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CALIFORNIA SEA LIONS ARE CAPABLE OF SEMANTIC COMPREHENSION

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Two California sea lions (a 6-year-old female, Rocky, and a 3-year-old male, Bucky) were trained in a symbolic matching paradigm. Gestural signs produced by movements of the trainer's arms and hands referred to types of *objects, modifiers*, and *actions*. Both sea lions were eventually trained with three-sign constructions consisting of Modifier + Object + Action in that order. An example of a three-sign sequence is BLACK BALL MOUTH [glossed as "go over to the black ball (and not the gray or white balls or the black, white, and gray pipes) and place your open mouth on it]. Rocky's modifiers consisted of size and color attributes, and Bucky's modifiers consisted of different locations of the objects.

After 24 months of training, Rocky had a comprehension vocabulary of 20 signs (5 modifiers, 10 objects, and 5 actions), and after 20 months of training, Bucky had a comprehension vocabulary of 16 signs (2 modifiers, 8 objects, and 6 actions). Semantic comprehension is considered to be demonstrated if an organism can follow directions when each sign is contrasted with every other in a series of commands. Currently, Rocky's semantic comprehension consists of 190 three-sign combinations, and Bucky's semantic comprehension consists of 64 three-sign combinations.

Until recently, perhaps the greatest limitation to the study of the cognitive skills of nonverbal infants, mentally handicapped individuals, and animals stemmed from procedures that restricted their training to relatively simple instrumental responses to specific environmental stimulus objects (see Blough & Blough, 1977, and Schusterman, 1980, for critical reviews of operant methods to study the sensory and perceptual capabilities of nonverbal animals). In linguistic parlance, the nonverbal animals were trained with holophrastic commands, i.e., stimulus objects were to be acted upon in a specified way (e.g., touched or

This paper is dedicated to the memory of WINTHROP N. KELLOGG, whose truly creative and dedicated work on the neural mechanisms of learning, the developing mind of a home-raised chimpanzee, and the echolocation capabilities of dolphins continues to be an inspiration to contemporary comparative psycholgists.

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approached) when, and only when, a signal or stimulus was given (stimulus control). The command signal contained a complete phrase which included the object class, the object qualities, the location of the object, and the action to be taken. There were no attempts by investigators to use stimulus control procedures in which the behavior of nonverbal animals was regulated by separate signals designating objects, object qualities, and actions. Thus, the opportunity to determine whether nonverbal animals deal with instructions in which signals are recombined in different ways, i.e., whether they are capable of semantic comprehension (Premack, 1976), was rarely considered. The behavior modification approach to the study of animal learning has its counterpart in the trained animal acts in zoos, circuses, and oceanariums. For example, dolphins and sea lions are trained to perform a series of intricate maneuvers and subtle discriminations by Skinnerian "shaping," "chaining," and "fading" techniques. However, the trainer's hand signals or rudimentary words are holophrastic commands referring to both actions, objects, and object qualities and are usually not divided into separate meanings. Thus, dolphins seem to show no understanding of retrieving the ball rather than the ring (unless the trainer points to it) or vice versa, or leaping over the ring instead of the ball or vice versa. Even in the training of a capuchin monkey to perform as an aide for a quadriplegic, there appears to be no use of signals to refer to various aspects of the environment. Instead, the monkey's performance seems to depend on a series of "shaped" and "chained" behaviors primarily under the control of the trainer's verbal command "do this" or "fetch" in conjunction with a pointer (Willard et al., 1982). As Richard Solomon (1981) has recently noted, most nonverbal "animals are much smarter [and] much more capable than they appear to be, either in their natural habitat or at the hands of experimental psychologists" (p. 2), and I might add, most animal trainers.

Recently, however, these restrictive study techniques for probing an animals's cognitive capacities have been overcome. This has been particularly true in studies dealing with spatial memory (e.g., Menzel, 1978), abstract reasoning, and symbolic communication (Premack, 1983; Savage-Rumbaugh, 1981)). Gestural symbols (Gardner & Gardner, 1969), plastic symbols (Premack, 1983), a keyboard with symbols (Rumbaugh, 1977), and computer-generated acoustic symbols (Herman, 1980) have been used to generate rather extensive vocabularies in chimpanzees, gorillas, and bottlenosed dolphins (*Tursiops truncatus*). In the case of an African gray parrot, the vocabulary consisted of spoken English words (Pepperberg, 1981). Indeed, playback experiments in the field suggest that the "untrained" vocalizations given by vervet monkeys function in a rudimentary representational fashion, designating objects or events (Cheney & Seyfarth, 1982; Seyfarth, Cheney, & Marler, 1980). The present study with sea lions is most similar to Herman's studies on dolphins (Herman, 1980; Herman, Richards, & Wolz, 1981, December) in which the emphasis is on vocabulary comprehension rather than on a productive vocabulary. Griffin (1981) has recently reviewed this comparative psychological approach to the animal mind.

At our laboratory in Hayward and at Marine World/Africa, USA we have been training and testing two California sea lions (*Zalophus californianus*) in symbolic communication experiments in which gestural signs refer to types, attributes, and locations of objects as well as actions to be taken. The distinctive gestural signs are produced by movements of a trainer's arms and hands. The present results encompass nearly 24 months of training for Rocky and 20 months of training for Bucky. During this period, we have collected a substantial amount of data on the ability of Rocky and Bucky to comprehend signs which could be combined into a phrase made up of sequences of two or more signs or "words," with each sequence or construction conveying a unique instruction. Comprehension was measured by the accuracy and consistency of the sea lion's responses to the gestural phrases. The convention used in this paper is to identify gestures with putative meanings by capitalized words. A combination of two signs was always presented sequentially as Object + Action, e.g., FRISBEE FLIPPER-TOUCH (glossed as "go to the frisbee and touch it with your front flipper"). Modifier signs were added before the Object + Action string so that three-sign strings currently consist of Modifier + Object + Action in that order. Modifier signs that are currently comprehended by one or the other of the sea lions refer to the qualities or attributes of the objects (e.g., the shade of gray or the size of the object) and the location of the objects (located on land or in the water). An example of a three-sign sequence is BLACK BALL MOUTH [glossed as "go over to the black ball (and not the gray or white balls) and place your open mouth on it]. Object modifiers are used when identical pairs or triads of objects are simultaneously available. In the case of color modifiers, at least six objects must be present, e.g., three balls that are colored black, white, and gray, and three baseball bats that are colored black, white, and gray.

Methods

Sea Lions and Apparatus

Bucky (a 3-year-old male born in captivity) was housed, trained and tested in a concrete tank of 7.6-m diameter with a water depth of about 3 m, and Rocky (a 6-year-old female born in the wild) was housed, trained, and tested in a rectangular pool that is 3.5 m x 11.1 m and has a water level of about 1.2 m. In order to train and test the sea lions, a trainer sat at the edge of the tank (usually at one of two designated positions), placing an outstretched foot (housed in a black rubber boot) in the water. The trainer's foot or boot was a signal for the sea lion to station itself by placing its chin on the toe of the boot. The water in Rocky's pool was shallow enough for her to place her rear flippers on the floor of the tank in a Chaplinesque stance while stationing and receiving gestural signals. Bucky's tank was deep enough so that while he stationed with his chin on the trainer's toe, he continually tread water with his flippers.

All objects were plastic and floated on the surface of the water. Initially, the original colors of the objects were used for both sea lions. Later, however, variants of the original color were used (see Table 1). In particular, when shades of gray or colors were trained as modifier signals, Rocky's objects were painted with K-Mart fast drying spray enamel. The colors used were flat white (#3729), flat black (#3727), and gray primer (#3738).

Signals

The gestural signs were made with the arms and hands while the trainer was seated at the edge of the pool and the sea lion was stationed with its chin

Table 1
Descriptions of the Objects Including Generic and Trade Names of Objects Used in Experiments with California Sea Lions

Object Class and Description[a]	Color	Object Characteristics Length[b]	Diameter[b]	Circumference[b]
PIPE (a piece of PVC)				
R-S	white	33	—	9
R-V	white, black, gray	81,33	—	9
B-S	white	45	—	19
B-V	black	36	—	15
BALL				
R-S	yellow	—	—	71
R-V	white, black, gray	—	—	34,71,105
B-S	white	—	—	65
B-S	red	—	—	68
RING				
R-S	red	—	26	4
R-V	white, black, gray	—	36,26	4
B-S	white	—	26	4
B-S	red	—	26	4
WATER WING (square-shaped and worn on child's arm)				
R-S	orange	17 x 17	—	—
R-V	white, black, gray	17 x 17	—	—
CLOROX BOTTLE				
R-S	white	31	—	49
R-V	green, gray, white, black	26,31,34	—	34,49,95
B-S	white	31	—	49
B-V	white	26	—	39
CAR (toy)	red	42	—	—
FRISBEE				
B-S	yellow	—	23	—
B-V	white, black, red	—	27	—
DISC (top of 3-gallon Coleman cooler)	red	—	28	—
BAT (baseball)	red	70	—	28
CUBE (made out of PVC with a hollow cavity)				
R-S	white	13 x 13	—	10
R-V	white, black, gray	29x29, 13x13	—	10
FOOTBALL				
R-S	white	34	—	46
R-V	white, black, gray	17, 34	—	27,46

[a] Initials refer to standard (S) and variant (V) objects used with Bucky (B) and Rocky (R).
[b] Measurements are given in centimeters.

on the toe of the trainer. The signs were, for the most part, arbitrary with regard to their assigned meaning. They were selected in terms of their ease of detectability and their distinctiveness from one another as judged by the authors of this paper (see Figure 1). The gestural signs for actions were movements of a single arm or hand while those for objects and modifiers consisted of movements by both arms and hands of the trainer. In the case of Bucky, no consideration of his reactions to the signs was given and the signs were made rapidly without pausing for more than about 0.25 s between successive gestures. A complete gesture generally took between 0.5 s and 1 s to complete. In contrast, Rocky learned to turn her head following each successive gesture designating object qualities

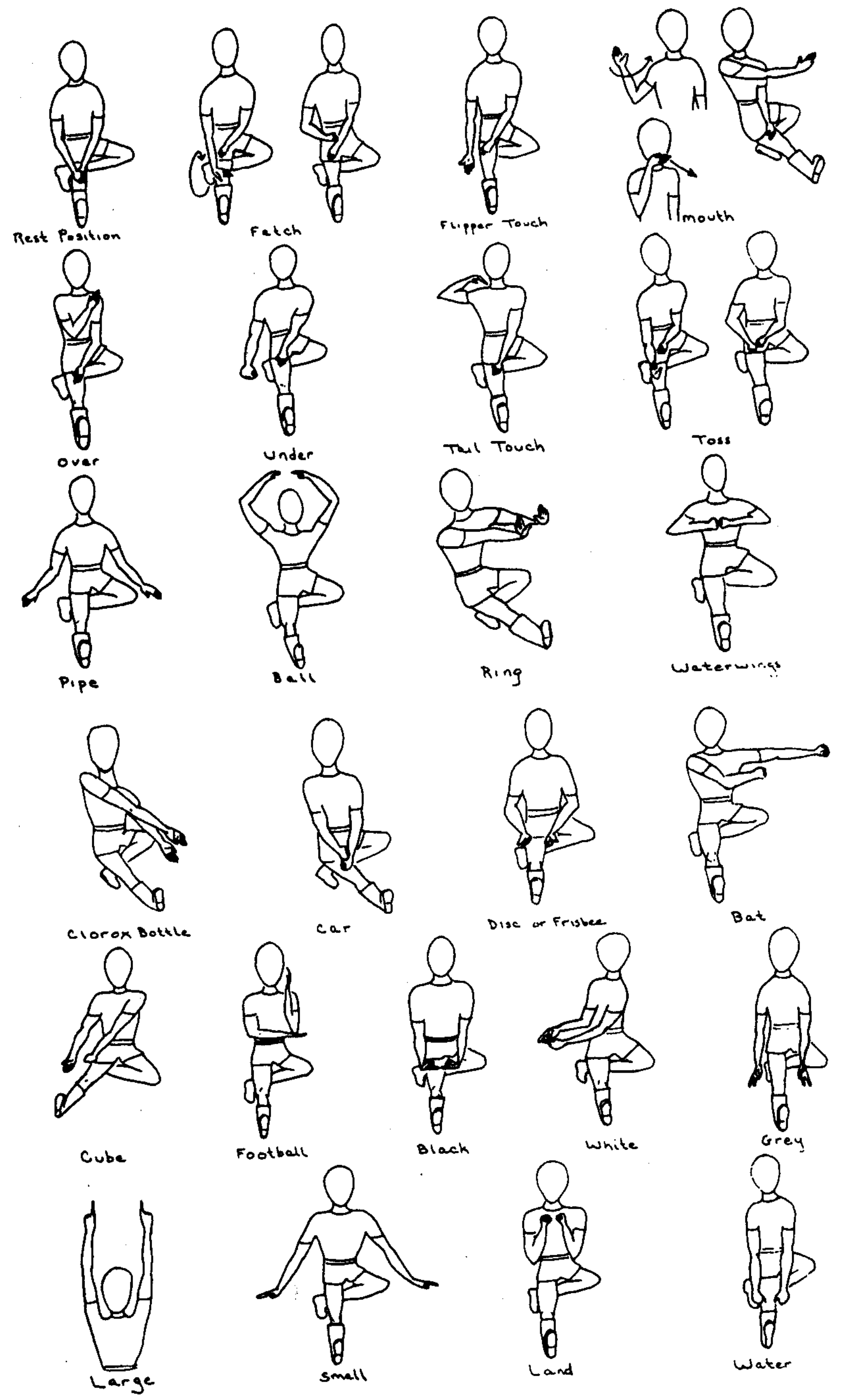

Figure 1. Drawings of the gestures used to signify objects, actions, and modifiers (object qualities and locations).

Figure 2. Rocky orienting to a gray Clorox bottle. Other objects floating on the surface of the water include black and white Clorox bottles and black, white, and gray water wings. The blindfolded trainer is holding the gestural sign referring to Clorox bottle until the sea lion restations on the toe of her boot. The trainer had already transmitted the gesture referring to gray in the three-sign construction GRAY CLOROX BOTTLE MOUTH.

and objects, and the trainer paused maintaining hands and arms in the positions as shown in Figures 1 and 2. While the pauses following modifiers were very brief, usually about 0.125 s, those following an object gesture were usually about 1 s in duration. A complete gesture took about 1 s. A list of the signs and the order in which they were learned by each sea lion is shown in Table 2.

Many different trainers were used throughout the course of the study resulting in considerable variation in signing. However, with a few days of experience, both sea lions adjusted to these individual variations in the signs, and error rates did not fluctuate significantly as a function of different experienced signers.

General Procedure

Throughout the nearly 2 years of her training and testing, Rocky usually had two sessions per day consisting of between 50 to 100 trials, 6 days per week. The sessions generally lasted about 40 min with a 15– to 30–min break between sessions. Although initially Bucky was not trained as regularly as Rocky, throughout the past 9 months training was on a schedule similar to Rocky's except that Bucky was generally trained 5 days per week rather than 6 days per week.

The small, fully grown female, Rocky, was maintained on 4 to 5 kg of freshly thawed Columbia River smelt and herring each day while the rapidly

Table 2

List of Gestural Signs Designating Types of Objects, Modifiers, and Actions

ROCKY Order	ROCKY Sign	ROCKY Sign Type[a]	BUCKY Order	BUCKY Sign	BUCKY Sign Type[a]
1	FETCH	A	1	FETCH	A
2	FLIPPER-TOUCH	A	2	FLIPPER-TOUCH	A
3	MOUTH	A	3	MOUTH	A (aborted)
4	PIPE/	O	3	TAIL-TOUCH	A
5	BALL	O			
6	RING	O	4	TOSS	A
7	WATER-WING	O	5	BAT/	O
			6	RING	O
8	CLOROX BOTTLE	O	7	FRISBEE	O
			8	BALL	O
9	CAR	O	9	CLOROX BOTTLE	O
10	(GO) OVER	A			
11	DISC	O	10	(GO) OVER	A
12	(GO) UNDER	A	11	PIPE	O
13	BAT	O	12	CAR	O
14	WHITE/	M	13	(GO) UNDER	A
15	BLACK	M	14	CUBE	O
16	CUBE	O	15	LAND/	M
17	GRAY	M	16	WATER	M
18	FOOTBALL	O			
19	LARGE/	M			
20	SMALL	M			

[a]O denotes objects; M, modifier; and A, actions.

growing male sea lion, Bucky, received 6 to 7 kg of smelt and herring. Both sea lions received pieces of cut herring and smelt (weighing approximately 15 g) as a reward for correct responses.

During testing, each trial consisted of two or more signs which were combined in a relatively random fashion depending on the type of comprehension testing that was being conducted. Following the action sign, the sea lion was released from station by the trainer removing his/her toe from the sea lion's chin. The "go" signal was given approximately 0.5 to 1 s following the action gesture. After the "go" signal was given, the trainer opened his/her eyes, or if opaque goggles were being worn, flipped the goggles up and informed the sea lion that it was wholly correct by blowing a whistle, or that it was incorrect by saying "no." Judgment as to the correctness of a response with regard to the type of action and the object toward which the action was directed was almost perfectly reliable with essentially 100% agreement among observers.

During testing and under some training conditions, the following controls were instituted to guard against a "Clever Hans" phenomenon. At least one, and frequently two observers, either on a platform overlooking the tank or at tankside, recorded the sea lion's behavior on data sheets and sometimes on videotape while remaining mostly out of view of the sea lion. A tankside person (who had no knowledge of the reinforcement contingencies) threw objects in after each trial and then hid from the sea lion. At this point, the trainer, wearing opaque goggles, proceeded to station the sea lion and presented a successive series of gestural signals that had been called out by one of the observers on the platform. After each trial (or under some conditions a set of from two to about five trials) the sea lion retrieved all the objects (see Results and Discussion). These efforts effectively prevented the trainer and others from readily cueing the sea lions to respond to a specific object.

Results and Discussion

The first phase of training and testing stressed action signs. Generalization tests determined the degree to which signaled actions toward specific objects could be immediately transferred or extended to new objects or new situations. The second phase dealt with object naming, Object + Action integration, and emphasized the use of new and different signs to designate new and different Objects + Actions. The third phase attempted to test the notion that in sea lions, gestural signals designating objects give rise to mental images of those objects. During the fourth stage of training and testing, which dealt with object modifiers, the sea lions had to learn that signs not only designated types or classes of objects, but that signs could also refer to the attributes or the location of objects.

Actions

Following station training, the first signs introduced to both sea lions were actions which were directed toward a single unnamed object (see Table 2). The training of actions was by Skinnerian shaping procedures in which successively closer approximations of the ultimately desired response class was immediately followed, first by an acoustic conditioned reinforcer or "bridging signal" (a whistle), and then by a thrown fish reward. The actions were then placed under control of gestural signs. While a sea lion was stationed, an action sign was given and positive reinforcement became available only if the appropriate action was taken. During the early stages of training, an object was tethered on a string adjacent to the sea lion.

Although both sea lions were originally trained with a small white ball, action signs given during generalization tests showed that FETCH, FLIPPER-TOUCH, MOUTH, and TOSS were performed on the first occasion with such novel objects as a white pipe, a red baseball bat, a yellow frisbee, an orange water wing, and a white Clorox bottle (Schusterman, Silva, Navid, Brick, & Neklason, 1981, December). Bucky, in particular, showed a variety of noncontextual or generalized actions toward objects. For example, Bucky used either the right or left flipper when signed to FLIPPER-TOUCH. When the signal for TOSS was given, depending on the size and shape of the object, Bucky threw objects either by grasping them in his mouth and doing a head shake while releasing the object or by swimming beneath the object and shoving it out of the water with his nose. He executed the fetching action in a similar fashion, altering his motor responses to suit the size and shape of the object. Perhaps the most noteworthy example of response generalization to objects in new situations occurred when, for the first time, Bucky was given the separate signs for FLIPPER-TOUCH and TAIL-TOUCH while an object was on the adjacent pool deck rather than floating on the water. With little hesitation, he leaped out of the pool on to deckside, and made the considerably different, but nontheless appropriate,

Figure 3. Bucky doing a TAIL-TOUCH to a pipe in water

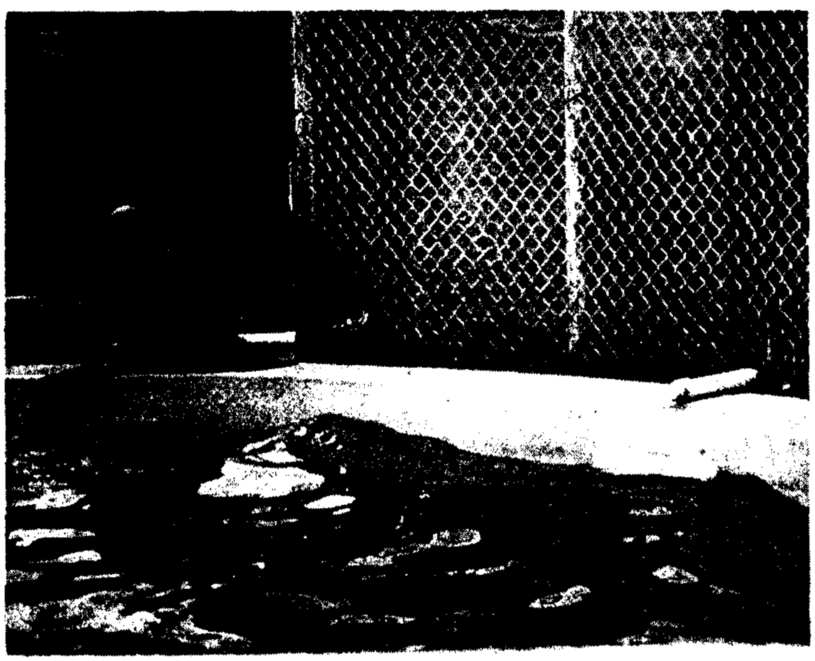

Figure 4. Bucky doing a TAIL-TOUCH to a pipe on LAND. Note that there is a pipe in the water. Bucky is responding correctly to the three-sign contruction LAND PIPE TAIL-TOUCH.

motor adjustments, while performing the unmistakable actions of touching his backside to an object (see Figures 3 and 4) and flippering an object. Moreover, Bucky tossed and fetched objects on land the first time he was signaled to do so.

Rocky showed less response generalization than Bucky for two reasons. Firstly, the originally trained actions of flipper-touching and mouthing allowed for little response variability, i.e., relatively narrow response classes were used, and this training seemed to transfer to other action classes. Secondly, since the action MOUTH is difficult to differentiate from fetching with the mouth or tossing with the mouth, instating this action appeared to have discouraged the conceptual generalization of several other actions by Rocky.

The present results on the extension of action signs learned under somewhat restrictive uses to new uses by sea lions appears similar to Herman's findings with dolphins (Herman, 1980; Herman et al., 1981, December). Both types of marine mammal appear capable, to some degree, of transforming signs, which refer to actions to be taken, into some kind of cognitive representation of the action's outcome. We believe that the differences between Rocky's relatively narrow conceptualization of some action classes and Bucky's broader conceptualization of action classes point to the important role that response shaping plays in the development of cognitive representations.

Objects

During the first stage of training, two tethered objects were positioned on either side and slightly behind the stationed sea lion and could be repositioned after each trial. In order to inform the sea lion that the trainer's gestures signified an object, we differentially reinforced the sea lion's orientation toward one or the other of the two objects in the presence of one or the other of the two gestural signals (BALL and PIPE for Rocky and BAT and RING for Bucky). The movements toward the objects were probably related to the sea lions' earlier experience with gestures designating actions to be taken toward an object.

Thus, for both sea lions, the first two objects were mapped directly onto gestural signs. The paradigm used was a type of conditional reaction or conditional discrimination (Lashley, 1938) analogous to symbolic matching or matching-to-sample procedure (Carter & Werner, 1978) in which the arm and hand gestures are comparable to the sample stimuli which stand for one of the comparison stimuli or objects. As in symbolic matching, the relation between the gesture (sample) and the objects (comparison stimuli) is arbitrary. For all intents and purposes, our conditional discrimination problems, in which there is a different sign for each object, requires the same reinforcement contingencies as does symbolic matching.

With the help of prompting cues at the beginning, which consisted primarily of running blocks of trials with the same sign, both Rocky and Bucky mastered this stage of object naming (attaining 20 consecutive correct responses) in 716 and 802 trials respectively, before each of them was confronted with their first two-sign combination in the syntactical form of Object + Action. Whereas Rocky immediately integrated the Object + Action signs appropriately and perfected her performance ($\geq$ 90% correct responses) after 90 additional trials, Bucky had difficulty integrating Object + Action signs and performed reliably ($\geq$ 85% correct responses) only after he had been given 762 trials.

The initial difference between Rocky and Bucky in the integration of Object + Action signs probably depended on the way each of them oriented to an object after receiving the object sign. Differences in their orienting responses have persisted throughout the experimental series and probably account for Rocky's generally superior learning of what new gestural signals mean and the integration of modifiers into multiple sign constructions. Starting wth the first Object + Action combination, Rocky broke station after being signaled BALL, and turned and faced (pointing her nose) directly towards the ball. She then restationed for the action gesture FLIPPER-TOUCH, and when that signal was transmitted, she immediately swam to the ball and touched it with her flipper. Since she had not, as yet, been trained with the "go" signal and was able to stand on her hind flippers while stationing and orienting, Rocky had a distinct advantage over Bucky in being able to look for an object as soon as a sign was given. Bucky, in contrast, had already been trained with a "go" signal and, having to tread water while stationing, appeared quite constrained in orienting to objects with only relatively slight head turns and eye movements. The "go" signal was not used with Rocky until she had learned several different combinations of objects and actions. The trainers learned to pause between gestures designating objects and those designating actions until cued by Rocky restationing (either by feeling her restation on their toe or hearing an observer call out "now").

After the sea lions learned to associate gestures with objects by differential food reinforcement of orientation responses and subsequent to their learning of Object + Action integrations, new two-sign combinations were introduced to both sea lions without requiring orientation responses. Object + Action combinations were used to introduce a new object name or a new action name. In these instances, the new name was immediately used in a two-sign string together with the suitable old name. If the new name designated an object, it was combined with a familiar action name; if it designated an action, it was combined with a familiar object name.

New object names were introduced by pairing the novel, and as yet, unnamed object with an old, and already named, object. Under these conditions, both sea lions learned to associate or match the unfamiliar gesture with the unfamiliar object quite rapidly. Indeed, depending on the *familiar-unfamiliar* pairing, the match between a novel gesture and a novel object was frequently immediate as reflected by an errorless performance. As the sea lions' comprehension vocabulary of object signs increased, there was a corresponding increase in wholly correct responses during the first training session with new object signs. Action errors rarely occurred during most phases of training, including those occasions when action signs were introduced for the first time. Apparently, experience with this type of symbolic matching paradigm resulted in the sea lions forming a generalization or a learning set related to the association of novel, unusual, or odd gestures with novel, unusual, or odd stimulus configurations.

The very rapid and seemingly "natural" association that our sea lions made between two novel signals (the gesture and the object) leading to food appears quite adaptive for a predatory species. It has been suggested that a "searching image" is the most important factor influencing prey selection and that novelty, in the sense of unusualness or oddity, is perhaps more important than conspicuousness (Mueller, 1971). According to several accounts, odd appearing or odd acting individuals are particularly vulnerable to predators (Errington, 1946). Potential prey by looking and behaving unusually or in a novel fashion (in contrast with other individuals) may be signaling their relative helplessness or lack of vigor as young, old, and sick individuals usually do. Rapid matching of novel signals leading to food thus may be related to the kinds of signal relations that sea lions encounter when attempting to feed at sea.

Generally, poor initial performance in learning new object names seemed to depend on the similarity of the objects. For example, Rocky immediately matched the new gesture BAT with a red plastic bat when given the red ring as an alternative object (8 consecutive correct matches with the signs BAT and RING). When she was confronted next with three object alternatives (bat, ball, and pipe), she matched the appropriate signs to each of these objects in 19 of 21 trials. However, Rocky made three incorrect matches in six trials when the bat was paired with the similar appearing plastic red car (both were the same shade of red, and both had a similar shape). Following errorless performance on eight trials of bat-Clorox pairings and the making of a single error on eight bat-disc pairings, Rocky was returned to the bat-car pairings and matched signs with objects correctly on 9 of 10 consecutive trials after 20 trials and five incorrect matches.

Eventually, as the performances of both sea lions stabilized, as many as eight objects (and five or six actions) were available on a single trial. Soon after object-orientation training was completed, the sea lions began retrieving or fetching the objects between trials without being signaled, and the tethers on the objects were removed.

As was the case earlier with generalization of actions, both sea lions showed some degree of object constancy and object generalization, i.e., symbols were matched to the appropriate objects despite their changed orientation due to wind and wave action and changed appearance due to wear and tear and partial submergence under water. Because of Bucky's tendency to grasp objects with his mouth, sometimes his objects appeared to us to be nearly unrecognizable. Nevertheless, he maintained stable performance with these objects. However, in our formal tests of generalization, we found that some objects which were variants of the standard objects, having the same shape but differing considerably in color or brightness were usually not treated as the equivalent of the standards. For example, although Rocky was matching symbols to standard objects with an accuracy of 95%, when given 18 probe trials in which variants were substituted for standards in four object classes, her matching accuracy fell to 39% for a smaller ball, 67% for a longer pipe, 78% for a white, instead of a red, ring, and 72% for a smaller green Clorox bottle instead of a white standard Clorox bottle. In a similar experiment with Bucky, whose baseline averaged 87% correct responses in matching gestural symbols to standard objects, 20 probe trials resulted in matching accuracies of 10% for a shorter and thinner black pipe in lieu of a longer and fatter white pipe, 95% for a red instead of a white ball, 40% for a red instead of a white ring, 85% for a small rather than a standard Clorox bottle, and 60% for a red rather than a yellow frisbee. These results suggest that both color (brightness) and size were important factors in the classification of most objects by both sea lions.

As the experimental series continued and objects and actions, as well as modifier signals were added, multiple exemplars of objects were used, e.g., balls, pipes, frisbees, rings, etc., of different sizes, colors, and shades of gray. This was done with the aim of facilitating generalization by the sea lions of a symbol from a specific exemplar to a broader object class, i.e., of widening the context of symbolic matching. In the first column of Table 3, the current (through April, 1983) performance levels of both sea lions are shown on test trials of Object + Action strings in which there were at least two exemplars for at least four of the object classes used. The number of objects available on a given trial

Table 3

Percentage of Wholly Correct Responses as a Function of Sign Combinations[a]

	ROCKY			
Sign Combinations	O + A	M(B,W) + O + A	M(B,W,G) + O + A	M(L,S) + O + A
Usual Number of Objects Present	6	6	6	6
Level of Training	Complete	Complete	Complete	In Progress
Trials	854	384	574	294
% Correct	96	90	87	74
	BUCKY			
Sign Combinations	O + A			M(W_a, L_a) + O + A
Usual Number of Objects Present	6			4
Level of Training	Complete			In Progress
Trials	600			280
% Correct	90			86

Types of signals: O = objects, A = actions, and M = modifiers.
Object quality modifiers: B = black, W = white, G = gray, L = large, and S = small.
Object location modifiers: L_a = Land, and W_a = water.
[a] The % correct for a given number of trials is deflated since the sea lions can make as many as three errors on a single trial. Also, it should be noted that except for the modifier training of LAND/WATER for Bucky, at least six objects and five actions were available under all other testing conditions.

ranged from five to eight, but was usually six. Rocky comprehended five action signs and Bucky had six in his repertoire. The percentage of trials on which the sea lions erred included either object or action errors, and if both errors were made, then the percentage of errors was inflated. However, action errors, for both animals usually accounted for less than 10% of total errors on trials in which Object + Action instructions were given.

Our findings that California sea lions not only rapidly learn to symbolically match human arm and hand gestures with objects, but also transfer this performance to novel stimuli, contrast with Constantine's failure to find transfer of the matching performance to novel stimuli by harbor seals (*Phoca vitulina concolor*) in a more conventional three-key matching procedure (Constantine, 1981, December). However, as Constantine points out, when species comparisons are made using complex concept formation tests, results may vary with both the test procedures and as a function of the individual's prior history with the test stimuli. In contrast, comparisons made with Herman's dolphin, Akeakamai, (Herman, 1980; Herman et al., 1981, December), who, like our sea lions, learned to match human gestures with objects, indicate that California sea lions and a bottlenosed dolphin acquire novel symbolic matches very rapidly.

Our sea lion study was modeled after Herman's dolphin study, and neither of these studies were explicitly designed to test some models of conditional learning put forward by Carter and Werner (1978) on the basis of experiments with pigeons. According to Carter and Werner, the model that best describes symbolic matching (as well as other types of conditional discriminations) in pigeons is a multiple-rule model in which pigeons learn a set of sample-specific S^D rules. Supposedly, pigeons do this by making a unique, but unspecified, covert response or "coding event" to each sample stimulus. Then they choose by pecking a comparison stimulus that is dependent upon each unique response emitted during the presence of the sample. Carter and Werner thus make the case, at least for pigeons, that the sample stimulus provides a cue for a chain of behavioral sequences that mediates the choice of comparison stimuli with a different chain for each novel sample (see Blough, 1959 and Epstein & Skinner, 1981). Indeed, experiments do suggest that without pecking the sample key, pigeons have more difficulty in matching the sample with the comparison stimuli (Eckerman, Lanson, & Cumming, 1968). In contrast, neither Herman's dolphin, Akeakamai, nor our sea lions were required to make an overt response comparable to the pigeon's pecking the sample. In fact, the specific behaviors of the sea lions during presentation of the gestural signs were totally unrelated to the response patterns required when acting upon the comparison stimulus objects. Moreover, the sea lion and dolphin results on symbolic matching suggest that conditional discriminations learned by these nonverbal mammals are best described by a single-rule model or strategy which generalizes across changes in specific stimuli, such as has been demonstrated in chimpanzees (Schusterman, 1962). In the present context, the rule might be: "A familiar object which is correct in the presence of a familiar sign is incorrect in the presence of an unfamiliar or novel sign."

Missing Object Experiment

Both sea lions reacted appropriately the first time they were confronted with an Object + Action sequence, combining novel signs about novel objects with signs about familiar actions. An interesting question about signs referring to objects is whether they are transformed into cognitive representations or mental images of the objects or whether response coding occurs when the sea lion orients or, in the case of Rocky, points its snout in the direction of the object. Although there are several ways of asking this question, perhaps the simplest way is to design a Piagetian-like experiment in which the signal for an object is given, but the object is not present. How long will the sea lion actively search for the absent object? Furthermore, when given instructions to act upon an object which is missing, will the sea lion perform the appropriate action on some other available object or will the sea lion refuse to take action following its search and remain at station when given the "go" signal, i.e., will it balk? Earlier work with Rocky, in which she occasionally searched for the signaled object but seemed unable to find it because it was hidden (either behind another object or in a shadowy corner of the tank), indicated that she would spontaneously balk when she could not locate an object. Reinforcement was never provided under such conditions. Thus, a formal experiment with Rocky was designed in which, on any given trial, from five to seven objects were present, but occasionally the blind trainer was instructed to give Rocky gestures referring to an object that was not present in the tank (a "missing-object trial" or probe). Since the tankside person placed the objects into the tank, the blind trainer was unaware that the signals she gave referred to missing objects.

When the missing object experiment was conducted, Rocky's comprehension vocabulary consisted of eight object signs and five action signs. Three to five missing-object trials were superimposed upon sixty baseline trials per session.

Two sessions were run each day with approximately eight probes given every day for a total of 122 probes. Every sign for an object class was combined with an action sign at least three times. Rocky's search pattern following the trainer's sign for an object was timed by means of a stopwatch. An observer started the stopwatch as soon as Rocky lifted her chin from the trainer's toe and started her search, and stopped it when her search was completed and she restationed herself. In addition to the stopwatch measurements, two test sessions (including eight probe trials) were videotaped and, using the "pause" control during playback, the number of video frames were counted during each of Rocky's object searches.

The results of this experiment were very clear-cut. Rocky was wholly correct on 96% of the 854 baseline trials in which she did not balk. She balked on 5% or 46 of the 900 baseline trials, while she balked on 86% of the probe trials (105 balks in 122 probes). Rocky's mean search times on probe trials exceeded her mean search times on baseline trials on each of the 15 days the experiment was conducted ($p < .01$, sign test). Rocky's search times on baseline trials in which she was correct were much shorter ($\bar{X} = 1.4$; $SD = 1.3$) than on probe trials in which she balked ($\bar{X} = 5.0$; $SD = 1.4$), on probe trials in which she "prospected," i.e., acted on nonsignaled object ($\bar{X} = 4.7$; $SD = 1.8$), and on baseline trials in which balked ($\bar{X} = 4.6$; $SD = 1.3$). Her longest search occured on a probe trial on which she balked and lasted 9.5 s.

These results appear difficult to explain in S-R terms and may be interpreted as meaning that sea lions transform visually encoded hand signals into imaginal representations of objects. Roitblat (1982) and Terrace (1982) have recently pointed out that recognizing that animals are capable of encoding the relationships between stimuli not immediately present is but the initial step in studying the complex ways that memory and thinking may occur in some nonverbal animals. In contrast, although Rocky's searching behavior reflects some sort of mental event, the searching is derived from her orientation responses—an attempt to produce a stimulus—and indicates that the solution to the symbolic matches are made considerably easier [as Skinner (1969) has noted] when the stimulus is present. Indeed, Rocky's performance has been consistently superior to Bucky's in symbolic matching and, as pointed out earlier, may be attributed to Rocky's superior orientation to an object immediately following a gestural sign.

Thus far, we have not formally addressed the question of whether the order in which the signs are given is important for maintaining performance levels. However, a few "probe" trials have been presented to Rocky in which either two signs designating different objects preceded the action sign or the action sign preceded the object sign. When given two object signs, Rocky responded to the second object sign (i.e., the one preceding the action sign), and she ignored the first sign designating an object. Reversal of Object + Action constructions has repeatedly resulted in Rocky balking.

Modifiers

A high percentage of wholly correct responses to any one of a number of signals designating a class of objects plus any one of a number of signals referring to a class of actions demonstrated some degree of semantic comprehension of these elements by California sea lions. In addition to Object + Action strings, we have recently been able to teach sea lions that gestural signs that precede signs referring to object and action classes modify the object class referred to. In other words, such modifier signals designate the qualities of an object class such as its size, or color attribute (in shades of gray), or the location of the object. If we place the modifier and the object sign sequence within the context of a conditional discrimination or what has been called higher order sign learning (Riopelle, 1960), then, the correct match may be designated by two successively different signs. For instance, the first sign may designate size (LARGE and SMALL), or color attributes (BLACK, WHITE, and GRAY), or places (WATER and LAND) and the second sign may refer to one of a class of objects (e.g., BALLS, CLOROX BOTTLES, CUBES, RINGS, etc.). The action, which is taken toward a single designated object, is then controlled directly by one sign. Three-sign constructions, including modifiers, that specify objects which are either black, white, gray, large, or small have been learned by Rocky, and modifiers designating either land (the deck around the pool) or water, on which the objects are located, have been learned by Bucky. For example, if there are three different color attributes (black, white, and gray) for each of two different kinds of objects (black, white, and gray discs and black, white, and gray water wings), then WHITE DISC OVER instructs Rocky to go to the *white disc* (and not the *gray* or *black disc,* not the *white water wing*) and jump over it.

Black, white, and gray. Teaching the modifiers BLACK and WHITE to Rocky took 8 weeks of intensive work. BLACK and WHITE were trained in reference to pairs of identical objects of different shades floating on the surface of the water. With the exception of the disc and pipe, all previously "named" objects were used in a variety of paired object combinations (e.g., a pair of black and white water wings and a pair of black and white Clorox bottles) in order to prevent association of the modifier sign with any particular object. Instructions to Rocky frequently took the form of a three-sign string, such as BLACK BALL FLIPPER-TOUCH. The two principal cueing techniques used were to spatially segregate the black and white objects floating in the tank and to run blocks of trials (sometimes as many as 10 consecutive trials) of either all BLACK or all WHITE. The block size was reduced as preselected performance criteria occurred until finally relatively random sequences of BLACK and WHITE trials replaced blocks of BLACK and WHITE trials, and black and white objects floating in the tank were no longer segregated, but were randomly spaced throughout the tank.

It became immediately apparent during the first training session that Rocky had previously been coding some objects primarily in terms of their brightness characteristics. For example, she was immediately successful in matching BLACK, but not WHITE, to the formerly red bat and orange water wing (all sets of objects were painted white and black), and she was equally successful in matching WHITE, but not BLACK, to the formerly yellow ball, the white pipe, and white Clorox bottle. Apparently, Rocky's discriminative behavior was initially controlled by the signs for objects and by the brightness values of the objects themselves, and not by the gestural signs for BLACK and WHITE. However, about halfway through the first training session, she began attending to the modifier signs, but appeared to have difficulty integrating Modifer + Object signs. As expected, the previously learned object signals took precedence over the modifier signals. Thus, if cars and bats were floating in the tank and

Rocky was signaled BLACK CAR FETCH, she was more likely to retrieve either the white or black car than the black ball. On some trials, two-sign strings consisting of a modifier and an action (omitting the object sign) were given, and Rocky usually performed the correct action on either the closest appropriately shaded object or an appropriately shaded object for which she had a preference, but which was located some distance from her station. There trails indicated that although Rocky's behavior was under the control of the color signals, it was not at this stage of training controlled by the combined color-object signals.

During a later stage of learning the three-sign construction of BLACK and WHITE modifiers, objects, and actions, Rocky frequently turned her head and oriented to one of the correctly colored objects as soon as she was instructed with the modifier signal (further evidence that her behavior was indeed controlled by both BLACK and WHITE signs). Then she repositioned herself to receive the object signal. Following reception of the object signal, Rocky frequently turned her head (see Figure 2) and repeatedly looked back and forth between the two different shades of the appropriate object (virtually ignoring the inappropriate objects). During this stage of learning, Rocky usually chose to perform the signaled action on the object that appeared (to us at least) to be most easily recognized (e.g., an upright car oriented 90° in the median plane compared to an upside down car oriented 0° in the median plane). Once Rocky learned to ignore the contextual cues related to object orientation, even with three different types of objects colored black and white, her performance soared and eventually stabilized at better than 85% wholly correct responses (see Table 3). Approximately 90% of the total errors were modifier errors; 9% were object errors and less than 1% were action errors. More than one type of error on a single trial was uncommon and accounted for less than 10% of all those trials on which errors were made. Transfer of BLACK and WHITE signals to the previously "named" pipe and disc was almost immediate and persistent even though these objects had not served as exemplars during the previous training of BLACK and WHITE.

The modifier signal GRAY was added to Rocky's symbolic repertoire in a single training session with no effort made to cue Rocky by running especially long blocks of GRAY, WHITE, or BLACK trials or segregating objects in the tank. Initially, three small balls colored black, white, or gray were used. As soon as the novel signal GRAY was presented, Rocky turned and looked at the gray ball before restationing to receive the object sign. Within a few trials, she was performing actions on the gray ball when instructed to do so just as she had been doing with the BLACK and WHITE signs. After Rocky learned to match the sign GRAY to one of three shades of small balls, she transferred immediately to a single set of three shades of large balls and three shades of Clorox bottles. Combining three shades of Clorox bottles with three shades of either small or large balls in Rocky's tank resulted in nearly 100% transfer by Rocky to such three-sign strings as GRAY BALL FLIPPER-TOUCH or GRAY CLOROX BOTTLE FLIPPER-TOUCH, etc. Transfer with three-sign constructions of the newly acquired modifier GRAY to all previously named objects has yielded between 70 to 90% correct responses.

Currently, in the context of what we call "color attribute trials" in which Rocky is given two different types of objects (e.g., balls and cubes) varying over three shades of color (black, white, and gray) for a total of six objects floating in her pool, she gives 87% wholly correct responses (see Table 3). The vast majority of Rocky's errors (consisting of 85% of her total errors) are related to color, and over 80% of these have been symbolic mismatches of gray and white. Object errors accounted for 14% of Rocky's total errors and action errors account for less than 1%.

Rocky's current strategy is to make what appears to be a perfunctory head orientation when the color modifier gesture is transmitted. Immediately upon reception of the object sign, she then checks out the designated class of objects (ignoring the irrelevant types of objects) by looking back and forth, either between *gray* and *white* objects of the same type or *gray* and *black* objects of the same type, before restationing herself to receive the action sign. Exceptions to this strategy occurred when the classes of objects available had a similar appearance, such as a small football and a small round ball or a small Clorox bottle and a regular-sized football. Under these conditions, Rocky sometimes looked back and forth between the similar appearing different object types. Thus, Rocky seems to maintain a memory trace for the color attribute and integrates it with the mental image of the object before she uses her fully integrated search image during the matching process.

Large and small. The exemplars for the size modifiers were balls, Clorox bottles, cubes, and footballs. In training Rocky on size modifiers, we took advantage of the sea lion's apparent tendency to associate or match novel gestural signs with novel stimulus configurations leading to food. In addition, we incorporated within the training design the experimental finding from such diverse species as canaries, domestic cats, and chimpanzees, that an odd element from a given stimulus dimension or category, such as size, stands out perceptually from the others (see Riopelle, 1960, for a review). We benefited from this oddity preference (within the size or volume category) because the types of objects used had already been named or gesturally labeled so that when three objects were available (large and small objects of one class or type and a single large or small object of another type), the odd-sized object "stood out" and the odd type of object, not being signaled, was unlikely to be responded to. Thus, for example, if the novel gesture for LARGE preceded the familiar sign for BALL, and there was a small white ball, a small white football (two small objects), and a large white ball (the *odd-sized* large object) available, then an appropriate action toward the large ball or odd-sized object was correct. If the novel gesture for SMALL preceded the familiar sign FOOTBALL, and there was a large white football, a large white Clorox bottle (two large objects), and a small white football (the odd-sized small object) available, then an appropriate action toward the small football or odd-sized object was correct. With this type of regimen, i.e., size oddity as the major prompting cue, Rocky began to "symbol" match almost immediately (70% correct responses). When Rocky's performance reached the 80% correct response level (after 10 training sessions), the odd-sized cue was eliminated and a single pair of objects was made available (e.g., large and small white Clorox bottles). Transfer to this problem resulted in perfect scores (better than 90% correct responses) for all types of objects (balls, Clorox bottles, cubes, and footballs) despite a random sequence of LARGE and SMALL signs. When objects differed with regard to both size and object class (large and small white balls and large and small white cubes), Rocky's performance dropped to about

65% correct responses, suggesting she had not completely integrated the size modifier and the object modifier. Her performance on the cubes was particularly poor and may be accounted for by the fact that these objects were constructed from PVC pipe and lacked the surface area of the balls, Clorox bottles, and footballs.

Although Rocky's training with size modifiers is still continuing, she currently incorporates modifiers in her comprehension of three-sign constructions with a proficiency level of 74% wholly correct responses (see Table 3). In the sample of trials analyzed, 79% of all errors were modifier errors, 21% were object errors, and Rocky made no action errors. Rocky's typical orientation responses following each gestural symbol in the size task have been similar to those described for the color attribute task. She made a relatively small, almost perfunctory, head movement following the sign for size, and after the object sign was given, she looked primarily at the appropriate objects (ignoring the inappropriate ones if the object classes were distinctly different from one another) until she made her decision as to which was the correct size. Thus, it appeared that Rocky used the same kind of strategy in processing the *size* attribute Modifier + Object + Action sequence as she did in processing the *color* attribute Modifier + Object + Action sequence.

Land and water. Bucky learned to integrate LAND/WATER modifier signs with object and action signs within 1 week of training (about 75% wholly correct responses). As in teaching Rocky the modifiers related to the color and size attributes of the objects, the modifiers LAND and WATER were taught to Bucky in relation to two pairs of identical objects. In this case, however, each member of a pair was placed either on the surface of the water or on the deck and the cement rim surrounding the tank (see Figure 4). The actions performed were fetching, touching with the "tail" or flipper, and tossing. The objects were bats, Frisbees, Clorox bottles, and pipes. Directions to Bucky took the form of a three-sign construction such as LAND PIPE TAIL-TOUCH [glossed as "go to the pipe on land (i.e., on the deck or the cement rim around the tank) and not the pipe on the water and touch it with the posterior portion of your body"]. Although the sign LAND originally designated the deck area from where the trainer sometimes transmitted signals (see Figure 4), after Bucky integrated the LAND/WATER modifier signs with the object signs, "land" objects were placed anywhere around the rim of the tank where Bucky could see them by lifting his head up from the water. Thus far, the modifier LAND refers to objects around Bucky's tank and no attempt has been made to determine whether Bucky's concept of "land" would transfer to other pools and tanks.

Table 3 shows that Bucky is currently performing at the level of 86% wholly correct responses with three-sign strings including LAND/WATER modifiers when two pairs of objects are available. Like Rocky, Bucky makes more modifier errors than object errors. Modifier errors account for 70% of Bucky's total errors, whereas object errors account for 25% and action errors make up the rest.

Summary and Conclusions

Two California sea lions (a 6-year-old female, Rocky, and a 3-year-old male, Bucky) were trained in a symbolic matching paradigm. Gestural signs produced by movements of the trainer's arms and hands referred to types of *objects, modifiers,* and *actions.* Object signs designated different sizes and colors of pipes, balls, rings, Clorox bottles, Frisbees, etc. Modifier signs designated qualities or attributes of the objects related to size (large and small) and color (black, white, and gray) or location (land and water). Action signs designated actions to be taken toward the objects (e.g., mouthing the pipe or the ball or placing the flipper on the pipe or the ball). Both sea lions were trained with three-sign constructions consisting of Modifier + Object + Action in that order. Rocky's modifiers consisted of size and color attributes, and Bucky's modifiers consisted of different locations of the objects.

After 24 months of training, Rocky had a comprehension vocabulary of 20 signs (5 modifiers + 10 objects + 5 actions), and after 20 months of training, Bucky had a comprehension vocabulary of 16 signs (2 modifiers + 8 objects + 6 actions). True semantic comprehension is considered to be demonstrated if an organism can follow directions when each sign is contrasted with every other in a series of instructions (Premack, 1976). Currently, Rocky's semantic comprehension consists of 190 three-sign combinations, and Bucky's semantic comprehension consists of 64 three-sign combinations. In terms of the amount of training time necessary for semantic comprehension to occur, California sea lions compare favorably to bottlenosed dolphins (Herman, 1980).

Premack (1983) has recently evolved a comparative hypothesis suggesting a qualitative difference between the cognitive mechanisms of primates and nonprimates. Primates are considered to have the potential of abstract representation, while nonprimates have only an imaginal or pictorial representation. Premack suggests that simultaneous same/different matches require abstract representation and are, therefore, beyond the abilities of nonprimates or non-language-trained apes. By teaching California sea lions modifier signs for SAME and DIFFERENT, several implications of Premack's comparative hypothesis regarding abstract and imaginal codes may be tested.

Finally, it should be noted that there are several ways of approaching and operationally defining an animal's capacity for symbolization and semantic comprehension (e.g., compare Premack, 1976, with Savage-Rumbaugh, 1981). Our approach with California sea lions indicates that they are able to learn to comprehend symbols using methods similar to those that have been used with pigeons. California sea lions are also able to learn to comprehend a variety of combinations of symbols, i.e., they are capable of semantic comprehension, in ways which are similar to bottlenosed dolphins. Although we have not, as yet, demonstrated contextually-free semantic comprehension in our sea lions in the same way as Savage-Rumbaugh (1981) has done with chimpanzees, our sea lions show a fair degree of generalized semanticity as demonstrated by comprehension of signs referring to relatively broad categories of types of objects, colors, sizes, and locations and by Rocky's reactions to signs referring to objects not present.

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