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Sequence, Syntax, and Semantics: Responses of a Language-Trained Sea Lion (*Zalophus californianus*) to Novel Sign Combinations

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We present a sea lion's (*Zalophus californianus*) responses to anomalous (unfamiliar) combinations of signs created by reordering, deleting, or adding signs. The sea lion's responses to these anomalous combinations demonstrated that she had learned a number of syntactic relations from exposure to a limited set of standard combinatorial forms. The learned syntactic relations included two types of conditional relations, (a) sequential conditional relations between sign classes and (b) hierarchical conditional relations between subsets of signs within a combination. The sea lion's responses also showed that she made little, if any, use of logical or semantic properties of the signs. We propose that the emergence of semantically or logically based syntactic relations may depend on the ability to form stimulus equivalence relations between signs and referents.

One of the distinctive features of human language is that a limited repertoire of words can be fashioned into an essentially infinite variety of meaningful expressions because humans learn a set of syntactic devices for combining words. A criticism leveled against language studies with apes was that the apes were not taught rules for combining signs nor did they show any reliable spontaneous tendency to combine signs in an ordered way (Petitto & Seidenberg, 1979; Ristau & Robbins, 1982; Terrace, Petitto, Sanders, & Bever, 1979).

Herman, Richards, and Wolz (1984) sought to overcome this problem by developing a languagelike learning task that tested the ability of bottle-nosed dolphins to perform a task specified by structured sets of acoustic or gestural cues. We have used the same technique with another species of marine mammal, the California sea lion (Schusterman & Gisiner, 1988; Schusterman & Krieger, 1984).

The structure, or syntactic rules, applied to sign combinations are described in Herman et al. (1984) and Schusterman and Gisiner (1988). The animals were considered to have learned some type of generalized syntactic structure if they responded correctly to novel instructions created by substituting familiar signs into newly trained combinatorial forms. The ability of the subject to respond appropriately to any of a set of elements with common response contingencies or sequential positions after training with only one or a few members of the set also constitutes evidence of functional equivalence class formation (Sidman, Wynne, Maguire, & Barnes, 1989; Sigurdardottir, Green, & Saunders, 1990; Vaughan, 1988).

In order to more explicitly characterize the additional learned relations that constitute the syntax used by language-trained dolphins or sea lions, the researchers have presented their animals with unfamiliar combinations of signs to test the animals' ability or inability to extend learned syntactic relations to new combinatorial forms (Herman, 1987; Herman et al., 1984; Schusterman & Gisiner, 1988). Herman (1987) initially used the term *anomalous* to refer to *ungrammatical,* structurally novel combinations, but the criteria for separating grammatical from ungrammatical forms were not well defined. We have therefore broadened the definition of *anomalous* to include all combinatorial forms unfamiliar to the animals.

In this article we present a larger set of data on a sea lion's responses to anomalous combinations than has previously been reported (Schusterman & Gisiner, 1988; Schusterman & Krieger, 1984) and propose that the syntactic comprehension of sea lions, and probably of dolphins as well, is based on functional equivalence class formation and conditional discrimination learning abilities.

We also show that a linguistic interpretation of the data, based on logical and semantic relations between signs, is not consistent with responses to some anomalies. We suggest that a set of emergent relations between signs and referents known as *Sidman equivalence* or *stimulus equivalence* (see Sidman & Tailby, 1982) may be necessary for the logical and semantic operations we see in human linguistic performance.

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Method

Subject, Apparatus, and Baseline Procedure

The experimental subject was Rocky, an adult female California sea lion (*Zalophus californianus*). At the start of the experiment, she had approximately 5 years of experience with her artificial language. The experimental apparatus and procedures for presenting standard sign combinations are fully described in Schusterman and Krieger (1984) and Schusterman and Gisiner (1988).

The training stages are outlined in Table 1. First, differential reinforcement of a response after presentation of a specific signal (a gesture, visual display, or acoustic signal) produced a relation between a signal and a response (S–R pairing) or between a signal and one of several items in the environment (S–S pairing). These S–S pairings are very similar to arbitrary matching-to-sample procedures (see Schusterman, Gisiner, Grimm, & Hanggi, in press).

After separate repertoires of paired relations were learned, a signal to specify an item and one to specify a response action were given in combination (Table 1, Stage 3). Reinforcement was made contingent on the subject's producing the signaled response to the signaled object. Additional signs to modify response behavior were then added to the initial combinatorial form (Table 1, Stages 4–5).

Table 2 contains a list of Rocky's standard combinatorial forms, along with the total number of unique instructions possible within each combinatorial form. From these 7,067 combinations, Rocky received a different randomized set of about 70 combinations each day during baseline training and maintenance sessions. Each session was balanced for the number of uses of each sign (i.e., equal numbers of trials for each action sign) and for each combinatorial form (i.e., equal numbers of two-sign, three-sign, four-sign, and all relational combinations). Within a block of sessions (usually 8–10 sessions), the mix of trials was also balanced for usage of a sign in combination with other signs (i.e., equal use of a given action sign with all object signs) and for usage of a sign in different combinatorial forms (i.e., equal use of a given object sign in two-sign, three-sign, four-sign, and all relational combinations).

Details of experimental procedure are given because the proportional balance between these variable aspects of the task might affect the probability that the subject would make one type of response rather than another when exposed to novel or ambiguous combinations, such as the anomalous combinations. For example, when all other variables were equal, if relational combinations were given twice as frequently as nonrelational combinations in daily baseline sessions, then the subject would be more likely to produce a relational response when given a novel combinatorial form that contained both relational and nonrelational cues.

Table 1
Training Stages in the Artificial Language Taught to a California Sea Lion (Zalophus californianus)

Stage	Training
1. Actions (A)	shape response put response under control of a gestural sign
2. Objects (O)	put pointing orientation to an object shape under the control of a gestural sign
3. Integration (O–A)	combine separate behavioral repertoires from Stages 1 and 2
4. Add modifiers (M–M–O–A)	add conditional cue for object brightness to O cue add conditional cue for object size to O cue combine brightness and size modifiers (in either order) with O cue
5. Relational (O–O–A)	shape response (take Object A to Object B) put response under control of gestural signs by adding an object sign to designate object B (separated by a pause) to combined object A + FETCH action signs

Table 2
Sign Combinations in Subject's Repertoire of Standard Combinatorial Forms (Given During Baseline Sessions)

Sequence type	No. combinations
Single object sequences	
O–A	76
M–O–A	528
M–M–O–A	240
Relational sequences[a]	
Three sign	
O–p–O–A	130
Four sign	
M–O–p–O–A	313
O–p–M–O–A	376
Five sign	
M–M–O–p–O–A	384
O–p–M–M–O–A	464
M–O–p–M–O–A	956
Six sign	
M–M–O–p–M–O–A	1,192
M–O–p–M–M–O–A	1,192
Seven sign	
M–M–O–p–M–M–O–A	1,216
Total	7,067

Note. O = subject (shape) sign; A = action sign; M = modifier sign; and p = pause.
[a] Object combinations of the same object (e.g., PIPE, PIPE FETCH) were excluded.

Rocky's Response Behavior

Figure 1 illustrates the events in a standard signing and response procedure. During the signing process Rocky produced a different orienting head movement after receiving each of the three classes of signs (modifier, object, and action). These are responses that Rocky developed without deliberate shaping or differential reinforcement by her trainers. These responses are referred to as *orienting responses* to distinguish them from the differentially reinforced *performance response* that followed completion of the entire signaling process.

Orienting responses. Orientations after an object sign (Figure 1, Panels A and E) were variable in length, from 0.6 s to more than 10 s, with a median time of approximately 1.2 s. During an object orientation Rocky turned and pointed with her head at objects, presumably putting them in her best field of binocular vision. She might point at several objects during this visual search and even swim out to objects for closer inspection. After locating the object Rocky returned to station on the signaler's extended foot and awaited the next signal.

When given a modifier sign, Rocky turned her head quickly to the left about one-quarter turn or less (Figure 1, Panels C and D). The entire orienting response took only about 0.5 s, and although a portion of the pool area fell within her view, the movement was so rapid that we can make no guesses about her searching behavior. The modifier orienting response resembled an intention to start an object orientation, from which the modifier orientation was probably derived (Schusterman & Krieger, 1984), but it had become so stereotyped with repetition that it was easily distinguished from an object search.

When given an action sign, Rocky did not move from station until released (withdrawal of the signaler's foot; Figure 1, Panel F). Rocky's orienting response to the action sign could be distinguished from

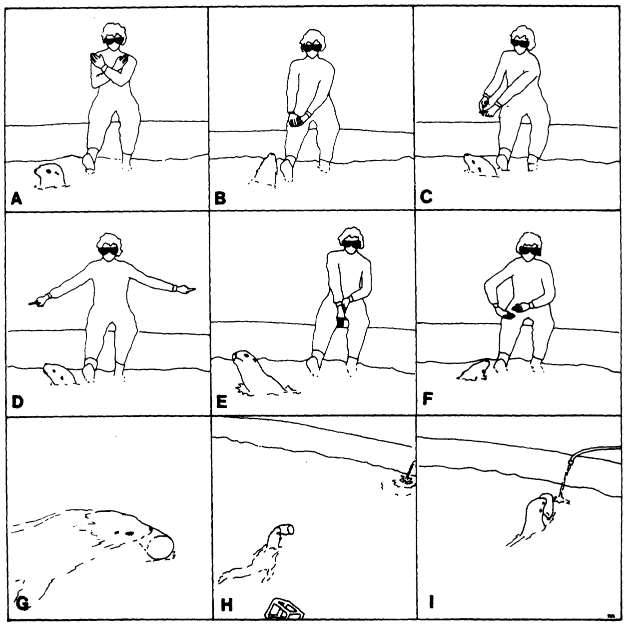

Figure 1. Example of a standard sign combination and response for the sea lion Rocky. (The complete sign sequence is WATER, WHITE SMALL BOTTLE FETCH. The general combinatorial form is O–p–M–M–O–A. A. The object sign WATER is given, and Rocky turns to search for the object. B. The signaler pauses between the signs designating the two separate objects in the relational sign combination; Rocky remains at station, awaiting the next sign. C. The modifier WHITE is given, and although Rocky turns slightly to her left, she does not scan the pool area. D. The modifier SMALL is given, and again, Rocky turns slightly to her left but does not scan the pool area. E. The object sign BOTTLE is given, and Rocky searches for the object designated by the combined modifier and object signs [WHITE SMALL BOTTLE]. F. The action sign FETCH is given, and Rocky remains at station until released by the signaler's foot drop. G. Rocky goes to the bottle and has started to move it while scanning the pool for the destination or goal item, in this case, a stream of water. H. Rocky approaches the stream of water while pushing the bottle. I. Rocky places the bottle in contact with the stream of water, a correct, reinforced response to the sign combination.)

orienting responses elicited by modifier and object signs but could not be used like the other orienting responses to indicate that the animal had seen and properly classified the sign. During the pause between sets of signs designating each object in a relational instruction, Rocky remained at station (Figure 1, Panel B), as she did when given an action sign.

Performance response. After signaling, Rocky was given a release signal. If she then produced a response that completely corresponded to the signs given, she was rewarded with a piece of fish (food reinforcement). If all or part of the response did not correspond to the signs given or there was no response (she balked), the signaler waited until Rocky restationed and then began a new trial. Rocky's postrelease response when she missed a sign or when she failed to find the designated object during her orientation response was to balk: That is, she remained at station and did not attempt to perform an action on an object (Schusterman & Krieger, 1984). The balk was a spontaneous behavior that apparently originated as a labor-saving strategy when a designated response object was missing or hidden. Because sea lions in general are strongly food motivated, and Rocky was no exception, a balk indicated that Rocky must have had very little expectation of being able to perform a response that would result in a food reward. From our point of view, if Rocky was unsure how to respond, the balk was a more desirable response than a prospecting response or a guess, because a guess could not be distinguished from an incorrect interpretation of the combined signs.

Conventions for Representing Signs, Signs Classes, and Responses

English language labels for signs are given in uppercase letters. For example, the signs to instruct Rocky to fetch the white small bleach bottle to a stream of water would be written as WATER, WHITE SMALL BOTTLE FETCH.

The general combinatorial form in the preceding example is expressed as O–p–M–M–O–A, wherein *O* indicates any object sign, *M*, any modifier, and *A*, any action sign. The *p* indicates a pause of approximately 1 s between the two sets of signs that designate each object in a relational instruction.

The animal's responses are presented in all lowercase letters in the tables; in the text responses are additionally set off by quotes. A completely correct response to our example sequence would therefore appear in text as "(to) water, white small bottle fetch." The parenthetical *to* is included to indicate to the reader which of the two objects is the destination item in a relational instruction.

In the tables, words in bold indicate the portions of a sign sequence and response that correspond. For example, the sign sequence CUBE, **BALL TAIL** shows that only the signs in bold (**BALL** and **TAIL**) matched Rocky's response, and the response **"ball tail"** shows that both the action and object of her response match signs given to her. In general terms, words not in bold in the sign sequence indicate signs not incorporated into Rocky's response, and words not in bold in Rocky's response indicate components of her response that did not correspond to signs she was given.

Experimental Procedure for Presenting Anomalous Combinations

Anomalous sign combinations given to Rocky between December 1986 and June 1988 are shown in Table 3. The experimental procedure for presenting anomalous combinations was designed to maximize Rocky's reliance on relations learned from the originally presented and familiar combinatorial forms and minimize the effects of new learning from repetition of an anomalous combination. The anomalous combinations were presented as infrequent single probes and averaged less than one presentation per day (less than one per 70 standard baseline combinations), with as long as 2 months between successive presentations of the same anomalous form. The subject received a maximum of two anomalous probe trials per session, each of a different form. All anomalous probes were unreinforced.

Results

Sequential Conditional Discriminations Based on Standard Sign Order

The standard sign combinations given to Rocky (Table 2) all followed conventions for the sequential arrangement of signs. Table 4 expresses these sequential ordering conventions as pairwise sequential relations between two events. For example, standard combinations never started with an action

Table 3
Anomalous Sign Sequences Given to Subject (December 1986 to June 1988)

Anomaly type	Example	No. trials
Transposed signs		
Transposed modifier and object		
O–M–A	CUBE SMALL MOUTH	7
O–M–M–A	BALL BLACK LARGE FLIPPER	6
M–O–M–A	WHITE CUBE SMALL UNDER	6
Transposed object and action		
A–O	TAIL CAR	10
O–A–O	RING FETCH BAT	12
A–O–p–O	FETCH WATERWING (pause) CAR	7
Omitted signs		
Omitted object		
M–A	WHITE OVER	6
M–M–A	LARGE BLACK FETCH	4
Omitted action		
O	PIPE	4
O–p–O	PERSON (pause) BAT	4
Omitted modifier		
O–A	BALL OVER	6
Added signs		
Added modifier		
M–M–O–A (nonbelonging)	BLACK LARGE WATERWING FETCH	6
M–M–O–A (conflict)	BLACK WHITE PIPE TAIL	6
M–M–M–O–A	BLACK LARGE SMALL CONE OVER	18
Added action		
O–A–A	CAR OVER MOUTH	16
Relational sequence, nonrelational action		
O–p–O–A (not fetch)	BALL (pause) CUBE FLIPPER	12
Nontransportable transported item		
O–p–O–A	BOTTLE, PERSON FETCH	3
Pause anomaly		
O–p–A	BAT (pause) UNDER	6
Total		149

sign but only with a modifier or object sign. If a modifier sign was given, another modifier or an object sign might follow, but an action sign never followed a modifier. These conditional rules for sequential pairing of signs not only produced all of the standard combinatorial forms taught to Rocky but, more important, had the potential to set up two classes of anomalous combinations, those that conformed to standard sequential sign pairings and those that did not.

Table 5 lists Rocky's orienting responses to anomalous combinations that did not conform to the standard sequence rules in Table 4. In almost all of these anomalies (62 of 70, or 89%), Rocky produced an orienting response that was consistent with a sign class that would have normally appeared in that sequential position in a standard combination but that was inconsistent with the sign class actually given in the anomalous combination. For example, when given the anomalous sequence M–M–A or M–A (no object sign), Rocky gave an object orientation to the action sign in 9 of the 10 trials (Table 5). Rocky's performance responses to the sequentially anomalous combinations were also disrupted: Her responses to the 70 sequentially anomalous trials consisted of 55 balks (79%), 15 responses that did not completely match the signs given (21%), and no responses that corresponded to all the signs given.

In some anomalous forms there was more than one sequence anomaly and therefore more than one potential orienting error (see Table 5). For example, O–M–M–A contains a modifier sign after an object sign and an action sign after a modifier sign.

Hierarchical Conditional Relations

By the results just reported, we demonstrate that Rocky learned conditional relations between sequentially ordered sign classes and that these sequential conditional relations were an integral part of the process by which Rocky arrived at a response. Now we demonstrate that Rocky's response behavior was also controlled by learned conditional relations between subsets of signs within a complete sequence. The conditional relations between subsets of signs are referred to as *hierarchical relations* because specific signs or combina-

Table 4
Conditional Sequential Pairings of Signs in Subject's Standard Combinations

Sign W	Sign X
Start	Modifier or object
Modifier	Modifier or object
Object	Pause or action
Pause	Modifier or object
Action	Release

Note. Sign W sequentially precedes Sign X in standard sign combinations.

Table 5
Orienting Errors to Sequentially Anomalous Sign Sequences

Standard form	Sequence anomaly	Orienting response	Errors	Total trials
O–A	A–O	*o*–a	3	9
		a–*a*	6	9
	O–A–O	o–a–*a*	11	12
O–p–O–A	A–O–p–O	*o*–o–p–o	5	7
		a–*a*–p–*a*	2	7
	O–p–A	o–p–*o*	5	6
(M–)M–O–A	(M–)M–A	(m–)m–*o*	9	10
M–O–p–O–A	M–p–O–A	m–*o*–a–a	8	8
O–p–M(–M–)O–A	O–M(–M–)A	o–m(–m–)*o*	5	13
		o–*a*–*a*–*a*	3	13
M–O–A	M–O–M–A	m–o–*a*–a	5	5
Total			62	70

Note. O = object (shape) sign; A = action sign; M = modifier sign; and p = pause. Erroneous components of response are identified by italics.

tions of signs had to be present within a sequence in order for other hierarchically secondary signs to conditionally modify or change the final response. These relations between signs were not necessarily sequential: Signs given earlier in the sequence might not have any relevance to the response outcome until later signs or sets of signs were given.

Object–Action Anomalies

Before this first sign combination, Rocky had been able to direct an action at any object in the pool, regardless of the object's shape, and she had performed only one action (pointing) during all object discrimination training trials. The first sign combination (Stage 3; see Table 1) required Rocky to use information from both an object sign and an action sign to form her response. All subsequent training stages were impositions of conditions on the initial O–A pairing and as such were dependent on Rocky's being able to put together information from an object and an action sign. Furthermore, in Rocky's standard combinations the object sign always came immediately before the action sign.

Table 6 lists all anomalies that were either lacking an object or an action sign (22 balks in 22 trials) or that did not contain an O–A sequential pairing (27 balks and 2 responses that did not correspond to the signs given in 29 trials). Conceivably, there were a number of potential responses to these anomalies: balking, performing the designated action on any object in the pool, performing any action on the designated object, or if both an object and action sign were given, performing the designated action on the designated object. Rocky did not produce any response that completely corresponded to the signs given when an anomalous combination did not contain an O–A sequential pair. For example, when given the action sign FLIPPER, Rocky did not approach and flipper any object, and when given the missing object anomaly LARGE FETCH, Rocky did not fetch a large object to the signaler.

Modifier Anomalies

After the training of the O–A sign pairing, Rocky was taught to integrate additional signs that imposed conditions on object selection by adding relative size or brightness discriminations to the shape discrimination imposed by the object sign. The added class of signs was referred to as the *modifier class* because it modified object choices (Stage 4; see Table 1).

Modifier signs required an object sign, but object signs did not require a modifier sign. Modifier signs required a subsequent object sign, even in contexts where modifier information alone could provide Rocky with the necessary discriminative cues for selecting a single correct response item. For example, in the first replicate of a missing object sign anomaly, WHITE OVER, there were only two objects in the pool, both of the same shape; one was white and the other was black. Rocky did not, however, attempt to perform an action with either of the objects and instead balked on all 10 replicates of the missing object sign anomaly.

In comparison, Rocky treated modifier signs as optional even when the context (two or four choice items of the same shape) normally required modifier signs. In this anomaly the sign combination (O–A) was not anomalous in form but

Table 6
Subject's Responses to Anomalies Without an O–A Sequential Pair

Sequence	Response: Balk	Response: Other
Omitted object		
M–A	6	0
M–M–A	4	0
A	4	0
Omitted action		
O	4	0
O–p–O	4	0
Transposed modifier and object		
O–M–A	7	0
O–M–M–A	5	1
M–O–M–A	6	0
Transposed object and action		
A–O	9	1
Total	49	2

Note. O = object (shape) sign; A = action sign; M = modifier sign; and p = pause.

anomalous for the context in which it was given, thus pitting the structural or syntactic relations between signs against the referential relation between signs and referents. Because there was a possibility that Rocky might use the absence of the modifier sign as a cue to confine her search to object shapes represented by only a single object, we also included two to four other objects in the pool, which made a total of four to eight objects available for response.

In all 6 replicates of this anomaly, Rocky performed the signed action on the nearest object of the signed shape (this was not necessarily the first or only object she saw during her orienting response to the object sign). For example, in the first replicate of this anomaly, she was given the sign sequence BALL OVER when there were two balls in the pool along with several other objects of different shapes, a context that would normally require the addition of a modifier sign to indicate which of the two balls was the one-and-only correct response item. Rocky unhesitatingly performed a "ball over" response to the nearest of the two balls. She gave no indication of behavior influenced by the contextual anomaly between signs and referents. Nothing in her orienting or response behavior indicated that she was sensitive to the possibility that more than one appropriate choice might be available or that she was in conflict about the response she was making (e.g., she made no prolonged searching or unusual orienting movements).

Multiple modifier signs did not have to be given in a fixed sequence. We stated above that Rocky was sensitive to and learned sequential ordering relations between sign classes. However, when a second modifier category (size; LARGE and SMALL) was added to the first trained modifier category (brightness; WHITE, GRAY, and BLACK), the two modifier classes were presented equally often as size–brightness (e.g., LARGE BLACK BALL FETCH) or brightness–size (e.g., BLACK LARGE BALL FETCH). Table 7 shows that there was no significant difference in Rocky's performance on modifier pairs in her baseline sessions, regardless of modifier sign order. Despite a demonstrated sensitivity to sequence regularities, Rocky was nevertheless able to combine signs that were not paired in a regular sequential relation and maintained both fixed order and free order relations between signs within a combination without confusion.

Table 7
Subject's Responses to Interchangeable Modifier Combinations in Standard Two-Modifier Sequences

Modifier pair	Errors	Total trials
LARGE BLACK	1	62
BLACK LARGE	4	87
LARGE WHITE	5	68
WHITE LARGE	6	68
SMALL BLACK	4	78
SMALL WHITE	1	72
WHITE SMALL	6	100
M	4.0	76.1

Note. All chi-square tests on the data were nonsignificant.

Effects of Interference and Proximity on Modifier Use

Because Rocky was able to process multiple modifiers in her standard combinations, we designed anomalies that preserved the form of standard combinations but were anomalous in terms of the responses indicated by the combined signs (see Table 3, Added modifier anomalies). In the first case Rocky received a standard M–M–O–A sequence that contained two conflicting modifiers (e.g., BLACK WHITE PIPE FETCH) rather than one size and one brightness modifier. In all six replicates of this anomaly, Rocky used the second modifier, the one that immediately preceded the object sign (i.e., "white pipe fetch" not "black pipe fetch"; $p = .0156$, binomial test). There were 4 to 10 objects present during each trial ($Mdn = 6$), and these included objects that corresponded to the signs given (e.g., a black pipe and a white pipe) and at least one other object of each modifier category (e.g., a black bat and a white waterwing), so that an object could not be singled out on the basis of its being the lone or odd representative of one of the modifiers given.

In the second type of multiple modifier anomaly, a nonbelonging size modifier was placed either first (3 trials) or second (3 trials) in a modifier pair. The size modifier was called a *nonbelonging* modifier because it had never been used in combination with the object sign used in the anomaly, and in fact there was only one size of the signed object shape. Thus, the combinations BLACK LARGE WATERWING FETCH and SMALL WHITE CAR UNDER were anomalous because they imposed a size modifier on an object that did not come in two different sizes. In all six replicates of this anomaly, Rocky's response included the correct action, object shape, and color modifier, regardless of the position of the nonbelonging size modifier (e.g., Rocky's responses to the above examples were "black waterwing fetch" and "white car under"). For all trials there were 4 to 10 objects in the pool ($Mdn = 6$), and these included both objects of the indicated shape (e.g., a black car and a white car) and at least one pair of objects that did differ in size (e.g., a large white football and a small white football), which allowed Rocky to apply the size modifier information during her orienting or performance responses.

Given Rocky's performance with conflicting modifiers, we had hypothesized that Rocky might have more difficulty selecting the correct brightness modifier if it were separated from the object sign by a nonbelonging size modifier, because of interference by the nonbelonging modifier. However, Rocky had no more trouble making the correct brightness modification when the brightness modifier sign was separated from the object sign by a nonbelonging modifier than she did when the brightness modifier sign was sequentially contiguous to the object sign.

To further explore the effects of interference and sign proximity on Rocky's ability to incorporate multiple modifiers into her responses, we gave Rocky triple modifier anomalies that contained two conflicting modifiers together with a modifier of the other type (i.e., if we used two conflicting brightness modifiers, then the third modifier was a size modifier). The relative positions of the modifiers created three different types of triple modifier anomalies, which differed in the degree of separation of the other modifier and the object sign by the conflicting modifiers (see Table 8). There were 4 to 10 objects present, such as all four objects of the indicated shape (e.g., large white, small white, large black, and small black cones), during these anomalous trials (*Mdn* = 8).

Both the Modifier 1–2 and Modifier 1–3 conflicts presented Rocky with a size modifier, brightness modifier, and object sign in uninterrupted sequence. For example, the Modifier 1–2 conflict sequence SMALL LARGE BLACK BALL MOUTH allowed Rocky to select the response item "large black ball" by using the last two modifiers plus the object sign. Similarly, the Modifier 1–3 conflict sequence LARGE BLACK SMALL BOTTLE FETCH allowed Rocky to select the response item "black small bottle" by using the same three consecutive signs. Rocky made an object choice that matched the last two modifiers (second and third modifiers) in 8 of 12 trials (Table 8).

However, Rocky had more difficulty selecting a response item if she could not put together an uninterrupted sequence of an object sign and one of each modifier class. In the Modifier 2–3 conflict anomaly, the three signs for brightness, size, and object shape were unavoidably separated by a conflicting modifier. For example, an object choice for the signs given in LARGE BLACK WHITE BOTTLE FLIPPER could have been either "large black ... bottle" or "large ... white bottle." Compare the results for the Modifier 1–2 and Modifier 1–3 conflict trials to the disruption of responding that occurred in the Modifier 2–3 conflict trials: In 6 replicates of the Modifier 2–3 Conflict anomaly, Rocky produced only one object choice for the signs given and balked on 4 of the other 5 replicates (she did not balk on any of the other triple modifier anomalies).

Relational Anomalies

The training of the relational response was achieved, like modifier training, by imposing an added conditional relation on responses indicated by O–A sign combinations. Relational instructions were formed by the addition of a second object sign (with optional modifiers) to a FETCH object–action pairing, by which we conditionally changed a single-object, nonrelational instruction like BAT FETCH to a relational instruction like BALL, BAT FETCH (fetch the bat to the ball).

Rocky did not respond to relational anomalies that did not contain an O–A pair. All relational anomalies that did not contain an O–FETCH sequential sign pair resulted in balks (Table 6). Rocky balked on all four presentations of the O–p–O anomaly (e.g., PERSON, BALL rather than the standard form PERSON, BALL FETCH) even though the missing action sign, FETCH, was the only action sign ever given to Rocky in the relational context. If Rocky had simply processed signs in the order given, then the O–p–O sequence might have been sufficient to elicit a relational fetch response, because the action sign in this context did not supply additional semantic content to the instruction. Rocky also balked on all 7 replicates of the anomalous form (A–O–p–O), which included an object sign and a FETCH action sign but were not in the standard O–A order (e.g., FETCH WATERWING, CAR rather than the standard form WATERWING, CAR FETCH).

Rocky used the relational cue only when the action sign was FETCH. Further evidence for the hierarchical precedence of the object–action pair within the relational combination came from anomalies in which a different action sign was substituted for FETCH (e.g., CUBE, BALL TAIL). Table 9 shows that in 11 of 12 replicates of this anomaly, Rocky's response matched the O–A pair and was not affected by the second object sign (as a cue to perform a relational response).

Relational Anomalies That Elicited Relational Responses

The anomalous form O–A–O contained a standard O–A pairing (wherein A is FETCH), and Rocky was able to produce a relational response to 5 of 12 replicates of this anomaly (she

Table 8
Subject's Responses to Triple-Modifier Anomalies

Anomaly type and sign sequence	Response
Modifier 1–2 conflict	
SMALL **LARGE BLACK BALL MOUTH**	**large black ball mouth**
WHITE BLACK **SMALL BALL UNDER**	**white small ball under**
SMALL **LARGE BLACK CONE TAIL**	**large black cone tail**
BLACK **WHITE LARGE FOOTBALL FLIPPER**	**white large football flipper**
LARGE SMALL BLACK **CONE OVER**	**large** white **cone over**
BLACK **WHITE SMALL CUBE UNDER**	**white small cube under**
Modifier 1–3 conflict	
BLACK **LARGE WHITE BALL** TAIL	**large white ball** [to disc]
SMALL BLACK LARGE **BOTTLE FETCH**	**small black bottle fetch**
BLACK **SMALL WHITE BALL MOUTH**	**small white ball mouth**
SMALL **BLACK LARGE CONE MOUTH**	**black large cone mouth**
WHITE LARGE **BLACK BALL FETCH**	small **black ball fetch**
LARGE **BLACK SMALL BOTTLE FETCH**	**black small bottle fetch**
Modifier 2–3 conflict	
LARGE BLACK WHITE BOTTLE FLIPPER	balk
BLACK SMALL LARGE CONE OVER	balk
WHITE LARGE SMALL CUBE TAIL	balk
WHITE LARGE SMALL **BOTTLE UNDER**	**white large bottle under**
LARGE **BLACK** WHITE **BALL** TAIL	small **black ball** flipper
LARGE WHITE BLACK CUBE OVER	balk

Note. Corresponding components of correct responses are identified by words in bold.

balked on the other 7 replicates). All 5 responses were relational fetches in which the transported object matched the sign that preceded the FETCH action sign (the same as a standard relational FETCH). For example, when Rocky was given the anomalous instruction CUBE FETCH CAR, her response was to fetch the cube to a black pipe (see Table 10).

Another anomalous form (O–A–A) illustrates the hierarchical organization of a response based on the initially trained O–A pair. Table 11 shows that Rocky produced a response other than the one indicated by the nonrelational O–A pair in 10 of 16 (63%) replicates of this anomaly. Distribution of responses over time was not even ($H = 11.24$, $p < 0.05$; Kruskal-Wallis test), which indicates that Rocky was not responding randomly to the O–A–A anomalies: Her first 6 responses included one of the two signed actions and were followed by four balks in the next 6 trials; the final 4 presentations of this anomaly elicited a flipper action, regardless of the action signs given (none were FLIPPER). If this apparent pattern was the result of learning from the unreinforced O–A–A probe trials, it was the product of a truly amazing feat of memory. As many as 106 days passed between successive presentations of this anomalous form (range, 4–106 days, $M = 23 \pm 28.9$, $Mdn = 10$). Between presentations of this anomalous form, Rocky was exposed to hundreds or even thousands of differentially reinforced standard combinatorial forms and approximately one unreinforced anomalous trial per day, drawn from 17 other different anomalous forms (see Table 3).

Anomalies That Tested for Expanded Referential Relations Between Signs and Referents

Some anomalous combinations listed earlier also presented opportunities for Rocky to demonstrate that she had formed additional relations between the sign and the referent other than those explicitly trained (paired associate relations) or those demonstrated earlier (sequential and hierarchical conditional relations between functionally equivalent classes of elements). The specific anomalies and the potential responses are described now.

Table 9
Subject's Responses to Anomalous Commands in Which the Action Had Not Been Previously Used With Two Object Signs

Sign sequence	Response
CUBE, **BALL TAIL**	**ball tail**
BOTTLE, **FOOTBALL UNDER**	**football under**
CAR, **BAT MOUTH**	**bat mouth**
BALL, **BAT UNDER**	**bat under**
DISC, **BALL OVER**	**ball over**
FOOTBALL, **WATERWING TAIL**	**waterwing tail**
PERSON, **DISC MOUTH**	**disc mouth**
WATERWING, **PIPE MOUTH**	**pipe mouth**
WATER, **BAT UNDER**	**bat under**
WATERWING, **CAR FLIPPER**	black ring, **car** fetch
RING, **WATERWING OVER**	**waterwing over**
BALL, **CUBE FLIPPER**	**cube flipper**

Note. Corresponding components of correct responses are identified by words in bold.

Table 10
Subject's Responses to the O–A–O Anomalous Form

Sign combination	Response
WATERWING FETCH BOTTLE	balk
BOTTLE FETCH BALL	balk
RING FETCH BAT	balk
PIPE FETCH CAR	**pipe fetch (to) car**
BOTTLE FETCH CAR	balk
RING FETCH CAR	balk
CUBE FETCH CAR	**cube fetch** (to) pipe
BALL FETCH PIPE	**ball fetch** (to) bottle
DISC FETCH WATERWING	**disc fetch** (to) ring
BAT FETCH BOTTLE	**bat fetch** (to) football
FOOTBALL FETCH CONE	balk
BLACK CAR FETCH PIPE	balk

Note. O = object (shape) sign, and A = action sign. Corresponding components of correct responses are identified by words in bold. The object that served as the destination object in a response is preceded by a parenthetical *to*. The standard relational sign combination is of the form O–p–O–A (e.g., BALL, BAT FETCH). For the O–A–O anomaly (e.g., BALL FETCH BAT), there are potentially two response types that make use of all the signs: Both depend on whether the relation of the two designated objects is determined by their relative sequential positions (e.g., [to] ball, bat fetch) or by their relation to the action sign (e.g., ball fetch [to] bat).

Sequence Anomalies

All anomalous combinations that contained an action and an object sign (with optional modifiers) conveyed information sufficient to elicit a correct response if just the information of the individual signs was considered, without regard to conventions of sign ordering. Thus, the anomaly FLIPPER BALL (A–O) could direct Rocky to flipper a ball as well as the standard BALL FLIPPER. Indeed, one of our major purposes in developing the relational instruction was to create a combinatorial form in which a syntactic device (sign order) added information not conveyed by the signs alone (Herman et al., 1984). Nevertheless, despite the semantic unambiguity of single object instructions, all such instructions given out of the usual order failed to elicit a response and resulted in Rocky's balking or responding incorrectly (see the last row in Table 6). In other words, given an equal opportunity to apply learning about sequential and semantic relations, Rocky consistently applied learned sequential relations.

Conflicting Modifiers

In the conflicting modifier anomaly, Rocky was instructed to respond to a BLACK WHITE BALL or a LARGE SMALL CONE. If Rocky had been operating on an expanded semantic understanding of the modifiers, the semantic implications of the conflicting modifiers might have elicited a startle or other abnormalities in orienting responses after the presentation of the conflicting modifier. Alternatively, Rocky might have attempted a response to both modifier designations (e.g., responding to both the black ball and the white ball or to both the large and small cones).

Table 11
Subject's Responses to Added Action Anomalous Sequences

Trial	Sequence	Response	Type
1	**CAR OVER** MOUTH	**car over**	first
2	**CONE OVER** TAIL	**cone over**	first
3	**DISC** TAIL **FLIPPER**	**disc flipper**	second
4	**BALL UNDER** MOUTH	**ball under**	first
5	**PIPE** MOUTH **FLIPPER**	**pipe flipper**	second
6	**WHITE BOTTLE** OVER **MOUTH**	**white bottle mouth**	second
7	**PIPE** TAIL UNDER	**pipe** over	neither
8	RING FLIPPER OVER		balk
9	**FOOTBALL** OVER MOUTH	**football** flipper	neither
10	WATERWING FETCH TAIL		balk
11	BLACK BAT FLIPPER OVER		balk
12	BOTTLE OVER FLIPPER		balk
13	**DISC** TAIL UNDER	**disc** flipper	neither
14	**CUBE** MOUTH UNDER	**cube** flipper	neither
15	**FOOTBALL** MOUTH TAIL	**football** flipper	neither
16	**CONE** MOUTH FETCH	**cone** flipper	neither

Note. Corresponding components of correct responses are identified by words in bold. For response types, first = response corresponds to first action sign, and second = response corresponds to second action sign.

Impossible Instructions

Rocky was given three standard relational sign sequences (O–p–O–A) that instructed her to transport objects secured to the pool wall and therefore immovable. These objects were PERSON and WATER (a stream of water from a hose). For example, CAR, PERSON FETCH instructed Rocky to take the immovable (in her experience) person to a toy car in the pool. Rocky had considerable experience with the immovability of these items because she consistently gathered in all objects except the person and the water at the end of each block of trials (every 3–8 trials). In all three of these impossible instructions, Rocky did not reject the instruction as impossible when it was given, but instead she began a response and broke it off only when she arrived at the immovable object. Her responses did not provide evidence for an expanded semantic relation between the signs and referents (understanding derived from the signs alone, without direct access to the referents themselves).

Discussion

Rocky's responses to the anomalous combinations showed that she had learned relations between combined signs in addition to the specifically trained relations between individual signs and their referents. The learned relations functioned as a syntax: Some anomalous forms were unintelligible (to Rocky) in that they did not elicit a response even though the information from the signs was sufficient to designate a response; other anomalous forms consistently elicited only one or a few types of responses even though there were other types of response also consistent with the signs or a subset of the signs in the anomalous combination.

None of the syntactic relations Rocky learned were logically necessary, with the exception of the ordering relation between the two object signs in relational combinations (see Schusterman & Gisiner, 1988). The relational combination (O–O–A) had been introduced specifically to add structural complexity to the artificial language because in all other combinations the signs alone, regardless of their order, were sufficient to indicate a response through their paired associate relations. The fact that Rocky did learn additional unnecessary relations implies that these logically unnecessary relations were in fact a necessary part of the process by which Rocky translated combined signs into a response. Some relations between signs, like the interference and sequential proximity effects noted in the modifier anomalies and previously noted in relational combinations (Schusterman & Gisiner, 1988), appear to be relatively straightforward consequences of limitations in working memory. Others, like the sequential relations between signs and the hierarchical relations between response components, clearly required more complex cognitive learning abilities.

Sign Sequence

Rocky's orienting responses to sequence anomalies demonstrated that she had learned the standard sequential relations of her familiar sign combinations. When presented with nonstandard sequences (sequence anomalies), she gave standard and therefore inappropriate orienting responses to signs that were out of sequence.

The data from the sequence anomalies alone give the superficial impression that the orienting response was no longer controlled by the sign that immediately preceded it, sign X, but by the sign that preceded sign X in sequence, sign W (see Table 4). However, two aspects of Rocky's standard response behavior cannot be reconciled with this simple interpretation. First, some standard sequential relations had more than one acceptable sign class X following sign class W. For example, either a modifier or an object sign could follow a modifier sign (see Table 4). Given that Rocky did not make orienting errors in standard sequences, the sign class X (e.g., modifier or object sign) must have played some role in determining which of the two potential orienting responses was in fact appropriate to the sign X given. Specifically, if a modifier sign was given as sign W, then either a modifier sign or an object sign might follow as sign X. If sign X was a modifier, Rocky produced a modifier orientation; if sign X was an object sign, Rocky produced an object orientation. Furthermore, when sign X was an object sign, Rocky oriented to an object in the pool that matched that sign (see Figure 1). Therefore the orienting response must have been controlled to some extent by the object sign X.

An alternative explanation that accounts for both the effects of sign X and sign W on the orienting response is that sign W created an expectancy about sign X. In general usage the term *expectancy* implies an unverifiable internal state of the subject and therefore may be scientifically unacceptable to many serious students of animal learning and behavior. However, the net effect of the learned sequential relations on response behavior was indistinguishable from the effect of an expectancy. We therefore believe we are justified in referring to these learned sequential relations between signs as *expectancies,* with the understanding that the word *expectancy* is used to refer to a relation between observable events and excludes any claims about the internal state of the subject. Specifically, the word *expectancy* is used to refer to a situation in which a response behavior is not consistent with a cue (sign X) that immediately precedes the response and is normally associated with the response but is consistent with a cue or cues that came even earlier (sign W).

Finally, an emergent effect of these learned sequential relations must be noted. Rocky did not respond to sequences other than the ones learned, even when the unfamiliar sequences contained all the signs needed to specify a response. In other words, whatever benefit there was to learning predictable sequential relations between events, there was also a cost: The subject was rendered unable to respond to a large set of logically meaningful instructions because the signs were not in standard order.

Hierarchical Conditional Relations

The results showed that Rocky had learned hierarchical relations between signs or subsets of signs that corresponded to successive stages in her training. The initial or primary stage was the designation of a complete response by an O–A sign pair. Successive training stages imposed conditional restrictions on object choices (modifiers) or conditionally changed responses (relational FETCH) and thus were hierarchically dependent on the presence of the preceding stage (O–A).

Object–Action Anomalies

Rocky did not respond to any anomalous form that did not contain an O-A sign pair (Table 6). In contrast, if hierarchically secondary signs were missing, as in the missing modifier anomalies, or were inappropriate to the context established by the O–A pair, as in the nonbelonging modifier and non-FETCH relational anomalies (Table 9), Rocky nevertheless responded and her responses matched the sequentially paired object and action sign within the anomalous combination.

Modifier Anomalies

The modifier anomalies revealed a number of learned relations that Rocky applied only to modifier signs.

Modifier signs required an object sign, but object signs did not require a modifier sign. Modifiers were optional and dependent signs. That is, Rocky produced a response in the absence of modifiers even when modifier information was required to designate a single correct response item, but she did not produce a response when a modifier sign without an object sign was sufficient to designate a single correct response item.

The dependency of modifier information on object shape information was consistent with Rocky's training history, in which modifiers were only used in addition to object signs and never by themselves. Rocky's orienting responses also showed that Rocky waited for an object sign before searching for a response item that matched the modifier and object signs. As Figure 1 shows, Rocky did not scan the pool for potential correct choices after receiving the WHITE and SMALL modifiers but instead waited for an object sign (BOTTLE) and then used the criteria established by all three signs in her search for the correct response item (WHITE SMALL BOTTLE). This means that Rocky had to retain in memory some representation of the modifier sign information while she attended to and processed other signs before she could use the cues provided by object and modifier signs to find a response object during her object orientation. Some idea of Rocky's representation of the modifier information was obtained by Schusterman and Krieger (1986), but the subject of mental representation is a complex topic that cannot be adequately addressed in this article (see Roitblat, 1987).

Multiple modifier signs did not have to be given in a fixed sequence. Rocky's responses to standard double modifier combinations (Table 7) showed that she could learn to integrate information that was not presented in a fixed sequential relation to other information. As we stated earlier, Rocky showed a strong predisposition to learn sequential ordering relations between signs, and her response behavior was strongly controlled by these learned ordering relations. However, when presented with combined signs that did not have fixed ordering rules (double modifiers), she was able to incorporate information from the signs into a response, regardless of modifier sign order (Table 7).

Effects of interference and proximity on modifier use. The multiple modifier anomalies demonstrated that interference between signs of the same class favored retention of the relatively more recent (later in sequence) member. In the conflicting modifier anomaly, two modifiers that designated conflicting properties of an object (e.g., BLACK WHITE BALL FETCH) were given to Rocky, but her response consistently matched the second of the two conflicting modifiers, that is, the relatively more recent modifier in the sequence. In a previous study (Schusterman & Gisiner, 1988), we found a similar interference–recency effect operating on the signs that designated the two objects in standard relational combinations. The fact that a nonbelonging size modifier did not interfere with retention of a belonging brightness modifier suggests that Rocky may have treated the two types of modifiers (size and brightness) as two different functional equivalence classes, even though both types of modifiers operated as a single functionally equivalent class in other syntactic relations (e.g., sign sequence).

Sequential proximity also played a role in the integration of multiple modifiers and an object sign into a single orientation and response item choice. When the brightness modifier–size modifier–object sign sequence that designated a response object was interrupted by a conflicting modifier pair (Modifier 2–3 conflict anomaly, Table 8), Rocky was unable to select a response item to match the signs given and in fact balked in 4 of the 6 trials. In comparison, the Modifier 1–2 and Modifier 1–3 conflict anomalies contained uninterrupted sequences of brightness modifier–size modifier–object sign. Rocky did not balk on any of these anomalies and her response item matched the signs in uninterrupted sequence in 8 out of 12 trials. The syntactic effects of recency and sequential proximity are probably not learned relations but are most likely imposed by memory and recall processes.

Relational Anomalies

Rocky's responses to the relational anomalies showed that the relational response was hierarchically secondary to, and dependent on, designation of a nonrelational fetch response by an O–A combinatorial form in which the action was FETCH.

Rocky did not respond to relational anomalies that did not contain an O–A pair. The A–O–p–O anomaly (with the action FETCH) contained all the signs present in a standard relational instruction but out of their usual order. The O–p–O anomaly contained all the signs semantically necessary to designate a relational response because there was only one action sign (FETCH) used in a relational combination. The appropriate response could therefore have been inferred by default from the two object signs alone. However, Rocky balked on all presentations of both of these anomalous forms.

Rocky used the relational cue only when the action sign was FETCH. Use of an action other than fetch in a relational combination (O–p–O–A) resulted in responses that matched only the nonrelational O–A sign combination (see Table 9). This means that the conditional relations between signs that controlled Rocky's performed response were not necessarily sequential: Rocky obviously received the object sign at the start of the sequence because she oriented to the object that matched the sign, but she did not use this information in her response because the last sign in the sequence, the action sign, had specified a response that did not make use of the information. Therefore, the operational utility or inutility of the signs for the first object was not revealed until the last sign was given.

Relational anomalies that elicited relational responses. Rocky's responses to two other anomalous forms that did contain O–A sign pairs offer further evidence that response formation did not follow the sequential order of the signs as they were given. Rocky produced a relational response to 5 of 12 replicates of the anomalous form O–A–O (Table 10). In all 5 responses the transported object corresponded to the object sign that immediately preceded the action sign. These data show that Rocky was able to use an added object sign to conditionally alter a nonrelational fetch to a relational fetch, even when the added object sign was not in its usual sequential relationship to the O–A sign pair. It is interesting to note that Herman et al. (1984) used this relational form (O–A–O) with one dolphin and used the other form (O–O–A, Rocky's standard relational form) with another and obtained comparable results from both dolphins.

Rocky was also able to respond to another anomalous form that appended an action sign to an O–A pair (the O–A–A anomaly, Table 11). Three of her first 4 responses corresponded only to the O–A pair, and her response was unaffected by the presence of a second action sign, just as her responses to nonbelonging modifier and non-FETCH relational anomalies had been unaffected by the presence of inappropriate signs. Rocky balked on 4 other presentations of this anomaly. However, on the remaining 9 presentations, she responded with actions other than the one indicated by the first action sign. Thus the second action sign functioned like the added object sign in a relational FETCH instruction, conditionally changing the response. It is tempting to speculate further on the types of strategies that Rocky may have been using during her production of these altered responses, given that the overall pattern of responses was nonrandom. However, none of the apparent trends in the data are statistically significant. We therefore limit our conclusions to noting that Rocky was able to spontaneously respond to this anomaly, that her responses were consistent with the hierarchical conditional relations developed by training with the standard combinatorial forms, and that with differential reinforcement, consistent responding could probably have been established and thus could have added the O–A–A form to her repertoire of standard combinatorial forms.

Anomalies That Tested for Expanded Referential Relations Between Signs and Referents

We were unable to obtain evidence that Rocky had learned additional relations between sign and referent that might be interpreted as evidence for a greater semantic relation between sign and referent than the specifically trained paired associate relationship (i.e., evidence that the signs had acquired more meaning about the referent than the meaning given the sign by its paired associate relation with the referent). We caution against overinterpretation of these results. We do not wish to imply that a sea lion or any other nonhuman is incapable of forming a greater semantic relationship between sign and referent, nor do we wish to imply that we have exhausted the training and testing possibilities for demonstration of such learning (Schusterman et al., in press; also see our discussion of stimulus equivalence in our Conclusions). In addition, our data do not rule out the possibility that Rocky possessed and was operating on an expanded semantic relation between sign and referent that our tests failed to reveal. We do wish, however, to limit our discussion of the learning and cognitive capabilities of animals to experimentally demonstrated, verifiable phenomena. Because our tests did not provide an expanded referential role for the signs, we have limited our conclusions about Rocky's performance to the demonstrated conditional relations between response elements without speculating about the semantic relation between sign and referent.

Role of Functional Equivalence Classes

A learning ability central to both the sequential relations between signs and the hierarchical relations between response components was the ability to form functional equivalence relations between sets of signs (Sidman et al., 1989; Vaughan, 1988). The result was that both sequential relations between signs and hierarchical relations between response components operated consistently for all members of a functionally equivalent group of signs. The alternative possibility that a subject could learn to respond to each unique combination by trial-and-error alone and then retain and successfully recall the appropriate response for each of thousands of combinations is very remote indeed and is not supported by Rocky's consistent ability to respond appropriately to novel standard combinations and some novel anomalous combinations (Schusterman & Gisiner, 1988; Schusterman & Krieger, 1984).

An additional implication of functional equivalence relations is that each signal acquires multiple operational roles or connections. For example, the gestural signal FETCH not only served as a cue for a specific response action (paired associate relation) but, as a member of a functional equivalence class that included all action signs, also served as a cue in the sequential relations between signs. The complexity of the functional relations formed is illustrated by the exclusion of the FETCH sign from the set of all other action signs when a second object sign was present: Under these conditions a FETCH sign indicated a relational fetch, whereas all other action signs indicated a nonrelational response (Table 10). To the best of our knowledge, our results provide the most complex context in which an animal has been tested for the formation of functional equivalence relations. The number and complexity of the functional equivalence relations entailed by a single cue suggests a model for the expansion of the referential meaning of words in human language, but Sidman et al. (1989) made a strong case for the necessity of another learning ability, the ability to spontaneously learn reflexive, symmetric, and transitive relations between stimuli (stimulus equivalence), which has not been directly tested in this study.

Conclusions

We must also point out that other aspects of the task, besides the number and variety of cues and their combinatorial complexity, must be accounted for as one judges the learning capabilities of a subject. These include the probability of reinforcement (which was not manipulated in this experiment; all anomalous trials were unreinforced), the probability of encountering particular instructions or combinatorial forms (in this experiment all combinatorial forms were presented in equally balanced numbers), and the energetic cost or risk of different responses (for example, if modifiers were not given, Rocky performed the energetically least expensive response; she went to the nearest of several objects that matched the object sign). Overall, we ought to expect the subject to respond in a way most likely to maximize reinforcement (in this case, food) per unit of time or per unit of effort or to minimize cost or risk. To give a hypothetical example, if the frequency of relational instructions in baseline sessions had been twice that of nonrelational instructions, then we might expect the subject to produce a relational response to anomalous combinations that offered a choice between a relational response and a nonrelational response, because the subject's experience has been that a relational instruction (and response) was twice as probable as a nonrelational instruction and response.

This viewpoint is consistent with contemporary decision theory, signal detection theory, and animal learning theories (see Dickinson, 1980) that take into account the role of learning as a biological structure that subserves the organism's overall need to detect and respond appropriately to environmental events, whether these events are tracking schools of fish or responding to combined signs that also yield fish (see Schusterman, 1976). Although we did not manipulate these variables in our experiments, a comparison between our experiments with sea lions and similar experiments by Herman and his colleagues with dolphins does reveal performance differences attributable to differences in reinforcement contingencies in the two experimental procedures.

Comparison With Herman's Dolphin Language Experiments

Herman's (1986, 1987; Herman et al., 1984) accounts of performance on languagelike complex learning tasks in dolphins have used logical and semantic explanations that did not emphasize the reinforcement contingencies of the experimental design. This has made it difficult to determine whether sea lions and dolphins, given superficially similar tasks that yielded somewhat different results, were using different learning abilities or were using similar learning abilities that operated under different reinforcement contingencies.

The responses of sea lions and dolphins were similar for many anomalous forms (see Herman, 1986, 1987; Herman et al., 1984). In all such anomalies the nonlinguistic conditional relations learned by Rocky would be the simplest and therefore most parsimonious explanation of both dolphin and sea lion responses. Where differences in response behavior by dolphins and sea lions did occur, they can in most cases be plausibly connected to differences in reinforcement contingencies. For example, when the dolphins received nonsense signs in place of standard object or action signs or received transposed object–actions signs, they did not balk like the sea lions but instead produced a prospecting response that contained an arbitrarily chosen action or object that did not match the nonsense sign or one of the signs out of normal sequential order. It seems likely that the key to this performance difference between sea lions and dolphins was not the dolphin's recognition of a sentence that needed meaningful information to be complete and the willful selection of information to make the sentence complete but was simply that any and all of the dolphins' responses were reinforced whereas none of the sea lion's responses were reinforced. In other words, for the dolphins, but not the sea lion, it paid to guess.

Dolphins' responses to anomalies that are more recently reported (Kuczaj, Herman, & Holder, 1989) suggest to us that different contingencies associated with dolphin relational responses, including the relatively high frequency of relational combinations in baseline sessions, the use of action signs exclusively associated with relational responses (Herman et al., 1984), and the differential use of specific relational goal items associated with a high probability of reinforcement (Herman, 1987), have resulted in a relatively higher probability of relational responding to anomalies that contained both relational and nonrelational features.

Herman's linguistically based description of the dolphins' performances (Herman, 1987) is also problematic because it does not offer testable hypotheses about what, specifically, a dolphin has or has not learned once it has established competence in responding to a limited set of combinatorial forms. For example, it is not clear why Herman (1987) considered the novel form FRISBEE FETCH *THROUGH* HOOP (added element italicized) more grammatical than *SPEAKER,* PERSON PEC-TOUCH, especially given that our results indicate that the learned conditional relations between elements favor building new combinations by adding signs to the beginning or end of existing combinations, but not between elements of an existing combination.

This problem is compounded by the attachment of a linguistically based explanation to every response possibility (see Herman, 1987; Herman et al., 1984). A failure to respond indicated that the sentence had no meaning within the dolphins' language, a response to only part of the anomaly indicated recognition of a sentence embedded in the anomaly, and a response in the absence of information was the result of the dolphins' contributing missing semantic elements. If the dolphins used these criteria, any response they made or could make qualified as evidence of complex, linguistically based processing of the signs. This explanatory structure leaves no response criteria that may serve as evidence of less-than-linguistic understanding of the signs.

Difficulties in Applying Linguistic Terms to Animal Cognition: Suggestions for an Alternative Approach

At present, probably the greatest obstacle to understanding the relation between complex nonlinguistic cognition and language is the deficiency of our understanding of the evolution and ontogeny of human language skills, including syntactics. In earlier articles (Schusterman & Gisiner, 1988, 1989), we have pointed out that linguistic terms, which describe abilities emergent from undefined learning processes during human development, are not capable of providing operational criteria for linguistic or prelinguistic performance by animals. However, stimulus equivalence theory suggests an operational approach to a child's language development. If various stimuli are shown to be substitutable for one another, that is, the child's behavior is controlled by members of an equivalence class, then perhaps each stimulus serves as a referent for or is semantically equivalent to all other class members (Sidman & Tailby, 1982). Moreover, if untrained equivalence relations are similar to the novel recombinations of utterances characterized by human language, then stimulus equivalence paradigms allow a functional analysis of language competency (cf. Sigurdardottir et al., 1990).

In this article we show that the syntactic rules learned by a sea lion were explicable in terms of general cognitive learning abilities. We point out some departures of the sea lion's syntax from logically or semantically permissible syntax and propose that a greater semantic contribution to syntax may require the emergence of stimulus equivalence relations (e.g., reflexivity, symmetry, and transitivity) between signs and referents (see Sidman & Tailby, 1982; Sidman et al., 1989).

The fact that the syntactic abilities of sea lions and dolphins are explicable in terms of general learning abilities ought not to rule out the possibility that these abilities may be involved in human linguistic performance as well. In fact, it seems highly implausible that the linguistic abilities of humans have arisen in complete ontogenetic and phylogenetic isolation from nonlinguistic learning abilities.

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