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Artificial Language Comprehension and Size Transposition by a California Sea Lion (*Zalophus californianus*)

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A variation of the conditional discrimination procedure defines relations between stimuli (for example, gestural signs and their referents), and it has been used to study language comprehension in California sea lions. The animals followed instructions given by a trainer's gestures designating properties of size, brightness, and location (*adjectives*), types of objects (*nouns*), and actions (*verbs*). The signs can be combined and recombined according to a conditional sequence or syntax. In this study, we sought to determine whether adjectives for size had an absolute meaning, that is, small and large, as well as a comparative meaning, that is, smaller and larger. A sea lion, Rocky, was given experience with signs designating standard small and large spheres in commands like LARGE BALL MOUTH. On transposition tests, the small ball was removed and the previously designated large ball was paired with an even larger one. The results showed that the adjectives had both an absolute and a relative meaning. Object choices and searching behavior revealed that the sea lion processed information about the relation of size as well as about the specific characteristics of the sizes of spheres that instantiated the relations.

Gestalt psychologists and early cognitivists interpreted transfer to stimulus values outside the particular range of the dimension (e.g., size or brightness) on which an animal was trained as evidence that animals respond to stimulus relations rather than to specific stimulus values (Kluver, 1933; Kohler, 1918/1939). This was regarded as analogous to the way people (and perhaps bottlenosed dolphins as well; see Richards, 1986) transpose a melody from one key to another, and the transposition phenomenon was considered a critical refutation of the conditioning of specific stimulus–response (S–R) pairs. However, in 1937, it was shown that transposition could be explained by broadening S–R theory's basic mechanisms of habit and inhibition to include notions of stimulus generalization gradients (Spence, 1937; see Reese, 1968, and Riley, 1968, for thorough discussions of relational learning in animals). More recent research into selective attention and specific searching images has again suggested a more cognitive interpretation of the transposition phenomenon (Dawkins, 1971; Lawrence & DeRivera, 1954; Schusterman, 1967; Sutherland & Mackintosh, 1971).

In this article, we report on size transposition by a California sea lion (*Zalophus californianus*), named Rocky, which had previously learned that different arm/hand gestures by a blindfolded trainer designated different sizes, brightnesses, and shapes of objects (Schusterman & Krieger, 1984). On transfer test trials, a small ball was removed and the previously designated large ball was paired with an even larger one. Especially long search time following the gestural sequence SMALL BALL + an action sign was hypothesized to reflect the sea lion's coding for the absolute characteristic of size, whereas accuracy of judgments was hypothesized to reflect its coding about the relational or conceptual attribute of size (Premack, 1978).

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Artificial Language Comprehension

Recently, the conditional discrimination model—"if A1, then B1 or if A2 then B2"—has proven useful in the comparative analysis of animal cognition and language learning (Burdyn & Thomas, 1984; Carter & Werner, 1978; D'Amato & Salmon, 1984; Schusterman & Krieger, 1984; Sidman & Tailby, 1982). Since under moderately high lighting conditions, sea lions have relatively good visual acuity in air (Schusterman, 1972), we were able to use a visual form of the conditional discrimination paradigm to teach 2 sea lions that either one, two, or three gestural signs, given sequentially by a blindfolded trainer, designated a specific object from among an array of as many as 10 objects. The objects floated on the surface of the water some distance (between about 1 and 5 m) from the searching animal. The last signal given controlled the type of action the sea lion was to perform on the designated object (i.e., designated by the conditional arm/hand gestures). The four-sign sequence SMALL BLACK BALL FLIPPER TOUCH is analogous to a four-word imperative sentence or command, meaning "go over to the small black ball (and not the small, white ball, or the large, black and white balls, or the small, black and white Clorox bottles, etc.) and touch it with your flipper."

Within about 2.5 years, 1 sea lion (Rocky) comprehended 11 signs designating objects (balls, cubes, pipes, Clorox bottles, etc.), 5 signs called *modifiers*, or *adjectives*, designating object properties (size and brightness), and 6 signs controlling different actions. Rocky understood combinational sequences of signals (even novel ones) with as many as 504 different meanings (Schusterman, Krieger, & Johnson, 1983). Currently, Rocky can be signaled to transport or "fetch" the second designated object over to the first designated object, thereby increasing her comprehension repertoire of uniquely meaningful "sentences" to literally thousands with a potential sentence length of 7 signs (Schusterman, 1986). An example might be the command, SMALL BLACK CUBE—LARGE WHITE BALL FETCH, which is glossed as "go to the large white ball (and not any of the other objects) and take it to the small black cube (and not any of the other objects including the signaler)." Details of such sentence comprehension may be found in the artificial language study of bottlenosed dolphins (*Tursiops truncatus*) recently conducted by Herman, Wolz, and Richards (1984).

In a study of object permanence (Schusterman & Krieger, 1984), Rocky was given signs for objects that were hidden or absent from the array of objects. Such trials resulted in prolonged searches before Rocky returned to station. Usually, searching time was spent looking at objects of a specific shape, brightness, and size, and the sea lion frequently showed a tendency to spontaneously balk when the signaled object was not found. Such behavioral patterns led us to believe that California sea lions transform signals into representations of objects. Suggestions that carnivore cognitive organizations may be on the verge of being representative further prompted us to conduct a transposition experiment within the conceptual framework of "object permanence" (Etienne, 1984).

We believe that conceptually and methodologically, this study with Rocky was unlike other transposition experiments in the following significant ways: (a) Rocky had already acquired a size concept prior to the present transposition study. The concept seemed to be related to both the volume and height of objects (e.g., balls, Clorox bottles, inverted cones, cubes, and footballs) and independent of a wide variety of shapes and brightnesses. (b) Because the procedure for testing transposition depended on a series of conditional discriminations, the standard large ball (when it was paired with the standard small ball) could be designated SMALL BALL when it was re-paired with an even larger ball on size transposition test trials. (c) It was assumed that sea lions, as well as many other vertebrate species, are capable of learning, more or less concurrently, about stimulus relations and about the specific values that instantiate those relations (see Hulse & Cynx, 1985, for recent evidence that some songbirds process acoustic patterns both absolutely and relationally) and that measuring latencies should demonstrate the learning of both factors (Premack, 1978).

Method

Subject, Apparatus, and Procedure

At the time the experiment was conducted, Rocky was about 10 years old. Details of the general methodology and testing situation have already been published (Schusterman & Krieger, 1984). Suffice it to say that the testing pool was rectangular in shape, 3.5 m wide and 11.1 m long, with a water level of 1.2 m.

Throughout the course of the study, two blindfolded student trainers without knowledge of the transpositional phenomenon took turns signaling Rocky. The trainer made gestural signs seated at the edge of the pool, and the sea lion was stationed with its chin on the toe of the trainer (see Figures 1, 2, and 3). When a sign designated an object, the sea lion always initiated a search pattern by lifting her head from station and looking at objects floating in the pool. Searches ended when the animal restationed in order to receive the action sign (e.g. see Panel C in Figure 1, and Panel N in Figure 3). After the trainer dropped his or her foot (a *go* signal), the animal left station and usually swam in the direction of the object to which it had last oriented, and then it performed the signaled action (see each of last panels in Figures 1, 2, and 3). Counting video frames during a search served as a measure of the latency period between when the sea lion responded to the initial elements of the sign BALL until the time it made an object choice followed immediately by restationing.

Over a period of 6 weeks, which included 25 baseline training sessions of at least 60 trials each, there were 14 sets of four probe trials (these included 7 sets with different size white balls and 7 sets with different size black balls) superimposed on the baseline. Baseline trials always involved from four to eight objects in the pool, and during probes, there were always a pair of either white or black balls and two other objects (e.g., large and small black Clorox bottles or a white and a black cube, etc.). Probes and baseline trials were alike in all other respects. One half of the set of probes was considered as a control in which the gestural signs SMALL and LARGE were given in the presence of the different sizes (in circumference) of the standard balls (*small* = 34 cm and *large* = 71 cm). The other half set of the probes was the transposition or transfer tests in which the gestural signs SMALL and LARGE were given in the presence of the test balls [*small* = 71 cm,, and *large* = 105 cm (white) or 115 cm (black)]. Standard or control trials and transposition trials were similar in all respects except that the standard small ball (34 cm) was replaced by the largest ball (105 or 115 cm) and differential reinforcement was not used on transposition trials—that is, responses to either ball were reinforced. In order to ensure that the sea lion saw both balls simultaneously, during probe sets, the balls were placed no more than about a meter apart and at a distance of from 2 to 3 m from the sea lion's position.

During baseline only, the standard balls were used as exemplars for the three-sign sequences SMALL BALL + Action and LARGE BALL + Action, but all three different-size balls (including test balls) were used as single exemplars for the two-sign sequence BALL + Action (see Table 1 for the number of trials given for each ball size). This was done in order to be sure that the test or largest balls were accepted, or perceived, or conceptualized as balls, and because sea lions tend to avoid very large spherical looking objects (Schusterman, Rice, & Kellogg, 1965). By giving Rocky experience with the largest spheres, it was assumed that such avoidance reactions would be minimized during tests of transposition. Until the first transposition test, the largest ball had never been paired with the standard large ball, and Rocky had never been given the size gestures SMALL and LARGE in the presence of these balls.

It should be emphasized that extreme care was taken to minimize any type of cue or event that would differentiate transpositional testing from control trials and baseline trials, or to allow transpositional trials to, in some fashion, be conditional on special features that were not also encompassed in control and baseline trials. These included: (a) Some baseline trials in which only four objects were in the pool including balls of different size, (b) baseline trials in which balls were placed relatively close to one another, (c) randomizing and balancing the sequence of the signs SMALL or LARGE + BALL during

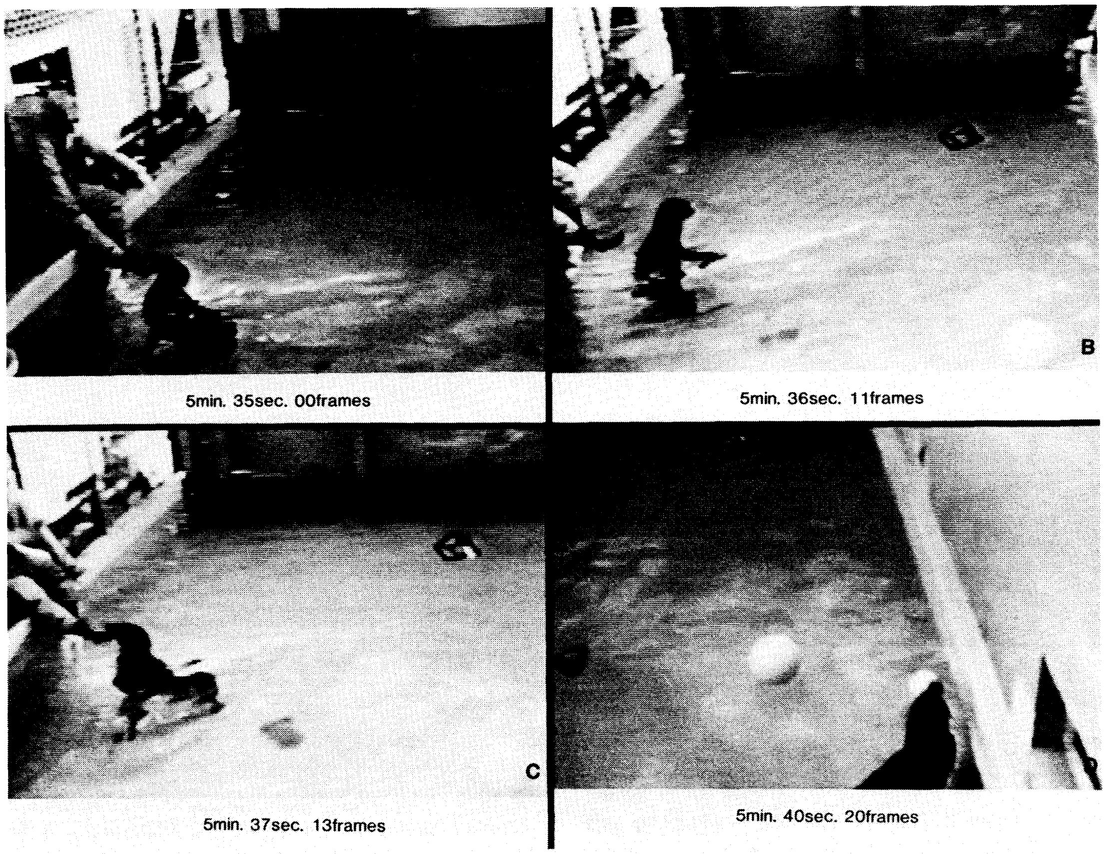

Figure 1. Videotape frames showing Rocky's performance during a control probe with standard-size small and large balls. (A: At station receiving blindfolded trainer's sign SMALL; B: Orienting toward the standard small ball after having received signs SMALL + BALL; C: Restationed and receiving OVER sign; D: Porpoising over the standard-size small ball. Those are 20 frames per 0.1 s. Note large cube in upper left-hand corner of pool [in the shadows] and the small cube in the upper right-hand area of the pool.)

probe trials, and (d) placing the balls in different relative positions within the pool.

In Table 1 we list the ball sizes used in each of the conditions of the experiment along with each type of command given.

Results

Table 1 summarizes the sea lion's performance in terms of correct responses and transposition responses on baseline trials, on control probe trials with standard-size small and large balls, and on transposition tests with the standard large ball paired with an even larger ball (replacing the standard small ball). The first noteworthy point is that Rocky committed only two errors in 68 baseline trials in which she was given three-sign constructions referring to different sized balls. This suggests that at least in regard to correct responses, transposition trials had no appreciable effect on baseline performance. We should point out that throughout the 6 weeks of baseline trials, Rocky's overall performance was quite impressive. On 2,500 trials, performance levels were 94, 82.5, and 90% wholly correct responses for two-, three-, and four-sign constructions, respectfully. Object errors accounted for 25% of total errors, actions accounted for less than 1%, and modifier errors accounted for all the rest. Rarely was there more than one error per instruction, even when double modifiers were used in four-sign constructions like SMALL WHITE FOOTBALL OVER.

The most noteworthy point in Table 1 is that on 13 of 14 sets of transposition probes (i.e., on 27 of 28 total trials) in which the sign BALL was preceded either by the signs SMALL or LARGE, Rocky performed the appropriately signed action to either the smaller or larger of the two balls regardless of their absolute size. Thus, when the sequence SMALL BALL + Action was given, Rocky responded to the standard large ball on all 14 occasions,, and when the sequence LARGE BALL + Action was given, she responded on 13 of 14 occasions to the newly introduced larger ball ($ps < .01$; binomial tests). The single nonrelational response occurred on the second transpositional set when she responded to the standard large ball (the smaller of the two balls).

In Figure 4, mean latencies indicative of the sea lion's searching time to find an object (i.e., the time immediately following the reception of the BALL signal until the time of restationing to receive the action signal) are compared under standard or control conditions and under conditions of trans-

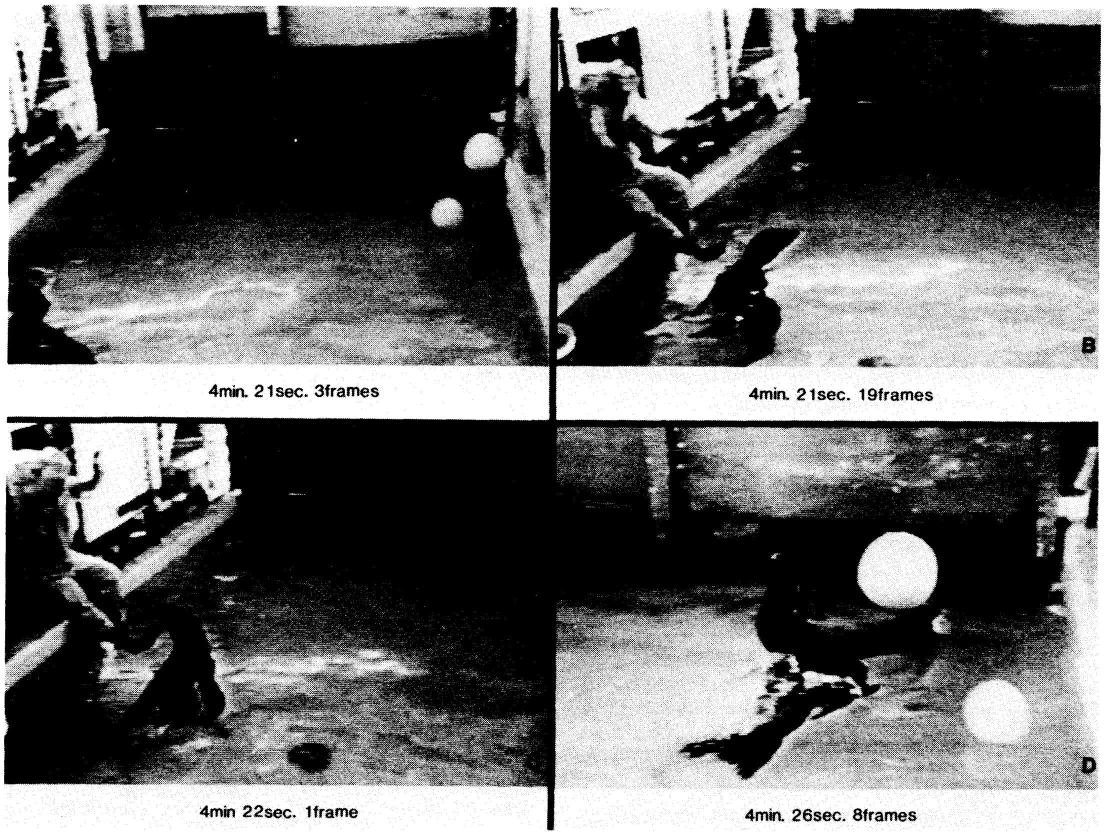

Figure 2. Videotape frames of Rocky's performance during a transposition test with the standard-size large ball and the larger test ball. (A: At station and about to receive BALL sign following previously given LARGE or LARGER sign; B: Orienting to the larger ball while blindfolded trainer was still gesturing; C: Returning to station as trainer's gesturing continued; D: Touching the large test ball with her flipper.)

position testing. Removing the standard small ball and replacing it with the largest ball had a profound effect on the sea lion's searching time. Although mean search times for the standard small and large balls were very similar—283 frames and 292 frames (about 20 frames/tenth of a second), respectively, or about 1.4 and 1.5 s, those mean search times for the smaller and larger balls during transposition (the single failed transposition test set is not included in the tabulations shown in Figure 5) were very different—1,108 frames and 192 frames, respectively, or about 5.5 and 1.0 s ($p < .01$; sign test). Searches for the smaller ball during transposition were significantly longer than searches for either the small or large ball under standard conditions or control tests ($ps < .01$; sign tests). The longest search time under these conditions was about 14.5 s, and the shortest was about 3.5 s. However, mean search times for the larger ball during transposition tests were surprisingly shorter than searches for the small ball ($p < .10$; sign test) and the large ball ($p < .05$; sign test) during standard probes.

Rocky's performance during a typical standard or control trial (in this case to the gestural sequence SMALL BALL OVER) is shown in Figure 1 in frames from the videotape. It can be seen that she turned and oriented toward both balls (Panel B) immediately upon receiving the gestural sign BALL and then quickly restationed, got the action signal, and porpoised over the standard small ball (Panel D). In Figure 2, the pictures from the videotape tell a similar story when the gestures LARGE or LARGER BALL FLIPPER TOUCH were given during a transposition trial.

Frames from the videotape shown in Figures 1 and 2 may be compared with those shown in Figure 3. Here Rocky was signaled to respond to the small or smaller of the two balls on a transposition trial (Panel A), and her orientations were quite different from those seen in the previous figures. Panel B shows that Rocky first oriented toward both the standard large ball and the larger ball. As shown in Panels C and D, the sea lion followed this by searching the other end of the pool (where two different-size Clorox bottles were afloat). Panel E shows that Rocky again looked at the balls, and in Panel F, she turned and looked toward the far left-hand corner of the pool. This was followed by another look at the balls (Panel G) and then again at the Clorox bottles (Panels H and I). Rocky next looked at the standard large ball intently (Panel J), followed by an orientation to the larger ball (Panel K). After another search of the other end of the pool (Panel L), she reoriented to the standard large ball (intently looking at it and the larger ball for about 2 s). After a final orientation to the standard large ball (i.e., the smaller of the two balls), Rocky restationed (Panel N) and received the action sign UNDER. In Panel O, the sea lion is shown going under and

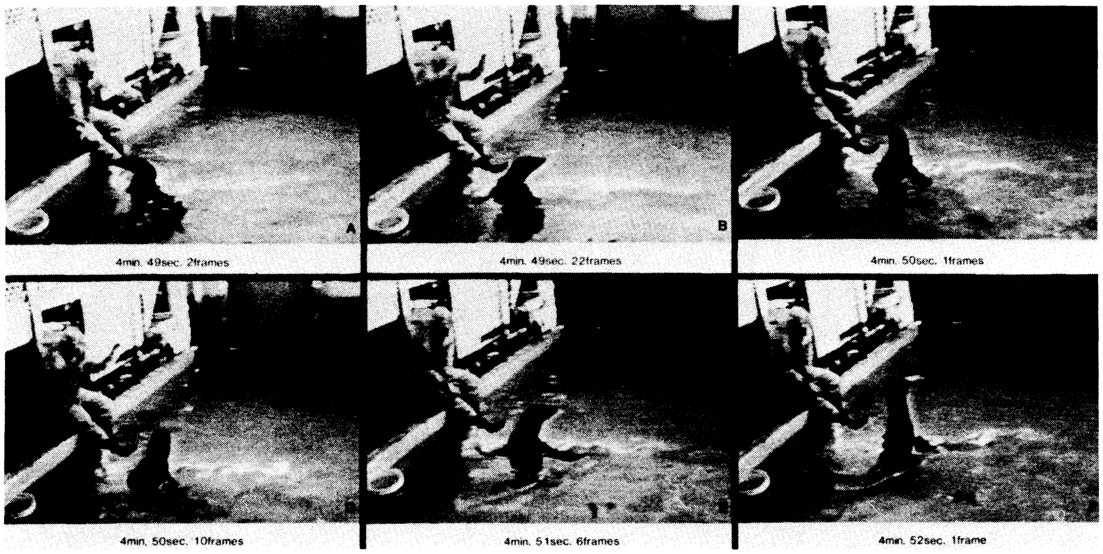

Figure 3. Videotape frames of Rocky's performance during a transposition test with standard-size large ball and the larger test ball. (The standard-size small was absent. **A**: At station receiving trainer's gestural sign SMALL, 4 min 49 s, 2 frames; **B**: Orienting to both balls immediately following the BALL sign, 4 min 49 s, 22 frames; **C**: 4 min 50 s, 1 frame; **D**: 4 min 50 s, 10 frames; **E**: 4 min 51 s, 6 frames; **F**: 4 min 52 s, 1 frame;

touching the smaller ball. Altogether on this trial, part of Rocky's fourth transposition test in which the gestures SMALL or SMALLER BALL + Action were given, the sea lion looked at each area of the pool on at least four different occasions with most of her time spent looking at the standard large ball. Although Rocky displayed shorter search times than that depicted in Figure 3, the general pattern of the searches was similar for all such transposition trials.

Discussion

We have confirmed the hypothesis that on a size transposition test, the latency and subsequent judgment concerning the attributes of an object no longer present would reflect something about a sea lion's cognitive manipulation of percepts and memories or, in short, its thoughts about the specific attributes as well as about the relations exemplified by those attributes. The hypothesis was derived from ideas first put forward by Premack (1978), and it concerned the nature of symbolic learning by chimpanzees about stimulus relations and about particular instances reflecting those relations.

We think it is ironic that although S–R theory might have difficulty accounting for Rocky's prolonged searches in the absence of the standard small ball, that is, looking for the specifically designated object, the sea lion's subsequent relational reaction to the standard large ball is in accordance with Spence's original discrimination learning theory (Spence, 1937). To be more precise on this point, we believe that Spence (1937), on the basis of generalization gradients generated by spherical objects of a specific size, would have predicted that once Rocky made visual contact with both spheres, she should have merely looked back and forth between them before choosing the smaller of the two. In fact, this prediction was not upheld. Instead, on all 14 test trials when the sequence SMALL BALL + Action was given, after visual contact with the balls was made (usually within about 1 s of Rocky's initial orientation to them), she invariably continued searching around the pool several times before finally resorting to the strategy that we think would have been favored by Spence (1937). The irony is that within this context, searching for the absolute characteristics of an object is best described cognitively whereas the relational choice can readily be explained in terms of a 50-year-old behavioral theory.

As suggested previously (Schusterman & Krieger, 1984), we view results as indicating that sea lions are capable of transforming the integrated gestural signs referencing the size, brightness, and shape of objects into mental representations of those objects. Our latency data on transposition trials in which Rocky was signaled to react to the missing *small* ball and ultimately reacted to the *smaller* ball is reminiscent of the mental chronometry demonstrated by humans trying to decide whether the same shapes in different orientations match one another (Shepard & Metzler, 1971). We believe that the results obtained with the disappearance of the small ball show that sea lions initially use a specific search image and then modify that image so as to be able to respond to the relations or comparisons of values within a given dimension.

On the other hand, the brief orientation latencies preceding the sea lion's relational choices of the larger balls are not consistent with Premack's (1978) earlier suggestion. These results may be accounted for by several factors, some of which have a noncognitive motif, and are, therefore, not entirely consistent with the cognitive interpretations of the latency data obtained within the object permanence framework.

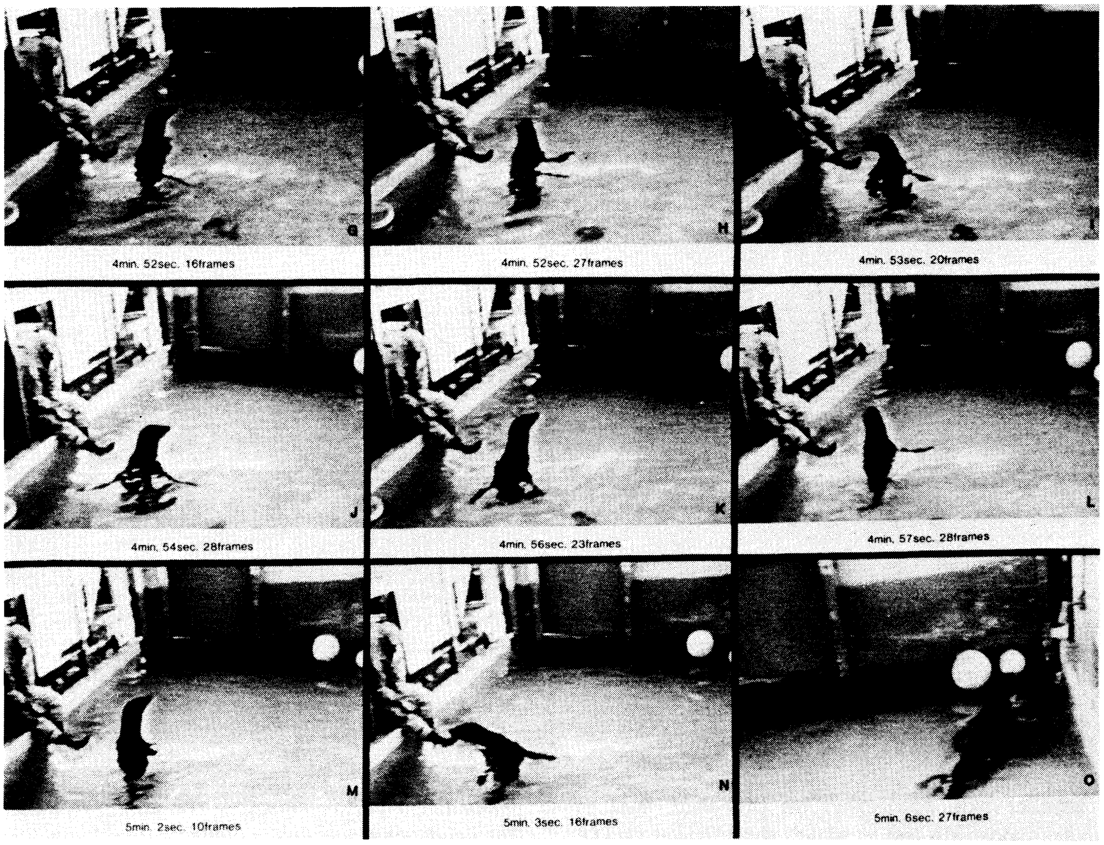

Figure 3 (*continued*). **G**: 4 min 52 s, 16 frames; **H**: 4 min 52 s, 27 frames; **I**: 4 min 53 s, 20 frames; **J**: 4 min 54 s, 28 frames; **K**: 4 min 56 s, 23 frames; **L**: 4 min 57 s, 28 frames; **M**: 5 min 2 s, 10 frames; **N**: 5 min 3 s, 16 frames; **O**: 5 min 6 s, 27 frames. Note the position of the trainer's hands in Panels E through N. This is the starting as well as the terminal position for the gestural sign BALL. As soon as the trainer's hands approximated this position, Rocky began her orienting behavior.)

First, from a psychophysical standpoint, we would point out that the standard small balls (34 cm) were less than half (48%) the size of the standard large balls (71 cm), which in turn were much more than half (62–68%) the size of the largest test balls (105 and 115 cm). Thus size generalization by Rocky should have been greater from the 71-cm balls to the 105- and 115-cm balls than from the 71-cm balls to the 34-cm balls. Second, the largest balls, being so bulky, were probably more conspicuous and thus drew Rocky's attention more rapidly than any of the other objects in the pool,

Table 1
Performance of California Sea Lion Rocky on Baseline, Standard Probes, and Transposition Tests

Ball size (circumference in cm)	Type of command	No. of trials	Baseline performance: Correct responses	Standard or control probes: Correct responses	Transposition Tests: Transposition responses	Percent correct or percent transposition
34	BALL + Action	16	15	—	—	94
71	BALL + Action	18	18	—	—	100
105 or 115	BALL + Action	16	15	—	—	94
34	SMALL + BALL + Action	36	35	—	—	97
71	LARGE + BALL + Action	32	31	—	—	97
34	SMALL + BALL + Action	14	—	14	—	100
71	LARGE + BALL + Action	14	—	14	—	100
71	SMALLER + BALL + Action	14	—	—	14	100
105 or 115	LARGER + BALL + Action	14	—	—	13	93

Note. The first three rows show baseline performance levels with each of the three different-size balls, that is, standard and test balls when instructions *excluded* size modifiers. The next two rows show baseline performance with standard balls when instructions *included* size modifiers. The final four rows include performance levels first on standard probes and then on transposition tests.

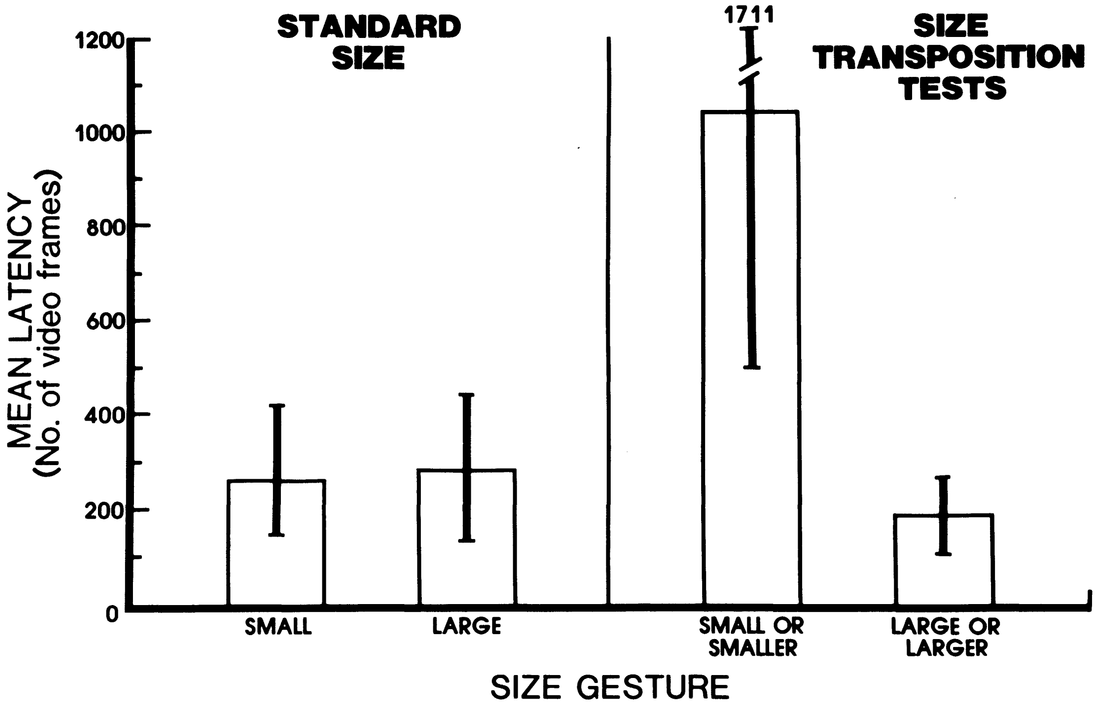

Figure 4. Rocky's mean latencies in number of video frames as a function of ball sizes, pairings, and correlated gestural signs.

including the standard large ball. Along these lines, we have strong anecdotal evidence suggesting that Rocky, as well as other California sea lions in our artificial language comprehension program, tries to remember where objects are located either as they are thrown into the pool or on the basis of active searches during previous trials. Thus, on any given trial, before conducting an active environmental search, sea lions attempt to keep track of the location of objects by either passively seeing where the objects land, by more actively orienting to objects as they are placed in the pool (see Herman & Forestell, 1985, for a description of this type of "memory strategy" by a bottlenosed dolphin), or by remembering object locations from previous trials. In the case of the large test ball, Rocky was observed to watch actively where it was placed in the pool. Evidence supporting the notion that among several factors, it was the conspicuousness of the large test balls, as well as memory strategies, which resulted in short orientation latencies following the three-sign construction LARGE BALL + Action, comes from the finding that on 10 of 14 such test trials, Rocky looked either primarily or solely at the larger ball (i.e., either she made a very brief comparison between the balls or she made none at all). This further suggests that when Rocky transposed the LARGE sign to mean LARGER, her judgment was frequently made prior to being signaled, that is, in anticipation of the gestural sequence LARGE BALL + Action.

The brief searches preceding Rocky's relational choices of the larger balls can also be interpreted within an S–R theoretical framework (Spence, 1937). According to the theory, Rocky's previous reinforcement history would have generated generalization gradients of inhibition and excitation. These would have been conditioned to the standard small and large ball, as discriminative or choice stimuli, as well as to the associated conditional or gestural signals SMALL and LARGE. In theory this should have yielded a net associative value of reinforcement, which, when the sign LARGE was given, was even greater for the larger test ball (relative to the standard large ball), than the net associative value of reinforcement was for the standard large ball (relative to the standard small ball) when the sign SMALL was given.

Finally, it is worth remarking that our results are related to a recent scheme about an animal's general capacity for conceptual behavior, which is divided into two major categories—*class* concepts and *relational* concepts—each with their own subcategories (Thomas, 1980). Thus Rocky responds accurately to different gestural signs or words "symbolizing" or referencing a variety of small and large objects, including spheres (e.g., inverted cones, footballs, cubes, and clorox bottles), black, white, and gray objects (in addition to the above, these include, plastic baseball bats, discs, plastic toy cars, water wings, rings, and pipes). The words also refer to different shapes; that is, the objects themselves, despite wide variation in the following characteristics: (a) size, (b) brightness or color (in shades of gray), (c) orientation (object constancy), (d) distance (size and object constancy), (e) ambient light conditions (brightness constancy), (f) combinations of the above including number of objects available for comparison. The modifiers or adjectives can be multiply conjunctive, that is, two modifiers (size and color) mark or target an object (see Thomas, 1980). In addition, the adjectives for size can be shifted in meaning for Rocky from the absolute form, namely, large or small to the comparative or relational form, namely, larger or smaller, and Rocky can carry out literally thousands of commands, each with a different meaning and most of which are totally novel on the basis of the recombination of words according to the syntax or conditional sequences currently in operation (Schusterman, 1986).

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