The Psychological Record, 1993, 43, 823-839

A CALIFORNIA SEA LION (*ZALOPHUS CALIFORNIANUS*) IS CAPABLE OF FORMING EQUIVALENCE RELATIONS

RONALD J. SCHUSTERMAN
California State University
and
University of California-Santa Cruz

DAVID KASTAK
University of California-Santa Cruz

If a nonhuman animal matches the silhouette "crab" (A) to that of a "tulip" (B) and is further taught to match "tulip" (B) to the silhouette "radio" (C), will it immediately match "radio" (C) to "crab" (A)? To date formation of an equivalence relation of this type has not been demonstrated in animals. In our study, designed to give a sea lion match-to-sample experience with examples of sample and comparison stimuli switching roles, a 7-year-old female (Rio) was trained and tested with 30 potential classes, each consisting of 3 different shapes. Twelve of the 30 classes were used for training relational properties of symmetry and transitivity, and 18 classes were reserved for a final equivalence test. Following an initial failure to do symmetry on the first trial of novel relations (B→A: 8/12), Rio did symmetry (C→B: 11/12) and transitivity. (A→C: 11/12) before mastering equivalence on the first trial of 18 novel relations (C→A: 16/18). Results suggest that equivalence concepts are not mediated by language, but may be a prerequisite for linguistic competence.

The concept of equivalence relations was derived from a study on reading and auditory-visual equivalences (Sidman, 1971). In this research, Sidman applied a match-to-sample (MTS) format to train

The experimental work reported in this paper was funded by contract N00014-85-K-0244 from the Office of Naval Research and by a grant from the Center for Field Research to Ronald J. Schusterman. Bob Gisiner, Brigit Grimm, Evelyn Hanggi, Michel Coulliais, and Ema Spada helped enormously during the early stages of this project and we thank them for their many contributions. Later on Colleen Reichmuth, Tammy Berger, Alyson Henschel, Leif Johnson and several student interns and assistants and many Earthwatch volunteers gave us invaluable assistance. Thanks! We thank Lanny Fields and Tony Nevin for "cleaning up" our original manuscript. Finally, we are indebted to Murray Sidman for his stimulating articles and for giving us a framework for the study of marine mammal cognition. In this regard we also thank others who have given us guidance, shared ideas and manuscripts, and generally aided in the clarification and formulation of our ideas on equivalence relations. These include Lanny Fields, Bill McIlvane, Gina Green, Bill Dube, Richard Saunders, Steven Hayes, Charlie Catania, Bob Stromer, and Harry Mackay. The experiment was first described orally at the First International Congress on Behaviorism and the Science of Behavior held in Guadalajara, Mexico, October 5-9, 1992. Preliminary material was presented at Harvard University in June, 1992. Reprints may be obtained from Ronald J. Schusterman, Department of Psychology, California State University, Hayward, CA 94542.

conditional discriminations in a mentally retarded boy. The subject matched pictures of objects, like a cat, to spoken words as well as matching printed words to the corresponding spoken words. Subsequently, the subject showed that he could spontaneously relate the printed word cat to the picture of a cat and vice versa even though the printed word and picture had not previously been explicitly paired but had only been related to the spoken word.

Experimental demonstration of equivalence involves testing for the properties of reflexivity, symmetry, transitivity, and most importantly the combined effects of the latter two properties in the associations formed between three or more stimuli, in the context of a matching-to-sample procedure. If tests show that trained relations have all of the properties, then the stimuli comprising the conditional relations are referred to as members of an equivalence class (Sidman & Tailby, 1982).

Reflexivity, or identity matching, is demonstrated when an animal that has been trained to relate various identical stimuli can do so immediately and accurately when presented completely novel stimuli (Kastak & Schusterman, 1992). Symmetry is demonstrated when an association between nonidentical stimuli is shown to be reversible [i.e., when trained to match A_1 (sample) with B_1 (comparison), the subject is able to match B_1 (sample) with A_1 (comparison)]. Finally, transitivity can be exhibited by the ability of the subject to relate stimuli which share an intermediate stimulus, yet have never been presented together in the MTS context (i.e., when trained to match A_1 to B_1 and B_1 to C_1, the subject immediately perceives a relationship between A_1 and C_1). If the subject of this experiment can immediately match C stimuli with the appropriate A stimuli (a combination of symmetry and transitivity) then a combined test for equivalence has been passed (Sidman, 1990).

In the seminal papers of Sidman and his colleagues (e.g., Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982) the connection between the formation of equivalence classes and the symbolic function of language is clearly placed in a comparative/behavioral framework. From such a standpoint the ability of organisms to respond to stimulus-stimulus or S-S relations as interchangeable members of an equivalence class develops gradually from an earlier ability to respond to S-S relations as conditional or "if . . . then" discriminations. Indeed, in attempting to do a behavioral analysis of language acquisition tasks by apes and marine mammals it has, thus far, been unclear exactly which relations were explicitly and systematically trained, and whether equivalence relations (those with the properties of reflexivity, symmetry, and transitivity) emerged as a consequence of this training. (For pertinent discussions on marine mammal language acquisition, see Gisiner & Schusterman, 1992; Herman, 1988, 1989; Schusterman & Gisiner, 1988, 1989, in press; and for similar discussions on ape language acquisition, see Dugdale & Lowe, 1990; Lipkins, Kop, & Matthijs, 1988; Premack, 1986; Savage-Rumbaugh, McDonald, Sevcik, Hopkins, & Rubert, 1986).

A demonstration that a nonhuman animal can form equivalence relations should make it clear that equivalence relations do not require language; until now, however, there have been no thoroughly convincing demonstrations of the formation of equivalence relations in nonhumans. For that reason, it has been argued that language is necessary for the emergence of equivalence. (For discussions of the comparative psychology of stimulus equivalence, see Catania, 1992; Dugdale & Lowe, 1990; Hayes, 1989; Sidman, 1990.) The purpose of the current experiment was to demonstrate that a California sea lion (*Zalophus californianus*) could pass tests of equivalence (i.e., matching C stimuli to A stimuli after being trained to match A to B and B to C), using a simple-to-complex protocol similar to that used to facilitate equivalence class formation in college students (Adams, Fields, & Verhave, 1993). In a simple-to-complex protocol, subjects learn (through trial and error training) A-B relations and B-C relations. The subjects are tested for the emergent C-B and B-A relations (symmetry) and A-C relations (transitivity) and taught these relations explicitly (if the test results are negative) through further trial and error training. Following these instructional phases, testing for equivalence (C-A), using novel relations, can be conducted. The purpose of the simple-to-complex protocol is to train responses which are based only upon relevant information learned through experience with numerous examples of forward (A-B, B-C, A-C) and reverse (C-B, B-A, C-A) associations. We believe that the breadth of experience gained through extensive training will allow a subject to unequivocally demonstrate stimulus equivalence.

Two recent investigations concluded that common chimpanzees (*Pan troglodytes*) are either incapable of inferring symmetrical relations between arbitrarily paired visual stimuli (Dugdale & Lowe, 1990) or can do it only partially or weakly (Tomonaga, Matsuzawa, Fujita, & Yamamoto, 1991). We hypothesize that these failed or only weakly successful outcomes would have been considerably more successful if the investigators used a programmed instructional sequence which gave their chimpanzee subjects a greater breadth of MTS experience with examples of sample and comparison stimuli switching roles *prior* to tests of novel symmetrical relations. Another problem in interpreting these negative findings on chimpanzees is that their performance on test trials in both studies were subject to extinction procedures. Similar criticism can be applied to all of the previous studies suggesting that nonhuman primates and pigeons were incapable of inferring symmetrical relations between arbitrarily paired stimuli in an MTS task (e.g., see Sidman et. al., 1982). Our experiment with a California sea lion was designed to eliminate many irrelevant sources of stimulus control in an MTS task. To that end, the following provisions were included in the experimental design:

1. Thirty potential 3-member classes were trained. The first 12 were designated to provide the sea lion MTS experience with examples of sample and comparison stimuli switching roles.
2. The final 18 3-member classes were used for the CA equivalence

test, Trial 1 being the critical test trial. The sample size was large enough so that extinction procedures did not have to be used.

3. Prior to training some of the AB and all of the BC relations in the arbitrary MTS procedure, the sea lion's facility to infer reflexive relations with many of the same stimuli was demonstrated through tests of generalized identity matching (Kastak & Schusterman, 1993).

Method

Subject, Apparatus, and Procedure

When the study began (1988) one animal (Rocky) was 12 years old and the other (Rio) was 3 years old. Both sea lions performed well in the learning and maintenance of the AB relations and in other experiments connected with maintaining these relations (Schusterman, Grimm, Gisiner, & Hanggi, 1991; Schusterman, Gisiner, Grimm, & Hanggi, 1993). However, Rocky began to show subpar performance during initial testing for reflexivity, on generalized identity MTS (Kastak & Schusterman, 1993) and then had difficulty learning and maintaining BC relations. Because of Rocky's difficulties in retaining the information of AB and BC relations, this sea lion has not, as yet (March 1993), been given the CA equivalence test. In contrast, Rio had no difficulty learning and maintaining BC relations and was therefore given the CA equivalence test in August, 1992. The rest of this report is a description of the training and test procedures and outcomes used to assess Rio's ability to show stimulus equivalence with visual stimuli.

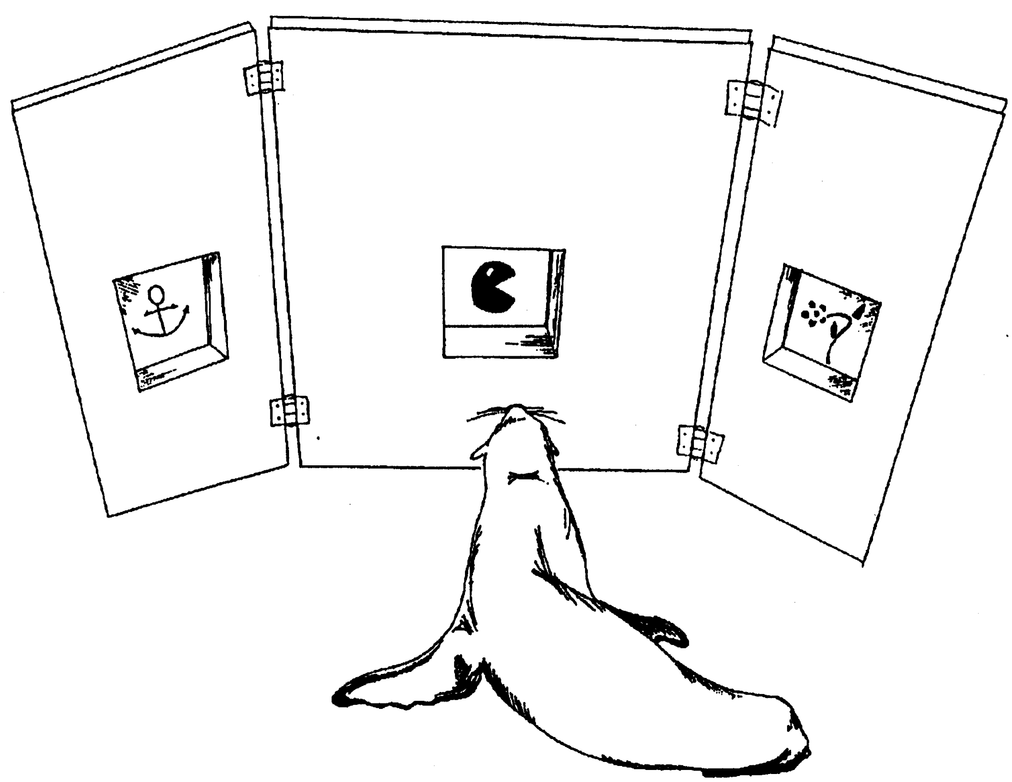

Figure 1. The matching-to-sample apparatus.

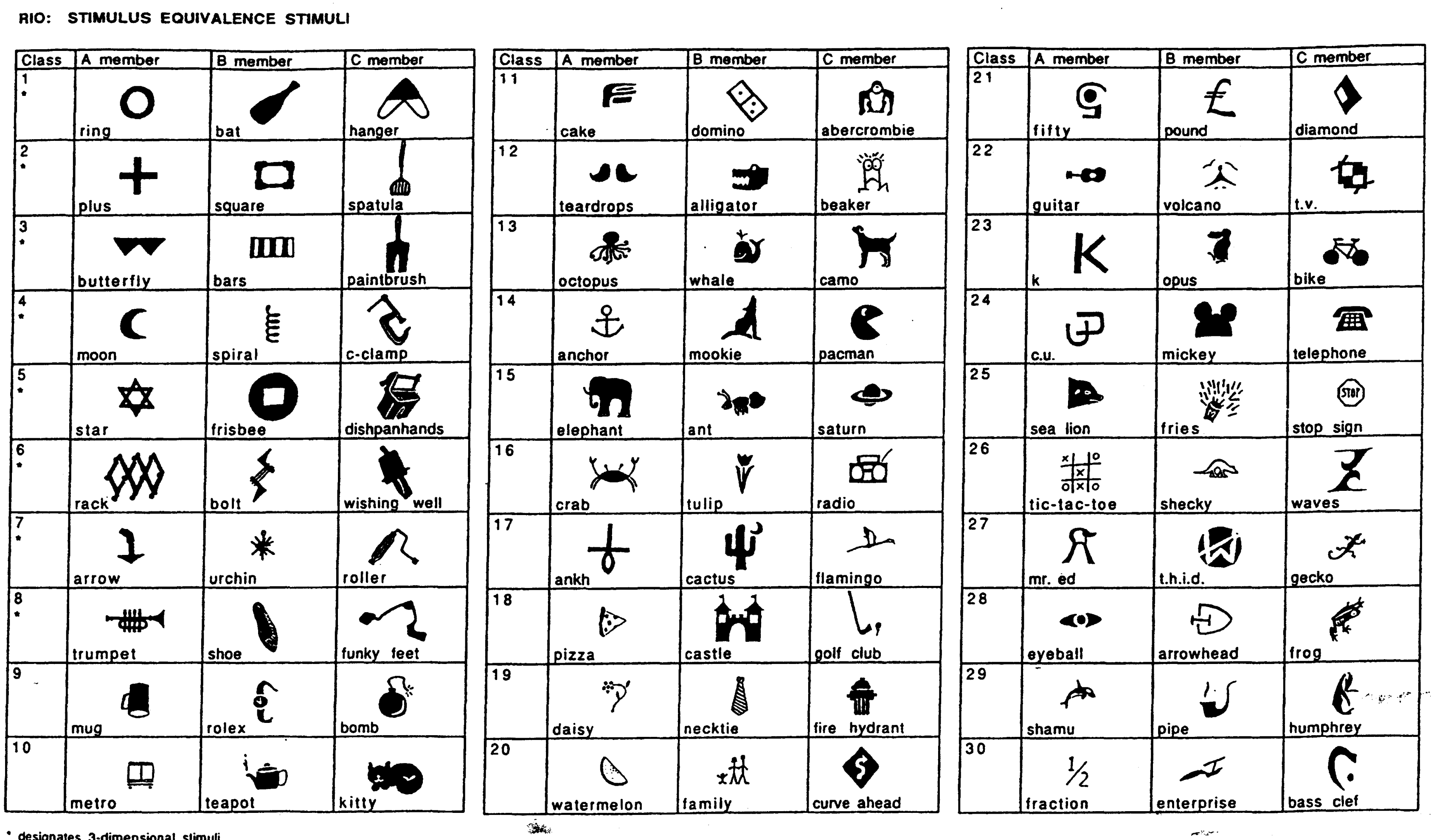

Figure 2. The 90 stimulus configurations comprising 30 potential 3-member equivalence classes for California sea lion, Rio.

Rio has been housed outdoors in pools and haul-out areas at Long Marine Laboratory in Santa Cruz, California and for this experiment she was trained and tested on a haul-out deck adjacent to a 7.6-m diameter pool. Experimental sessions were usually conducted five days/week, mostly between 9 A.M. and noon. Rio was fed about 4kg of freshly thawed cut herring and capelin, one third of which was ordinarily consumed during experimental sessions. The matching-to-sample apparatus consists of a set of wooden boards containing three window-fronted boxes in which the stimuli are placed (see Figure 1). The middle board, housing the sample window is 120 cm square, and the side boards are 120 cm high and 61 cm wide. The stimulus boxes are 30 cm by 30 cm square and 10 cm deep, and covered by sliding opaque doors which allow the stimuli to be placed inside, out of view of the subject. During the experiments, the stimuli were placed in the boxes by two assistants receiving instructions from the experimenter via radio headphones. The two comparison stimuli were placed in their respective boxes simultaneously, so the subject could not be cued to the correct choice by the timing of its placement. A third assistant was also seated behind the boards in order to deliver a piece of fish as reinforcement for correct responses. (Additional details of the apparatus can be obtained from Schusterman et al., 1993).

The stimulus members (A, B, and C) belonging to each of 30 potential equivalence classes are shown in Figure 2. Stimuli for the first eight classes (marked with an asterisk in the figure) were three-dimensional "junk" objects constructed of wood, steel, and/or plastic, painted black, and presented against a white background. Stimuli for the next 22 classes were planometric, consisting of black shapes painted on white backgrounds on 30 cm-square pieces of plywood. The matching procedure was a two-choice simultaneous one, that is, after the sample was presented, it remained exposed while both comparison stimuli were presented. After an interval of 2-4 seconds, the subject was released from station (directly in front of the center box) in order to point at its choice. A response was defined by the nose of the subject breaking the plane formed by the front of the stimulus box (see Figure 1). Agreement between two judges regarding correct or incorrect responses was nearly perfect. Correct responses were rewarded with a piece of fish. All trials were balanced for left and right correct choices, and all responses were differentially reinforced.

Procedural Sequences: Training, Testing and Baselines

The goal of the experimental sequence was to maximize Rio's passing of tests by ensuring that all prerequisites for a given test had been demonstrated before the test was given. Thus, after training AB, symmetry test BA can be given because AB is its only prerequisite. Following training BC, symmetry test CB can be given because BC is its only prerequisite. Because AB and BC are the prerequisites for a transitivity test, after they have been trained the AC transitivity test can

Table 1

Procedural Sequence for Stimulus Equivalence: Training and Testing

SEQUENCE	PROCEDURE	SPECIFICS	BASELINE PERFORMANCE*
1	Train A→B relations (potential classes 1-30)		
2	Remove 12 A→B relations for symmetry testing and training	The stimuli comprising these relations were removed at random, and included both two- and three-dimensional stimuli from early, middle, and late phases of training	
2a	Test for B→A symmetry; Train to criterion (6 potential classes)	Potential class numbers 1, 3, 5,12,18, & 24	97.7% N=257
2b	Test for B→A symmetry; Train to criterion (6 potential classes)	Potential class numbers 9,13, 21, 23, 26, & 29	91.7% N=97
3	Train B→C relations (potential classes 1-30)		92.9% N=1910
4	Remove 12 potential classes for C→B symmetry, AC transitivity, and C→A symmetry (equivalence) training and testing	Same potential classes removed for testing in step 2	
4a	Reacquisition phase for maintenance of 6 B→C relations to be tested and trained for symmetry	Done to insure high levels of baseline (B→C) performance on first six potential classes to be tested for C→B symmetry	91.9% N=99
4b	Test for C→B symmetry; Train to criterion (6 potential classes)	Potential class numbers 1, 3, 5, 12, 18, & 24	92.5% N=80
4c	Reacquisition phase for maintenance of 6 B→C relations to be tested and trained for symmetry	Done to insure high levels of baseline (B→C) performance second six potential classes to be tested for C→B symmetry	87.8% N=98
4d	Test for C→B symmetry; Train to criterion (6 potential classes)	Potential class numbers 9, 13, 21, 23, 26, & 29	96.9% N=64
4e	Test for A→C transitivity; Train to criterion (6 potential classes)	Potential class numbers 1, 3, 5, 12, 18, & 24	87.5% N=32
4f	Test for A→C transitivity; Train to criterion (6 potential classes)	Potential class numbers 9, 13, 21, 23, 26, & 29	84.3% N=32
4g	Test for C→A symmetry; Train to criterion (6 potential classes)	Potential class numbers 1, 3, 5, 12, 18, & 24	93.8% N=64
4h	Test for C→A symmetry; Train to criterion (6 potential classes)	Potential class numbers 9, 13, 21, 23, 26, & 29	83.9% N=31
5	Test for equivalence (C→A) on remaining 18 potential classes (numbers 13-30). No training to criterion		
5a	C→A test for first 6 potential classes	Potential class numbers 2, 6, 8, 16, 20, & 25	87.5% N=16
5b	C→A test for second 6 potential classes	Potential class numbers 4, 7, 10, 11, 15, & 27	93.8% N=16
5c	C→A test for third 6 potential classes	Potential class numbers 14, 17, 19, 22, 28, & 30	87.5% N=16

*Following each training and testing phase, relationships learned to criterion were immediately incorporated into baseline. Performance levels were dynamic; scores appearing in the third column reflect the *average* baseline performance during a given testing phase. Fluctuations in baseline performance are most likely the result of incorporation of test stimuli into baseline phases.

be conducted. Subsequent training of AC is a prerequisite for conducting the CA symmetry test. Once all of these tests have been passed in the context of the first 12 problem sets, the prerequisites for the equivalence test have been demonstrated and therefore the CA test can be conducted on Problems 13-20.

Table 1 presents the procedural sequence for training and testing equivalence relations. After learning the first two AB problems [ring→bat and plus→square (see Figure 2)] by trial and error, the next six sample/S+ pairings were introduced one at a time and Rio was allowed to use "exclusion" to acquire these AB relations (Schusterman et al., 1993). In these MTS problems all S- comparisons were familiar to Rio because they were drawn from the previously learned relations, and they were paired against novel S+ comparisons and their associated novel samples (see Schusterman et al., 1993). The next 22 ABs were learned by trial and error (i.e., introduced two at a time). After each problem (set of two stimuli) was learned, it was incorporated into the baseline of previously learned stimuli. At this point B stimuli could appear as S+ or S- with any other previously learned B stimulus serving as the alternate comparison.

Following tests of Rio's ability to infer BA symmetry on 12 of these problems, the sea lion was given 30 BC problems two at a time. When the problems were learned (by trial and error) they too were incorporated into the baseline of previously learned stimuli. The C stimuli could now appear as S+ or S-, with any previously learned B or C stimulus serving as the alternate comparison. Subsequently, 12 potential classes for CB symmetry, AC transitivity and CA symmetry (equivalence) testing and training were removed from the pool of 30 potential equivalence classes leaving 18 classes for the ultimate CA equivalence test (see Steps 4 through 5C in Table 1).

For symmetry, transitivity, and equivalence testing, stimuli from the pool of relations chosen for a particular test day appeared as both S+ and S- on all test trials (e.g., if A→C transitivity was being tested, the S- stimuli for all test trials were C class members chosen at random from that day's test pool). The only exceptions to completely random selection of S- stimuli were that 3-dimensional objects were only compared to other 3-dimensional objects and selection of S- stimuli was balanced, that is, all stimuli from the test pool were used as S+ and S- an equal number of times. Once the test was finished, relations from the test pool were incorporated into the baseline and S+ stimuli were paired randomly with all previously learned comparisons of the same class member as S- stimuli.

Criterion. For the exclusion phase of A→B training, criterion consisted of consistent 90% correct response levels on each of the relations being trained, but was not explicitly defined. For training by trial and error, criterion consisted of two consecutive sessions of 90% correct responses (36 out of 40 trials correct) on each relation followed by one session of overlearning. For B→C training, criterion consisted of

Table 2

Rio's Performance on Symmetry Tests I & II (B→A Problems 1-12)

TEST I Class	Trials 1-4	Block	Pass-Fail
1	XXII	2/4	F
3	IIXI	3/4	P
5	XIII	3/4	F
12	IXII	3/4	P
18	IIIX	3/4	P
24	XXII	2/4	F
TOTAL		16/24	3P-3F

TEST II Class	Trials 1-4	Block	Pass-Fail
9	IXII	3/4	P
13	IIII	4/4	P
21	IIII	4/4	P
23	XXXI	1/4	F
26	IXII	3/4	P
29	IXII	3/4	P
TOTAL		18/24	5P-1F

I = correct response, X = incorrect response. PASS = Trial 1 CR *and* at least 3/4 CR in block.

two consecutive sessions of 87.5% correct responses on each of the relations being trained (21 out of 24 trials correct) followed by one session of overlearning.

Testing. As indicated in Table 1 (see test phases 2a,b; 4b,d,e,f,g,h; and 5a,b,c) all test sessions consisted of six problems. Trials from each of these were superimposed on a baseline of previously trained stimuli. A session consisted of four test trials for each problem (24 total test trials) along with 16 baseline trials for a total of 40 trials per session.

Assessment. For symmetry, transitivity, and equivalence testing, criterion consisted of two consecutive sessions of 87.5% correct responses on the relations being trained (21 out of 24 trials correct), with the provision that no more than two errors could be made on the same test (S+) stimulus. Passing the tests of symmetry, transitivity, and equivalence depended on two factors. First, performance on Trial 1 had to be correct, and second, Rio also had to make at least 3 of 4 correct responses on the first 4 trials of a problem. The Trial-1 factor was used in order to show that Rio's performance did not depend on reinforcement, and results from additional trials were used to show that her performance was relatively reliable (albeit with reinforcement).

Results

AB and BC acquisition. Rio learned 8 AB relations by exclusion and

Table 3

Rio's Performance on Symmetry Tests I & II (C->B Problems 1-12)

TEST I Class	Trials 1-4	Block	Pass-Fail
1	XXII	2/4	F
3	IIIX	3/4	P
5	IIXI	3/4	P
12	IIII	4/4	P
18	IIIX	3/4	P
24	IIII	4/4	P
TOTAL		19/24	5P-1F
TEST II Class	**Trials 1-4**	**Block**	**Pass-Fail**
9	IIII	4/4	P
13	IXII	3/4	P
21	IXXI	2/4	F
23	IXII	3/4	P
26	IIII	4/4	P
29	IIII	4/4	P
TOTAL		20/24	5P-1F

I = correct response, X = incorrect response. PASS = Trial 1 CR *and* at least 3/4 CR in block.

22 AB relations by trial and error and all 30 BC relations by trial and error. Rio's scores, in terms of errors to criterion were $x = 36.2 \pm 31.7$ for AB acquisitions and 17.8 ± 13.5 for BC acquisitions.

B→A symmetry test for first 12 AB relations. Table 2 shows Rio's performance on the first two BA symmetry tests (Problems 1-6 and 7-12). Using the combined criterion of responding correctly on the first trial of a relation *and* obtaining at least 3 correct responses during the first 4 trials of a problem, Rio passed 3 of 6 problems on the first test and 5 of 6 problems on the second test or 8 of 12 problems overall, which is not significantly better than expected by chance ($p > .10$, binomial, 2-tailed test). However, Rio showed improvement on the second test (Problems 7-12) following BA (symmetry) training on the earlier six problems.

C→B symmetry test for first 12 BC relations. Table 3 depicts Rio's response to the next two symmetry tests (CB Problems 1-6 and 7-12). In both Test I and Test II, Rio passed 5 of 6 problems for a total of 10 out of 12 BC symmetry relations passed; a statistically significant achievement ($p < .05$, binomial, 2-tailed test).

A→C transitivity test for first 12 AB, BC relations. Table 4 shows Rio's responses to the first two transitivity tests (AC Problems 1-6 and 7-12). In Test I, Rio passed 5 of 6 transitive problems, and in Test II, she passed all 6 transitive problems. Rio's combined test score on these relations was 11 passes and 1 fail, and is significantly better than would be expected by chance ($p < .01$, binomial, 2-tailed test). Indeed, in

Table 4

Rio's Performance on Transitivity Tests I & II (A→C Problems 1-12)

TEST I Class	Trials 1-4	Block	Pass-Fail
1	IIII	4/4	P
3	IIII	4/4	P
5	XIII	3/4	F
12	IIII	4/4	P
18	IIXI	3/4	P
24	IIII	4/4	P
TOTAL		22/24	5P-1F
TEST II Class	**Trials 1-4**	**Block**	**Pass-Fail**
9	IIII	4/4	P
13	IIII	4/4	P
21	IIII	4/4	P
23	IIII	4/4	F
26	IIII	4/4	P
29	IIII	4/4	P
TOTAL		24/24	6P-0F

I = correct response, X = incorrect response. PASS = Trial 1 CR *and* at least 3/4 CR in block.

these "forward" AC relations, with which Rio had no previous experience, she performed at a level comparable to the previously trained forward relations of AB and BC (i.e., at about 95% correct responses).

C→A symmetry test for first 12 AB, BC, and AC relations. Table 5 depicts Rio's achievement on the last two symmetry tests of the first 12 potential classes (CA Problems 1-6 and 7-12). Rio passed 4 of 6 symmetry problems on Test I and 6 of 6 symmetry problems on Test II for a combined performance on the CA symmetry test of 10 passes and 2 fails. Her scores were significantly better than chance ($p < .05$, binomial, 2-tailed test).

C→A equivalence test for the next 18 potential classes. The final test conducted in this series assessed Rio's ability to combine transitive and symmetrical relational abilities in order to form equivalence relations on 18 potential 3-member stimulus classes without having had any previous symmetrical or transitive experience with them. The third column of Table 1 shows Rio's baseline performance during equivalence testing (88-94% correct responses) and Table 6 shows her initial performance for all 18 problems. Rio passed 14 of these indicating she formed equivalence relations with a probability significantly better than chance ($p < .05$, binomial, 2-tailed test). More important, perhaps, is the finding that the sea lion made only two first-trial errors out of 18 presentations ($p < .01$, binomial, 2-tailed test).

Table 5

Rio's Performance on Symmetry Tests I & II (C→A Problems 1-12)

TEST I Class	Trials 1-4	Block	Pass-Fail
1	IIII	4/4	P
3	XIIX	2/4	F
5	IIIX	3/4	P
12	IIII	4/4	P
18	IXXI	2/4	F
24	IIII	4/4	P
TOTAL		19/24	4P-2F

TEST II Class	Trials 1-4	Block	Pass-Fail
9	IIII	4/4	P
13	IIII	4/4	P
21	IIII	4/4	P
23	IIXI	3/4	P
26	IIIX	3/4	P
29	IIII	4/4	P
TOTAL		22/24	6P-0F

I = correct response; X = incorrect response. PASS = Trial I CR *and* at least 3/4 CR in block.

Discussion

Following a demonstration of California sea lions to spontaneously or immediately transfer their identity MTS performance without decrement to novel visual stimuli (Kastak & Schusterman, 1993), we examined the ability of one of these sea lions, Rio, to form concepts of symmetry and transitivity within the context of conditional discriminations. Because symmetry and transitivity are necessary properties of equivalence relations, Rio's test reactions suggest that each S-S relation, that is, each sample stimulus and its arbitrarily paired comparison stimulus had formed a class of equivalent stimuli. However, early trained conditional relations between A_1-A_6 and B_1 - B_6 may not have been conceptualized as equivalent by Rio, because by our criteria the sea lion failed this initial symmetry test. Rio's initial failure in generalizing a symmetric principle is consistent with previous failures of nonhumans to demonstrate symmetry in doing conditional discriminations (e.g., Sidman et al., 1982). Indeed, in the general discussion of their negative findings Sidman et al. do suggest that, although nonhuman animals might have difficulty forming equivalence classes, providing enough examples might bring about the emergence of symmetry. A similar point about training a symmetry concept in chimpanzees was made by Hayes (1989). Multiple exemplar training with pigeons in somewhat different contexts has facilitated the

Table 6

Rio's Performance on Stimulus Equivalence Test (C→A Problems 13-30)

Class	Trials 1-4	Block	Pass-Fail
2	IIIX	3/4	P
4	IXXI	2/4	F
6	IIII	4/4	P
7	IIII	4/4	P
8	IIII	4/4	P
10	IIII	4/4	P
11	IIIX	3/4	P
14	IIII	4/4	P
15	XXII	2/4	F
16	IIII	4/4	P
17	IXIX	2/4	F
19	IIII	4/4	P
20	IIXI	3/4	P
22	XIII	3/4	F
25	IIII	4/4	P
27	IIII	4/4	P
28	IIIX	3/4	P
30	IIII	4/4	P
TOTAL		61/72	14P-4F

I = correct response, X = incorrect response. PASS = Trial I CR *and* at least 3/4 CR in block.

acquisition of a relational category such as identity (Wright, Cook, Rivera, Sands, & Delius, 1988) and object categories such as cats, flowers, cars, and chairs (Bhatt, 1988).

Rio began showing signs of generalized sample-comparison interchangeability soon after she received symmetry training. Although Rio did not pass the original BA symmetry test of 12 problems, the conjoint criterion of Trial-1 correct *and* 3 of 4 correct responses on the first four trials might be considered overly vigorous. However, by more lenient standards, Rio did quite well. Her performance on the first block of four trials for each of these first 12 symmetrical problems was at 70% correct responses (34/48); a significantly better than chance performance ($p < .01$, binomial, 2-tail test).

To determine equivalence class formation without reinforcement, experimenters have typically used nonreinforced probe trials superimposed on baseline (e.g., Sidman et al., 1982). Therefore, our Trial-1 results for Rio are probably the most persuasive outcome in the experiment. Trial 1 performance by Rio was typically the same as that which occurred on the next three trials (see Tables 2-6). Thus Rio's test performances were steady state and the finding that the performances on the first four trials did not change despite contingent reinforcements, suggests that feedback did not influence her performance on the initial test trials, that is, the relations between the stimuli in the class controlled performances.

We believe the critical factor in Rio's subsequent performances in passing tests of symmetry, transitivity, and equivalence stems directly from her experiencing enough exemplars to grasp these interrelated concepts. Thus, after being taught that a number of samples and comparisons are interchangeable, Rio rapidly learned to respond to novel symmetrical relations the first time she encountered them. As Hayes (1989) has noted, derived symmetry, from the standpoint of conditioning theory, should be much more difficult for a nonhuman animal than derived transitivity, because the former defines a bidirectional S-S relation and the latter defines a unidirectional S-S relation. Thus Rio's unidirectional performance on the first 12 AC problems was not surprising. This kind of transitivity of conditional relations had been demonstrated previously by D'Amato, Salmon, Loukas, and Tomie (1985) in cebus monkeys (*Cebus apella*).

Paralleling the findings with college students (Adams et al., 1992), the simple-to-complex training and testing probably facilitated the learning of classes by the sea lion by the establishment of all prerequisite repertoires before Rio was presented with any emergent relations test.

Once Rio learned a conditional relation to a criterion, multiple negative comparisons were used for all sample/S+ pairs during succeeding baseline sessions. This means that an equivalence class for Rio (e.g., Class 16 in Figure 2) might be characterized "If the sample is *crab*, then *tulip* is the correct comparison and vice versa" and "If the sample is *tulip*, then *radio* is the correct comparison and vice versa" and "If the sample is *radio*, then *crab* is the correct comparison and vice versa." The question is whether valid symmetry, transitivity or equivalence tests require not only interchangeable samples and correct comparisons from a given class but also require the original incorrect comparisons to be present on each test trial. An argument might be raised that during an equivalence test the relation is "If the sample is *radio* and the S+ is *crab* while the S- is always *elephant* (from Class 15), then *crab* is the correct comparison." Because Rio's baseline performance with any given conditional relation did not appear to vary as a function of the S- comparison it seems likely that within this context the S- comparisions were irrelevant to the relation between samples and relevant S+ comparisons. This interpretation of the use of multiple negative comparisons as irrelevant after criterional learning has already been achieved in conditional relations is consistent with recent findings on human subjects in the formation of equivalence relations (Adams et al., 1993; Kennedy, 1991). From this we conclude that the emergent relations Rio acquired reflect the formation of equivalence classes.

Cognition has been defined in terms of relating different unconnected information in new ways and to do this in order to solve one's problems (Markl, 1985). The current study was undertaken to learn more about the limits of California sea lion cognition and to determine whether its cognitive skills might be considered prelinguistic.

The positive results of our experiment showing that a nonhuman nonverbal animal, that is, a California sea lion, can pass tests of symmetry, transitivity, and equivalence provide strong evidence that language is not necessary for the formation of equivalence relations. Being skillful enough to place stimuli which are dissimilar, yet interrelated, into the same class is precisely the kind of competence it takes to manipulate symbols meaningfully. These skills appear similar to those exhibited by chimpanzees when presented with a piece of plastic and required to do a feature analysis of its referent (Premack, 1986), or asked to categorize signs according to the functional similarity of their referents (Savage-Rumbaugh, 1986), or spontaneously giving a gestural sign for a dog upon hearing the bark of a dog after being trained to give the sign upon seeing a dog or a picture of one (Terrace, 1986). Equivalence relations may also explain the recent findings by Cheney and Seyfarth (1990) that vervet monkeys, like humans, classify vocalizations according to their referents or meaning, and not just according to their physical similarity. Thus, two different vervet calls given to members of other groups—a chutter and *wrr*—are classified as equivalent. Stimulus equivalence may also be in evidence when different vocalizations are given as alarm calls in the presence of a leopard: These are short, high-pitched chirps from vervet females and long, low-frequency barks from vervet males. Formal equivalence testing in vervet monkeys has been suggested in order to determine the extent to which vervet calls are semantic (Schusterman, 1990).

The cognitive abilities required to form equivalence relations, or what Thomas (1980) calls bidirectional concepts, may be a prerequisite for linguistic competence rather than the other way around. Even if we assume that human language depends on a specific linguistic element, it is likely that a level of general intelligence must be present for the addition of a unique linguistic element to be effective. This line of reasoning comes from Premack (1986), who links the development of language to a general representational competence. Such general intelligence in the form of symbol manipulation seems to occur in several mammalian and avian taxa, and is not found exclusively in monkeys, apes, dolphins, and humans.

From the functional standpoint, the ability to think without language, that is, to form abstract concepts like sameness, symmetry, and transitivity, should increase an animal's fitness (reproductive success) by allowing it to adapt rapidly to changing environmental conditions. Reacting to dissimilar stimuli as members of a single class (e.g., individuals from the same matriline) is one way of chunking information and attaining a considerable degree of cognitive economy. We suspect that California sea lions and other animals that are quite gregarious and live in social groups might identify family members, friends, neighbors, and territorial rivals (see Schusterman, Hanggi, & Gisiner, 1992, for a summary and review of individual recognition in California sea lions) by using a variety of sensory cues that make up equivalence classes.

References

ADAMS, B. J., FIELDS, L., & VERHAVE, T. (1993). Effects of test order on intersubject variability during equivalence class formation. *The Psychological Record*, 43, 133-152.

BHATT, R. S. (1988). *Categorization in pigeons: Effects of category size, congruity with human categories, selective attention, and secondary generalization*. Ph.D. thesis: Iowa City: University of Iowa.

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

CATANIA, A. C. (1992). *Learning* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

CHENEY, D. L., & SEYFARTH, R. M. (1990). *How monkeys see the world*. Chicago: University of Chicago Press.

D'AMATO, M. R., SALMON, D., LOUKAS, E., & TOMIE, A. (1985). Symmetry and transitivity of conditional relations in monkeys (*Cebus apella*) and pigeons (*Columba livia*). *Journal of the Experiment Analysis of Behavior*, 44, 35-47.

DUGDALE, N., & LOWE, C. F. (1990). Naming and stimulus equivalence. In D. Blackman & H. Lejeune (Eds.), *Behavior analysis in theory and practice* (pp. 115-138). Hillsdale, NJ: Erlbaum.

GISINER, R., & SCHUSTERMAN, R. J. (1992). Sequence, syntax and semantics: Responses of a language-trained sea lion (*Zalophus californianus*) to novel sign combinations. *Journal of Comparative Psychology*, 106, 78-91.

HAYES, S. C. (1989). Nonhumans have not yet shown stimulus equivalence. *Journal of the Experimental Analysis of Behavior*, 51, 385-392.

HERMAN, L. M. (1988). The language of animal language research: Reply to Schusterman and Gisiner. *The 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.

KASTAK, D. A., & SCHUSTERMAN, R. J. (1992). Comparative cognition in marine mammals: A clarification on match-to-sample tests. *Marine Mammal Science*, 8, 414-417.

KASTAK, D., & SCHUSTERMAN, R. J. (1993). Immediate transfer of visual identity matching-to-sample in two California sea lions (*Zalophus californianus*). Manuscript submitted for publication.

KENNEDY, C. H. (1991). Equivalence class formation influenced by the number of modes separating stimuli. *Behavioral Processes*, 24, 219-245.

LIPKENS, R., KOP, P. F. M., & MATTHIJS, W. (1988). A test of symmetry and transitivity in the conditional discrimination of performances of pigeons. *Journal of the Experimental Analysis of Behavior*, 49, 395-409.

MARKL, H. (1985). Manipulation, modulation, information, cognition: Some of the riddles of communication. In B. Holldobler & M. Lindauer (Eds.), *Experimental behavioral ecology and sociobiology* (pp. 163-194). Sunderland, MA: Sinauer Associates.

PREMACK, D. (1986). *"Gavagai" or the future history of the animal language controversy*. Cambridge, MA: MIT Press.

SAVAGE-RUMBAUGH, E. S. (1986). *Ape language: From conditioned response to symbol*. New York: Columbia University Press.

SAVAGE-RUMBAUGH, S., MC DONALD, K., SEVCIK, R. A., HOPKINS, W. D., & RUBERT, E. (1986). Spontaneous symbol acquisition and communicative use by pygmy chimpanzees (*Pan paniscus*). *Journal of Experimental Psychology*: General, 115, 211-235.

SCHUSTERMAN, R. J., (1990). Stimulus equivalence and cross-modal perception: A testable model for demonstrating symbolic representations in bottlenose dolphins. In J. Thomas & R. Kastelein (Eds.), *Sensory abilities of cetaceans* (pp. 677-684). New York: Plenum Press.

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

SCHUSTERMAN, R. J., & GISINER, R. (1989). Please parse the sentence: Animal cognition in the Procrustean bed of linguistics. *The Psychological Record*, 39, 3-18.

SCHUSTERMAN, R. J. & GISINER, R. (in press). Pinnipeds, porpoises and parsimony: Animal language research viewed from a bottom-up perspective. In R. W. Mitchell, H. L. Miles, & N. S. Thompson (Eds.), *Anthropomorphism, anecdotes, and animals: The emperor's new clothes?* Lincoln: University of Nebraska Press.

SCHUSTERMAN, R. J., GISINER, R., GRIMM, B. G., & HANGGI, E. B. (1993). Behavior control by exclusion and attempts at establishing semanticity in marine mammals using matching-to-sample paradigms. In H. Roitblat, L. Herman, & P. Nachtigall (Eds.), *Language and communications: A comparative perspective* (pp. 249-275). Hillsdale, NJ: Erlbaum.

SCHUSTERMAN, R. J., GRIMM, B. K., GISINER, R., & HANGGI, E. B. (1991). Retroactive interference of delayed "symbolic" matching-to-sample in California sea lions. Paper given at the Annual Meeting of the Psychonomic Society in San Francisco.

SCHUSTERMAN, R. J., HANGGI, E. B., & GISINER, R. (1992). Acoustic signalling in mother-pup reunions, interspecies bonding, and affiliation by kinship in California sea lions (*Zalophus californianus*). In J. Thomas, R. Kastelein, & A. Supin (Eds.), *Marine mammal sensory systems* (pp. 533-551). New York: Plenum Press.

SIDMAN, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research*, 14, 5-13.

SIDMAN, M. (1990). Equivalence relations: Where do they come from? In D. Blackman & H. Lejuene (Eds.), *Behavior analysis in theory and practice: Contributions and controversies* (pp. 93-114). Hillsdale, NJ: Erlbaum.

SIDMAN, M., RAUZIN, R., LAZAR, R., CUNNINGHAM, S., TAILBY, W., & CARRIGAN, P. (1982). A search for symmetry in the conditional discriminations of rhesus monkeys, baboons, and children. *Journal of the Experimental Analysis of Behavior*, 37, 23-44.

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.

TERRACE, H. S. (1986). *Nim: A chimpanzee who learned slgn language*. New York: Columbia University Press.

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

TOMONAGA, M., MATSUZAWA, T., FUJITA, K., & YAMAMOTO, J. (1991). Emergence of symmetry in visual conditional discrimination by chimpanzees (*Pan troglodytes*). *Psychological Reports*, 68, 51-60.

WRIGHT, A. A., COOK, R. G., RIVERA, J. J., SANDS, S. F., & DELIUS, J. D. (1988). Concept learning by pigeons: Matching-to-sample with trial-unique video picture stimuli. *Animal Learning and Behavior*, 18, 287-294.