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Irene M. Pepperberg
Northwestern University

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KEYWORDS

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ABSTRACT

An African Grey parrot, Alex, learned to report on the absence or presence of similarity and difference between two objects. Alex was shown pairs of objects that were (a) totally dissimilar, (b) identical, or (c) similar or different with respect to one of three attributes (color, shape, or material). In the first two cases, he responded to the respective queries of "What's same?" or "What's different?" with the vocalization "none," and in the third case he responded with the appropriate category label ("color," "shape," or "mah-mah" [matter]). His accuracy was 80.9% to 83.9% for pairs of familiar objects not used in training and 72.5% to 78.4% for pairs whose colors, shapes, and materials were unfamiliar. The data provide evidence that this parrot's abilities are comparable to those of mammals that have been trained to report on the presence or absence of objects or features of objects.

The ability to understand the concept of nonexistence, or even the simpler notion of absence, denotes a relatively advanced stage in the linguistic and cognitive development of an organism (see Brown, 1973). An organism, whether human or nonhuman, reacts to absence only after acquiring a corpus of knowledge about the expected presence of events, objects, or other information in its environment; that is, only when there is a discrepancy between the expected and the actual state of affairs (see de Villiers & de Villiers, 1979; Hearst, 1984; Skinner, 1957). Bloom (1970) suggests furthermore that not only comprehension but functional verbal production of terms relating to nonexistence is necessary before an organism can be considered to have acquired this concept.

Experimental demonstration of the concept of nonexistence can be difficult. For example, humans routinely perform better on tasks for which the goal is the search for the presence rather than the absence of certain features, or for which judgments are made on the basis of affirmation and occurrence rather than negation and nonoccurrence, even if the tasks are of purported equal difficulty (see discussion in Hearst, 1984). Even when subjects clearly comprehend the nature of a task concerning some aspect of nonexistence, performance on the task often does not reflect the level of comprehension. One of the few ways to avoid this performance/comprehension disparity is to require positive actions in response to nonoccurrences so that the subject can recognize the salience of "absence" or other aspects of negation (Fazio, Sherman, & Herr, 1982; Hearst, 1984).

Ethological studies, although not specifically designed to examine the concept of nonexistence, have shown that some animals naturally exhibit positive behaviors that are correlated with the absence of certain signals. Birds, for example, will react to the absence of signs of territorial defense (e.g., song) from their conspecific neighbors with positive acts of territorial invasion (e.g., great tits, Krebs, 1977; red-winged blackbirds, Peek, 1972; Smith, 1979), and some male warblers change the proportion of song types in their repertoires after loss of their mate (e.g., Adelaide's warblers,[1] yellow warblers,[2] chestnut-sided warblers, Kroodsma, Bereson, Byers, & Minear, in press). However, each of these types of behavior corresponds to a single situation, and may be as much -the result of the removal of a factor that was inhibiting its expression (e.g., a neighbor ready to do battle) as recognition of the absence of a particular stimulus. These types of behavior, although suggestive, can therefore only be considered indirect evidence for a general concept of nonexistence.

Most psychological experiments with animals and, interestingly, with humans have also provided only indirect evidence for concepts of nonexistence or absence (for reviews, see Hearst, 1984; Herman & Forestell, 1985). Subjects in such studies usually were performing feature-negative discriminations and were therefore likely to have been responding on the basis of something other than nonexistence. In any case, these subjects were not required to generalize their responses beyond their very specific training paradigms. These subjects may actually have been responding to whether an object had or had not been previously experienced (e.g., as part of a test of memory), or to whether two items were entirely identical or somewhat dissimilar ("not same") without necessarily performing on any basis other than match-to-sample. In some cases, the subjects may have simply been learning where to look (e.g., Sokolov, 1963). Even if the tasks were designed so that the subjects had to respond to the presence or absence of a particular stimulus, little learning took place unless this single, arbitrary stimulus was extremely salient. Human subjects, for example, were often unable to learn the discrimination if the critical factor was part of a compound stimulus such as "smoke" emanating from a chimney in a cartoon (see Hearst, 1984; Jenkins & Sainsbury, 1969, 1970).

For these reasons, human comprehension of nonexistence is often studied descriptively rather than experimentally. Bellugi (1967) and Bloom (1970), for example, observed how the use of terms for nonexistence and absence emerged as part of the development of the syntax, semantics, and pragmatics of negation. Descriptive situations for animals in which response to absence can be most closely compared to those of humans are thus likely to occur in projects designed to train the subject in the use of human-based communication codes (i.e., codes based on rules presumed to underlie human systems; see Gardner & Gardner, 1978; Premack, 1976; von Glasersfeld, 1977). Such communication studies may then form the basis for further experimental work.

Studies with Animal Subjects Trained in Interspecies Communication

Two different marine mammals, a dolphin (Herman & Forestell, 1985) and a California sea lion (Schusterman & Krieger, 1984), have learned to respond to questions about the existence of objects in their environment. The dolphin presses a paddle placed to its left (the "no" paddle) to designate that an object is not present or a different style of paddle placed to its right (the "yes" paddle) if the object is present. The sea lion responds with a nonreinforced "balk" when asked to perform an action (e.g., flipper-touch) on an absent object: The animal performs a visual search and then refuses to leave its station. Gardner and Gardner (1978) report that chimpanzees will use American Sign Language to comment upon the absence of a familiar object at a customary location, and Rumbaugh and Gill (1977) report similar behavior in a chimpanzee trained to communicate through a computer-mediated system.

Data from my own studies provide evidence that an African Grey parrot (*Psittacus erithacus*) reacts to the absence of a requested object (Pepperberg, 1981, 1987c, 1988b). This parrot, Alex, uses the English "no" (pronounced "nuh") to refuse an object that is offered in place of one that he had requested (e.g., presentation of Y after he had produced "I want X"). "Nuh" is also used to reject an object that is not acceptable for other reasons (e.g., a toy such as a cork that had already been chewed so much as to be of little interest or possibly unrecognizable). Although these data indicate an awareness that something is not present, they provide little direct evidence for a general concept of nonexistence.

In conjunction with previous findings, however, my data did suggest that Alex would be a viable subject for a formal study on nonoccurrence: He had already demonstrated aspects of other conceptual abilities at levels comparable to those of nonhuman primates (labeling, Pepperberg, 1981; comprehension of categories, Pepperberg, 1983; recognition of quantity, Pepperberg, 1987b; comprehension of same/different, Pepperberg, 1987a). Furthermore, his ability to respond on the basis of "same" and "different" would provide a practical paradigm for the experiment. Because Alex could already respond to queries of "What's same?" or "What's different?" for pairs of novel objects on the basis of categorical concepts (rather than specific instances) of color, shape, and material (Pepperberg, 1987a), a logical next step would be to test whether he could generalize this ability to report on the absence of similarity or difference between objects.

METHOD

Subject

The experimental subject, an African Grey parrot named Alex, had been the focus of a study on interspecies communication and cognitive abilities since 1977. He was allowed free access to all parts of the laboratory (contingent upon his vocal requests; e.g., "Wanna go gym") for the 8 hours per day that trainers were present; hence, trials occurred at various locations. He was, however, confined to an area consisting of a desk top and a wire cage (62 by 62 by 73 cm) at other times and during sleeping hours. Water, a standard psittacine seed mix (sunflower seeds, dried corn, kibble, oats, safflower, etc.), and a limited selection of chewable objects (e.g., wooden plant stakes) were available continuously; fresh fruits, vegetables, specialty nuts (cashews, almonds, pecans, walnuts), and his other toys (keys, variously shaped pieces of wood, paper, rawhide, etc.) were provided at his vocal request (e.g., "I want cork").

Experimental Design

The task designed for the parrot must be functionally equivalent to those used with chimpanzees and marine mammals for the results to provide comparative data. The design also must be consistent with Alex's experimental history concerning concept acquisition and use of a vocal repertoire. A task based upon the same/different paradigm would take these constraints into account.

Alex had already demonstrated that he could respond to queries of "What's same?" and "What's different?" with the appropriate category label ["color," "shape," "mah-mah" (matter)], rather than a specific object or attribute label, for pairs of exemplars that differed with respect to any combination of these variables. He performed equally well even when the objects were novel. This paradigm could readily be extended to include questions to which he could reply "none" *in addition to* "color," "shape," and "matter" when certain information concerning abstract categories was not present. Such a protocol ensured that (a) the symbolic concepts tested would be more abstract than those examined in standard conditional discrimination paradigms (e.g., see discussion in Pepperberg, 1987a, on the difference between responses based on match-to-sample and oddity-from-sample vs. those based on same/difference), (b) Alex's responses could not be based on memory of the object or its location (e.g., whether an exemplar had been presented as a previous sample stimulus), (c) the bird's responses would demonstrate his comprehension of arbitrary symbols representing attributes of real-world objects, (d) the findings could not be dismissed as stimulus-specific associations: Alex, if successful, would indeed be responding by generalizing the concept of absence rather than by learning rote responses to particular sets of objects (i.e., first-trial transfer test results on novel objects would have to show transfer of the abstract relations), and, finally, (e) the performance/comprehension disparity noted in other studies (see above) would not be a concern because Alex would make a positive response to designate absence.

In sum, Alex was presented with two objects that could be identical or could differ with respect to one, some, or all of three properties: Color, shape, or material (e.g., two round rose metal keys; a yellow rawhide pentagon and a gray wooden pentagon; a green wooden triangle and a blue wooden triangle; a yellow rawhide pentagon and a gray wooden square). He was then queried "What's same?" or "What's different?" The correct response was "none") or the label of an appropriate category, not the specific color, shape, or material marker that represented the correct response (e.g., "color," not "yellow"). To be correct, Alex would therefore have to (a) attend to multiple aspects of two different objects; (b) determine, from a vocal question, whether the response was to be on the basis of "sameness" or "difference"; (c) determine, based on the exemplars, what, if anything, was "same" or "different" (e.g., were they both blue, or triangular, or made of wood?); and then (d) produce vocally the label for one of these particular categories or the response "none."

The complexity of the task presented to Alex is best appreciated by contrasting it with the procedures used in most studies on nonoccurrence in animals. Other projects commonly use (a) a two-choice procedure whereby the subject merely indicates whether a single, learned stimulus or part of a stimulus (e.g., a green dot) is or is not present or whether there is some correspondence between sets of objects; and (b) a topographically similar (and thus possibly easier to acquire) response for both answers (e.g., lever pressing or key pecking; see Michael, Whitley, & Hesse, 1983), or a single response versus withholding of that response. Subjects in these protocols (which do not require the fine-grained analysis of the present same/different paradigm) are therefore not asked to provide a description of the basis upon which the response has been made (see Pepperberg, 1987a). Alex, however, could not respond correctly without processing all the information on the several similarities or differences: Pairwise trials of total similarity or difference were to be intermixed with those for which he must respond with the vocal label of one of three dimensions that is same or different depending upon the question asked. Note, too, that most animal subjects have significantly more difficulty when asked to respond on the basis of whether a single attribute is present or absent than when asked to respond on the basis of greater degrees of contrast (e.g., McClure & Helland, 1979; see also Jenkins & Sainsbury, 1969, 1970).

Exemplars to be Used

Alex was trained on a small subset of familiar exemplars: Objects that were red, green, or blue, triangular or square, rawhide or wood. He was then given two series of transfer tests. The first transfer series involved exemplars that had not been used in training but that were familiar from other studies; we thus avoided novelty effects (see Zentall, Edwards, Moore, & Hogan, 1981; Zentall & Hogan, 1974). For this series, there were approximately 70 different possible objects that could be paired (food items were rarely used), four possible correct responses, and two different questions. For example, if we asked "What's same?", desired the response to be "color," and chose a round green key as one of the exemplars, this key could be paired with two-, three-, four-, five-, or six-cornered objects of paper, wood, or rawhide, three-, four-, or six-cornered objects of plastic, plus objects such as green clothespins, wooden or plastic cubes or spheres, plastic boxes and cups, and so on. A similar set of permutations existed for responses of "shape," "matter," "none," and the question "What's different?" The second transfer series involved a similar number of exemplars of novel combinations of colors, shapes, and materials that were obtained especially for these tests. These objects were shelved and handled by the trainers (as part of laboratory cleaning) in Alex's view for several days before use to avoid a possible fear response, but the colors, shapes, or materials of these items were never labeled.

Although the results of these experiments may be viewed as primarily providing information on the parrot's concepts of "same," "different," and additional evidence for comprehension of categorical concepts, the data also provided evidence for comprehension of absence; that is, the ability to recognize that a pair of two novel objects may or may not have something in common. A correct response suggested that the parrot was not responding to specific instances of color, shape, and material (i.e., particular sets of objects or classes of stimuli), but rather on the basis of the abstract concepts, even when the particular attributes of each exemplar were unfamiliar and the specific combinations of color, shape, and material for each exemplar, as well as for the pair, had never before been seen on a test.

Training Procedures-General

The general training procedures for label acquisition and the rationale for their use have been described in detail elsewhere (Pepperberg, 1981, 1985, 1987a, 1987b, 1988a, 1988b); only a review will be given here.

The primary technique, called the model/rival (M/R) approach, has humans demonstrate to the parrot the types of interactive responses desired. This procedure is based on a protocol developed by Todt (1975) for examining vocal learning in Grey parrots, but also derives much from the social modeling theories of Mowrer (1960) and Bandura (1971). In the presence of the bird, one human acts as a trainer of a second human, presenting objects, asking questions about these objects, giving praise and reward for correct answers, and showing disapproval for incorrect answers (errors similar to those being made by the bird at the time; e.g., "wood" for "green wood"). The second human acts both as a model for the bird's responses and as a rival for the trainer's attention. Roles of M/R and trainer are frequently reversed, and the parrot is given the opportunity to participate in these vocal exchanges.

During training on label acquisition, each correct identification was rewarded with the object itself, a system that permits the closest possible correlation between the object or category and the label to be learned. This protocol was crucial for initially training the ability to label (see discussions in Pepperberg, 1981, 1983, 1988a). For the present study, in which Alex was presented with questions about a pair of exemplars, he always received both objects for a correct response. So that Alex would work with objects in which he had little interest, we modified the procedure to allow him to request alternative objects as his reward (see Pepperberg, 1987b, 1987c), a protocol that ensured that an inappropriate response was not a possible request for a preferred item. He had already been trained to preface requests with the phrase "I want . . ." and to use object labels alone (e.g., "blue wood") for identifications (Pepperberg, 1988b); a previous study showed that Alex usually (about 75% of the time) did indeed use the objects he requested. Not only would he eat the walnut, use the key to scratch himself, or the cork to clean his beak, but he would refuse substitute items, usually with the vocalization "no" and a repetition of the original request (Pepperberg, 1987c). Thus, during the study, a response such as "cork" to a question on same/different was considered an error, whereas "I want cork" was taken as a valid (if interruptive) request rather than a mistake. However, only after Alex produced correct responses to the targeted objects were his requests for an alternative accommodated.

Training Procedures-Same/Different

A summary of these procedures follows; details are in Pepperberg (1987a).

During training on "same/different," Alex observed the following: A trainer would hold two objects in front of the M/R, and ask either "What's same?" (e.g., for a red wooden triangle and a green rawhide triangle) or "What's different?" (e.g., for a red wooden square and a blue wooden square). Both questions and various object pairs were interspersed in a single session, although we specifically limited training to the subset of already familiar exemplars described above. The M/R would respond with the label for the correct category and be rewarded with the objects (or the right to choose a reward), or err and be scolded. If an error was made, the objects would momentarily be removed from view (a timeout), then represented and the question repeated. Roles of trainer and M/R would then be reversed.

Training sessions on same/different occurred two to four times per week and lasted 5 min to 1 hr. The length of the session on same/different depended on Alex's attention span-he often became restless during sessions devoted to a single task. He ceased to work, began to preen, or interrupted with many successive requests for other items ("I want X") or changes of location ("Wanna go Y"; see Pepperberg, 1983, 1987b). Similar "boredom" behavior has been observed in meerkats,[3] raccoons (Davis, 1984), chimpanzees (Putney, 1985), and Long Evans hooded rats (Davis & Bradford, 1986). For Alex, this problem was resolved through concurrent training or testing on various other capacities in any given session. During training on same/different, the concurrent tasks involved number concepts (Pepperberg, 1987b), additional labels (Pepperberg, 1987c), photograph recognition, and object permanence (Pepperberg & Kozak, 1986).

Training on "None"

We again used the M/R technique to demonstrate the targeted behavior. Training lasted for 3 months; sessions were of similar length and frequency as those on same/different. Training to produce the label involved a small set of objects initially used in the same/different study, and began after that study was completed. So that Alex would learn "none" in the appropriate context, sessions included questions, ("What's same?", "What's different?") for which "color," "shape," or "matter" also were correct.

Criterion Prior to Testing

Normally, the criterion as to when a newly acquired targeted skill (e.g., the ability to label an object) can be tested formally is based on the clarity of Alex's speech ("production") and not on the accuracy of his performance of the task in question ("comprehension"; see discussion in Pepperberg, 1981). This criterion separates the effect of our procedures on our subject's ability physically to emit a label from their effect on his ability to make a correlation between the label and its referent. Only when the former skill is considered satisfactory (interobserver agreement of 90%) do we deem the latter ready for testing (Pepperberg, 1981, 1983). The length of time needed to train Alex to produce a vocalization in a recognizable manner thus does not necessarily correspond to the time needed for comprehension of the task for which this vocalization is required. The period indicates only how long it takes Alex to learn to manipulate his vocal tract in the appropriate manner; in some studies, he has demonstrated comprehension of a task before he has acquired the labels appropriate to that task (Pepperberg, 1981, 1983, 1987a). It is also possible that a vocalization could be recognized aurally as a label by all trainers before Alex comprehends the connection between this object label and its referent. His comprehension, therefore, could be poor at the onset of testing. Label production, however, has only preceded label comprehension for those cases in which we have given Alex a novel object to correspond to a novel vocalization he has spontaneously produced in the absence of a referent (e.g., seed corn for "rock corn"[4]).

Test Procedures

Testing began in December 1986 and continued through December 1987 with pairs that were constructed of objects that were familiar to Alex from other studies (e.g., Pepperberg, 1987a, 1987b; Pepperberg & Kozak, 1986) but that were not used in training any aspect of the same/different task (see above). These items combined all the additional colors, shapes, and materials available in the laboratory, and included novel combinations of objects that had been paired as "novel" exemplars for transfer tests in the earlier same/different study (Pepperberg, 1987a). Thus, although individual objects had been used in previous questions on same/different, the pairings of objects were constructed so as to always be novel. These trials were interspersed randomly with (a) transfer trials that, beginning at the end of May 1987, used novel items never before presented on a test; these were objects of colors, shapes, and materials that Alex often could not label (e.g., a miniature pink rubber flamingo); (b) test trials on other subjects such as vocal comprehension and two-dimensional representations; and (c) training sessions on simultaneous numerical stimuli. Questions on same/different were asked one to four times per week, and neither Alex nor the trainers could predict which questions on which topic would appear on a given day. The number of questions per set of exemplars varied (see below). No transfer trials were administered during July and August 1987, and few were administered during September 1987, because of trainer vacations and a relocation of the laboratory. Some previous trials were repeated during this period so as not to interrupt laboratory routine, but these results are not included in the analysis.

Specifics of the protocol used in all tests were presented in Pepperberg (1981, 1987a); a summary is as follows: To lessen the possibility of trainer induced cuing, trials were conducted by students who had never trained Alex on any aspect of the same/different task (see Pepperberg, 1981). One student was responsible for determining the question, forming the collections, and ordering the questions. A different student presented to the bird, using this variable but previously determined order, the objects to be identified.

Alex was thus shown an exemplar or number of exemplars and then asked questions on any of several possible topics (e.g., "What's this?", "What's the color of the metal key?", "What shape is the wood?", "How many?", "What's same?", or "What's different?") and was required to formulate a vocal English reply from the more than 80 possible responses in his repertoire (Pepperberg, 1987c). Thus, even though the range of correct responses to questions of "What's same?" or "What's different?" was limited to four choices ("color," "shape," "matter," or "none"), in any session Alex also had to choose from among many possible responses to other questions such as "How many?" or "What color?" in order to be correct (Pepperberg, 1983, 1987b). Shape and color questions were used in data collection for a comprehension task (see below), or as a second question when Alex responded to "What's this?" by identifying correctly only the material of a colored or shaped object. (Such "generic" answers were considered errors; Pepperberg, 1981.) "How many?" was used during concurrent training on sequential numerical concepts.

The principal trainer was present, but during test trials sat with her back to Alex, did not look at him during presentation of the test object(s), and therefore did not know what was being presented. The principal trainer repeated aloud what she heard Alex say. This procedure ensured that the occasional indistinct vocalization (e.g., "ree" for either "green" or "three") was not accepted as correct. Both principal trainer and student examiner had to agree for the label to be counted as correct. If the label repeated by the principal trainer was indeed the correct response (e.g., the appropriate category label), Alex was rewarded by praise and the object(s).

The number of questions on a specific pair of exemplars depended on Alex's accuracy. If he was correct on the first trial, there were no additional presentations of the same material during that test (i.e., there was only a single, "first trial" response). If the identification was incorrect or indistinct, the student examiner removed the object(s), turned his or her head (a momentary timeout), and emphatically said "No!" The examiner then implemented a correction procedure in which the misnamed object or collection was immediately repeatedly presented until a correct identification was made; errors were recorded. The parrot thus found-and seemed to learn-that an incorrect identification (e.g., substitution of the name of a preferred object for the one presented) was fruitless; instead, a quick, correct identification allowed him to request a preferred item. Because immediately repeated presentation of an object or collection of objects during a test occurred only when the response to the initial presentation was incorrect, the testing protocol penalized use of a "win-stay" strategy: Incorrect repetition of a previously correct response (e.g., the name of the previous exemplar) elicited no reward. The testing procedure thus provided a definite contrast to training protocols that rely on, and occasionally reinforce, repetitive behaviors. At all stages, the overall test score (results for all trials) was 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 (percentage of first trials that were correct) are reported for comparison.

Note, too, that it was occasionally the examiner who stood corrected. In about 5% (1 in 20) of the trials (particularly during student exam periods), an examiner would err and scold Alex for a correct response. Alex would repeat his correct response, despite procedures that encourage a lose-shift strategy. The examiner would then recognize her error, and Alex would get his reward. Although this is not a formal blind test, it produces the same results. (Other forms of blind tests have been described elsewhere; see Pepperberg, 1987a.)

In addition to avoiding the boredom factor noted above, intermingling different types of questions on tests or during training on other topics prevented "expectation cuing": In single-topic tests, contextual information (the homogeneous nature of questions that have a relatively restricted range of answers) could focus the subject's attention to a small part of his repertoire and thus be responsible for a somewhat better performance than would be otherwise justified by a subject's actual knowledge of the topic. But Alex was never tested exclusively on questions of same/different, and, more importantly, was never tested successively in one session on similar questions ("What's different?") or questions that had one particular correct response (e.g., "color"). A question would be repeated in a session only if his initial answer was perceived as incorrect. Thus, in any session Alex had to choose from among all the possible responses in his repertoire in order to be correct (Pepperberg, 1983, 1987a, 1987b).

RESULTS

Training on "None"

Alex first produced "none" in the presence of his trainers after ca. 7 weeks of modeling. Four more weeks were necessary to ensure that "none" was being reliably produced (i.e., that it was recognized aurally by all trainers). For "none," interobserver agreement on taped samples was 88.9% to 92%. As mentioned above, the length of time needed to train Alex to produce "none" in a recognizable manner did not necessarily correspond to the time needed for comprehension of the task for which it was being trained.

Tests with "None" for Familiar Objects not Used in Training

Alex's score for questions of same/different for which his possible responses were "color," "shape," "matter," or "none" was 76 of 94 (80.9%) on first-trial performance, $p < .00001$ on binomial test with a chance value of 1/4. Table 1 gives a breakdown of performance on test trials. For all trials (first trials plus correction trials; see Pepperberg, 1987a) his score was 94 of 112 (83.9% correct). Note that choice of 1/4 was conservative, in that it ignored the possibility that Alex could have emitted any of the vocalizations in his repertoire other than "color," "shape," "matter," or "none." In all cases, the first single vocalization Alex uttered was one of these four labels. Other vocalizations he produced were phrases that encoded requests for other objects or activities (e.g., "I want X!"; see Pepperberg, 1987a, 1987b, 1987c), and were not errors in the task. His score for questions for just those pairs of objects for which the answer was "none" was 20 of 24 (83.4%) for first trials only, $p < .00001$, and 24 of 28 (85.7% correct) for all trials.

Transfer Tests with Novel Objects

Alex's score was 66 of 91 (72.5% correct) on first-trial performance, $p < .00001$ with a chance value again of 1/4, and 91 of 116 (78.4% correct) for all trials. His score for questions for just those pairs of objects for which the answer was "none" was 18 of 23 (78.3% correct) for first trials, $p = .00007$, and 23 of 28 (82.1% correct) for all trials. As before, the first single vocalization Alex uttered in response to our questions was one of the four appropriate labels, although phrases that encoded requests for other objects or changes of location were also common. Details of errors are given in Table 2.

Table 1. Alex's responses to queries of "What's same?" or "What's different?" to pairs of objects that were similar but not identical to those used in training. The results are for all trials (first trials plus correction trials). Statistics are reported in the text.

Question	Correct response (no. times made)	Incorrect response (no. times made)
What's same?	Color (11)	None (1)
	Shape (10)	Matter (1); None (2)
	Matter(14)	Color (2)
	None (12)	Shape (1); Matter (1)
What's different?	Color (13)	Shape (1); Matter (1); None (1)
	Shape (12)	Color (2)
	Matter(10)	Shape (1); None (2)
	None (12)	Color[a] (1); Shape (1)

[a] The shades of blue of one pair of triangular metal keys were slightly different in that one was somewhat more greenish than the other. This difference might have been more pronounced to Alex than to his trainers, because his peaks of color sensitivity are unlikely to be identical to those of humans. Parrot eyes, however, unlike those of many other birds, have few oil droplets, and the supposition is that their color sensitivity, although not identical, is more similar to that of humans than other birds (Walls, 1967, pp. 499-503, 657).

DISCUSSION

The data indicate that our subject, an African Grey parrot, shows some comprehension of the concept of "absence." Although the conditions of the tests were not identical to those performed with mammalian subjects (see Gardner & Gardner, 1978; Herman & Forestell, 1985; Pepperberg, 1987a; Premack, 1976; Schusterman & Krieger, 1984), the data provide evidence for comparable abilities: Alex was able to respond on the basis of the absence of similarity and difference in a manner that was neither a test of memory nor a form of match-to-sample or oddity-from-sample. He was not responding to specific instances or sets of objects, nor from a repertoire restricted to a limited number of responses, but rather was providing a description of the attributes, if any, that were shared by two exemplars. In other words, he was discriminating accurately, by means of arbitrary symbols (i.e., English labels), either the presence or absence of the specific categories that these objects might have in common. This ability extended immediately to objects that were not used in training and also to objects that were novel and whose attributes often could not be labeled.

Table 2. Alex's responses to queries of "What's same?" or "What's different?" to pairs of objects different from those used in training, including object made of colors, shapes, and materials for which he might not have labels. These results are for all trials (first trials plus correction trials). Statistics are reported in the text.

Question	Correct response (no. times made)	Incorrect response (no. times made)
What's same?	Color (11)	Matter (2); None (1)
	Shape (11)	Color (1); Matter (2); None (1)
	Matter(11)	Shape (1); None (2)
	None (12)	Color (1); Shape (1)
What's different?	Color (11)	Shape (1); Matter (1); None (1)
	Shape (12)	Color (2); Matter (2)
	Matter(12)	Color (1); Shape (2)
	None (11)	Color (1); Shape[a] (1); Matter (1)

[a] One of the objects was a perfect cube and the other was a rectangular solid.

The level of Alex's abilities might best be appreciated by examining the precautions that were taken to ensure the abstract nature of the task.

Precautions against responses based on match-to-sample or oddity-from-sample. This study was designed specifically so that Alex could not respond simply on the basis of matching (i.e., total similarity or identity) or nonmatching (difference in any or all attributes) of the pairs of exemplars. Because the questions on presence or absence of similarity or difference were presented to Alex as an extension of the previous study on same/different, most questions were about pairs of objects that had a single attribute that was same or different (i.e., those for which "color," "shape," or "matter" were appropriate answers). Thus, completely identical or dissimilar pairs made up only a small proportion of the total possible combinations, and Alex, to maintain his high overall level of accuracy, had to attend to the questions and do a feature analysis of the pairs of objects before responding (see Premack, 1983, for further discussion).

Furthermore, because probe trials in the previous study on same/different had demonstrated that Alex could also successfully report on what was different when more than one attribute was different or what was same when more than one attribute was same (e.g., "What's same?" for a pink paper square and a brown paper square, Pepperberg, 1987a), there was a second way in which use of the same/different paradigm retained the need for a feature analysis and provided a safeguard against responses based on total similarity or difference: Alex could, for example, be asked "What's same?" for identical objects and thus be required to answer "color," "shape," or "matter," rather than "none." Two such trials were in fact administered to determine whether Alex would perform the task. We did not perform a complete set of such probes because of the large number of trials that would have been necessary to establish statistical significance with a chance value of 3/4. However, for each trial Alex did respond with the label of one of the appropriate categories rather than "none," suggesting that he was indeed both processing the questions and performing some form of feature analysis.

Precautions against responses made on the basis of memory, recognition of specific stimuli, or in the absence of symbolic comprehension. Because Alex's response to the questions were "none") or a category label rather than a specific object or attribute label, any possible set of objects could be used as exemplars-even ones that were novel and whose labels were unknown. When this experiment began, Alex could already produce vocal (English) labels for seven colors [green, rose (red), blue, yellow, gray, orange, purple], several shapes (two-, three-, four-, five-, and six-corner for, respectively, "eye"-shaped, triangular, square, pentagonal, and hexagonal forms), four materials [paper, wood, hide (rawhide), and cork]; could label various metallic items (key, chain, grate); and could combine these labels to identify approximately 80 different objects. He also had considerable experience responding to questions about objects that incorporated novel combinations of multiple attributes of color, shape, and material (Pepperberg, 1983, 1987a). His responses on tests were therefore unlikely to be made on the basis of absolute physical properties or by learning the answer to a given pair (see Premack, 1976, p. 132): The number of possible permutations of question topic, correct response, and combination of exemplar attributes was very large. Moreover, labels for all these items, as well as labels for foods, locations, and quantity, were always available in the repertoire as possible answers. Consequently, Alex was not, like subjects in other animal experiments (e.g., Premack, 1983), limited merely to choosing between physical (or even vocal) symbols representing "same" or "different" (or "present" vs. "absent," or even among "color," "shape," "matter," or "none") nor was he limited to choosing physically between only two objects that were similar to or different from a sample (Pepperberg, 1987a): He thus had to continue to respond on the basis of the abstract categories rather than on memory or recognition of specific stimuli.

Furthermore, Alex had to transfer between like and unlike pairs of colors, like and unlike pairs of shapes, and like and unlike pairs of materials, all of which varied from the training exemplars. In other words, he demonstrated transfer among stimulus domains as well as among various instances of each domain (Pepperberg, 1987a; see Premack, 1976, pp. 354-355, for the importance of such transfers in determining that the behavior is not simply stimulus generalization).

Precautions against the performance/comprehension distinction. Previous studies (e.g., Hearst, 1984) had shown that positive actions in response to nonoccurrence enabled subjects to perform at the level of their comprehension of the task. In contrast, a subject that was instructed to withhold a response to designate nonoccurrence performed comparatively poorly. Use of "none" in the present study provided a positive response to the absence of similarity or difference, and thus avoided the possible disparity between Alex's comprehension of the notion of absence and his ability to demonstrate that comprehension.

Precautions against responses based on presence or absence of novelty. We were also careful that the responses to the questions were not based on novelty. By the time we performed the novel transfer tests, it was sometimes difficult to obtain objects that differed simultaneously in all dimensions from those objects that had been used in previous transfer tests on same/different (Pepperberg, 1987a), and for a few object pairs only one or two of the three categories were entirely novel (e.g., car-shaped rubber erasers provided only a novel material). We therefore ensured that the questions on such trials were counterbalanced so that, for example, the familiar color was not always what was "same," or that the unfamiliar material was always what was "different." Were that the case, Alex could have responded on the basis of familiarity or unfamiliarity (see Premack, 1983, p. 127).

Despite these precautions to ensure the abstract nature of the task, Alex's comprehension of absence may presently be limited to the same/different task. Evidence from the single trial in which he was asked to generalize to the presence or absence of particular objects, as opposed to their attributes (see Herman & Forestell, 1985), was equivocal. The trial was part of a simultaneous, continuing investigation of vocal comprehension. In that study, Alex views trays of various collections of differently shaped and colored exemplars of different materials and is asked questions such as "What's the color of the metallic key?" or "What's three-cornered?" He can answer correctly only by processing the information in the question and eliminating irrelevant objects from consideration (e.g., the tray for the first question above might include paper, metal, and plastic keys; a toy car, and a metallic nailfile; see Essock, Gill, & Rumbaugh, 1977; Granier-Deferre & Kodratoff, 1986). To test generalization of "absence," we asked "What's purple?" in the absence of a purple exemplar. Instead of responding "none," Alex said "Want grape." Although the likelihood of his requesting that particular item was small (e.g., 1/11 even if we limit "chance" to food items rather than his entire repertoire), the request might not have been connected to the absence of a purple exemplar: Requests for grapes as well as other foods occur frequently. Only a subsequent study to determine whether Alex would respond to the absence of yellow items with "Want banana" or "Want corn," the absence of orange items with "Want citrus" or "Want carrot," and red items with "Want banerry (apple)" (i.e., requests for items that come in only a single color) might permit such a correlation.

One might argue that Alex responded "none") to questions of "What's different?" for identical pairs not because of a concept of nonexistence, or because a feature analysis provided no basis for difference, but rather by quickly recognizing the special case of identity. In some studies, a short latency to respond would suggest such a mechanism (e.g., Dooling, Brown, Park, Okanoya, & Soli, 1987). The implication is that the subject first decides "identical" versus "not identical," and, if the latter, then decides what is "not identical." Alex's latency of response could not be measured, nor would it provide any relevant information, because his readiness to respond to a given set of exemplars was correlated to his level of interest in these items rather than any other factor (Pepperberg, 1987a, 1987b). Other factors, however, suggest that it was unlikely that these questions on difference were viewed as a special case: Alex was no more accurate on these questions than any others (in particular, the response "none" was given with comparable accuracy to "What's same?"), he responded appropriately when asked to report on an attribute that was same for an identical pair (see above), and, finally, he maintained the ability to respond to questions about two identical objects phrased as "How many?" with the appropriate vocalization "two X" (see Pepperberg, 1987b). In any event, these questions on difference for identical pairs could not be omitted from the study, because they were needed as a contrast to "What's same?" for completely dissimilar pairs-that is, it was important that Alex could not regard "none" as a response solely to "What's same?"

Whether Alex's demonstrated capacities are the result of his extensive training on language-like tasks has been discussed in detail elsewhere (see Pepperberg, 1987a, 1987b, 1987c, in press; Pepperberg & Kozak, 1986). Whatever the effect of his previous training on the current study, clearly use of a two-way communication code allows us most efficiently to examine such concepts as same/different and absence, and, in particular, enables us to perform interspecies comparisons in as direct a manner as possible (Pepperberg, 1986). The present results suggest that Alex has limited use of some concept of nonoccurrence (e.g., see Bloom, 1970), and that this use is directly comparable to that of other animals that have undergone similar training.

NOTES

[1] Staicer, C. A. (1987, August). Intersexual functions of song in a tropical warbler. Paper presented at the annual meeting of the American Ornithologists' Union, San Francisco, California.

[2] Spector, D. (1987, August). Male yellow warblers' use of their songs for mate attraction. Paper presented at the annual meeting of the American Ornithologists' Union, San Francisco, California.

[3] Moran, G., Joch, E., & Sorenson, L. (1983, June). The response of meerkats (*Suricata suricatta*) to changes in olfactory cues on established scent posts. Paper presented at the annual meeting of the Animal Behavior Society, Lewisburg, Pennsylvania.

[4] Pepperberg, I. M. (1983, June). Interspecies communication: Innovative vocalizations of an African Grey parrot. Paper presented at the annual meeting of the Animal Behavior Society, Lewisburg, Pennsylvania.

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