Language and Communication: Comparative Perspectives
Edited by H. L. Roitblat, L.M. Herman & P.E. Nachtigall.
Lawrence Erlbaum Associates, Hillsdale, New Jersey.

12 Behavior Control by Exclusion and Attempts at Establishing Semanticity in Marine Mammals Using Match-to-sample Paradigms

Ronald J. Schusterman, Robert Gisiner, Brigit K. Grimm, and Evelyn B. Hanggi

Match-to-sample (MTS) is a sequential "if . . . then" or conditional discrimination. There are several characteristics of the MTS procedure that make it suitable for studying such aspects of animal cognition as short-term memory, perceptual categorization or concept formation, counting, abstraction and some aspects of language, especially semantic comprehension. (For reviews of MTS paradigms as they relate to concept formation, abstraction, and semanticity, see Schusterman & Gisiner, 1989; Sidman & Tailby, 1982; Carter & Werner, 1978.) When visual cues are used in MTS, a sample stimulus is displayed, usually in a central position, equidistant from subsequent choice stimuli. The sample stimulus is followed by comparison or choice stimuli. The comparison stimuli are presented simultaneously on two or more side panels. If the physical characteristics of sample and comparison configurations are different, the relations between these types of stimuli are considered "arbitrary" (Cumming & Berryman, 1965). In animal language research, sample stimuli as well as comparison stimuli may be presented in a variety of ways (Schusterman

& Krieger, 1984). In the original and simplest case, there are two sample stimuli and two comparison stimuli. In this chapter, the two sample stimuli are designated as A_1 and A_2 and two comparison stimuli are designated as B_1 and B_2. Reinforcement contingencies are arranged by the experimenter so that an animal's choice of B_1 is correct and reinforced in the presence of A_1, but not in the presence of A_2, while its selection of B_2 is correct and reinforced in the presence of A_2 but not in the presence of A_1. For example, a monkey may be trained to match a set of geometric figures as samples (A_1 = circle; A_2 = triangle) to pictures of animals as comparisons (B_1 = hawk; B_2 = leopard).

Several investigators have attempted to study semanticity and/or symbolic learning in a variety of animal taxa by using some version or other of a conditional discrimination within an MTS paradigm (for a review, see Roitblat, 1987). Animal language researchers frequently say that samples have a "symbolic" relation to comparison stimuli. However, these animal language researchers have not always explicitly stated what operations in their experiments allowed them to infer that their animal subject was developing a comprehension of anything more than an "if . . . then" relation between the sample or so-called symbol and the corresponding comparison or so-called referent. For example, Savage-Rumbaugh (1988) used a conditional discrimination within an MTS paradigm to determine whether a pygmy chimpanzee (*Pan paniscus*) could differentiate spoken words and relate them to the appropriate geometric figures or lexigrams. The pygmy chimpanzee, Kanzi, had to select by touching one of three lexigrams contingent on the word he heard (produced by a person or by a speech synthesizer) through headphones. Even after Kanzi had learned to match a set of spoken word samples to the corresponding lexigram comparisons, it should not be assumed that his behavior was symbolic and that the spoken words and the geometric forms were symbols. Instead, we should consider that perhaps Kanzi had only learned a conditional relation that has no intrinsic symbolic significance. In this context a determination of whether Kanzi was acting symbolically awaits further testing.

Recently Sidman (in press) and his colleagues (see, e.g., Sidman & Tailby, 1982) have suggested that if stimuli are serving as symbols, then they should be interchangeable or equivalent with the things they designate. That is, in linguistic parlance the symbol and referent should each stand for one another, and in discrimination learning parlance, the conditional-discrimination procedure should have generated equivalence relations. In the monkey example we used earlier, the monkey is trained to match Set-A geometric form samples to Set-B picture comparisons (AB). If the Set-A and corresponding Set-B stimuli are equivalent, then the monkey should be able to do the opposite, that is, match Set-B samples to corresponding Set-A comparisons without any additional training. This is called a test of *symmetry*. The new conditional discriminations (BA matching) must emerge without having been explicitly trained. If the conditional relations are not equivalence relations, then the monkey will not pass the test. Failure by the monkey would indicate that the conditional relations between stimulus classes within Sets A and B had not become equivalent, and that conditional relations between geometric forms or lexigrams and pictures of animals had not, as yet, achieved symbolic status. The concept of equivalence relations in general and the test of symmetry in particular are important because they can be applied precisely to behavioral phenomena that appear symbolic. According to Sidman (in press), although it may not be possible to determine which is cause and which is effect, the question of whether verbal behavior is necessary for equivalence relations to emerge would be answered negatively if such relations could be demonstrated unequivocally with nonhuman animals. Distinguishing between truly symbolic animal behavior and animal behavior based on unidirectional stimulus relations may enable animal language researchers to determine the relationship between "naming," "rule governance," and equivalence relations.

Our chapter is divided into two sections. First, we show how animals, once they have learned the original conditional discrimination (if A_1 then B_1 and if A_2 then B_2) with much difficulty, will then consistently select a novel comparison (designated as Y_1) errorlessly or nearly so in the presence of a novel sample (designated as X_1) instead of selecting the familiar or trained comparisons B_1 or B_2. (Trials testing whether an animal is responding appropriately will be designated as X(Y,B) and A(B,Y), with the letter outside the parenthesis representing the sample; the first letter within the parenthesis represents the appropriate comparison and the second letter represents the alternate comparison.) We further show that such behavior probably does not reflect an immediate association between a new signal and an "unnamed" object as has been claimed for dolphins in "language" learning experiments (Herman, Richards, & Wolz, 1984). Rather, selection of novel comparison objects probably depends on control by "exclusion" ("if *not* A_1, then Y_1, etc."). It is only many trials later that the effects of exclusion emerge as a novel conditional performance in contexts where the basis for exclusion is no longer immediately available, for example, when two novel comparison stimuli are available instead of only one. Thus, we propose that what appears to be immediate or errorless learning of an association or a relationship between the novel sample and the novel comparison is not. Rather, the association is learned following choices of the novel comparison by the exclusion principle. First, the animal chooses the novel comparison stimulus because its behavior is controlled by the exclusion

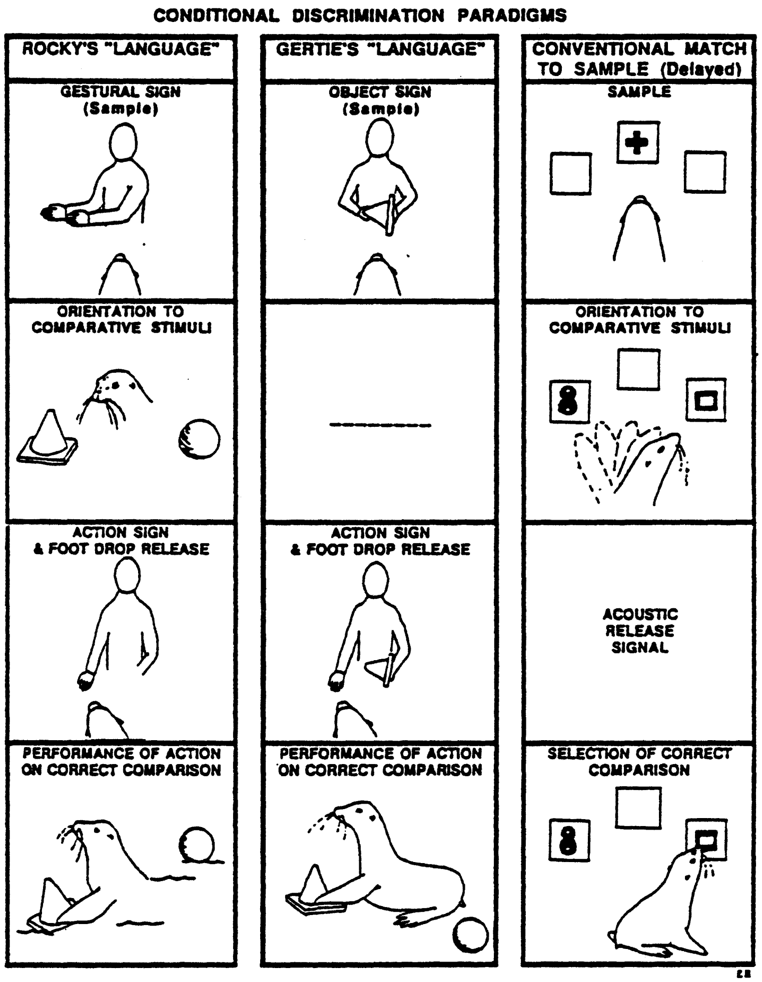

Figure 12.1. Three different types of conditional discrimination paradigms used with sea lions. All paradigms shown begin with presentation of a "symbolic" sample and end with a response to a comparison stimulus.

principle. Then, only after an animal's choices of the novel comparison have been reinforced in the presence of the novel sample, does a relationship develop between the two stimuli. Second, we develop a thought experiment using Sidman's equivalence relations model (1986) to show how a conditional discrimination is an initial stepping stone in developing simple semantic relations (Catania, 1980). In this part of the chapter we apply the idea of stimulus class equivalences to teaching a harbor seal to understand and say human words that refer to real world objects.

CONTROL BY EXCLUSION

Even large-brained anthropoid apes such as chimpanzees have difficulty learning that sample A_1 and comparison B_1 are paired associates just as sample A_2 and comparison B_2 are paired associates. Learning to relate A_1 to B_1 and A_2 to B_2 invariably takes hundreds or even thousands of trials depending on the specific MTS procedure (e.g., see Nissen, Blum, & Blum, 1948). So it would be quite significant if individuals of a species could consistently form such associations immediately and virtually without error. Herman et al. (1984) reported just that, using bottlenose dolphins (*Tursiops truncatus*) as subjects. Without stating the problem in those terms, these investigators used conditional discriminations within an MTS paradigm to study what they called sentence comprehension. In the case of one dolphin named Akeakamei (or Ake for short), arm/hand gestures served as discriminative stimuli for actions and as sample conditional cues for objects and the location of objects in a pool. One of their many interesting findings was that "It was sometimes sufficient to pair a new signal with an unnamed object for the dolphin to associate the two immediately. Successful association was indicated by the dolphin continuing to respond appropriately to the previously unnamed object in the presence of the new signal and of other objects" (Herman et al., 1984, p. 157). Schusterman and Krieger (1984), using a 6-year-old female California sea lion (*Zalophus californianus*) named Rocky, replicated several aspects of the dolphin study. After requiring 716 trials to relate one gesture (A_1) with the object "pipe" (B_1) and a different gesture (A_2) with the object "ball" (B_2) (see column 1 in Figure 12.1 for an outline of this MTS procedure), Rocky immediately appeared to relate a novel gesture with a novel object (e.g., a "ring") by selecting it consistently instead of selecting either the ball or the pipe. The previously learned relations between the arbitrary gestures for pipe and ball remained intact when each of these old comparison stimuli were paired with each other or with the newer object "ring." In other words, dolphins and sea lions seem to acquire new conditional relations immediately and without error when the available comparison stimulus objects are previously trained ones.

In the next part of this chapter we summarize several experiments that document more completely how dolphins and sea lions might seemingly associate signals or sample stimuli and their "referents" or comparison stimuli immediately and without error.

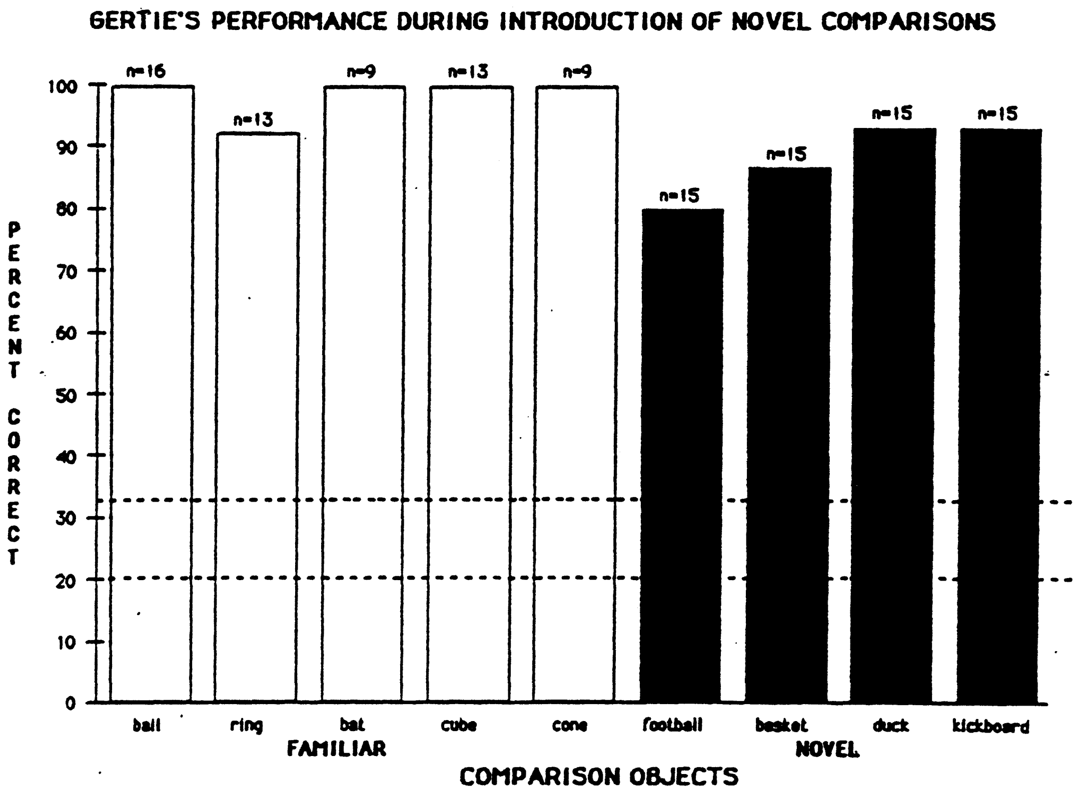

Figure 12.2. Correct choices of familiar and novel objects by Gertie. On each test trial a single novel object was available with several familiar ones. Correct responses were conditional on the object shown to Gertie. The number of MTS trials for each comparison object is displayed above the bars. The parallel dotted lines indicate the range of chance performance based on the number of comparisons available on any given trial.

Rocky's Initial Experiments

Detailed descriptions of the general methods, training procedures and apparatus are given by Schusterman and Krieger (1984, 1986) and Schusterman and Gisiner (1988). Over a period of about 2 years we conducted tests of novel conditional relations with sea lion Rocky within the context of an artificial language comprehension program. In all tests a new sample or gesture was introduced along with a new object. In most tests, the new object was presented with a single previously trained comparison object, and Rocky's task was to choose the previously trained comparison following the presentation of its associated or conditional signal and to choose the novel comparison conditionally on the presentation of the new signal. All correct responses were reinforced with a piece of fish. Eleven unique novel signals with their related objects were introduced this way, tested against all other familiar objects resulting in 54 different X(Y,B) combinations and 54 different A(B,Y) combinations. The first eight trials of each combination constituted a test. In order to ensure that both exploratory and fearful motivations toward the novel object were minimized, Rocky was always given a series of habituation trials prior to novel vs. familiar comparison testing when the novel object was first paired with its novel signal. On these habituation trials no object signals were given. Instead, Rocky was signaled to perform one of usually three different actions (FETCH, FLIPPER TOUCH, or MOUTH). Because the novel object was the only one in the pool she performed this action on the novel object. To control for context cues, similar trials were conducted with a trained object and were intermixed with novel object trials. Rocky invariably hesitated to touch novel objects on the first presentation, but after a few reinforced presentations, she performed actions on a novel object as readily as on a familiar or previously trained object.

The first column in Figure 12.1 illustrates the type of MTS task we used to determine whether Rocky selected novel over trained comparison items when the gestural sign was also novel. First she was given the novel object sign, which usually resulted in her orientation to the novel object. After repositioning, Rocky was given an action sign and released from station, which usually resulted in her performing an action on the novel object. Position of the novel and trained comparisons was randomized. Rocky was given an approximately equal number of successive novel X and trained A gestural signals with simultaneously available novel Y and trained B comparisons. She consistently made the correct choice (75% correct on the first eight trials) during 42 of 54 different X(Y,B) (novel correct) and 51 of 54 different A(B,Y) (familiar correct) tests (p's $< .01$, binomial test). Failure to make correct selections of the novel object usually occurred when the novel gesture was given and Rocky had to choose between the most recently trained object and the novel object (10 of 12 cases). This finding suggests that errorless associations between novel gestures and corresponding objects are more apparent than real. Therefore, it seems likely that recently trained objects had not been completely trained, that is, relations between these objects and their signs had not been fully formed.

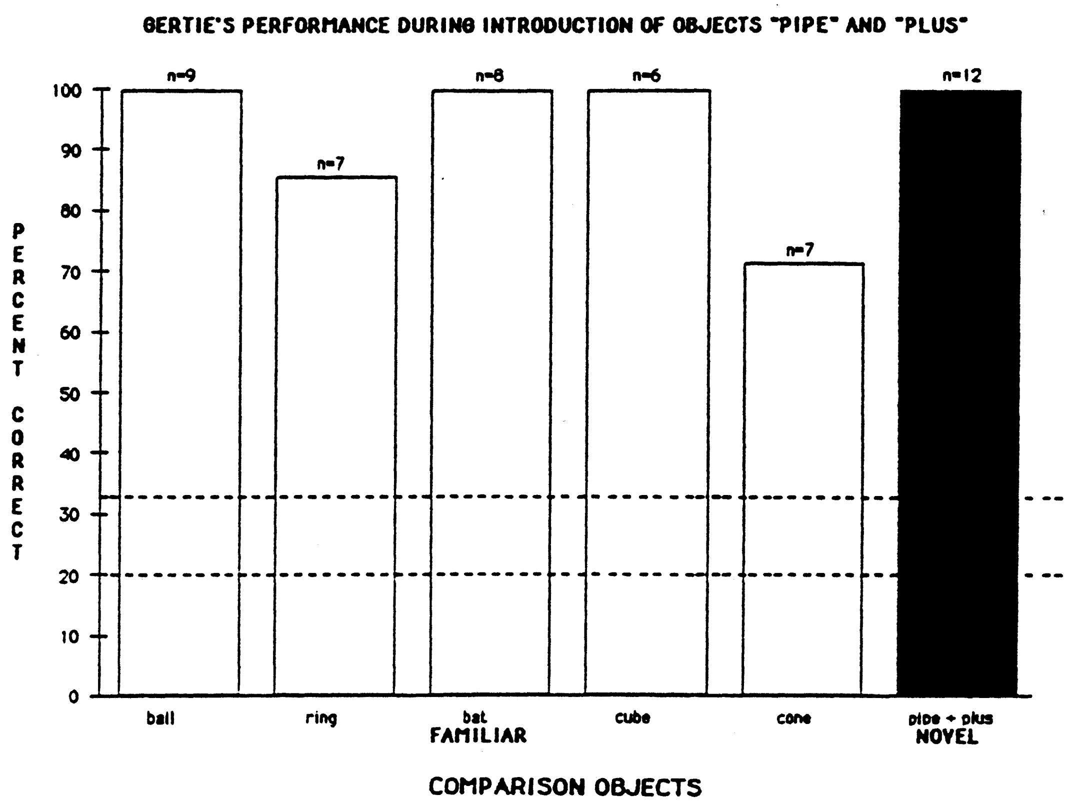

Figure 12.3. Gertie's correct choices of familiar and novel objects "pipe" and "plus" (combined). On each trial both novel comparisons were available along with several familiar ones. Correct responses were conditional on the object shown to Gertie. The number of MTS trials for each comparison object is displayed above the bars. The parallel dotted lines indicate the range of chance performance based on the number of comparisons available on any given trial.

Gertie's Experiments on Novel Paired Associates

Experiment 1. Gertie, a 6-year-old female California sea lion, performed in an MTS procedure which was somewhat different than the procedure used with Rocky. For complete descriptions of this procedure, see Schusterman and Gisiner (1988). Instead of being reinforced for selecting a comparison object conditional on a gestural sign, Gertie was reinforced for choosing an object conditional on being shown a duplicate object (regardless of its orientation). The top panel of column 2 in Figure 12.1 depicts the sample object displayed to

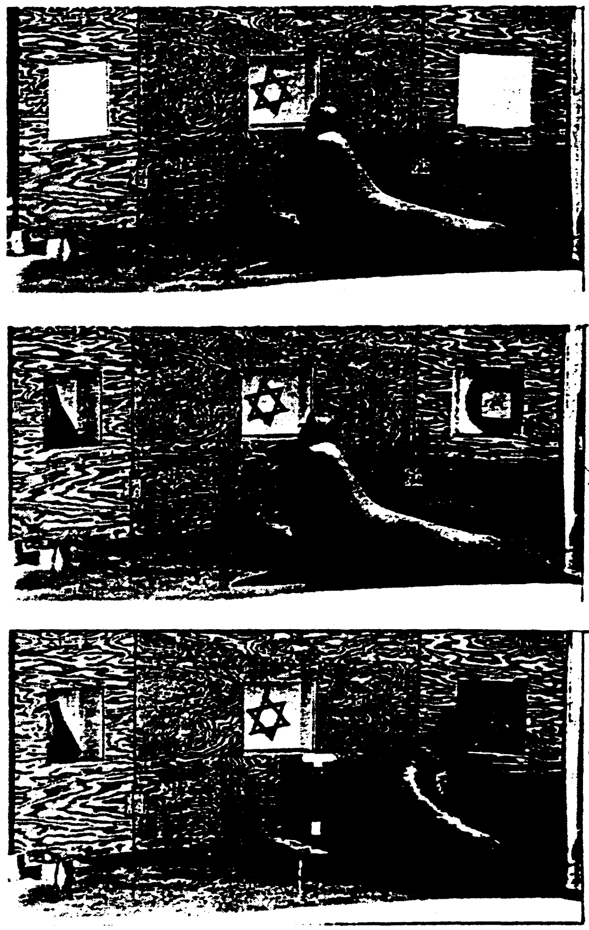

Figure 12.4. The MTS apparatus for testing sea lions. In the first panel the sea lion views the sample. During simultaneous MTS the comparisons are shown on the side panels four seconds after the sample has been presented. This is shown in the middle panel. In the delay procedure, the sample is hidden before the comparisons are shown. In the last panel the sea lion makes a correct choice following an acoustic release signal.

Gertie. This is followed by a gestural hand signal and a release. The last panel shows Gertie performing the signaled action on the appropriate comparison object.

Following an approximately 3 year artificial language comprehension program (Schusterman & Gisiner, 1988) in which Gertie learned to select eight different object shapes conditionally on being shown similar or different sample objects, we inserted a series of nondifferentially reinforced probe trials of the type X(Y,B) into standard conditional discrimination baseline sessions. We probed with four different novel or untrained objects to which Gertie was first habituated in much the same way as Rocky had been. Although the displayed objects were shown in a variety of orientations or angular planes, the comparisons floated on the surface of the water in the same plane. There were about six probes per day for 10 days superimposed on a baseline of about 60 trials. Each of the four novel objects was tested 15 times with displays of novel X samples, novel Y comparisons, and the previously trained or familiar B comparisons. On any given probe trial there was only one appropriate novel object and from two to four familiar or trained comparison objects.

On the first trial of each type of X(Y,B) probe Gertie selected the correct or novel object (four of four cases). Figure 12.2 shows Gertie's performance on both X(Y,B) probes and familiar A(B,Y) trials. The figure clearly shows that Gertie selected the novel Y comparison when novel X samples were displayed almost as consistently as she selected the familiar or B comparisons when trained A samples were shown. Gertie had some difficulty in finding the football because it was so small and inconspicuous and on several trials she appeared to search for it before selecting one of the available familiar objects. Selection of novel objects was significantly better than chance ($p < .01$, binomial test).

Although it seems unlikely, one could interpret Gertie's immediate selection of novel objects as identity matching, that is, the sea lion had acquired an identity or similarity concept. Another interpretation of her performance is that when *not* presented with an A sample she eliminated the B comparisons and chose the Y comparison by exclusion. Dixon (1977) first proposed the idea that humans might use a rule such as "any stimulus that is correct for spoken word A is incorrect for a different spoken word" (p. 441), and most recently the phenomenon of exclusion has been applied to MTS tasks with severely retarded persons (e.g., McIlvane & Stoddard, 1985). A similar finding from the Russian literature is cited by Slobin (1966), who states that teaching 2-year-old children the names of objects is easiest if the object is a new object among a collection of familiar ones that have already been named. In order to test whether sea lion Gertie was using exclusion or a sameness concept to select novel objects in an MTS procedure we performed another experiment in which two different novel objects served as samples and both were available as comparisons.

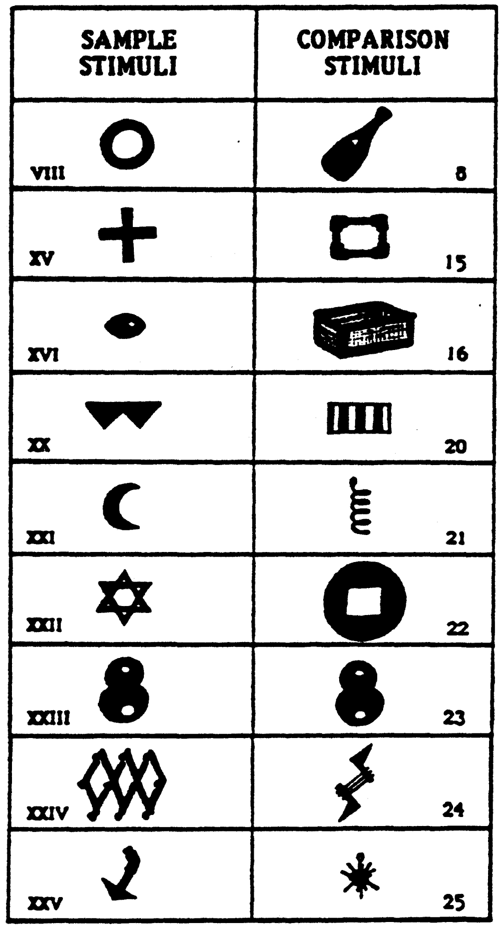

Figure 12.5. Representations of sample objects and their related comparisons. Roman numerals refer to sample stimuli and arabic numerals refer to comparison stimuli.

Experiment 2. This experiment was similar in all respects to the previous one except that on X(Y,B) probes two novel object comparisons were available along with from two to four familiar comparisons. Two probes were given each day for 6 days. The "pipe" and "plus" objects, following habituation, were each displayed as samples on six probe trials. On the first "pipe" probe Gertie went to the pipe and on the first "plus" probe she selected the plus. However, thereafter when Gertie was presented with the pipe as a sample she consistently selected the plus and when shown the plus she selected the comparison plus two times and the comparison pipe three times. As Figure 12.3 shows, Gertie selected novel comparisons each time a novel sample was displayed ($p < .01$). However, she showed no indication of identity matching in this MTS context. Figure 12.3 also shows that Gertie selected novel comparisons correctly at a slightly higher level than she selected trained comparisons. The results of this experiment support the idea that Gertie's choice of novel comparison stimuli was based on her exclusion of the trained comparison stimuli. This means that in animal language research when new "names" for objects are added, such conditional cues may not even be used initially. Instead a sea lion, dolphin, or chimpanzee may use exclusion or the process of elimination to select novel objects when given a new "name" or new conditional cue.

More Traditional MTS Experiments

Prior to beginning the following experiments our general procedure of using MTS within the context of artificial language comprehension was to initiate a trial or set of trials by throwing the comparison or "named" objects into the pool before displaying samples consisting of either gestures (Rocky) or an object (Gertie), after which the sea lions were released from station to find and act on the designated object (see Schusterman & Krieger, 1984, 1986; Schusterman & Gisiner, 1988). In order to control display of the sample or conditional cues more precisely, particularly in relation to the presentation of the comparison stimuli, we developed an apparatus and procedure that conformed to more traditional MTS tasks with animals (for a review see Roitblat, 1987). Figure 12.4 shows Rocky working on the MTS task that we currently use for studying "symbolic" learning and memory in California sea lions.

The apparatus is used to test sea lions on land and consists of three hinged wooden boards on casters. The center board is 1.2 X 1.2 m and contains an approximately centered 30-cm-square display box, 10 cm deep for presenting sample objects. The two side boards are 61 cm wide and 1.2 m high and also contain centered 30-cm-square display boxes, 10 cm deep for presenting comparison stimulus objects. During training and testing the side boards are angled about 20o. As can be seen in Figure 12.4, a sea lion can be trained to station its head on or near a headstand about 51 cm high and about 46 cm from the sample display and 76 cm from the comparisons. Stimulus objects like those shown in Figures 12.4 and 12.5 are hung from white cords, which are clipped to the top of hinged lids on the display boxes. The backs of the display boxes are painted flat white and most objects are three dimensional and all are painted flat black. During an intertrial interval (which lasts about 10-15 s) two operators behind the three wooden boards place objects into position while the sliding opaque panels in front of the display boxes remain closed. A trial begins when

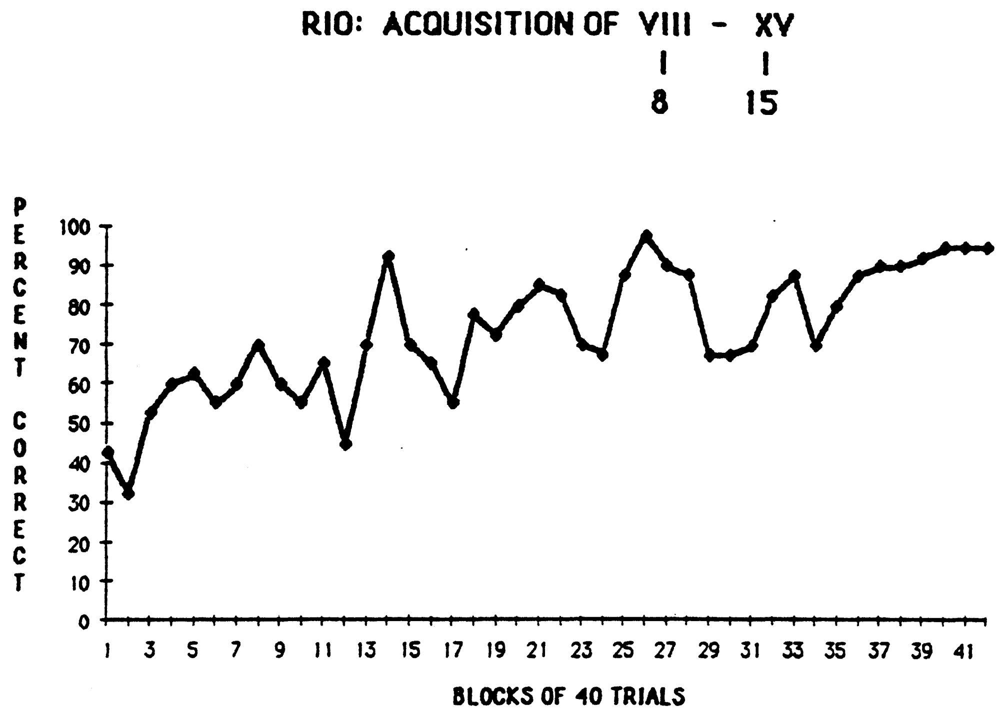

Figure 12.6. Rio's acquisition of the initial conditional discrimination in the MTS apparatus shown in Figure 12.4.

the panel in front of the sample box is slid horizontally to expose the object (see the first panel of Figure 12.4).

Exposure times for the sample were 4 s. In the delay conditions the sample box is closed for a period following the sample presentation. At the end of delay the two side panel doors are opened vertically and simultaneously by means of a pulley system mounted behind the three boards. In the simultaneous condition the sample panel remains open while the panels to the boxes containing the comparison stimuli are opened. As soon as the comparisons stimuli are visually accessible the sea lions orient to them and soon after this are released from station by an electronic acoustic release signal. Release signals are given after a variable delay generally ranging between 2 and 6 s. On release sea lions put their nose into one of the two comparison boxes thereby indicating their choice (see the third column in Figure 12.1 and see the last panel of Figure 12.4). Correct responses are immediately followed by an acoustic tone and then by a piece of fish thrown from behind the boards. Incorrect responses are immediately followed by a "no" signal and are not food reinforced. Note that the sea lions are never required to move toward or in any way overtly respond to

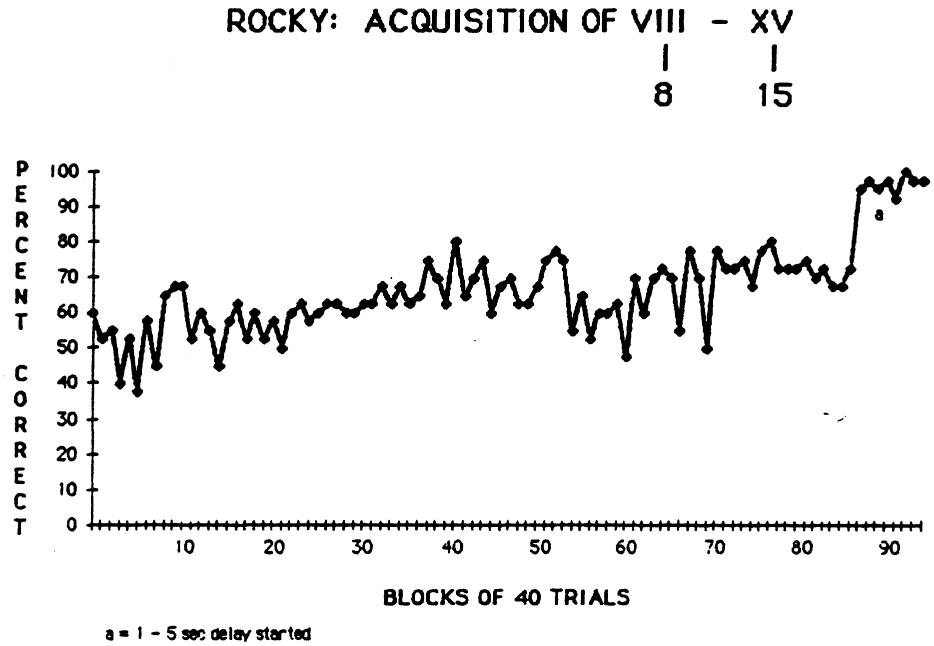

Figure 12.7. Rocky's acquisition of the initial conditional discrimination in the MTS apparatus shown in Figure 12.4.

the sample object (for contrast between our sea lion MTS training and conventional pigeon MTS training see Carter & Werner, 1978).

Experiment 1: Acquisition. A 3-year-old female sea lion, Rio, was first given training on a prototype of the apparatus shown in Figure 12.4. She was trained on an MTS task with two sample stimuli represented by Roman numerals VIII and XV in column 1 of Figure 12.5 and two comparison stimuli represented by Arabic numerals 8 and 15 in column 2 of Figure 12.5. A simultaneous condition was used, but as a variant on the usual MTS sequence, comparison stimuli were presented 4 s before the sample was presented. Using an acquisition criterion of 90% correct choices on two consecutive blocks of 40 daily trials, Rio appeared to learn relations between samples VIII and XV and their paired associate comparisons 8 and 15, respectively, within 1560 trials (see Figure 12.6). During the first 800 trials many different prompts were used, including eliminating position and comparison object preferences.

Rocky was trained to learn relations between sample VIII and comparison 8 and between sample XV and comparison 15 primarily in the apparatus shown in Figure 12.4. During the first 1240 trials the comparison stimuli were displayed before the samples. This sequence was changed gradually until a simultaneous condition was instated with the sample shown alone for 4 s and then accompanied by the simultaneous display of the comparisons. Using the same criterion we used with Rio, Rocky appeared to learn the relations between samples VIII and XV and their associated comparisons 8 and 15, respectively, within 3440 trials. Immediately after acquisition Rocky performed the MTS task consistently better than 85% correct responses even with delays of 1-5 s between the disappearance of samples and the appearance of comparisons (see Figure 12.7).

Experiment 2: Introduction of Novel Paired Associates. It appears that, like humans in language comprehension or naming tasks (Dixon, 1977), sea lions, dolphins, and perhaps chimpanzees use an exclusion rule to select novel "referents" in the presence of novel signs. The question we pose here is whether the same phenomenon can be demonstrated in sea lions on more controlled MTS tasks similar to those used to determine whether an exclusion rule controlled the behavior of handicapped teenagers (Stromer, 1986). The importance of taking a comparative perspective on exclusion is twofold. First, if animals use an exclusion principle, then this principle is not likely to be mediated by verbal behavior. Second, if the phenomenon is widespread and better understood, it can be used appropriately to train new conditional relations errorlessly in a variety of animal species for the purposes of studying cognition.

In the experiment, Rio was tested in a simultaneous condition in the apparatus shown in Figure 12.4. The sequence of sample-comparison pairs that was tested beginning with XX-20 and ending with XXIV-24 is seen in Figure 12.5. We should note that unlike the other three pairs, pairs XXII-22 and XXIII-23 were tested on alternate days. Generally, a new paired relation was first tested against the originally acquired conditional relations (VIII-8 and XVI-16), followed by testing against the next trained pair, etc. Test trials were superimposed on a baseline of already trained relations. Thus, Rio's task on test trials could be described as a requirement to choose the novel comparison instead of the trained comparison when a novel sample was displayed and to choose the trained comparison and not the novel one following the presentation of its related sample. All correct responses were reinforced with a piece of fish. Deciding when a sample-comparison became trained, or when the association between the two new stimuli had actually formed, was difficult (discussed later) and usually a novel pair was pitted against a familiar pair for between 400 and 600 trials. Thus, Rio was given between 200 and 300 novel or X(Y,B) trials and an equal number of familiar or A(B,Y) trials. Unlike the MTS task in the artificial language comprehension program, we did not habituate Rio to novel comparisons.

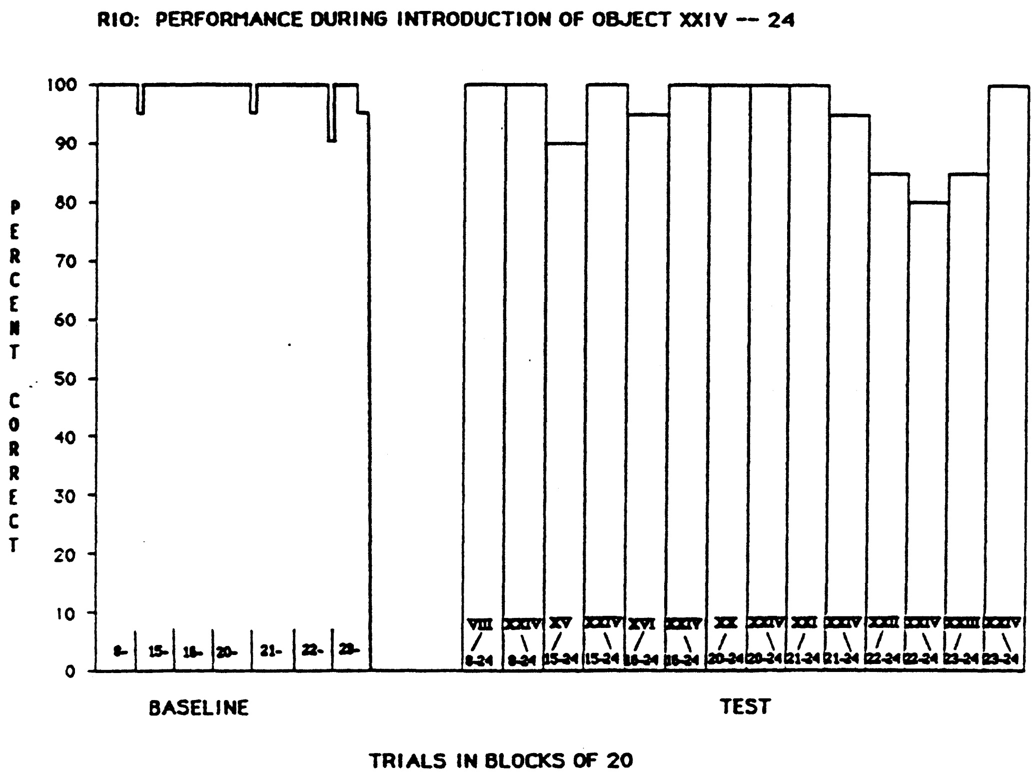

Figure 12.8. Rio's performance on the first 20 trials of novel pairing XXIV and 24. Baseline trials are compressed. Each baseline segment constitutes the percent correct choices and the indicated comparison stimulus or other trained comparisons. Thus, the first segment represents stimulus 8 as compared with all other trained stimuli - - - 15, 16, 20, 21, 22, 23, respectively. Baseline performance is contrasted with test trials where one comparison is novel. Testing stimuli are identified at the bottom of the bars, with a line connecting each sample to its correct paired comparison.

Figure 12.8 shows Rio's performance on the first 20 trials of novel pairing XXIV-24 tested with trained paired associates. Rio's performance on each of the four earlier novel pairings was quite similar to that shown in Figure 12.8. In this figure, performance on trained baseline paired associates is contrasted to performance on test trials when the comparison stimulus was newly introduced. During test trials, when novel relations were pitted against trained ones (i.e., the comparison stimuli consisted of one trained and one untrained or novel object), Rio's performance was nearly as good as that shown

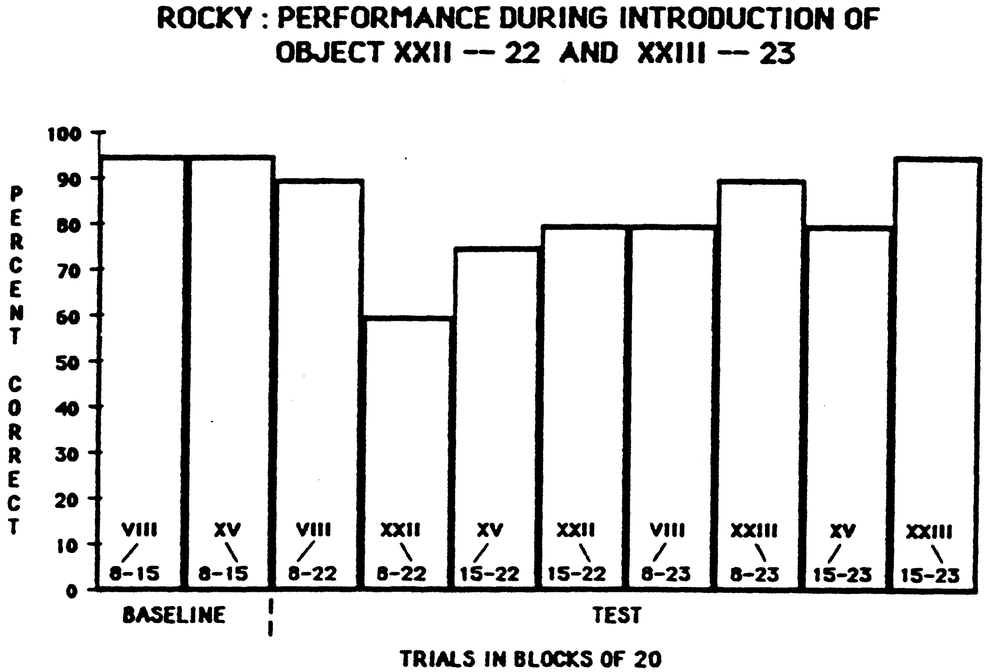

Figure 12.9. Rocky's performance on the first 20 trials of two novel pairings, XXII and 22, and XXIII and 23, tested with trained paired associates. (See Figure 12.8).

on "baseline" when only trained relations were used (i.e., when both comparison stimuli consisted of trained objects). On several of these "novel" conditional discriminations Rio made no errors at all. On the first trial of each unique pairing of novel and trained comparison stimuli, Rio, as expected, chose the novel comparison appropriately on 18 of 26 trials (p = .05, binomial test) and chose the trained comparison appropriately on 19 of 24 trials ($p < .01$, binomial test).

The procedures used for testing Rocky on the introduction of novel paired associates was similar to those used for Rio with the following exceptions. Rocky was given a conventional delayed MTS procedure with delays ranging from 1 to 5 s, and she was tested only with novel pairs XXII-22 and XXIII-23 against trained pairs VIII-8 and XV-15 on alternative days.

Rocky's results are shown in Figure 12.9, and although her preference for the appropriate comparison stimulus is apparent at the introduction of sample-comparison XXIII-23, she shows no strong preference for novel comparison stimulus 22. These results are best explained by Rocky's fearful behavior toward novel comparison objects. Although Rocky oriented to the novel comparison when first shown the novel samples, she always hesitated and then chose the trained or familiar but incorrect comparison. Indeed, initially Rocky never selected the novel comparison (0 of 4 cases) in the presence of the novel sample but always selected the trained comparison in the presence of the trained sample (4 of 4 cases). Had Rocky been habituated to the novel comparison stimuli so that she was not afraid to approach them, we think she would have behaved more like Rio in her selection of novel comparisons.

Experiment 3: Pitting Two Novel Paired Associates Against One Another. Rio and Rocky were given probes with the novel paired associates XXII-22 and XXIII-23 during the early and middle parts of the previously described testing phases. On the probes, the sea lions were forced to choose between the two novel comparisons in the presence of their corresponding samples. Choices were not differentially reinforced. If the animals were rapidly learning the relations between novel samples and novel comparisons, then they should have responded better than chance over the course of these probe trials. Instead, both sea lions showed chance performance during these novel-novel probes. Rocky responded appropriately on 9 of 20 trials (45%) and Rio responded appropriately on 53 of 92 trials (58%). Performance on all baseline pairings remained above 90% correct responses.

Experiment 4: "Blank" Sample Probes. Again, although the sea lions perform well and in many cases errorlessly on X(Y,B) trials, on $X_1(Y_1, Y_2)$ and on $X_2(Y_2, Y_1)$ trials performances initially remain at chance. Thus performance on the basis of what we have called exclusion does not necessarily reflect paired associate learning. Immediately following the previously described experiment, we decided to further check the influence of samples XXII and XXIII on Rocky's choice of the associated novel comparisons 22 and 23. In this experiment, on any given one of eight trials, novel comparisons 22 or 23 were displayed in one compartment while trained comparisons 8 or 15 were displayed in the other compartment. On all eight trials, the sample compartment was empty and when its panel slid open to begin a trial only the white background was shown for 4 s. On these "blank" sample probes, Rocky chose the novel comparisons on 8 of 8 trials ($p < .01$, binomial test). In a control experiment with 8 blank sample probes and two trained comparisons to choose from (8 and 15), Rocky distributed her choices randomly between the trained comparisons; choosing one six times and the other two times. These results strongly argue that initially, sea lions choose novel comparisons in the absence of trained samples instead of choosing them in the presence of the novel sample. Only later is the relation between new sample and new comparison

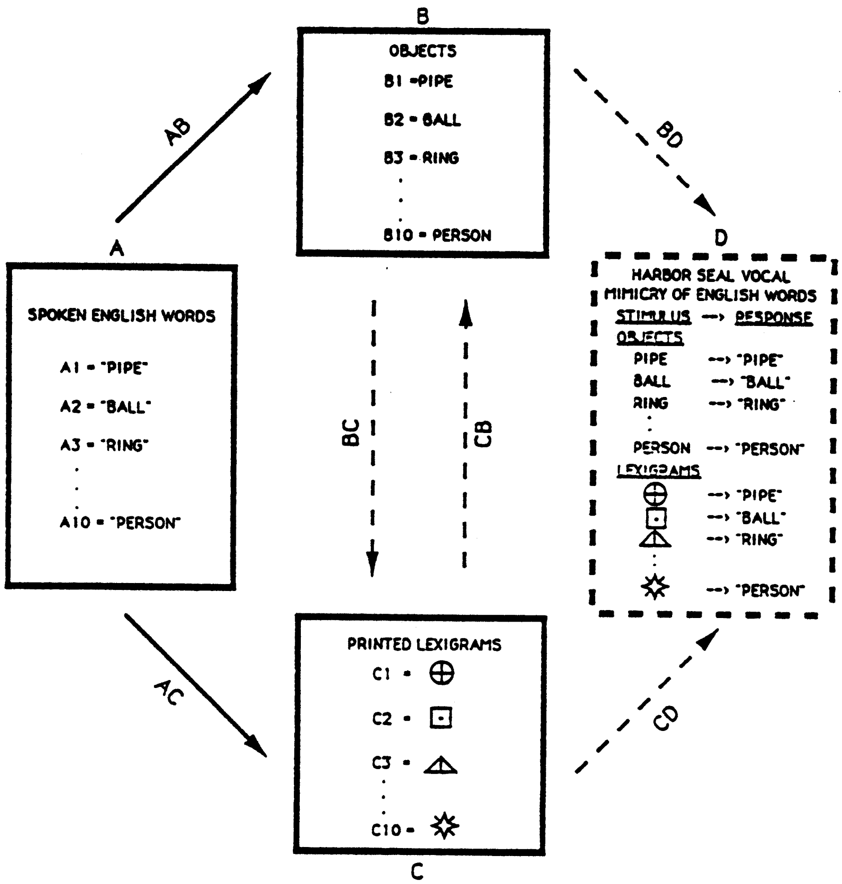

Figure 12.10. An equivalence paradigm for teaching a harbor seal semantic relations. Each of the three enclosed boxes A, B and C represent a set of 10 stimuli. Arrows AB, AC, BC and CB, each representing a set of conditional relations, point from sample to comparison stimuli. Solid arrows (AB and AC) represent relations that are explicitly taught to the seal and broken arrows represent conditional relations that are expected to emerge subsequently. For a given sample stimulus, the appropriate comparison is designated by the same number. Broken box D represents mimicked sounds by the seal which "name" stimulus sets B and C. Broken arrows from these stimulus sets to vocal mimicry of English words represent object naming (BD) and lexigram naming (CD).

stimulus learned. Another way of saying this is that an animal not presented with a trained sample will not choose the trained comparison but will instead choose the novel comparison by exclusion.

Although these experiments are far from definitive, they do suggest that in a variety of MTS contexts, some marine mammals are likely to choose the novel comparison object, not because they have learned that a relation exists between the novel "symbol" and the new object, but simply because they exclude the trained object in the absence of the trained symbol by a process of elimination.

A HYPOTHETICAL EXPERIMENT ON SEMANTIC COMPREHENSION: HARBOR SEAL AND STIMULUS EQUIVALENCE

Recently it has been reported that male harbor seals (*Phoca vitulina*) produce sounds that mimicked English words (Ralls, Fiorelli, & Gish, 1985), suggesting that it may be possible to teach harbor seals to produce and understand names for objects as has been reported with dolphins (Herman et al., 1984). In a concrete, but totally hypothetical, illustration, a male harbor seal may be shown two objects simultaneously or played two recordings of spoken English words in rapid succession-perhaps objects like a ball and a pipe in the first instance or the words "ball" and "pipe" in the second case. The seal must use a third stimulus, the sample or instructional cue, to determine to which object or which word the animal should respond. Sidman and Tailby (1982) and others have noted that the term "MTS" sometimes refers to a procedure and sometimes it refers to the results of a procedure. These two different meanings of MTS bear on fundamental issues in animal cognition (e.g., see the controversy between Herman, 1988, 1989, and Schusterman & Gisiner, 1988, 1989). For example, if a harbor seal performed appropriately on a matching task and its opposite, a mismatching or oddity task, the behavior does not necessarily imply that the seal has a "sameness" or "oddity" concept. The critical test of concept formation comes when the seal must match *novel* stimuli solely on the basis of their identity relationship. As in identity MTS, there is a tacit assumption in symbolic MTS that each paired associate of sample and comparison stimulus is related not merely by an if...then.. relation, but by equivalence (Sidman & Tailby, 1982). Thus, in the harbor seal example, it is easy to assume that each spoken English word sample and each object stands in an equivalence relation to one another (e.g., the seal makes both of these relationships: if spoken word "ball" then object ball, *and* if object ball, then spoken word "ball"). However, as Sidman and Tailby (1982) have shown, the arbitrary relationship between so-called symbols and their referents like identity matching remain in a unidirectional if-then relation and cannot be considered to form an equivalence class relationship unless there are explicit and independent tests. Simple behavioral variables may be mistakenly identified as evidence of complex cognitive processes, such as symbol manipulation, if the assumption of stimulus equivalence is in fact invalid (Mackay & Sidman, 1984).

If, as a result of the training on a series of conditional discriminations within MTS paradigms (if A_1 then B_1, if A_2 then B_2, etc., or if spoken word "ball" then object ball, if spoken word "pipe" then object pipe, etc.), there is the emergence of untrained relationships between dissimilar stimulus patterns, then the equivalence of stimulus classes can be said to exist. Stimulus equivalence has three defining characteristics: reflexivity, symmetry, and transitivity.

Reflexivity. Reflexivity emerges from generalized identity matching of the type: If A_1, then A_1; if A_2, then A_2; and if B_1, then B_1; if B_2, then B_2; etc. Thus, if hypothetically, it takes several trials before a naive harbor seal can consistently match the spoken word "ball" to itself, but then the seal matches the spoken word "pipe" to itself on the first trial and the spoken word "ring" to itself on the first trial, and if the seal also shows some difficulty in matching the object "ball" to itself, but then immediately can match the object "pipe" to itself and "ring" to itself, etc., then we can conclude that this seal who was taught a set of sample-comparison relations (spoken English words and objects) has demonstrated that these relations were reflexive by showing himself capable of matching the two kinds of stimuli to themselves. Moreover, ideally, to develop additional critical tests of class equivalency, another set of sample-comparison relations is needed (see Sidman & Tailby, 1982, for a description of the mathematical definition of equivalence relations and the way conditional tests are derived from such a definition). These could consist of spoken English words and printed lexigrams. Reflexivity would be further demonstrated if the subject could match each lexigram to itself.

Symmetry. Symmetric relations are shown when two or more dissimilar stimuli are related bidirectionally or reciprocally (e.g., if A_1, then B_1; if B_1 then A_1). Figure 12.10 illustrates a basic equivalence paradigm. The seal that has learned to match comparison stimulus B_1 to sample stimulus A_1 or comparison stimulus C_2 to sample stimulus A_2 must then, without additional training, be able to match A_1 as a comparison to B_1 as a sample and A_2 as a comparison to C_2 as a sample. Symmetry requires sample and comparison stimuli to be functionally interchangeable, or, stated another way, within the context of semantics, symmetry occurs when "conditional cues have become more than conventional discriminative stimuli . . [i.e.], when signs and their referents are shown to be immediately interchangeable" (Schusterman & Gisiner, 1989, p. 14).

Transitivity. The emergence of transitive stimulus relations from conditional discriminations requires three stimulus sets as illustrated in Figure 12.10. Transitivity is shown when previously untrained stimulus relations emerge following the training of a third set of stimulus relations-if A_1, then B_1; if B_1, then C_1; and if A_1, then C_1. Suppose our seal, having learned to select a pipe when it hears the word "pipe," and having learned to select the appropriate lexigram (C_1) when it hears the word "pipe", now without explicit training, chooses the object pipe when presented with the corresponding lexigram and chooses the lexigram (C_1) when shown a pipe. We may conclude that for the seal, the spoken word "pipe", the object pipe and the lexigram form a single equivalent class despite showing no physical similarity. The seal's emergent ability to do new types of matching tasks, BC and CB, will have confirmed the development of 10, three-member classes of equivalent stimuli: $A_1B_1C_1$ $A_2B_2C_2$, . . . and $A_{10}B_{10}C_{10}$, (see Figure 12.10). Moreover, one might want to conclude that by passing the stimulus equivalence test, this seal clearly shows that the conditional relations between words and their referents as well as lexigrams and their referents involve semantic relations. Indeed, if the male harbor seal can mimic English spoken names of the objects (BD) and lexigrams (CD), then the original teaching of 20 conditional relations to the seal will have resulted in the creation of 20 novel conditional relations and 20 naming relations or a total of 40 novel performances. In this hypothetical experiment symmetry and transitivity could be tested indirectly with a male harbor seal trained to mimic English words by determining whether the test subject vocalizes appropriately to objects or to printed lexigrams or both (see Figure 12.10).

GENERAL DISCUSSION

Our results on "errorless" acquisition by California sea lions of conditional relations between symbolic or arbitrary samples and comparisons, as a function of pitting novel or untrained comparisons against previously trained or conditioned comparisons (conditioned to an arbitrary sample), are virtually identical with similar results when 2-year-old children are trained to name objects (Slobin, 1966) and with those recently obtained on humans (both retarded and normal) in a variety of MTS paradigms (e.g., McIlvane & Stoddard, 1985). Such results suggest that in a variety of MTS contexts, but most assuredly in the two-comparison context, sea lions choose the novel comparison, not because of their common property of novelty or because of their previous "language training" as earlier suggested (Herman et al., 1984; Schusterman & Krieger, 1984), but because they exclude the trained comparison stimulus in the absence of a trained sample and thus select the untrained or novel comparison by default. The behavioral basis for the exclusion phenomenon may be a quite fundamental conditioning process, because it is only following preferences of untrained comparisons by exclusion that these marine mammals may start learning the relation between a novel sample and a novel comparison stimulus.

We have attempted to show that semantic comprehension in seals, sea lions and dolphins and other animals as well may begin with arbitrary conditional relations between signals (samples) and referents or objects (comparisons) and that initially the choice of appropriate referents is controlled by exclusion. It is only after an unspecified number of trials [perhaps about 150-200 X(Y,B) trials] that the effects of exclusion emerge as a novel conditional performance in contexts where the basis for exclusion is no longer immediately available. However, the ability to learn conditional relations is only an intermediary step in the hierarchy of learning abilities necessary to do semantic relations. Thomas (1980), for example, suggested that biconditional or symmetrical concepts are the highest forms of intellectual functioning. Symmetrical conceptualization may be critical for the emergence of semanticity. As Sidman and Tailby (1982) have stated so cogently: "Pointing to a picture in response to a printed word denotes . . . (semantic) . . comprehension only if the word and picture are related by equivalence and not merely by conditionality. Stimulus classes formed by a network of equivalence relations establish a basis for referential meaning. The equivalence paradigm provides exactly the test needed to determine whether or not a particular conditional discrimination involves semantic relations" (p. 20).

Although the ability of dolphins, apes, monkeys, and several other vertebrate taxa to respond to complex classes of stimuli is not in doubt, their ability to "refer" to objects, events, and relations and, in general, to manipulate symbols is very controversial. The origin and nature of symbolic activity, which invariably involves the logical properties of reflexivity, symmetry and transitivity, may be rooted in the way animals acquire rules to deal with social and nonsocial stimulus objects, events, and relationships. Sidman (1986) has shown that in humans conditional discriminations can lead to a semantic correspondence between each sample and its matching comparison stimulus, that is, a stimulus class equivalency within an MTS paradigm. Can dolphins and sea lions or for that matter chimpanzees do the same?

ACKNOWLEDGMENTS

This research was supported by contract N00014-85-K-0244 from the Office of Naval Research to Ronald J. Schusterman. We acknowledge the contributions of student volunteers in the Sea Lion Cognition Group at Long Marine Laboratory. We especially thank Barbara Emery for her help in preparing this manuscript.

REFERENCES

Carter, D. E. & Werner, T. J. (1978). Complex learning: A critical analysis. *Journal of the Experimental Analysis of Behavior*, 29, 565-601.

Catania, A. C. (1980). Autoclitic processes and the structure of behavior. *Behaviorism*, 8, 175-186.

Cumming, W. W. & Berryman, R. (1965). The complex discriminated operant: Studies on match-to-sample and related problems. In D. I. Mostofsky (Ed.). *Stimulus Generalization* (pp. 284-330). Stanford, CA: Stanford University Press.

Dixon, L. S. (1977). The nature of control by spoken words over visual stimulus selection. *Journal of the Experimental Analysis of Behavior*, 7, 433-442.

Herman, L. M. (1988). The language of animal language research: Reply to Schusterman & Gisiner, *Psychological Record*, 38, 349-362.

Herman, L. M. (1989). In which procrustean bed does the sea lion sleep tonight? *The Psychological Record*, 39, 19-42.

Herman, L. M., Richards, D. G., & Wolz, J. P. (1984). Comprehension of sentences by bottlenosed dolphins. *Cognition*, 16, 129-219.

Mackay, H. A. & Sidman, M. (1984). Teaching new behavior via equivalence relations. In P. H. Brooks, R. Sperber, & C. McCaulay, (Eds.), *Learning and cognition in the mentally retarded* (pp. 493-513). Hillsdale, NJ: Lawrence Erlbaum Associates.

McIlvane, W. J. & Stoddard, L. T. (1985). Complex stimulus relations and exclusion in severe mental retardation. *Analysis and Intervention in Developmental Disabilities*, 5, 307-321.

Nissen, H. W., Blum, J. S., & Blum, R. A. (1948). Analysis of matching behavior in chimpanzee. *Journal of Comparative and Physiological Psychology*, 41, 62-74.

Ralls, K. F., Fiorelli, P., & Gish, S. (1985). Vocalizations and vocal mimicry in captive harbor seals, *Phoca vitulina. Canadian Journal of Zoology*, 63, 1050-1056.

Roitblat, H. L. (1987). *Introduction to comparative cognition.* New York: W. H. Freeman.

Savage-Rumbaugh, E. S. (1988). A new look at ape language: Comprehension of vocal speech and syntax. In D. Leger (Ed.), *Comparative perspectives in modern psychology. Nebraska Symposium on Motivation, 1987* (vol. 35, pp. 201-256). Lincoln, NE: University of Nebraska Press.

Schusterman, R. J. & Gisiner, R. (1988). Artificial language comprehension in dolphins and sea lions: The essential cognitive skills. *Psychological Record*, 38, 311-348.

Schusterman, R. J. & Gisiner, R., (1989). Please parse the sentence: Animal cognition in the procrustean bed of linguistics, *Psychological Record.* 39, 3-18.

Schusterman, R. J. & Krieger, K. (1984). California sea lions are capable of semantic comprehension. *Psychological Record*, 34, 3-23.

Schusterman, R. J. & Krieger, K. (1986). Artificial language comprehension and size transposition by a California sea lion (*Zalophus californianus*). *Journal of Comparative Psychology*, 100, 348-355.

Sidman, M. (in press). Equivalence relations: Where do they come from: In D. E. Blackman & H. Lejeune (Eds.), *Behavior analysis in theory and practice: Contributions and controversies* (pp. 213-245). Hillsdale, NJ: Lawrence Erlbaum Associates.

Sidman, M. (1986). Functional analysis of emergent verbal classes. In T. Thompson & M. D. Zeiler (Eds.), *Analysis and integration of behavioral units*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Sidman, M. & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior*, 37, 5-22.

Slobin, D. (1966). The acquisition of Russian as a native language. In F. Smith & G. A. Miller (Eds.), *The genesis of language: A psycholinguistic approach* (pp. 129-148). Cambridge, MA: MIT Press.

Stromer, R. (1986). Control by exclusion in arbitrary matching-to-sample. *Analysis and Intervention in Developmental Disabilities*, 6, 59-72.

Thomas, R. K. (1980). Evolution of intelligence: an approach to its assessment. *Brain, Behavior and Evolution*, 17, 454-472.