials of this test indicates that the information was being transferred by symbols, not key position (Table 1, row 4).

The next control condition was designed to determine whether the observing animal, on any given trial, understood the information provided by the informer or whether he was merely matching the symbol provided by the informer. This was accomplished by providing the observer with photos of three foods after he had requested the food named by the informer (*11*). The observing animal was then asked on each trial to point to a photograph of the food which he had requested. If the informer's food name, the observer's food request, and the observer's indication of the correct photograph all agreed, the container was opened by the experimenter. If the appropriate food was found, it was shared (Table 1, row 5).

In a final control experiment, the animal who saw the container being baited was not allowed to use the keyboard to declare its contents. Both animals were then placed in the same room and allowed to interact and employ any gestural, vocal, or postural cues at their disposal to inform one another, if possible, of the container's contents. After 30 to 60 seconds, the second animal was encouraged to go to the keyboard and request the contents of the container. Only a few of these trials were given (Table 1, row 6) because of the high error rate (chance), lack of interest, and negative behaviors (for example, attempts to steal the container and to get us to press the keys).

The exchange of specific information between these two chimpanzees was made possible through their use of symbols. Errors were infrequent and were always names of other foods and drinks, never for nonedible objects also on the keyboard. The chimpanzees were mutually attentive, and if one appeared to have difficulty finding a key, the other one often tried to assist, though restrained from doing so.

Clearly, these chimpanzees could use symbols to transmit information to one another. Could they also simply ask one another for food on the keyboard? To answer this, we gave only one animal a variety of foods and allowed the other animal to watch through the window between the rooms. The observing animal spontaneously used the keyboard to request food. We encouraged the second animal to observe this request and comply with it. We then reversed the roles, giving food to the other animal. Again the observer spontaneously used the keyboard to request food and the animal with the food was encouraged to comply. From this point on, the animals began to exchange roles and comply with each other's requests (Fig. 2). The initial encouragement was necessary to facilitate the social behavior of giving, but was not needed to facilitate the use of symbols or the nature of the communication. Accu-

Fig. 2. Sherman complies with Austin's request for bread. He reads projectors and selects correct food from tray (top row); hands food to Austin (center row); licks fingers and "smiles" broadly in response to social praise extended to him by technician (bottom row).

racy in this task is difficult to measure. We must presume that the requester always asked for what he wanted and was therefore 100 percent correct. The recipient of the request generally replied in kind. "Errors" on the part of the recipient most often occurred when a highly preferred food was requested. The recipient appeared either to ignore the request or to act as though he hadn't understood but would be quite willing to offer a piece of chow instead of a piece of chocolate. Accuracy ranged across sessions from 70 to 100 percent, depending upon the willingness of the animals to comply with each other's requests. In general, the lower-ranking animal, Austin, always complied with Sherman's requests. Sherman also complied with Austin's requests but needed more frequent encouragement to do so.

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References and Notes

1. B. T. Gardner and R. A. Gardner, in *Behavior of Nonhuman Primates*, A. M. Schrier and F. Stollnitz, Eds. (Academic Press, New York, 1971), vol. 4, pp. 117-184.
2. W. O. Dingwall, in *Studies in Neurolinguistics*, H. Whitaker and H. A. Whitaker, Eds. (Academic Press, New York, in press).
3. R. S. Fouts, in *Proceedings of the Ninth International Congress of Anthropological and Ethnological Sciences* (Mouton, The Hague, 1973), pp. 371-390.
4. J. Van Lawick-Goodall, in *Primate Patterns*, P. Dohlinow, Ed. (Holt, Rinehart & Winston, New York, 1972), pp. 25-84.
5. E. W. Menzel and S. Halperin, *Science* **189**, 652 (1975).
6. D. M. Rumbaugh, Ed., *Language Learning by a Chimpanzee: The Lana Project* (Academic Press, New York, 1977).
7. The lexigrams are composed of nine common elements, with the elements of any given lexigram being arbitrary and noniconic. They are displayed in white relief on colored backgrounds. The background for all foods and drinks, including those used in this study, is red. Consequently, choice behavior had to be based on configurations of the lexigrams.
8. E. S. Savage-Rumbaugh and D. M. Rumbaugh, *Brain Lang.*, in press.
9. D. M. Rumbaugh and E. S. Savage-Rumbaugh, *Behav. Res. Methods Instrum.* **10**, 119 (1978).
10. The number of active keys (lighted) during the various phases of training and testing varied in accordance with the animals' increasing vocabulary. At each point, however, all word keys that were a part of the animal's working vocabulary were lighted, and their locations on the console were moved every few days. This number is given in parentheses in Table 1 for each test. The training and testing on the tasks described in this report represent only a small portion of each animal's language-training activities on any given day. The increase in vocabulary size seen throughout this period is due to training irrelevant to the particular information transfer task described here.
11. Photographs were made of all foods and drinks used in the study. The experimenter who baited the container handed three photographs, face down, to a blind experimenter who was to accompany the chimpanzee. One photograph was of the correct food, the other two were selected randomly.
12. Supported by grants from the National Institute of Child Health and Human Development (HD-06016) and Animal Resources Branch (RR-00165) of the National Institutes of Health. Large portions of this study were filmed. We thank J. Lawson, R. K. Davenport, N. Smith, T. Maple, and R. Nadler for helpful criticism. This research is part of an effort to determine the value of the chimpanzee as an animal model for language research that cannot be conducted with the human child. A major portion of our research program entails extending advancements made with chimpanzees as subjects to language-training research with mentally retarded children at the Georgia Retardation Center in Atlanta.

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Genetic Basis of XX Male Syndrome and XX True Hermaphroditism: Evidence in the Dog

Abstract. *Serological analysis of white blood cells from the members of a family of American cocker spaniels indicates that a form of abnormal sexual development, in which individuals with a female karyotype have testes or ovotestes, is caused by anomalous transmission of male-determining H-Y genes.*

In mammals the Y chromosome is male-determining. Under the influence of a Y-situated gene or group of genes the indifferent embryonic gonad becomes a testis. The testis then secretes hormones which actively impose maleness in a system that is inherently biased toward the female condition (*1*). Yet despite the male-determining role of the mammalian Y chromosome, testicular differentiation and subsequent male or hermaphroditic development have been observed in subjects with a female (XX) karyotype (*2*).

Generally, theories concerned with differentiation of testes in the absence of a detectable Y chromosome propose conservation of Y-chromosomal function in one form or another—for example, (i) Y-to-autosome translocation, (ii) Y-X interchange, (iii) mutational acquisition of Y-chromosomal function by autosomal or X-chromosomal genes, or (iv) presence of undetected Y-bearing cell lines. Cytological studies (*3*) have provided supporting evidence for (ii) and (iv) above, but in our experience testicular differentiation in the absence

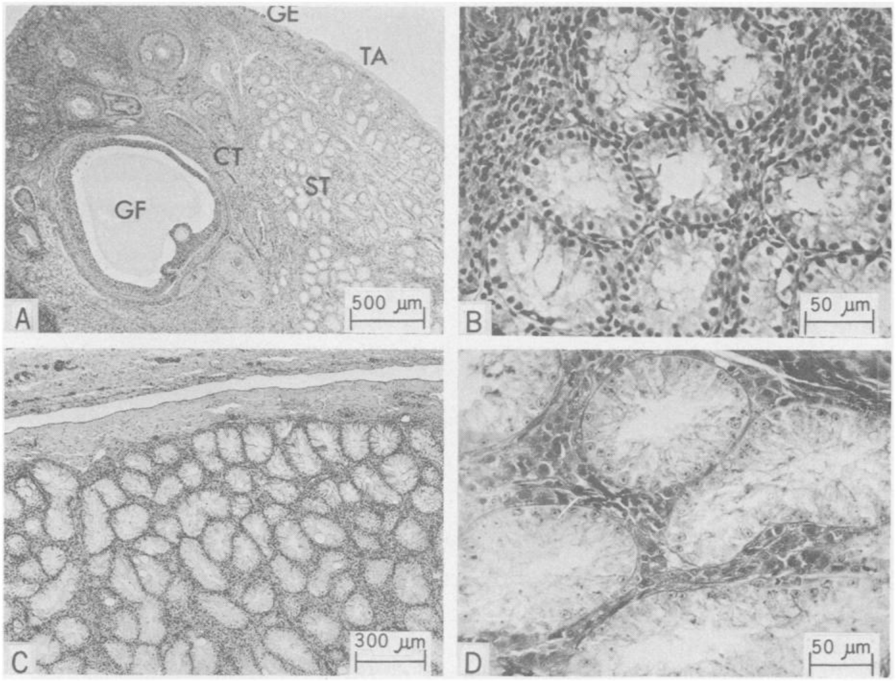

Fig. 1. Photomicrographs of gonadal tissue from XX male and XX true hermaphrodite. Ovotestis of the true hermaphrodite (A) (×36). This dog had bilateral ovotestes, both located in normal ovarian position (*7*). Under higher magnification (B) (×303), the seminiferous tubules are lined by vacuolated Sertoli cells; no spermatogenesis is evident. Leydig cells are present. Cryptorchid testicle of the XX male (C) (×53) contains lumenized seminiferous tubules varying in shape and size arranged in lobules by connective tissue trabeculae. Under higher magnification (D) (×283), the seminiferous tubules are lined by vacuolated Sertoli cells; no spermatogenesis is seen (Verhoeff's strain). Abbreviations: *CT*, connective tissue; *GE*, germinal epithelium; *GF*, Graafian follicle; *ST*, seminiferous tubules; and *TA*, tunica albuginea.

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