STUDIES TO DETERMINE THE INTELLIGENCE OF AFRICAN GREY PARROTS

Irene M. Pepperberg, Ph.D.
Department of Ecology and Evolutionary Biology
University of Arizona
Tucson AZ 85721
USA

from the *Proceedings of The International Aviculturists Society, January 11 - 15, 1995*

INTRODUCTION

Although parrots are not often mentioned in discussions about nonhuman intelligence, much data exist to suggest that psittacids are among the more intelligent animal species. During the 1940's and 1950's, for example, laboratory researchers in Europe demonstrated that Grey parrots could learn the kinds of symbolic and conceptual tasks that are generally considered as pre- or co-requisites for complex cognitive and communicative skills (reviews in Pepperberg1,2). More recently, field studies have reported behaviors that, when observed in nonhuman primates, are considered as evidence for human-like intelligence. Such behaviors include cooperative alarm signaling ("sentinel behavior") in flocks of Indigo macaws (Anodorhynchus leari)3 and individual recognition in Bahamian Amazons (Amazona leucocephala bahamensis).4

Another sign of intelligence, thought to be absent in most nonhuman animals, is the ability to engage in complex, meaningful communication; only recently has the general perception of parrots as mindless mimics been shown to be incorrect.2 Prior to the 1970's, researchers lacked knowledge of psittacine communication in the wild, and assumed that natural behaviors would not differ greatly from what had been observed in captivity: the ability of parrots to reproduce, with great accuracy, sounds such as those of human speech,5 but little (if any) ability to use these vocalizations in a meaningful way.6 The few studies in the 1950's and 1960's to challenge these perceptions -- e.g., Mowrer's attempts to teach mimetic birds to engage in meaningful communication with humans -- used standard psychological laboratory training paradigms and were not successful.7,8 Since the 1970's however, researchers working both in the field and in aviary settings have provided data to indicate that natural psittacine vocalizations might indeed be meaningful: Vocalizations appear to mediate social interactions between mated pairs and among flock members, and not only the physical structure but also the appropriate use of these vocalizations seems to be learned.3,4,9 Such findings on sophisticated vocal behaviors, when taken in conjunction with the data on complex problem-solving abilities, suggested that the psychologists' failures to achieve meaningful communication with their birds might be due to inappropriate training techniques, rather than to any inherent lack of intelligence in the psittacine subjects.1

My research has been a test of this premise. Starting in the late 1970's, I developed techniques that integrated the experimental rigor of the laboratory with what little was then known about psittacine communication in nature; I also borrowed ideas from projects designed to examine the bases for human social learning (reviews in Pepperberg2,9,10). I have used these techniques successfully to establish a form of interspecies communication with an African Grey parrot. The existence of such behavior demonstrates that at least one avian species is capable of interactive, referential communication. My students and I, moreover, use the ability to communicate to test the extent of this bird's intelligence. The following sections provide details of the procedures and a short summary of the results.

THE SUBJECT OF THE STUDY

The experimental subject, an African Grey parrot named Alex, has been the focus of a study on interspecies communication and avian intelligence since June, 1977. At the start of the project he was approximately 13 months old and had received no prior formal vocal instruction. He has free access to the laboratory room while trainers are present (~ 8 hrs/day), but is confined at other times to a cage (~62x62x73 cm) and the desk upon which it rests. Water and a standard psittacine seed mix (sunflower seeds, dried corn, oats, etc.) are continuously available throughout the day; fresh fruits, vegetables, specialty nuts (cashews, pecans, almonds, walnuts), and toys are used in training and are provided at his vocal requests.

RATIONALE FOR USING INTERSPECIES COMMUNICATION TO STUDY INTELLIGENT BEHAVIORS

Interspecies communication is a particularly powerful tool for assessing intelligence because it provides a simple, direct means for testing subjects. Unlike other systems, a two-way communication code (1) enables researchers to query their animal subjects in as direct a manner as they now query human participants in related studies; (2) enables researchers to communicate to their subjects, in the most efficient way possible, the precise nature of the questions being asked; (3) takes into account the animals' natural predispositions by providing a social context not entirely unlike their field situation;11 (4) allows comparisons not only between humans and other animals but also among widely-divergent animal species; (5) is an open, arbitrary system in which subtle variations create an enormous variety of signals that can be used to examine the nature as well as the ex-tent of the information perceived by the subject; (5) allows rigorous testing because the subjects can be required to choose their responses from their entire repertoire rather than from the subset relevant only to the topic of a particular question; and (6) is flexible enough to allow subjects to respond in novel and possibly innovative ways that may demonstrate intelligence beyond that required by the intended task (from Pepperberg12,13).

TRAINING TECHNIQUES

1. Use of Intrinsic Rewards (excerpted from Pepperberg1,2,10)

My students and I use several techniques to teach the parrot meaningful communication, but one feature all have in common is the consistent, exclusive use of intrinsic reinforcers -- i.e., when we teach Alex labels for particular items, his reward for producing the correct label is the object to which the label or concept refers. Thus, if Alex correctly identifies a cork, that is what he receives. This procedure insures, at all times, and at every interaction, the closest possible association of the label or concept to be learned and the object or task to which it refers.1,14

In contrast, programs such as Mowrer's relied on extrinsic rewards.7 Thus, on the few occasions when his subjects correctly labeled food or nonfood items, or made appropriate responses to various specific commands, they were rewarded with a single, particular favored food that neither directly related to, nor varied with, the label or concept being taught. I believe that extrinsic rewards may actually act to delay label or concept acquisition by confounding the label of the exemplar or concept to be learned with that of the food reward.14,15,16 Alex therefore never receives extrinsic rewards.

On occasion, Alex may receive a more general form of reward: Because it is sometimes difficult to maintain his interest in the set of objects that are being used to train a particular concept, he may be rewarded with the right to request vocally a more desirable item than the one he has identified ("I want X"). Such a protocol provides some flexibility but maintains the referentiality of the reward. Alex will never, for example, automatically receive a slice of banana when he identifies a cork. The banana must specifically be requested ("I want banana"), and trainers will not respond to such a request until the appropriate prior task is completed.17

2. The Model/Rival (M/R) Technique (excerpted from Pepperberg1,2,10)

The primary training system, called the model/rival, or M/R technique, is based on a protocol developed by Todt, an ethologist interested in social learning in parrots.18 Todt's procedures, in turn, derived much from the work of Bandura, who studied the effects of social modeling on learning in humans.19 The M/R procedure involves three-way interactions between two competent human speakers and the avian student. M/R training is used primarily to introduce new labels and concepts, but also aids in shaping correct pronunciation.

During M/R training, humans demonstrate to the bird the types of interactive responses that are to be learned. A typical interaction proceeds as follows: Alex is seated on his gym, his cage, or the back of a chair, and observes two humans handling one or more objects in which he has already demonstrated an interest. In the presence of the bird, one human acts as a trainer of the second human. The trainer presents the object(s), asks questions about the object(s) (e.g., "What's here?", "What color?", "What shape?"), and gives the human model praise and the object(s) in question as a reward for a correct answer. Disapproval for incorrect responses (erroneous answers that are similar to those being made by the bird at the time: unclear vocalizations, partial identifications, etc.) is demonstrated by scolding and temporarily removing the object(s) from sight. Thus the second human not only acts as a model for the bird's responses and as a rival for the trainer's attention, but also allows the parrot to observe the effects of an error: The model is asked to try again or talk more clearly if the response was (deliberately) incorrect or garbled.

Unlike the modeling procedure developed by Todt (and several other researchers10), our protocol also involves repeating the interaction while reversing the roles of the human trainer and model, and occasionally includes the parrot in the interactions. We thus demonstrate that the interaction is indeed a "two-way street": that one person is not always the questioner and the other always the respondent, and that the procedure can be employed to effect changes in the environment. Inclusion of role reversal in M/R training appears to counteract what would be, for our project, the drawbacks associated with Todt's method: Todt's birds, whose trainers always maintained their respective roles, would not respond to anyone other than the human who posed the questions. In contrast, Alex responds to, interacts with, and learns from all of the trainers with whom he comes in contact.

3. Sentence Frames (excerpted from Pepperberg13)

Because Alex's initial attempts at a new label are rarely exact reproductions of the human vocalization, we often use an additional procedure to clarify his pronunciation. My students and I present the new exemplar to him along with a string of sentence frames -- phrases like "Here's your paper!", "Such a big piece of paper!" These sentences allow us to give him additional exposure to a target word, such as "paper", in a consistent manner without presenting it as a single, meaningless, repetitive utterance. This combination of a particular form of vocal repetition and the physical action of presenting the object resembles the behavior parents and caretakers sometimes use when introducing labels for new items to very young children,20,21 and appears to have two effects: (1) Alex hears the label employed in normal, productive speech so that he experiences the label in the way in which it is to be used; and (2) he learns to reproduce the emphasized, targeted label without associating simple word-for-word imitation of the trainers with reward.

4. Referential Mapping (excerpted from Pepperberg10)

We use another set of procedures, called referential mapping, to assign meaning to novel vocalizations that Alex occasionally produces spontaneously. These spontaneous vocalizations are generally combinations and phonological variations of the specific vocal English labels that he has previously acquired. For example, after he learned "grey", he produced "grape", "grate", "grain", "chain", and "cane". Unlike the vocalizations that we train by the M/R procedure, these recombinations are not necessarily initially used intentionally to describe or request novel objects or circumstances. The procedures for dealing with these spontaneous modifications, however, neither attempt to nor need to evaluate the intentionality of Alex's behavior. Rather, trainers following these procedures respond to the novel speech acts as though he were intentionally commenting about or requesting objects, actions, or information.

Referential mapping formally consists of three procedures:

(1) All trainers respond to Alex's vocalizations with an appropriate object or action -- i.e., as if he does indeed understand the significance of what he is saying. Whether or not the parrot does intend to produce the combination is not important; we simply demonstrate that these phrases can be meaningful and that they can be used to control, or at least influence, his environment and the actions of his caretakers. Laboratory studies on both humans and birds suggest that experiencing the appropriate consequences of an utterance may assist learning, and analogous situations may occur in animal systems in nature. There is some evidence, for example, that young songbirds, through their interactions with adult conspecifics, learn not only what to sing but also how song is to be used (see reviews in Pepperberg17,22,23).

(2) We also employ a variation of the M/R technique to demonstrate further the possible relevance of Alex's spontaneous recombinations. Here two humans model a social interaction corresponding to the now-targeted vocalization: One human produces the novel vocalization while the other produces an object, an exemplar of the term (e.g., for colors), or demonstrates the action to which it refers. The roles of the humans are then reversed, so that the parrot observes that the vocalization is neither specific to nor controls only a particular individual's actions. If the parrot emits the vocalization during this demonstration, he is shown (and occasionally receives) the object or action (e.g., a "chain" of paper clips). The human trainers not only model identification of the object or action (by responding to each other's queries of

"What's this?"), but, when possible, also employ objects that demonstrate that the vocalization can have varied applications; e.g., produce "box" exemplars of different colors or sizes.

(3) Finally, human trainers use sentence frames to provide additional cues about the appropriate context in which the object or action label should be used. While the targeted object is being manipulated or the action demonstrated, either by the human or the parrot, humans produce sentence frames such as "You're eating a green nut!", "I'm holding a green nut!", "Do you want another green nut?", in which only the label for the action or object remains fixed and stressed. As before, Alex hears numerous repetitions of the label, but in a way that demonstrates the connection between label and its referent.

TESTING PROCEDURES

To evaluate what the parrot has learned, we regularly administer tests that simultaneously include questions on all of the tasks that have been trained.2 Test questions for each topic therefore occur only on average one- to four-times per week. Our detailed test procedure can be found in any of several prior publications (e.g., Pepperberg1,2,12,22). But, because confidence in our results requires confidence in both our controls against cuing and our method of scoring Alex's responses, I will review those aspects of our procedures in some detail.

1. Protocols to Avoid Inadvertent Cuing

a. Precautions against trainer-induced cuing1,2. Two procedures are used to avoid this type of cuing. One procedure is a design that prevents either the subject or the principal trainer from predicting which questions (or answers) will be tested on a given day. To construct a test, the trainers proceed as follows: The principal trainer first lists all of the possible questions about objects or combinations of objects for the topics that are to be examined. A student who will not administer a test then sets the question; e.g., forms the pairs (for questions on same/different) or collections (for numerical and comprehension questions), and randomly orders all the questions. The principal trainer then acts as a "blind" evaluator (see below) while other students present questions intermittently during training sessions on current (and thus unrelated) topics over the course of several days until all the questions on the test have been presented. At the same time that we were conducting the studies on number concepts and same/different, for example, we were training and testing additional labels,9,12,17,23,24 training photograph recognition, and testing object permanence.25 Test questions such as "How many?" were thus as likely to occur during training sessions on photograph recognition as during tests on "Where's the key?" The opportunity for any particular object or collection of objects to appear on a test might occur only once per week and therefore could not be predicted. A second precaution against cuing is to ensure that trials on a particular topic are conducted by students who had never trained the parrot on that topic. The same student could, however, test several other topics, so that the presence of a particular student would not serve as a cue as to which particular topic would be tested.

b. Precautions against "expectation cuing". Intermingling different types of questions (e.g., "How many?", "What's this?", "What color?", "What's same?", "What's blue?") on tests or during training on other topics not only prevents cuing by the trainers, but also ensures against "expectation cuing" that may occur when a subject "expects" questions to concern a single topic. If a subject uses contextual information in single-topic tests to limit its responses to a small subset of its repertoire, the range of knowledge being tested will be much more limited than the experimenter assumes, and this limit could enable the subject to perform at a level higher than would otherwise be justified by its real knowledge of the topic. Alex, however, is never tested exclusively on questions on a single topic (e.g., number labels) in one session, and, more importantly, is never tested successively in one session on similar questions ("What's same?") or questions that would have one particular correct response (e.g., "three wood"). A question is repeated in a session only if his initial answer is incorrect (see below).1 Thus, even though the range of correct responses to questions of, for example, "What's same?" or "What's different?" was limited initially to three labels ("color", "shape", or "matter"), and responses on number to five labels, in any session Alex also had to choose from among many possible responses to other questions such as "What's that?", "Where's the chain?", or "What color?" in order to be correct.12,25,26,27,28

c. Maintaining the subject's attention. Concurrent work on a variety of tasks not only prevents expectation cuing, but is also an important experimental protocol because Alex becomes restless during sessions devoted to a single task. He ceases work, begins to preen, or interrupts with many successive requests for other items ("I want X") or changes of location ("Wanna go Y"). Similar "boredom" behavior has been observed in several other animals.29

d. Additional controls. Although our formal procedures adequately protect against inadvertent cuing, two other circumstances provide additional controls. The first circumstance involves those trials in which the examiner errs: In about one in 20 trials (particularly during student exam periods), an examiner will err and scold Alex for a correct response. Alex will repeat his correct response, despite our procedures, which encouraged a lose-shift strategy. The examiner then usually recognizes her error, and Alex gets his reward. The examiner, were she producing inadvertent cues, would in these cases have been cuing Alex to respond with an incorrect answer, and thus the effect would be the same as a blind test. The second circumstance involves informal questioning by naive visitors who are unfamiliar with the several idiosyncratic labels that Alex uses for certain objects ("banerry" for apple, "truck" for toy metallic cars, "rock corn" for dried corn, "wheat" for cereal, "cork nut" for almond). People unfamiliar with Alex and with these labels have queried him about these objects; he has been correct on 7/8 first trials.

2. Determining Accuracy and the Correction Procedure

As noted above, the number of times an object or collection is presented to Alex depends upon his accuracy, which is determined as follows: The questioner (a student trainer), presents to the bird, in a variable but previously determined order, the object(s) about which he will be queried. The principal trainer sits in a corner of the room, does not look at Alex or the examiner during presentation of the test object(s), and thus does not know what is being presented. The student trainer asks one of the number of possible different questions, to which the bird responds. The principal trainer then repeats out loud what she heard the parrot say. (This repetition prevents the examiner from accepting an indistinct, incorrect vocalization that was similar to the expected, correct response; e.g., "gree" for "three"). If what the principal trainer heard was correct (e.g., the appropriate category label), Alex is rewarded by praise and the object(s). There are then no additional presentations of the same material during that test; i.e., there is only a single, "first trial" response. If Alex's identification was incorrect or indistinct, the examiner removes the object(s), turns his/her head (a momentary "time-out"), and emphatically says "No!" The examiner then implements a correction procedure in that the misnamed object or collection is immediately (re)presented until Alex gives the correct identification; errors are recorded.

Alex has learned, too, that repetition of an incorrect identification (e.g., repeated substitution of the label of a more desired object for the one presented) is fruitless; instead, a quick, correct identification allows him to request the preferred item. Because immediate re-presentation of an object or collection during a test occurs only when the response to the initial presentation is incorrect, the testing protocol penalizes a "win-stay" strategy: Repetition of a previously correct response (e.g., the name of the previous exemplar) elicits no reward. The testing procedure thus provides a definite contrast to training protocols that rely on, and occasionally reinforce, repetitive behaviors.

3. Scoring Procedure and Competence

Alex's test scores are used to evaluate his cognitive capacities on the various tasks. For most tasks, the test scores have been calculated in two ways. The overall test score for each task (results for "all trials)" is obtained by dividing the total number of correct identifications (i.e., the predetermined number of objects or collections) by the total number of presentations required. "First trial" results (% of first trials that are correct) are often reported for comparison. Alex consistently responded with a high degree of accuracy on all questions; p values are consistently less than 0.005, and for most tests less than 0.0001. The following sections describe the different topics, the different tasks used to study these topics, the results of testing, and the implications of the data for determining Alex's cognitive capacities.

RESULTS OF TRAINING

Using these techniques, my students and I have, over the course of several years, taught Alex tasks that were once thought beyond the capability of all but humans or, possibly, certain nonhuman primates.30 Alex has learned labels for more than 35 different objects: paper, key, wood, hide (rawhide chips), grain, peg wood (clothes pins), cork, corn, nut, walnut, showah (shower), wheat, pasta, box, banana, gym, cracker, scraper (a nail file), chain, shoulder, block, rock (lava stone beak conditioner), carrot, gravel, back, chair, chalk, water, nail, grape, cup, grate, treat, cherry, wool, popcorn, citrus, green bean, and banerry (apple). We have tentative evidence for labels such as bread and jacks. He has functional use of "no", phrases such as "come here", "I want X" and "Wanna go Y" where X and Y are appropriate labels for objects or locations. Incorrect responses to his requests by a trainer (e.g., substitution of something other than what he requested) generally results (~75% of the time) in his saying "No" and repeating the initial request.12,17 He has acquired labels for 7 colors: rose (red), blue, green, yellow, orange, grey, and purple. He identifies five different shapes by labeling them as 2-, 3-, 4-, 5-, or 6-cornered objects. He uses the labels "two", "three", "four", "five", and "sih" (six) to distinguish quantities of objects up to 6, including collections made up of novel objects, heterogeneous sets of objects, and sets in which the objects are placed in random arrays.26,27 He combines all the vocal labels to identify proficiently, request, refuse, categorize, and quantify more than 100 different objects, including those that vary somewhat from training exemplars. His accuracy has averaged ~ 80% when tested on these abilities.1,12,24,26,27

We have also examined Alex's capabilities to comprehend the concept of "category". Not only have we taught Alex to label any one of a number of different hues or shapes, but also to understand that "green", for example, is a particular instance of the category "color", and that, for any object that is both colored and shaped, the specific instances of these attributes (e.g., "green" and "three-corner") represent different categories. Thus he has learned to categorize objects having both color and shape with respect to either category based on a vocal query of "What color?" or "What shape?" (85.5%, all trials).28 Because the protocol often requires Alex to categorize the same exemplar with respect to shape at one time and color at another, the task involves flexibility in changing the basis for classification. Such flexibility, or capacity for reclassification, is thought to indicate the presence of "abstract aptitude".31

Alex has also learned abstract concepts of "same", "different", and to respond to the absence of information about these concepts if nothing is same or different. Such faculties were once thought beyond the capacity of an avian subject (note Premack30,32; but see Zentall, Hogan, & Edwards33). Thus, when presented with two objects that are identical or that vary with respect to some or all of the attributes of color, shape, and material, Alex can respond with the appropriate category label as to which attribute is "same" or "different" for any combination (80.8%, all trials; 76.0%, first trials; see Fig. 1).24 If, however, nothing is same or different, he has learned to reply "none" (83.9%, all trials; 80.9%, first trials).13 He can respond equally accurately to instances involving objects, colors, shapes, and materials not used in training, including those for which he has no labels. Furthermore, we have shown that Alex is indeed responding to the specific questions, and not merely responding on the basis of his training and the physical attributes of the objects: His responses were still above chance levels when, for example, the question "What's same?" was posed with respect to a green wooden triangle and a blue wooden triangle. If he were ignoring the question and responding on the basis of his prior training, he would have determined, and responded with the label for, the one anomalous attribute (in this case, "color"). Instead, he responded with one of the two appropriate answers [in this case, "shape" or "mah-mah" (matter)].13,24

Although our research on numerical concepts does not demonstrate that Alex has an understanding of "number" comparable to that of a human child, the data suggest that he does comprehend some concept of quantity.26,27 Thus, although we have yet to show conclusively that Alex can, for example, count sequential metronome clicks to tell us that he has heard "three", he can recognize and label different quantities of physical objects up to and including 6 (78.9%, all trials).27 The sets of objects need not be familiar, nor need they be placed in any particular pattern, such as a square or triangle. Furthermore, if presented with a heterogeneous collection -- of X's and Y's -- he can respond appropriately to questions of either "How many X?" or "How many Y?" (62.5%, all trials; 70.0%, first trials).27 Our work with heterogeneous collections has suggested even more advanced skills. Alex can be shown a "confounded number set" (collections of four groups of items that vary in two colors and two object categories--e.g., blue and red keys and cars) and be asked to label the number of items uniquely defined by the combination of one color and one object category (e.g., "How many blue key?).39 His accuracy (83.3%) replicates that of humans in a comparable study performed by Trick and Pylyshyn.38 Although we cannot claim that the mechanisms that Alex uses are identical to those of humans, the data suggest that a non-human, nonprimate, nonmammalian subject has a level of competence that, in a chimpanzee, would be taken to indicate a human level of intelligence.2,27

In a recent study, we determined formally how similar Alex's abilities are to those of marine mammals that have also been trained to use a system of interspecies communication.34 Most of the work with cetaceans and pinnipeds uses the comprehension mode; that is, researchers assess competence in cognitive and communicative skills by demonstrating how well their animal subjects understand the communication code.35 In contrast, much of the work with nonhuman primates and all of the prior work with Alex, although clearly involving comprehension, emphasizes instead the productive mode; that is, how accurately and appropriately the subjects can produce the code. To maintain our vocal paradigm but provide the necessary comparisons,36 my students and I chose to train and test Alex on a recursive task similar to those used with other animals. In a recursive task, a subject is presented with several different objects and one of several different possible questions or commands concerning the attributes of these objects. Each question or command contains several parts, the combination of which uniquely specifies which object is to be targeted and what action is to be performed. The complexity of the question is determined by its context (the number of different possible objects from which to choose) and the number of its parts (e.g., the number of attributes used to specify the target and the number of actions from which to choose). The subject must divide the question into these parts and (recursively) use its understanding of each part to answer correctly. The subject thus demonstrates its competence by reporting on only a single aspect (e.g., color, shape, or material) of, or performing one of several possible actions (fetching, touching) on, an object that is one of several differently colored and shaped exemplars of various materials. Alex was therefore shown trays of seven unique combinations of exemplars and asked questions of "What color is object-X?", "What shape is object-Y?", "What object is color-A?", or "What object is shape-B?" His accuracy for all questions, which was better than 80% (84.2%, all trials; 81.3%, first trials),34 was comparable to that of marine mammals (and also nonhuman primates) that had been tested on similar tasks.

We have recently taken this work one step further, by adding a conjunctive condition to the recursive task.37 Here Alex was again shown a 7-member collection but was now asked to provide information about the specific instance of one category of an item that was uniquely defined by the conjunction of two other categories; e.g., "What object is color-A and shape-B?". Other objects on the tray exemplified one, but not both, of these defining categories. Alex responded with an accuracy of 76.5%, which indicated that he understood all the elements in the question. Again, his data was comparable to that of marine mammals that had similarly been tested.

RESEARCH ON TWO ADDITIONAL SUBJECTS

In April, 1990, we acquired two new African Grey parrots: Kyaaro, a 3.5 mo male and Alo, a 7 mo. female. Using these birds, we have begun to test the relative importance of the three aspects that make up the M/R training procedure: 1) reference, 2) context, and 3) interaction. Reference is generally defined as the meaning of an utterance; e.g., the relationship between a label and the object to which it refers. Contextual applicability involves the particular situation in which an utterance is used and the effects of using the utterance. Social interaction signals which components of the environment should be noted, emphasizes common attributes--and thus possible underlying rules--of diverse actions, and allows input to be continuously adjusted to the level of the learner. Interaction may also provide a contextual explanation of the reasons for the actions and demonstrate the consequences of the actions. I studied the relative effects of three types of input: 1) audiotapes that were nonreferential, not contextually applicable, and noninteractive; 2) videotapes that were referential, minimally contextually applicable, and noninteractive; and 3) the usual M/R training that was referential, contextually applicable, and interactive. Neither Alo nor Kyaaro learned anything from the audio or videotapes. Alo and Kyaaro have learned to comprehend as well as produce new labels from the M/R training.40,41 Our results provide clear evidence for the importance of our training procedures if a parrot is to communicate with humans and not simply mimic human speech.

IMPLICATIONS OF THE RESULTS

Our findings, although they emphasize how well Alex can perform complex cognitive tasks, do not imply that all parrots -- or even all Greys -- are capable of such behavior. Rather, our data is meant to suggest the level of competence that may, with the appropriate environmental support, be within the capacity of the species. A bird that has spent its life confined to its cage and with limited interactions with humans would not have the opportunity to demonstrate such skills, whatever its inherent abilities. One of the goals of my research, therefore, has been to determine the forms that this requisite environmental support must take. Thus, although our program allows Alex, Alo, and Kyaaro to have considerable time outside of testing and training for "free-style" interactions with humans, we work within a consistent plan that has been designed to encourage referential communication and information processing, and to discourage mindless mimicry. The extent to which Alo and Kyaaro, if given as much training as Alex, can demonstrate such abilities remains to be seen.

REFERENCES AND NOTES

1. Pepperberg, I.M.: Functional vocalizations by an African Grey parrot (Psittacus erithacus). Z. Tierpsychol. 55:139-160, 1981.

2. Pepperberg, I.M.: An investigation into the cognitive capacities of an African Grey parrot (Psittacus erithacus). In Advances in the Study of Behavior. Edited by P.J.B. Slater, J.R. Rosenblatt, and C. Beer. New York, Academic Press, 1990.

3. Yamashita, C.: Field observation and comments on the Indigo macaw (Anodorhynchus leari), a highly endangered species from northeastern Brazil. Wilson Bull., 99:280-282, 1987.

4. Gnam, R.: Preliminary results on the breeding biology of Bahama Amazon. Parrot Letter 1:23-26 1988.

5. See, for example, Baldwin, J.M.: Deferred imitation in West African Grey parrots. IXth Int'l Cong. Zool., 536, 1914.

6. Lenneberg, E.H.: Biological Foundations of Language. New York, Wiley & Sons, 1967.

7. Mowrer, O.H.: Learning Theory and Personality Dynamics. New York, Ronald Press, 1950.

8. Grosslight, J.H., and Zaynor, W.C.: Vocal behavior of the mynah bird. In Research in Verbal Behavior and Neurophysiological Implications. Edited by K. Salzinger and S. Salzinger S. New York, Academic Press, 1967.

9. For details and original references, see Pepperberg, I.M.: The importance of social interaction and observation in the acquisition of communicative competence: Possible parallels between avian and human learning. In Social Learning: Psychological and Biological Perspectives. Edited by T.R. Zentall and B.G. Galef. Hillsdale, NJ, Erlbaum, 1988.

10. Pepperberg, I.M.: Referential mapping: A technique for attaching functional significance to the innovative utterances of an African Grey parrot (Psittacus erithacus). Appl. Psycholing. 11:23-44, 1990.

11. Menzel, E.W., Jr., and Juno, C. Social foraging in marmoset monkeys and the question of intelligence. Phil. Trans. Royal Soc., London B., 308:145-158, 1985.

12. Pepperberg, I.M.: Interspecies communication: A tool for assessing conceptual abilities in the African Grey parrot (Psittacus erithacus). In Language, Cognition, and Consciousness: Integrative Levels. Edited by G. Greenberg and E. Tobach. Hillsdale, NJ, Erlbaum Assoc., 1987.

13. Pepperberg, I.M.: A communicative approach to animal cognition: A study of conceptual abilities of an African Grey parrot (Psittacus erithacus). In Cognitive Ethology: The Minds of Other Animals. Edited by C. Ristau. Hillsdale, NJ, Erlbaum Assoc., 1991.

14. Pepperberg, I.M.: Object identification by an African Grey parrot (Psittacus erithacus). Abstr, Midwest Animal Behavior Meeting, W. Lafayette, IN 1978.

15. Greenfield, P.M.: Developmental processes in the language learning of child and chimp. Behav. Brain Sci. 4:573-574, 1978.

16. Miles, H.L.: Apes and language. In Language in Primates. Edited by J. de Luce and H.T. Wilder. New York, Springer-Verlag, 1983.

17. Pepperberg, I.M.: An interactive modeling technique for acquisition of communication skills: Separation of `labeling' and `requesting' in a psittacine subject. Appl. Psycholing. 9:31-56, 1988.

18. Todt, D.: Social learning of vocal patterns and modes of their applications in Grey parrots. Z. Tierpsychol. 39:178-188, 1975.

19. Bandura, A: Analysis of social modeling processes. In Psychological Modeling. Edited by A. Bandura. Chicago, Aldine-Atherton, 1971.

20. Berko-Gleason, J: Talking to children: Some notes on feedback. In Talking to Children. Edited by C.E. Snow and C.A. Ferguson. Cambridge, Cambridge University Press, Cambridge, 1977.

21. De Villiers, J.G. and De Villiers, P.A.: Language Acquisition. Cambridge, MA, Harvard University Press, 1978.

22. Pepperberg, I.M.: Social modeling theory: A possible framework for understanding avian vocal learning. Auk 102:854-864, 1985.

23. Pepperberg, I.M.: Comprehension of "absence" by an African Grey parrot: Learning with respect to questions of same/different. JEAB 50:553-654, 1988.

24. Pepperberg, I.M.: Acquisition of the same/different concept by an African Grey parrot (*Psittacus erithacus*): Learning with respect to color, shape, and material. Anim. Learn. Behav. *15*:423-432, 1983.

25. Pepperberg, I.M., and Kozak, F.A. Object permanence in an African Grey parrot *Psittacus erithacus*). Anim. Learn. Behav., *14*:322-330, 1986.

26. Pepperberg, I.M.: Vocal identification of numerical quantity by an African Grey parrot. Abstr. Psychonomic Society Meeting, San Antonio, TX, 1984.

27. Pepperberg, I.M.: Evidence for conceptual quantitative abilities in the African Grey parrot: Labeling of cardinal sets. Ethology *75*:37-61, 1987.

28. Pepperberg, I.M.: Cognition in the African Grey parrot: Preliminary evidence for auditory/vocal comprehension of the class concept. Anim. Learn. Behav. *11*:179-185, 1983.

29. Meerkats (*Suricata suricatta*), a raccoon (*Procyon lotor*), chimpanzees (*Pan troglodytes*), and rats. For original references, see Pepperberg, 1987.

30. Premack, D: On the abstractness of human concepts: Why it would be difficult to talk to a pigeon. *In* Cognitive Processes in Animal Behavior. Edited by S.H. Hulse, H. Fowler and W.K. Honig. Hillsdale, NJ, Erlbaum, 1978.

31. Hayes, K.J., and Nissen, C.H.: Higher mental functions of a home-raised chimpanzee. *In* Behavior of Nonhuman Primates, Vol. 4. Edited by A. Schrier and F. Stollnitz. New York, Academic Press, 1956/1971.

32. Premack, D: The codes of man and beasts. Behav. Brain Sci. *6*:125-167, 1983.

33. Zentall, T.R., Hogan, D.E., and Edwards, C.A.: Cognitive factors in conditional learning by pigeons. *In* Animal Cognition. Edited by H.L. Roitblat, T.G. Bever, and H.S. Terrace. Hillsdale, NJ, Erlbaum, 1984.

34. Pepperberg, I.M.: Cognition in an African Grey parrot (*Psittacus erithacus*): Further evidence for comprehension of categories and labels. J. Comp. Psych. *104*:41-52, 1990.

35. See, for example, Herman, L. Receptive competencies of language-trained animals. *In* Advances in the Study of Behavior. Vol 17. Edited by J. Rosenblatt, C. Beer, P.J.B. Slater, and M.-C. Busnel. New York, Academic Press, 1987.

36. Granier-Deferre, C., and Kodratoff, Y. Iterative and recursive behavior in chimpanzees during problem solving: A new descriptive model inspired from the artificial intelligence approach. Cahiers de Psychologie Cognitive, *6*:483-500, 1986.

37. Pepperberg, I.M.: Proficient performance of a conjunctive, recursive task by an African Grey parrot (*Psittacus erithacus*). J. Comp. Psych. *106*:295-305, 1992.

38. Trick, L., & Pylyshyn, Z. Subitizing and the FNST spatial index model. University of Ontario, COGMEM#44 (Based on a paper presented at the 30th Psychonomic Society Mtg, Atlanta, GA, November, 1989).

39. Pepperberg, I.M. Numerical competence in an African Grey parrot (Psittacus erithacus). J. Comp. Psych., 108:36-44, 1994.

40. Pepperberg, I.M. A review of the effects of social interaction on vocal learning in African Grey parrots (Psittacus erithacus). Netherlands J. Zool., 43:104-124, 1993.

41. Pepperberg, I.M. Vocal learning in Grey parrots (Psittacus erithacus): Effects of social interaction, reference, and context. Auk, 111:300-313, 1994.776