ANIMAL LANGUAGE RESEARCH: MARINE MAMMALS RE-ENTER THE CONTROVERSY

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A horse named Clever Hans, who lived in Germany at the turn of the century, drew world-wide attention because he could apparently talk and solve arithmetical problems. By tapping with his front leg the horse could not only do arithmetic, but could also combine letters into words, words into sentences, and thus express his thoughts. What his questioners were unaware of was that Clever Hans used a simple "go" or "no-go" set of cues. The "go" cue was a slight leaning forward by the questioner, the "no-go" cue was an inadvertent straightening-up by the questioner when the correct number of taps had been reached (Pfungst, 1911; Sebeok and Rosenthal, 1981). Every time the correct number of taps was given the horse received a food reward. There are two lessons to be learned from the Clever Hans Effect, as it has come to be known. The first lesson is an obvious one; take precautions to prevent inadvertent cueing of subjects in psychological experiments. The second, and related, lesson is that one should interpret animal behavior parsimoniously rather than otherwise, i.e. use simple and straightforward assumptions and explanations of behavior rather than invoking uncalled-for complex processes.

However, as several recent authors have pointed out (e.g. Griffin, 1984) simple explanations and assumptions should not obfuscate or deny the existence of complex processes. Two examples from the animal problem-solving literature serve to illustrate this point. In the first example, a recent experiment on size transposition by a California sea lion (*Zalophus californianus*), it was shown that the animal learned about stimulus relations as well as about particular instances reflecting those relations (Schusterman and Krieger, 1986). The authors had to invoke both a cognitive (search image) as well as a mechanistic (stimulus generalization) concept in order to interpret their data. The second example comes from Köhler's "insight" learning by chimpanzees (Köhler, 1925). Although the phenomenon cannot be explained by a simple stimulus generalization mechanism, in which transfer is based on a *perceptual* similarity, it is partially explainable *conceptually* in terms of "rule learning" or learning set (Harlow, 1949). In this case, chimpanzees, by means of transfer of training, transcend the perceptual characteristics of the stimuli and respond with an abstract rule or strategy (Schusterman, 1962). Epstein, Kirshnit, Lanza,

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and Rubin (1984) have recently shown that experience with each component of a complex task leading to a spontaneous interconnection of the components may provide a different interpretation of "insightful" problem solving.

This paper will address the issue of appropriate parsimonious explanations for the learning of symbols and syntax by two Atlantic bottlenose dolphins (*Tursiops truncatus*) and three California sea lions. We will address a few of the issues recently raised by language comprehension projects in which one female dolphin named Akeakamai and one female sea lion named Rocky have been signaled gesturally to perform actions on objects (Herman, in press; Herman, 1986; Herman, Richards, and Wolz, 1984; Schusterman and Krieger, 1984; Schusterman and Krieger, 1986). Objects, properties and locations of objects, and actions were assigned unique symbols which could be combined to generate a limited set of commands.

Brief Outline of the Animal Language Research (ALR) Controversy, with Special Emphasis on Marine Mammals

Many of us who are now comparative psychologists, ethologists and sociobiologists were, as children, thrilled, intrigued and inspired by Hugh Lofting's fictional country doctor, John Doolittle, who could talk with the animals. As noted by Lorenz (1952), the goal of talking with animals appears an ancient one and extends back at least to biblical times in the legend of King Solomon talking the language of "beasts and of fowl and of creeping things, and of fishes" (I Kings IV.33). Today we seem to be realizing our earlier dreams by finding numerous kinds of mental attributes that "dumb" animals share with linguistically sophisticated humans (Roitblat, 1987). Right from the start, however, contemporary ALR (as it has been called by Hoban, 1986) was considered controversial (Wood, 1973). The crux of the controversy appears to be centered around the "all-or-none" question of animals (particularly anthropoid apes) being capable of communicating linguistically. Furthermore, Premack (1986) and Hoban (1986) suggest that language is not a unitary phenomenon, probably did not evolve solely from call systems of nonhuman primates and does not function exclusively as a communication system. They contend, rather, that the antecedents of human language are multifaceted and include some of the following "higher order mental processes:" (a) storing networks of percepts to form concepts, (b) using symbols to refer to objects and events, and (c) organizing events into a serial order. These and other linguistic abilities frequently depend on higher order conditioning that allows associations to be formed between the signals themselves, producing "logical worlds . . . built of concatenated stimulus events" (Hollis, 1984).

Currently many investigators in ALR, despite earlier controversy, agree that anthropoid apes, unlike most five-year-old children, are not linguistically competent enough to produce or comprehend an intelligible sentence. However, with training they are capable of semantic communication using multisign sequences (Miles, 1983). They can communicate this way with their teachers and/or with one another in either Pidgin Sign English (Fouts, Fouts and Schoenfeld, 1984), or in an artificial language consisting of visual symbols (Savage-Rumbaugh, 1986). With few exceptions, the earlier all-or-none focus of ALR on grammatical competence has been abandoned in favor of attempts to describe and understand the emergence of symbolic communication capabilities in animals as a function of species differences, training and developmental variables. Attempts to determine the limits of artificial language acquisition in animals are of interest because they may enable us to pinpoint and analyze precursors of human language ability in the cognitive processing skills of nonhuman animals. What are some of the protolinguistic skills of animals, and are there some animal groups that are capable of acquiring a natural language?

The first failed attempts to teach spoken language to chimpanzees occurred during the 1930's and began as part of a series of cross-fostering studies aimed at describing the similarities and differences between the mental and physical development of human and chimpanzee infants (Kellogg, 1968). The breakthrough in ALR occurred in the late 1960's with two infant chimps (Washoe and Sarah) in programs initiated by Allan and Beatrice Gardner (1969) and by David Premack (Premack and Schwartz, 1966). Apes were considered logical choices for ALR based on a variety of homologous psychological traits shared by apes and humans, as a consequence of their relatively recent descent from common ancestors.

Lilly and Dolphins

Chimpanzees were not the only subjects of ALR in the 1960's. Several ALR programs which, in fact, preceded the ape investigations were inspired by John Lilly's (1961) attempts to teach Atlantic bottlenose dolphins to understand and speak English. Lilly's choice of dolphins for ALR was based on two interlocking criteria:

1. Bottlenose dolphins have a relatively large brain with a proportionally large neocortex. This can be expressed quantitatively as a high encephalization quotient or EQ (Jerison, 1973). According to Jerison, EQ is a measure of biological intelligence or information processing capacity. Whereas California sea lions and other pinnipeds have EQ's estimated to be between one and two, similar to those of terrestrial carnivores, the EQ's of dolphins* are more similar to chimpanzees, ranging between two and five (Eisenberg, 1981; Worthy and Hickie, 1986).

2. The bottlenose dolphin is a highly vocal and social creature and, according to Lilly, showed signs of possessing semanticity in its vocal communication with members of its own species. In addition, Lilly thought bottlenose dolphins were an exceptional species for ALR because they showed "kindliness" toward man and appeared to be capable of mimicking human voice sounds in an intelligible way (Lilly, 1961).

Although Lilly failed in his attempt to establish the English language as a direct means of communication between humans and bottlenose dolphins, his ideas stimulated several others to use dolphins in ALR (e.g. Bastian, 1967; Batteau and Markey, 1968; Lang and Smith, 1965). The follow-up work to Lilly's initial effort has been succinctly detailed and summarized by Wood (1973). We will briefly review the work of Batteau and his group since it and the ape work seem to have led rather di-

*We are speaking of dolphins as a group (relative to pinnipeds as a group). The EQ of the bottlenosed dolphin is about 2.8, at the middle lower end of the range. [EQ was computed with exponent (slope) = 0.755; constant = 0.0537. See Harvey, this volume, and the final "Afterthoughts" chapter. Ed.]

rectly to the resurgence of ALR with dolphins, particularly to research on "sentence comprehension" by dolphins (Herman, Richards, and Wolz, 1984).

Batteau's Failed Dolphin Language Studies

Batteau used Skinnerian shaping techniques to acquire a high level of stimulus control over three different "object-action" commands. The object-actions were "hit ball with pectoral flipper," "swim through hoop," and "retrieve bottle." Each of these object-actions was under the stimulus control of a whistle sound projected by an underwater speaker. The whistles were human vocal sounds transformed by Batteau's ingenious electronic devices. Additional whistle sounds controlled up to 15 separate behaviors; these included raising flukes, jumping, emitting sonar pulses, responding to their own "name," etc. With reference to Herman's later work, it is important to note that one of Batteau's dolphins, Maui, also learned to swim right or left in response to different signals and that she could mimic the sounds controlling many of the behaviors.

As most marine mammal trainers know, training dolphins to respond differentially to 15 or more distinct command signals is a far cry from demonstrating that a dolphin has even the basic rudiments of semantic comprehension. In fact, when probe trials were given by Batteau and Markey (1968) so that Maui was signalled to perform two behaviors in sequence without any new special training, the dolphin only performed the first object-action. This finding suggests that either Maui did not understand the task or that at least some dolphins may have difficulty with the grammatical rule of *recursion*. In addition, control trials showed that both dolphins had been conditioned to associate an object-action command signal with a specific location. For example, when the ball and hoop were reversed from their usual positions, the dolphins were confused and first went to the appropriately signalled object, but performed an incorrect action. Then they went to the inappropriate object and performed a correct action. It was also found that both dolphins were biased in their responses.

In Batteau's experiments the dolphins were trained to respond to holophrastic commands and not to separate elements of object and action, unlike the chimp language studies which were just beginning when Batteau met an untimely death by drowning. In the chimp language studies the investigators trained their animals to work with signs that could potentially be combined and recombined in such a way that each combination could convey a separate meaning.

Do Herman's Dolphins Comprehend Sentences?*

It is Herman and his colleagues (Herman, Richards, and Wolz, 1984) who, of all the investigators involved in ALR, have made the strongest claim to date that their dolphins have a "tacit knowledge of syntactic rules" and can comprehend literally thousands of novel sentences up to five words in length. The original claims by the

* [I have asked Professor Herman to review specialized issues raised here, and I discuss his comments in the "Afterthoughts" chapter (see also, Herman, 1987). Ed.]

Gardners and by Premack (Gardner and Gardner, 1969; Premack, 1976) that their chimpanzees combined symbols in grammatically competent fashion have since been shown to be exaggerated (Pettito and Seidenberg, 1979; Terrace, 1979).

The basic reasons Herman chose to use dolphins in ALR were the same as those stated by Lilly 15 years earlier: high EQ and a complex vocal communication system. The reason Herman has emphasized language comprehension in dolphins has been his belief that language comprehension and language production may develop as separate systems with comprehension emerging prior to production, and thus probably being more fundamental. For this reason, Herman (in press) has emphasized the study of receptive competencies in his ALR with dolphins. Support for this approach of stressing receptive competencies has recently come from the finding that Kanzi, a young pygmy chimpanzee, needed only exposure, not training, to attain symbolic skills comparable to those attained by common chimpanzees trained in the use and comprehension of symbols (Savage-Rumbaugh, Rumbaugh and McDonald, 1985). Savage-Rumbaugh and her associates think that Kanzi's learning of English merely by hearing it means that the capacity to comprehend speech is possibly an evolutionary precursor to its production, and that language comprehension, more than vocal speech production, is the "essence of language" (Savage-Rumbaugh et al., 1985).

Herman's two bottlenose dolphins, Akeakamai (Ake) and Phoenix, were taught a similar but not identical language in different modalities (an acoustic language for Phoenix and a gestural language for Ake). For purposes of exposition, and in order to make direct comparisons with our own parallel ALR on California sea lions, we will focus most of our comments on Herman's claims about Ake's linguistic competencies as reported in Herman, Richards, and Wolz (1984). In Ake's artificial language, relationships between objects were constructed by signing a goal item first, an item to be acted upon (transported) second, and finally the relational sign FETCH. Herman et al. (1984) referred to this relational sequence as an "inverse grammar."

Ake was trained in a gestural language in which signals were the movements of a trainer's arms and hands. Each object, position modifier and action was assigned a unique signal. The signals could then be combined and recombined following certain rules to produce a circumscribed but complete set of legal instructions. Thus, there was provision for substitution of items in object or action categories, making it possible to replace the object sign HOOP with the sign BASKET or the action sign UNDER with OVER. In addition to object and action signals Ake was given modifier signs referring to left and right and could be instructed to act on an object on her left, but only if there was a paired member on her right. Thus the categories of the dolphin Ake's gestural vocabulary included modifiers (LEFT, RIGHT), objects (e.g. WATER, BALL, PIPE, FRISBEE, etc.) and actions (TOSS, SPIT, TAIL-TOUCH, PECTORAL-TOUCH, etc.). Ake used two classes of objects; *non-transportable* objects that could be moved around the rim of the tank by the researchers (e.g. WATER, water jetted from a hose), and *transportable* objects that floated freely in the pool and could be moved by Ake (e.g. BALL). Ake also had two classes of actions; a relational action (e.g. FETCH, take a transportable object to another object) and direct actions (e.g. SPIT, spit a stream of water at an object). It is important to note that relational actions and direct actions were mutually exclusive categories. This was not the case in the sea lion Rocky's vocabulary where the identical FETCH sign functioned as a direct action or relational action, depending on the signs that preceded it.

At the time of Herman's publication of test data in 1984 (about six years after her training was begun) Ake's comprehension "vocabulary" included two modifier signs, eleven object signs, eight action signs and one relational sign (FETCH). Armed with this sparse vocabulary of 22 signs the dolphin Ake nevertheless had the potential to carry out over a thousand unique commands. An example of the longest sign sequence given to Ake might be WATER, RIGHT PIPE FETCH or RIGHT WATER, PIPE FETCH: these two different sets of instructions contain the same elements, but in a different order, giving each set of signs a different meaning. In the first sequence the referent WATER is the goal item and the referent RIGHT PIPE is the transported item, whereas in the second sequence the referent RIGHT WATER is the goal item and the referent PIPE is the transported item.

The sign sequences given to Ake formed two types of instructions. One type of instruction had the dolphin act on a single object and the other type had the dolphin perform an action relating two objects. By employing various discriminative learning techniques to teach Ake to 1) associate gestural signs with directions, objects, and actions and 2) discriminate between categories of signs by making Ake sensitive to the serial order or sequence of signs, Herman and his associates were able to demonstrate that Ake could respond appropriately to sentence-like commands containing as many as four signs. Moreover, by *generalizing* within categories of signs the dolphin could respond appropriately to a variety of novel commands. For example, Ake could respond correctly the first time she was given the instruction PIPE, RIGHT BALL FETCH ("take the ball on your right to the pipe") or RIGHT BALL, PIPE FETCH ("take the pipe to the ball on your right") after several experiences with commands like RIGHT BALL OVER ("jump over the ball on your right") and PIPE, BALL FETCH ("take the ball to the pipe").

Below are several statements by Herman et al. (1984) summarizing and interpreting the results of their tests of the linguistic competency of their dolphins, in particular Ake's competency on "sentence" comprehension in which the relational action FETCH is used:

> "In summary, the understanding of the function of object names as direct or indirect objects, and of how modifiers may be attached to object names, further illustrate the considerable sensitivity of dolphins to syntactic structure" (p. 199).
>
> "As in natural languages, tacit knowledge of the syntactic rules underlying the language was necessary for correct interpretation of the function of lexical items in the sentence, and for an understanding of the unique semantic proposition being expressed. This is most obvious for the inverse rules in Akeakamai's gestural language." (p. 203).
>
> "Within the nonlinear grammar, Akeakamai demonstrated her ability to assign and reassign functions to earlier words in a sentence, i.e., parse the sentence, on the basis of a succeeding word or words." (p.207)

As Herman himself has noted (1987), his ALR with dolphins was started following the heated criticisms of ALR with apes and thus was designed to avoid the methodological pitfalls of the ape language work. Nevertheless, the dolphin language work by Herman can and has been criticized from a conceptual standpoint. One can readily discern from the above quotes that the interpretation of the dolphin's performance by Herman et al. (1984) is in terms which are linguistically loaded (e.g. "grammar", "sentence", "lexical", "direct object", "indirect object", "semantic proposition"). In addition, these statements seem again to reflect an emphasis, as did earlier ALR, on grammatical competence as an all-or-none factor. This has led to rather sharp criticism from Premack (1986) on the grounds that this "flurry of linguistic terms is gratuitous" because an interpretation of the dolphins' performance requires no linguistic terms of any kind. According to Premack, "Herman et al. have shown two things: discrimination of temporal order and the learning of rules based on perceptual classes" (Premack, 1986, p. 26). The two rules used to generate all the instructions to the dolphins were: (1) (Modifier) + Object + Action, and (2) (Modifier) + Object A + (Modifier) + Object B + Action 2, where Action 2 was a signal instructing Ake to take Object B to Object A. Reversing the positions of the two object signals in the string reversed the meaning of the command. Although we agree that these competencies are the major ones that have been (more or less) demonstrated in Herman's dolphins, we disagree with Premack's dismissal of these competencies as unnecessary for demonstrating language learning. Rather, we believe that all of the cognitive abilities that the dolphins have demonstrated are necessary for language learning, but are perhaps not sufficient. (See Herman, in press, for a rebuttal of Premack's criticism of his ALR with dolphins.)

Hoban (1986) essentially agrees with many of Premack's criticisms of Herman's work and has added some herself. For example, we think that Hoban is correct in pointing out that Herman et al. have prematurely used the term "word" in their description of signs and their associated referents. Although it is true that the dolphins (as well as the sea lions) can correctly choose the ball or the pipe when given the BALL sign or PIPE sign, can they choose the correct signs for ball or pipe when they are presented with the referents ball and pipe? In other words, are the signs and their referents interchangeable as are human words and the things they signify? The answer is no. An even more advanced form of symbol use occurs when words or symbols refer to other symbols. There is no indication whatsoever that dolphins are, as yet, capable of using symbols or words to stand for one another. The referential quality of the dolphin symbols has not been as well established as that of the chimpanzee symbols used in ALR by Savage-Rumbaugh (1986).

In general, the arguments by both Premack and Hoban are that Herman's experiments, despite their methodological elegance, have not, as yet, demonstrated anything "even remotely reminiscent of linguistic skills in the behavior of the dolphins" (Hoban, 1986, p. 144). We agree that the results of Herman's ALR with dolphins have not been interpreted cautiously enough, i.e. the dolphin's language-like learning skills have not been conceptualized in accordance with Lloyd Morgan's Canon.

In the present paper it will be our contention that what has been taught to both the dolphins and the sea lions is indeed a language, albeit a pidgin or simplified language, consisting of three categories of signs arranged according to two types of rules which give the language its "openness" or "combinatorial productivity" (Miller, 1967). The syntax chiefly involves the temporal sequence or the serial order of signs. We will attempt to show that acquiring a *conditional sequential discrimination* is a key factor in the dolphin and sea lion being able to comprehend relationships encoded in gestural signs strung together to form sentence-like commands. We will support this hypothesis with data from a series of experiments with a California sea lion (Rocky) which directly parallel experiments conducted by the Herman group with a bottlenose dolphin (Ake). We will focus primarily on the most complex sign sequence form, the relational sequence. In the relational sequence dolphins and sea lions have learned a serial ordering rule that, in one form, can be expressed as "take the second designated object to the first designated object."

Methods

Sea Lions and Facilities

Our experiments with ALR have involved three California sea lions (*Zalophus californianus*): Bucky, a six-year-old male housed at Marine World/Africa USA in Redwood City, California (now located in Vallejo, California), Gertie, a five-year-old female housed at Long Marine Lab, University of California, Santa Cruz and Rocky, an eleven-year-old female also housed at Long Marine Lab. Since our research on relational sequences has gone furthest with Rocky, we will focus primarily on her performance in the experiments discussed in this paper. However, it should be noted that both Gertie and Bucky have also learned to carry out instructions relating two designated objects.

At Long Marine Lab, experiments were conducted in the sea lions' home pool, a 7.6m diameter by 1.8m deep circular concrete tank surrounded by a deck that is flush with the pool rim. During an experimental session, sea lions not being tested were placed in a separate adjoining pool area. The pools at Long Marine Lab are filled by a flow-through system that provides minimally-filtered seawater at ocean temperature (approximately 15°C).

Basic Procedure

The basic experimental procedure, controls and training techniques for giving single-object sequences to Rocky have been detailed by Schusterman and Krieger (1984; 1986). We should point out that we have used many blind procedures to guard against unintended cueing by the signaler and other individuals involved in the experiment. These control procedures indicated that Rocky, as well as the other two sea lions, responded only to the gestural signs given by the signaler.

Table 17.1 lists Rocky's repertoire of gestural signs used in the current experiments. The signs are given by the signaler in a specific sequence (Table 17.2). Figure 17.1. illustrates a typical relational sequence. A signal sequence started with Rocky "on station", her chin resting on the signaler's foot. The first sign and each subsequent sign in a sequence were cued by an observer who told the blindfolded signaler (via radio headphones) that Rocky was in position to receive the next sign. Rocky typically left station after an object signal, visually searched for the object and, after locating it, returned to station. She did not leave station or scan the pool area after modifier signals. This scanning search following the object sign is very informative regarding a sea lion's cognitive capabilities (see Schusterman and Krieger, 1986). Because the sea lion's eyes are aimed primarily forward and up it must essentially "point" with its head in order to bring the object into the field of focused, binocular vision. In comparison, bottlenose dolphins (like those used in Herman's ALR) have laterally placed eyes that can independently scan large areas, without their making head movements that might indicate what in particular they are looking at. These physical differences in visual perception can result in differences in training and signing. The dolphins received a rapid, uninterrupted signal sequence while, potentially at least, simultaneously scanning large areas of the pool environment with the eye not watching the signaler. Rocky, on the other hand, tended to interrupt attention to the signaler with sometimes prolonged (greater than 2 seconds) and methodical searches of the environment

Table 17.1. Current repertoire of gestural signs used with Rocky.

Objects	Modifiers	Actions
Transportable[1]	*Brightness*	*Direct*[4]
PIPE	BLACK	FETCH
BALL	WHITE	FLIPPER-TOUCH
RING	GRAY[3]	MOUTH
WATERWING	*Size*	OVER
CLOROX	SMALL	UNDER
CAR	LARGE	TAIL-TOUCH
DISC		*Relational*[5]
BAT		FETCH
CUBE		
FOOTBALL		
CONE		
Nontransportable[2]		
WATER		
PERSON		

Note: [1]Objects that can be moved by the sea lions.
[2]Objects movable by experimenters but not by sea lions.
[3]Not currently in use.
[4]Involves only one object.
[5]Involves two objects.

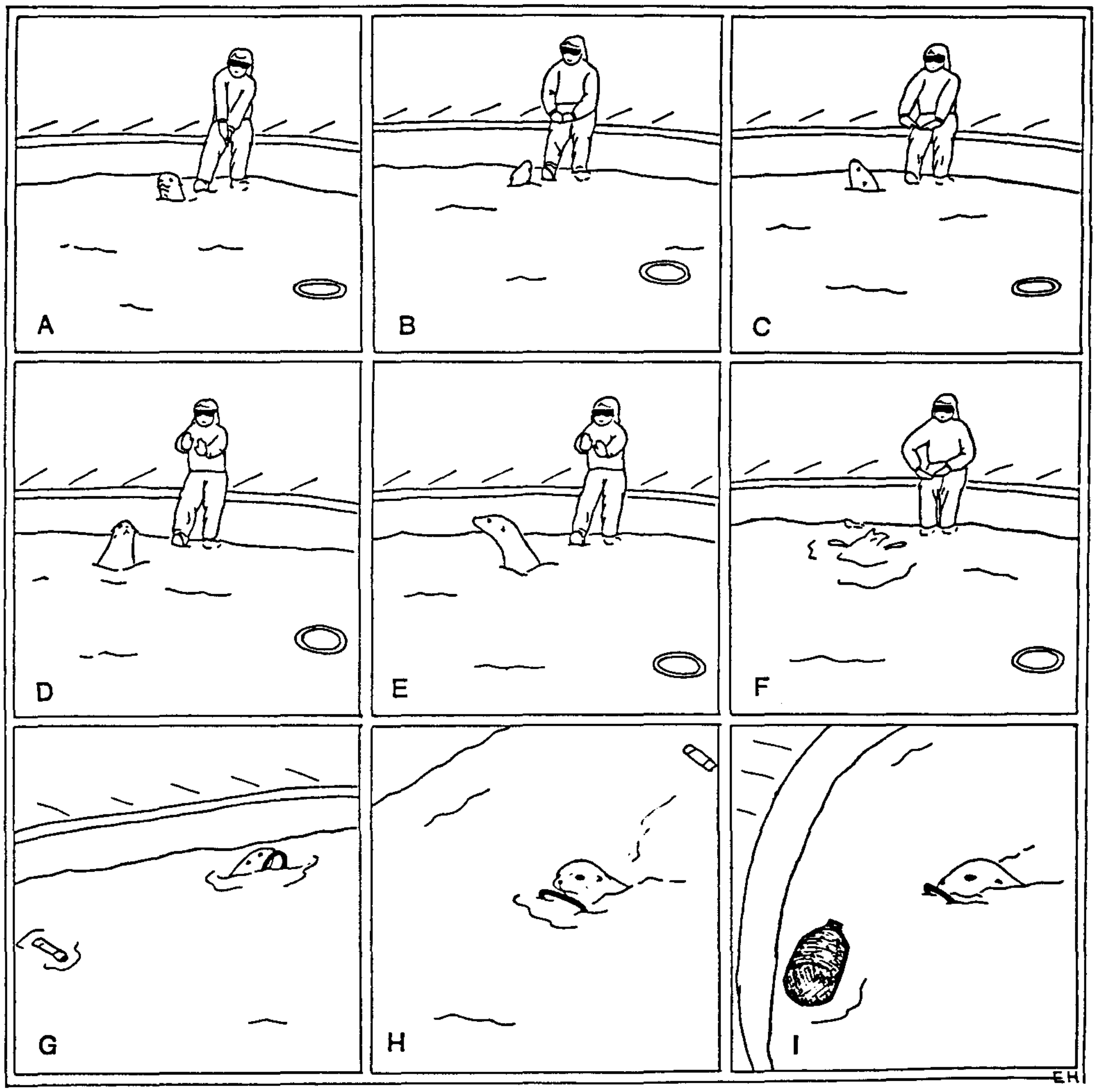

Figure 17.1. Example of a relational trial. The instruction given was CLOROX, BLACK RING FETCH. A) The signaler signs CLOROX, Rocky searches for the object. B) The signaler pauses between GI and TI sign sequences, Rocky remains at station. C) The TI modifier sign BLACK is given, Rocky turns slightly, but does not scan the pool area. D) The signaler gives the RING sign, in this frame Rocky is looking at the white ring. E) Rocky continues her search, she is now looking at the black ring (out of view in this frame). F) The action sign FETCH has been given and Rocky has been released (signaler lowers foot). G) Rocky has gone to the black ring and is starting to move it while scanning the pool for a goal item. H) Rocky is pushing the ring toward the clorox bottle (just out of view in this frame). I) Rocky is placing the black ring in contact with the clorox bottle which constitutes a successful response to the instruction CLOROX, BLACK RING FETCH.

Table 17.2. Sign sequences given to Rocky, with examples.

SINGLE OBJECT SEQUENCES	
Two Sign	
O+A	BALL OVER
Three Sign	
M+O+A	WHITE BAT TAIL-TOUCH
Four Sign	
M1+M2+O+A	LARGE BLACK CONE MOUTH
RELATIONAL SEQUENCES	
Three Sign	
GI+TI+A	BALL, RING FETCH
Four Sign	
M+GI+TI+A	WHITE CAR, DISC FETCH
GI+M+TI+A	WATER, SMALL CUBE FETCH
Five Sign	
M1+M2+GI+TI+A	BLACK SMALL CONE, BAT FETCH
GI+M1+M2+TI+A	CAR, WHITE SMALL BALL FETCH
M+GI+M+TI+A	LARGE CONE, BLACK RING FETCH
Six Sign	
M+GI+M1+M2+TI+A	WHITE DISC, SMALL BLACK CONE FETCH
M1+M2+GI+M+TI+A	WHITE LARGE CONE, SMALL BALL FETCH
Seven Sign	
M1+M2+GI+M1+M2+TI+A	SMALL WHITE CLOROX, BLACK SMALL CUBE FETCH

Note: O = object sign in a single object sequence.
GI = sign designating the goal item in a relational sequence.
TI = sign designating the transported item in a relational sequence.
M= modifier sign, modifies object sign following it.
A = action sign.

after each object signal, resulting in a much more extended signaling process. Following an action sign Rocky is usually (except on "no-go" trials) released from station by the signaler withdrawing her/his foot. The "no-go" trials help prevent the sea lion from anticipating release and thus not attending to the action sign. Occasionally, following a long, unproductive search for a specific object, Rocky returned to station and, following the action sign, she did not perform the indicated action, but remained at station when released by the signaler's foot-drop. The lack of a specific action following release was termed a *balk*.

Experimental Design

Experimental trials were inserted as probe trials in a semi-random manner into the standard daily training sessions, or "baseline." Each baseline session lasted about one hour and contained approximately seventy trials. The trials were divided into "sets" of four to eight trials. After each set the objects were replaced with a new group of objects. There were typically four to ten objects in the pool during each set (the mean was about six objects).

Approximately equal numbers of all single-object sequence forms (refer to Table 17. 2) were run in a semi-random fashion to maintain competency in all familiar sequence types. After the three-sign relational instruction had been trained it was included in the baseline sessions. Later, four-sign relationals were also added to the baseline sessions. This procedure maintained Rocky's competence in all sign sequence forms and provided relatively context-free baseline sessions (i.e. Rocky was not able to anticipate the type of trial she was about to be given).

Training the Relational Sequence

The principal topic of this paper is a special type of sign sequence referred to as the relational sequence, so-called because the outcome requires Rocky to fetch one object to a second, rather than to fetch a single object directly to the signaler. The order of the two object signs indicates the relation between them, that is, which object is the goal item (GI) and which is the transported item (TI). For Rocky, the first object sign indicates the GI and the second object sign indicates the TI. The terms GI and TI are solely descriptive and are not given a grammatical connotation or interpretation. In contrast, Herman et al. (1984) refer to the same sign sequence, when given to the dolphin Akeakamai, as an "inverse grammar" and use the grammatical terms indirect object (IO) for the first object sign and direct object (DO) for the second object sign. Our introducing superficially similar nomenclature may be initially confusing for some, but we believe it is important to free the performance of the relational action from grammatical terminology when such terminology is not needed and, indeed, contains surplus meaning.

The relational sequence was introduced to Rocky in April, 1985. Training began by teaching Rocky to fetch an object to something other than the signaler. A single object was placed in the pool and Rocky was released from station without being given any gestural signals. This elicited a standard response of fetching the object to the signaler: both Rocky and Gertie were normally required to periodically "gather up" the objects in the pool in order to have the session continue. A training target (a pool float at the end of a broom handle) was then introduced in the pool near the signaler. The target had been frequently used in other training situations and had a very strong association with reinforcement. After a few trials with the target Rocky had learned to transport the object in any direction to get it to the target, even away from the signaler.

In the next stage of training a second object was placed in the pool and the relational signal sequence was introduced. At this stage of the training process it started with a touch signal on Rocky's forehead indicating that this was a relational sequence, followed by the GI object signal, TI object signal, then the action signal. On the initial attempt Rocky made an intention movement to bring the TI to the GI, but then fetched the object to the signaler. In subsequent attempts the training target was used to guide Rocky to the GI and then removed just before she arrived. The target was quickly faded out of the procedure. The touch signal was soon dropped from the sequence because we felt it was distracting to Rocky. Her performance of the relational action did not change after the touch was discontinued. The context cue of two object signs was apparently sufficient to indicate a relational action.

After a few repetitions of the fully trained sequence with just two objects, we introduced alternating trials with other actions to eliminate context cues, then added one or two objects to provide a choice of destination objects. The entire training procedure took about two hours time distributed over three days. After this training, the simple three-sign relational sequence was incorporated into baseline sessions, intermixed with familiar single object sequences.

Experiments

Response bias for goal items on novel complex relationals. "Novel" sequences were sign combinations that had never been given to the subject. They were used in experiments to eliminate the potential of the animals producing rote responses to repeated familiar sequences. Since there were in fact thousands of unique instructions possible, it is unlikely that the animals were capable of organizing their response behavior in this way. Nevertheless, both we and the Herman group took the precaution of using novel sequences in most experiments. The relative effect of sequence novelty on performance is discussed further in the Results section.

Novel sign sequences were of two types: those that contained a combination of signs never before given to the animal, but of a sequence type that the animal had practiced (what Herman et al., 1984, refer to as "lexical novelty") or those that contained a novel number of signs. Herman et al. (1984) refer to the latter as "structurally novel" sequences, but that term is somewhat misleading since the only novelty was the addition of one (in Ake's case) or sometimes more (in Rocky's case) modifiers. Adding familiar modifiers to a familiar sequence to make it "novel" increased the complexity of the instructional sequence, but did not require truly novel response behavior, or novel integration of the information in the signs. Any other form of structural novelty (adding, subtracting, or rearranging signs) produced unusual responses that are discussed under the Anomalous Sequence headings of this paper.

In this experiment, novel sequences containing an unmodified or single modified GI and a double modified TI (e.g. WHITE WATERWING, SMALL WHITE BALL FETCH) were inserted as probes in standard baseline sets at the rate of two to four trials per session, for a total of 32 trials. Half (16) of the experimental trials had "positive" GI's and half had "nonpositive" GI's. The classification of an object as a positive or nonpositive GI refers to the probability of a correct response on a baseline relational with that object as the GI. For this experiment we arbitrarily designated all GI's with a greater than 0.5 probability of eliciting a correct response as being positive GI's (Table 17.3). For example, BAT was considered a positive GI because baseline trials with BAT as GI had a 0.81 probability of being correct based on performance of baseline trials immediately preceding the experiment.

CONE was a nonpositive GI because baseline relationals with CONE as GI had a probability of 0.23 of being correct. Table 17.3 also shows that the positive/nonpositive status of an object can change over time. Further investigation of this object-related response bias is in progress, but for our purposes in this paper this somewhat simplistic and arbitrary identification of positive and nonpositive goal items is in fact quite informative.

Each trial with a positive GI was replicated using a nonpositive GI. Both were run with the same number of objects in the pool, and the same TI. For example, the trial BLACK BAT, LARGE WHITE BALL FETCH, which includes a positive GI, was conducted under the same conditions as the trial BLACK CONE, LARGE WHITE BALL FETCH, which contains a nonpositive GI. In both trials the same number of objects were present in the pool, but two cones (a black and a white) had been substituted for two bats. The difference in performance on the two groups of novel complex relationals could therefore be attributed solely to the effect of the GI object.

Table 17.3. Rocky's response bias and consequent goal item (GI) object type.

Object (type)	Probability (and Number) of Correct Response Before Expt.	During Expt.	Status Change?
PIPE	0.25 (20)	0.13 (16)	N
BALL	0.13 (16)	0.00 (4)	N
RING (*)	0.56 (18)	0.50 (10)	N
WATERWING (*)	0.82 (11)	0.57 (7)	N
CLOROX BOTTLE (*)	0.67 (15)	0.63 (8)	N
CAR (*)	0.47 (15)	0.56 (16)	Y
DISC	0.18 (11)	0.50 (10)	Y
BAT (*)	0.81 (16)	0.44 (9)	Y
CUBE	0.11 (19)	0.05 (20)	N
FOOTBALL	0.33 (15)	0.50 (10)	Y
CONE	0.23 (13)	0.15 (13)	N
WATER (*)	0.57 (28)	0.88 (17)	N
PERSON (*)	0.44 (31)	0.76 (21)	Y

Note: (*) indicates positive GI object; i.e., Correct response probability > 0.50

Relationals to a nontransportable GI. The nontransportable objects WATER and PERSON were added to Rocky's repertoire after training on the relational behavior. Nontransportable objects differed from transportable objects in that they were always located on the rim of the pool and could not be moved by the sea lions. Transportable objects, on the other hand, floated in the pool and could be moved by the sea lions. Furthermore, wind and Rocky's movements caused the transportable objects to drift about the pool during a set, whereas nontransportable objects stayed in one place during an entire set, unless deliberately moved by the researchers. Nontransportable objects were usually moved only at the end of a set.

A limited number of three-sign relationals to nontransportable GI's were included in the baseline. Using our standard experimental procedure we also ran 42 novel relationals to nontransportable GI's (21 to WATER and 21 to PERSON). Table 17.3 indicates that nontransportable GI's were associated with a high probability of correct response.

Reversals. This experiment consisted of 54 paired *original* and *reversal* three-sign familiar relational sequences. The originals were run as probes in baseline sets until Rocky responded correctly and the response was reinforced. The reversal was run immediately after the reinforced original. In other words, if Rocky responded correctly to the sign sequence CAR, CONE FETCH we next gave her the sign sequence CONE, CAR FETCH.

A particular object was used as a GI in originals about as often as it was used as a TI to prevent the possibility of Rocky making a predictive association between certain GI objects and the possibility of a forthcoming reversal.

Modifier-reversals. This experiment was intended to illustrate a potential problem of modifier assignment in relational sign sequences. In this experiment a modifier sign in a novel complex relational command was "reversed" or switched from a GI modifier to a TI modifier or vice versa by changing its position in the second or "reversal" trial. The relative positions of the two object signs, however, remained unchanged: the GI in the first trial remained the GI in the second trial of the modifier-reversal pair. For example the sign sequence WHITE BALL, BAT FETCH is the modifier-reversal of BALL, WHITE BAT FETCH (the object signs remain in the same order). The modifier-reversal experiment was run in the same manner as the reversal experiment described in the preceding section, with one exception; the modifier-reversal trial was not run immediately after the successful, reinforced original because certain objects needed to be added or removed before it was possible to run the modifier-reversal trial. The modifier-reversal trial was given some time later, either a few trials later in the same set or as long as three days after the successful original.

Four modifier-reversal pairs were run with a single modified GI as the original and four pairs were run with a single modified TI as the original. In addition one pair was run with a double modified GI original and one pair with a double modified TI original, for a total of ten modifier-reversal pairs.

Anomalous sequences: Type I. The anomalous sequences in this experiment retained the double object signs indicative of a relational sequence, but had a different action sign substituted for the familiar FETCH action sign (the only action sign that had heretofore been associated with two object signs). An example of this kind of anomalous sequence is CUBE, DISC FLIPPER-TOUCH. This experiment was designed to exactly parallel an experiment with the dolphin Ake reported by Herman et al. (1984). Twelve novel anomalous sequences of this form were run as probe trials in baseline sessions, one or two per session. All responses were nonreinforced.

Anomalous sequences: Type II. This group of anomalous sequences either had their signs out of normal sequence, contained added signs, or were missing signs normally present. Fourteen novel anomalous sequences were run as probes, one or two probes per session. All responses were nonreinforced.

Calculating probabilities of correct response for relational fetch sequences. The method we used to calculate probabilities of chance correct responses to relational instructions differed from that used by Herman et al. (1984, Appendix A). Their calculations were based on the total number of potential "meaningful" sign combinations of that sequence form. According to their method, the likelihood of Rocky producing a correct chance response to a three-sign relational sequence would be the reciprocal of 130 or 0.0077 (refer to Table 17.4 for numbers of potential combinations in each sequence form). Some of the reasons for choosing the method we used over others are presented in detail at the end of the Results section. Here we present our basic assumptions as well as the mechanics of our method of calculating probabilities.

Table 17.4. Number of potential sign combinations in each sequence type in Rocky's repertoire.

Sequence Type	No. Combinations	
SINGLE OBJECT SEQUENCES		
O+A	76	
M+O+A	528	
M1+M2+O+A	240	
(TOTAL)		(844)
RELATIONAL SEQUENCES[1]		
Three Sign		
GI+TI+A	130	
Four Sign		
M+GI+TI+A	313	
GI+M+TI+A	376	
(TOTAL)		(689)
Five Sign		
M1+M2+GI+TI+A	384	
GI+M1+M2+TI+A	464	
M+GI+M+TI+A	956	
(TOTAL)		(1804)
Six Sign		
M+GI+M1+M2+TI+A	1192	
M1+M2+GI+M+TI+A	1192	
(TOTAL)		(2384)
Seven Sign		
M1+M2+GI+M1+M2+TI+A	1216	
GRAND TOTAL	7067	

[1]Matching object combinations, e.g., PIPE, PIPE FETCH, excluded.

After learning the basic relational task, the sea lion Rocky, and the dolphin Ake, erred almost solely on the goal item. They rarely failed to go to the correct TI or to take that TI to another object (correct action), but they often took the TI to an object other than the GI indicated by the signaler (see Tables 17.5, 17.6 and especially 17.7 for supporting data).

We therefore made the probability of a *completely* correct response dependent upon the number of objects in the pool available to serve as GI's. The probability that Rocky would go to the correct TI and take it to another object was nearly 1.0. Her selection of an object to serve as GI, if she was choosing at random, would be a function of the number of objects in the pool, less one (the object she was using as TI). If six objects were in the pool, five would be available for use as GI, and there would be a 1/5 (0.20) chance probability of taking the TI to the correct GI.

For a single trial, therefore, the probability of a chance correct response was calculated as $1/(x-1)$, where x equals the number of objects in the pool. For a group of trials, the estimated number of correct responses expected by chance was calculated by first dividing the trials into classes based on the number of objects in the pool and then multiplying the number of trials in each class by $1/(x-1)$. This method was derived empirically and is a conservative way to estimate chance performance to a relational instruction. That is, we slightly overestimate the likelihood of chance performance because our calculation did not include any other error factors, e.g. incorrect TI or incorrect action, etc., although these error factors contributed slightly to the total observed errors (see Table 17.7).

Results and Discussion

Baseline Relationals

We believe that our results with the sea lion Rocky are directly comparable to those of Herman et al. (1984) with the dolphin Ake. Ake's performance on familiar three-sign relationals was, like Rocky's, much lower than her performance on single object sequences of the same length. As Table 17.5 shows, the number of signs given in the instructions were relatively trivial compared to the type of instruction given: that is, whether it was a relational instruction or nonrelational. For example, compare Rocky's performance on M1+M2+O+A sequences (four signs) with her performance on GI+TI+A sequences (three signs).

Table 17.5. Rocky's performance on baseline sequences (data from September, 1986).

Sign Sequence	Prob. Correct	(C.R./TOTAL)
O+A	0.967	(349/361)
M+O+A	0.922	(403/437)
M1+M2+O+A	0.927	(268/289)
GI+TI+A[1]	0.436	(52/119)

[1]Includes only three-sign relationals to transportable GI's.

Table 17.6. Rocky's performance, in terms of correct responses (CR), on three-sign baseline relationals.

Time Period	Total Trials	Obs. CR	CR Prob.	Chance CR	Chance Prob.	chi^2	p
Jan-Feb '86	200	50	(0.25)	40	(0.20)	8.8	>0.10
May-Jun '86	200	82	(0.41)	46	(0.23)	30.2	<0.01
Sep-Oct '86	200	80	(0.40)	44	(0.22)	32.7	<0.01

Note: (d.f. = 4 on all chi^2 values)

Table 17.6 shows Rocky's performance values on the three-sign relational sequences given during baseline sessions from three different time periods: one period preceding the start of experiments (January-February, 1986), one period at the start of experiments (May-June, 1986) and one period at the end of the experiments (September-October, 1986). Rocky's performance prior to June, 1986 (as represented by data for January and February, 1986 in Table 17.6) was not significantly different from chance, based on our conservative method for calculating the probability of a chance correct response. Thereafter, her performance reliably exceeded chance values of probability.

Rocky's data indicate that, while she was responding at above chance levels (between 40 and 50% correct responses) on relationals, her performance on single object trials was almost perfect (exceeded 90% correct responses). Ake's data shows the same marked differences for probably the same reasons. We will attempt to demonstrate that Herman's interpretation of Ake's performance on relational instructions is not the most parsimonious explanation supported by his data and that both Ake's and Rocky's data better support a different interpretation.

First, almost all of Rocky's and Ake's errors on relational sequences were confined to the GI, the first sign or signs of the so-called "inverse grammar", those indicating the goal item (Herman's indirect object). Table 17.7 lists the proportion of total errors attributable to each element of the sign sequence. The table supports our viewpoint that when Ake and Rocky attempted to carry out a relational command they would either be correct and obtain a food reward or the would take the appropriate TI to the wrong GI and not be reinforced.

One factor that influenced Ake's ability to select the correct GI was the addition of a relative position (left/right) modifier to the GI (Herman et al., 1984). This apparently allowed Ake to remember the object's position, an easier mental task than remembering its identity encoded by the object sign. For Ake, the sign sequence form M+GI+TI+A resulted in a higher percentage of correct responses than the sequences GI+M+TI+A or GI+TI+A. The modifiers given to Rocky referred to object qualities (size/brightness) rather than object positions and there was, therefore, a decrement in performance on GI-modified relationals.

We found that factors not analyzed by Herman et al. influenced Rocky's performance of relational sequences but not on single-object sequences. These

Table 17.7. Proportion of total error attributable to each sign category of the three sign relational sequence (GI+TI+A).

	Total Trials	Total Errors	Probability of errors (by category)				
			GI[2]	TI[3]	A	Mult.[4]	Total
Ake[1]	53	18	0.89	0.055	0.0	0.055	1.00
Rocky[5]	200	120	0.975	0.0	0.0	0.025	1.00

Note: [1]data from Herman et al. (1984), Table 17.7, p. 170.
[2]GI = goal item.
[3]TI = transported item.
[4]Mult. = errors on more than one sign.
[5]Data for September, 1986.

factors may have had an effect on Ake's performance as well. They include:

1) The number of objects in the pool.
2) Bias for goal items.
3) Whether a goal item was fixed in space, that is whether it was a transportable or nontransportable object.
4) Whether the goal item and the transported item were reversed on successive trials.

The Effect of the Number of Objects in the Pool

If, as we hypothesize, Rocky had difficulty selecting a GI and was often selecting the GI object at random ("guessing") then her performance should vary with the number of objects available in the pool. Our data from the three-sign baseline relationals and from the reversal experiment support this hypothesis; the percentage of correct responses increased as the number of choice items decreased (Table 17.8).

Table 17.8 also shows that Rocky's performance on single object instructions did not vary as a function of the number of available objects. These results strongly support the notion that there were only two rules influencing Rocky's performance: one rule for integrating signs in order to act on a single object and a second rule for taking that object (TI) to one of several available GI's. As we have previously noted, Table 17.5 shows that the number of signs that are given in a sequence is relatively trivial. Rather, the critical factor is retaining information about the first designated object (GI) in a relational sequence. Despite the fact that Rocky produced an orientation to the appropriate object when the GI sign (the first object sign in the relational sequence) was given, information in the second object sign apparently interfered with memory for the first sign (retroactive interference).

Response Bias for Goal Items on Novel Complex Relationals

Rocky's performance on the 16 trials with positive GI objects was significantly

Table 17.8. Effect of number of objects on Rocky's probability of making a correct response (CR).

	Number of Objects in Pool						
	3	4	5	6	7	8	9+
RELATIONAL INSTRUC.							
Expected (relat.)[1]	0.50	0.33	0.25	0.20	0.17	0.14	<0.11
Baseline prob.[2]	---	0.41	0.41	0.37	0.29	0.14	0.0
Baseline (N)	(0)	(39)	(27)	(19)	(28)	(14)	(2)
Reversal prob.[3]	0.50	0.39	0.28				
Reversals (N)	(32)	(89)	(99)				
SINGLE-OBJ. INSTRUC.							
Expected (1 obj.)[4]	0.33	0.25	0.20	0.17	0.14	0.13	<0.11
Baseline prob.[5]	---	0.95	0.96	0.95	0.95	0.92	0.94
Baseline (N)	(0)	(42)	(181)	(306)	(306)	(153)	(97)

Note: [1]Expected = 1/(x-1), where x = the number of objects in the pool.
[2]Baseline prob. = 3-sign baseline relational trials, June, 1986
[3]Reversal prob. = familiar three-sign relational trials from the reversal experiment.
[4] Expected = 1/x, where x = the number of objects present in the pool.
[5] Baseline prob. = total single-object trials for June, 1986.

above chance (chi^2 = 19.0, d.f.=2, $p<0.01$) while her performance on the 16 trials with nonpositive GI objects remained at chance (chi^2 = 1.3, d.f.=2, $p>0.1$). The results are presented graphically in Figure 17.2.

These results show that carrying out a novel instruction relating two objects depends primarily on bias involving the goal item. Therefore, we believe that Herman et al. (1984) have misplaced their emphasis by stressing sequence novelty in their experiments. All of the trials in this experiment were novel combinations. Both their data and ours show that factors related to coding the GI in short-term memory, such as object number, position modifiers (Ake's LEFT/RIGHT modifier), or GI bias have a greater influence on performance than sequence novelty.

Relationals to a Nontransportable GI

When Rocky was given novel 3-, 4-, and 5-sign relationals to nontransportable goal items her performance was significantly above chance (Table 17.9). As previously noted in Table 17.3, nontransportable objects (WATER, PERSON) were highly positive GI's. In Figure 17.3 Rocky's performance on familiar three-sign relationals to nontransportable GI's is compared to her performance on three-sign relationals to transportable GI's and to performance expected by chance.

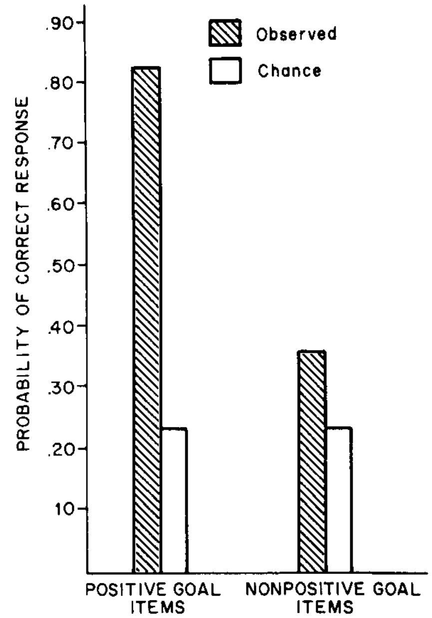

Figure 17.2. Relative probability of a correct response on novel complex relational instructions containing positive GI's versus those containing nonpositive GI's.

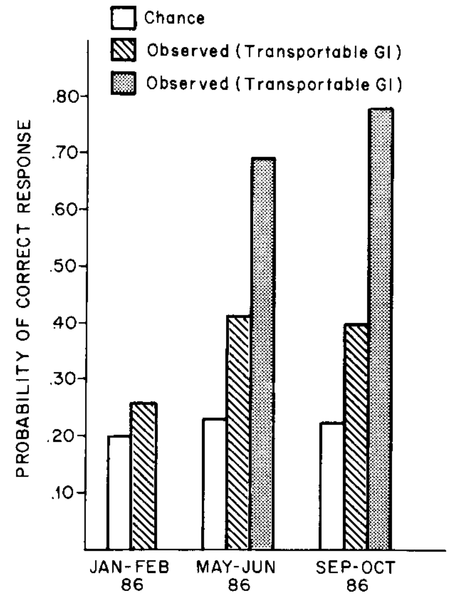

Figure 17.3. Rocky's performance on 3-sign baseline relationals to transportable and nontransportable GI's compared to predicted chance performance.

Table 17.9. Rocky's performance on novel complex relationals to nontransportable GI's (d.f.=2 for all chi^2 values).

Object	Total Trials	Correct (Obs.)	Correct (Exp.)	chi^2	p
WATER	21	14	4	29.5	<0.01
PERSON	21	9	4	7.0	<0.01
TOTAL	42	23	9	27.3	<0.01

In Table 17.10 (next page) numerical data from September 1986 are presented for familiar three-sign relationals to a nontransportable GI and to a transportable GI. The two sets of data are then combined to show how the relative proportion of relationals to positive destination objects (such as nontransportable objects) can alter the animal's overall performance level. Without breaking down the data on relational sequences into categories of GI's (such as nontransportable and transportable or positive and nonpositive) it is difficult to determine what factors influenced the sea lion Rocky or the dolphin Ake in arriving at a correct solution of the relational problem.

Table 17.10. Rocky's performance on familiar 3-sign relationals to transportable and nontransportable GI's.

Probability of Correct Response

	Jan-Feb '86	*May-Jun '86*	*Sep-Oct '86*
Transportable GI	0.25 (50/200)	0.41 (82/200)	0.40 (80/200)
Nontransport. GI	(see note)	0.69 (49/71)	0.77 (48/62)
TOTAL (Trans+Non)	0.25 (50/200)	0.48 (131/271)	0.49 (128/262)

Note: Nontransportable objects were introduced after February, 1986.

In the original report by Herman et al. (1984) there was no attempt at subdividing the GI into transportable and nontransportable categories. However, two years later Herman (1986) does note that there were fewer errors in Ake's relationals to a nontransportable GI (his "relocatable object"), but he still does not provide quantitative data on the relative error rates of relationals to transportable and nontransportable GI's, nor on the proportion of trials to nontransportable versus transportable GI's.

Reversals

The reversal experiment was designed to assess the relative effect of sign sequence and memory for object type on Rocky's performance of relational fetches. A feature of relational sequences that is not present in single object sequences is that elements can be transposed to create a sequence with new meaning. For example, the sequence BALL, RING FETCH can be changed to RING, BALL FETCH to make two legal, but different instructions. The sea lion can extract the correct information from the sequence only if it understands that sign order is important. If sign order is ignored the information in the signs themselves is not sufficient to yield an unambiguous message.

One might expect that Rocky's previous experience with sign transposition would predispose her to ignore sequence. Her two classes of modifier signs (size and brightness), when used in conjunction, are transposable, i.e. both BLACK LARGE CONE and LARGE BLACK CONE can be used to indicate the same object. Rocky accepted such transpositions from the time of their first introduction (Schusterman and Krieger,1986).

As Herman et al. (1984) pointed out, if the role of sign sequence in determining which object is to be the GI and which is to be the TI is not well understood or remembered by the animal then we might expect a number of errors in which the correct objects are used but in reverse relation (GI used as TI, TI used as GI). If this were the case, by reinforcing an original just before running its reverse, we might expect even more of these errors on the reversal due to the interference effect of the previous sequence. In fact, Rocky made no such errors on either the

Table 17.11. Rocky's performance on relational reversal pairs.

	Total Trials	Reversal Errors[1]
Original	166	0
Reversal	54	0

[1]If the instruction CUBE, RING FETCH is given, a reversal error response would be RING, CUBE FETCH.

original instruction or its subsequent reversal (Table 17.11).

If, on the other hand, the goal item in a relational sequence is not remembered then a preceding reinforced relational containing the same elements, albeit in a different order, might improve performance on the subsequent reversal by *priming* memory for the objects involved (Domjan and Burkhard, 1982). If, for example, the sequence PIPE, BALL FETCH is performed and reinforced, when the reverse sequence BALL, PIPE FETCH is given, Rocky would be primed to respond to the two objects, ball and pipe. Furthermore, Rocky will not have to choose the GI from two objects primed in memory since she is using one of the primed objects as the TI.

The other plausible priming scenario would yield the same effect. If, as we have previously hypothesized, Rocky has difficulty remembering the GI, but readily retains the TI of the original command in memory, then the GI of the reversal will still be primed. In simplified form we can think of the original command as the A-B sequence; if only the latter element, B, is primed, then on the reversal (B-A) the hard to remember element (the first) is the one that has been primed.

Table 17.12 shows that Rocky did perform considerably better on the reversal sequences than on the originals (chi^2 = 3.4, d.f.=1, $p<0.1$, one-tailed test). These results suggest that presenting signs referring to the same object on successive trials, despite their reversed order, enabled Rocky to "rehearse" or better attend to the signs and their associated referents. Additional experiments of this kind, especially one where the sequence was responded to incorrectly and followed by a reversed sign order should give us a much better understanding of the variables involved in what Herman et al. (1984) have called "comprehension of semantically reversible sentences."

Table 17.12. Correct responses to relational reversal pairs.

	Total Trials	Correct Responses	(%)
Originals	166	54	(32.5)
Reversals	54	25	(46.3)

Modifier Reversals

Herman et al. (1984) attach great significance to Ake's apparent ability correctly to assign a centrally placed modifier to the appropriate object in the sign sequence Object + Modifier + Object + Action. They attribute this ability to a "precedence rule" that indicated Ake understood "how modifiers may be attached to object names" and considered the correct assignment of the modifier to the appropriate object as another indicator of "the considerable sensitivity of the dolphins to syntactic structure." (Herman et al. 1984: p.199).

We, on the other hand, consider this a perfect example of the danger of applying gratuitous grammatically-rooted explanations to phenomena that admit a simpler explanation. In fact, the dolphin *cannot* misassign the modifier, because the objects in the pool will not allow it. If the sign sequence BALL, LEFT PIPE is given there must necessarily be only one ball, but two pipes in the pool. How could the animal express an incorrect assignment of the LEFT modifier sign to BALL if there were not two balls from which to choose?

With the understanding that context would not allow an inappropriate response of the form Herman et al. (1984) hypothesize, we ran ten novel modifier reversal pairs (Table 17.13). Remember that in these relational sequences "reversal" refers to the positional shift of a modifier from preceding the GI to preceding the TI or vice versa. Thus, the modifier-reversal of the instruction SMALL BALL, CUBE FETCH becomes BALL, SMALL CUBE FETCH.

Rocky's overall performance was significantly better than chance ($chi^2 = 16.5$, $d.f = 3$, $p<0.01$). There was no decrement of performance on modifier-reversals relative to originals as might be expected if modifier assignment on the original was confusing Rocky's modifier assignment on the reversal (Table 17. 13). We were also able to use Rocky's orienting behavior during the signal sequence to verify that Rocky was indeed incorporating the modifier into the orienting response for the appropriate object (see Figure 17.1 for an illustration of the orienting behavior).

Table 17.13. Rocky's performance on novel reversed-modifier pairs.

FORM OF ORIGINAL	Original	Reversal	Total
Four Sign Sequence			
M+GI+TI+A	0.57 (4/7)	0.75 (3/4)	0.64 (7/11)
GI+M+TI+A	0.31 (4/13)	0.25 (1/4)	0.29 (5/17)
Five Sign Sequence			
M1+M2+GI+TI+A	0.50 (1/2)	1.00 (1/1)	0.67 (2/3)
GI+M1+M2+TI+A	0.33 (1/3)	1.00 (1/1)	0.50 (2/4)
Total	0.40 (10/25)	0.60 (6/10)	0.46 (16/35)

Anomalous Sequences: Type I

Herman et al. (1984) called these sequences anomalous because the substitution of another action sign for the relational fetch action sign creates a sequence that cannot be carried out using the rules the animal had learned up to that point. The animal therefore had to "create" a response to the new sequence. Ake consistently (on eleven of twelve trials) performed a single object response to the correct second object using the correct action. The first object sign was either ignored or forgotten. Herman et al. (1984) interpreted this outcome as indicating that Ake processed but rejected the first sign and acted only on the second object plus action because it was the only legitimate instruction given her linguistic abilities. They consider the possibility of a recursive solution to the problem (performing the indicated action to each of the two objects in succession) and interpret Ake's failure to produce the recursive solution as a possible learning limitation in dolphins, generally.

However, within their linguistic model, there are more, equally consistent, potential outcomes. For example, Ake could have rejected the action sign as inappropriate and acted on the two object signs as implying a relational command, or she could have rejected the second object sign rather than the first. When tested on the same problem, Rocky performed almost exactly as Ake had. In 11 out of 12 anomalous sequences of the same form Rocky responded by performing the correct action to the second signed object (Table 17.14; $p<0.01$, binomial test). These results are virtually identical to those obtained from Ake. We interpret Ake's and Rocky's response to the anomalous sequence as we did the earlier finding that errors on relational constructions are most frequently GI errors. These findings are consistent with the notion that both Rocky and Ake use just two rules to comprehend all sets of instructions; namely, one rule to designate an object and another rule for bringing that object to another object.

Table 17.14. Rocky's responses to anomalous commands of the form GI+TI+A, where A is an action not associated with two object signs prior to the experiment.

Sign Sequence Given	Response
CUBE, BALL TAIL-TOUCH	BALL TAIL-TOUCH
CLOROX, FOOTBALL UNDER	FOOTBALL UNDER
CAR, BAT MOUTH	BAT MOUTH
BALL, BAT OVER	BAT OVER
DISC, BALL OVER	BALL OVER
FOOTBALL, WATERWING TAIL-TOUCH	WATERWING TAIL-TOUCH
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

These rules require that the animals depend on sign sequence alone to assign the appropriate meaning to each sign. Syntax, in the human grammatical sense, can change the meaning of words based on types of structural dependency other than word order. In the simplified language used in these experiments the syntax is only serial order or sequence, where the signs are related to each other only in terms of sequence and never in any other way. In human language the sequence can be changed and its meaning still remain the same. For example, "The boy bit the dog" and "The dog was bitten by the boy" mean the same thing because it is always the dog that is acted upon by the boy, despite changes in the positions of the nouns.

Anomalous Sequences: Type II

Type II anomalous sequences include a variety of sequence types designed to assess how Rocky processed sign sequences. The sequences are listed in Table 17.15 and have been subdivided into:

1.) *transposed sign sequences* in which a familiar sign sequence has its component signs rearranged in a novel form,

2.) *omitted sign sequences* in which a sign type normally present has been deleted from the sequence, and

3.) *added sign sequences* in which a sign type is present in the sequence more times than usual.

Rocky's orienting responses are given in parentheses in Table 17.15, so that the type of sign given and the observed response can be easily compared. Since she gave a distinctive orienting behavior after receiving an object sign, and another distinctive stereotyped behavior when she received a modifier sign, an inappropriate response on her part was informative about the type of sign she was anticipating. A dash was used if Rocky did not move her head from station when a signal was given. Since Rocky shows no overt response to an action sign, it wasn't possible to tell whether Rocky was not responding to the sign or treating it as an action sign.

Her responses to these anomalous sequences indicate that Rocky relied primarily on sign order to organize the information conveyed by the signaler's gestures. The fact that Rocky balked on transposed sign sequences containing all the necessary elements indicates that she is sensitive to the ordering of the signs. When the standard sequence was violated her orienting responses sometimes indicated that she was anticipating a different sign. For example, when given an action sign after a modifier sign in the sequence O+M+A, she performed an object orientation on the action sign. Her previous experience would lead her to expect an object sign after a modifier sign. Likewise, when she was given the added-modifier sequence BLACK LARGE WHITE BALL TAIL-TOUCH she performed an object orientation in response to the third modifier sign, probably because she expected an object sign to follow two modifiers, rather than a third modifier sign. When she was given the sequence WHITE OVER and only a black and white ball were present, the information was sufficient for Rocky to make a choice, but she did not respond (she balked). This could be interpreted either as her treating the modifier sign as an abstract property that must be assigned to an object, or as sensitivity to serial order (i. e. modifier signs must be followed by object signs and action signs must be preceded by object signs).

Table 17.15. Rocky's responses to Type II anomalous sequences.

Sign Sequence	Response
TRANSPOSED SIGNS	
<u>O + M + A</u>	
CUBE SMALL MOUTH	balk
(O) (M) (O)	
BALL BLACK FLIPPER	balk
(O) (M) (-)	
<u>O + M + M + A</u>	
CUBE BLACK SMALL UNDER	balk
(O) (M) (M) (-)	
<u>M + O + M + A</u>	
LARGE BALL WHITE OVER	balk
(M) (O) (M) (-)	
<u>A + O</u>	
TAIL CAR	balk
(-) (-)	
<u>O + A + O</u>	
WATERWING FETCH CLOROX	balk
(O) (-) (-)	
<u>A + O + O</u>	
FETCH FOOTBALL WATERWING	balk
(-) (-) (-)	
OMITTED SIGNS	
<u>M + A</u>	
WHITE OVER	balk
(M) (-)	
LARGE UNDER	balk
(M) (O)	
<u>O + A</u>	
BALL OVER	WHITE BALL OVER
(O) (-)	
CLOROX UNDER	BLACK LARGE CLOROX OVER
(O) (-)	
ADDED SIGNS	
<u>M + M + M + O + A</u>	
BLACK LARGE WHITE BALL TAIL	DISC, LARGE WHITE BALL FETCH
(M) (M) (O) (O) (-)	
<u>O + A + A</u>	
CAR UNDER MOUTH	CAR UNDER
(O) (-) (-)	
CONE OVER TAIL-TOUCH	CONE OVER
(O) (-) (-)	

Key to symbols: O = object signal; (O) = typical orienting response to an object signal; M = modifier signal; (M) = typical response to a modifier signal; A = action signal; (-) = no discernible response, which usually occurred when Rocky was given an action signal.

Finally, in the sequence with an added action sign (O+A+A) only the action sign immediately following the object sign was performed. Such a response fits with the hypothesis that the sign sequence gives meaning to the sign. An action sign not preceded by an object sign was out of context in this sequential language and was ignored by Rocky just as the first object sign was ignored in the Anomalous Sequences I (refer to Table 17.14).

Although sign sequence appears to be the major factor guiding Rocky's interpretation of the instructions, there is evidence that she classifies signs into functional categories as well. For example, Rocky's behavior following action signs was the same regardless of the action sign's position in the sequence (i.e. she stopped orienting to all subsequent signs). As noted earlier, she accepted transpositions of modifiers, and did so the first time the double modifier was introduced (Schusterman, unpubl.). She did not accept transpositions of objects and actions, modifiers and actions, or modifiers and objects.

She also treated modifier signs differently from object and action signs in that she performed an action to a correct object type if a necessary modifier was omitted, but balked on a M+A sequence when an object sign was not needed. For example, if there were a large and a small ball in the pool (along with other object types), she responded to the sequence BALL FLIPPER by performing a BALL FLIPPER response to one of the balls, even though the signs given were not adequate to specify to which particular ball the action was to be directed. When a modifier and action were given (e.g. WHITE OVER) she did not perform the indicated action, even though, in this case, the information given her was sufficient to indicate the correct response object.

Calculating Probabilities of Chance Correct Responses

No matter how complex the task, there is some probability that the animal could produce a correct response by chance alone. Herman et al. (1984) recognized that "models of completely random choice are inappropriate, and not conservative, given what is known about the dolphin's responses." We disagree, however, with their contention that there is not sufficient information to choose a model for calculating the probability of a chance correct response based on performance of elements or groups of elements within the sign sequence (a "phrase structure" model, in their terminology).

We have shown that errors in relational sequences are almost always GI errors, and this is true for both Rocky and Ake. We have further shown that Rocky's performance on relationals varies with the number of objects available, unlike her performance on single-object sequences which does not vary with the number of objects present. We suspect that a similar analysis of Ake's data would yield a similar result. These data indicated to us that the relational action and object to be transported (TI) were not being selected by chance, and that the probability of completing the entire instruction correctly rested principally on the probability of Rocky going to the correct goal item (GI).

Factors that enabled Rocky to retain the goal item's identity in memory, such as positive object bias, object mobility (nontransportable objects), or successive trials with the same objects (reversals), affected Rocky's ability to perform relational instructions successfully. We believe that the same variables probably affected the dolphin Ake's performance on relational fetch sequences.

Sequence novelty, heavily emphasized by Herman et al. (1984), did not appear to affect Rocky's or Ake's performance significantly, when compared with performance of familiar sequences. Thus, once Rocky had learned the basic three-sign relational instruction, she was capable of successfully completing novel relational instructions of seven signs. Emphasizing sequence novelty and the potential number of unique sequences within a sequence type (e.g. three-sign relationals), as Herman et al. (1984) have done, does not reflect some of the most critical variables actually affecting performance of the animals.

Furthermore, their method of using the potential number of unique sequences within a type imposes some unrealistic assumptions about the animal's potential responses. First, this method assumes that all the objects are available to the animal in every trial (since they assume that the animal can produce any sequence within a type). However, all objects are *not* present for every trial. If there is no "fish" item present (see Table 17.1 in Herman et al., 1984) then all potential responses using the item "fish" are obviously impossible and should not be included in a calculation of the probability of a correct response. Their method also excludes responses outside the sequence type, yet such responses are quite possible. For example, if a three-sign relational instruction was given, but Ake used one of two hoops (left and right) as a GI, then her response would be considered a four-sign relational.

For these reasons we rejected the method used by Herman et al. (1984) to calculate the probability of a correct response to a relational instruction by chance and instead chose to make the probability of a chance correct response to such an instruction dependent on the number of goal item choices available.

Summary and Conclusions

The ALR effort, after almost three decades, has yet to find a nonhuman animal having all the attributes of human language. Most particularly, efforts at demonstrating syntactic competency based on symbol sequentiality have resulted in ambiguous results (Terrace, 1979). However, this paper suggests that with similar training and testing regimens two different types of marine mammals -- the high EQ bottlenose dolphin and the lower EQ California sea lion --show similar abilities cognitively to process a syntax consisting of ordered strings of signs relating two objects. We believe that such an explanation relies on learning and cognitive skills and not on linguistic skills as such.

Both sea mammals responded at better than chance levels to novel sets of instructions (conveyed by a trainer's gestural signs) by carrying out different behaviors depending on the serial order of the signs. Even with the same signs, differences in sequence convey differences in meaning, e.g. the sign sequence BALL, BLACK PIPE FETCH produces the instruction "take the black pipe to the ball" whereas the sign sequence BLACK BALL, PIPE FETCH produces the instruction "take the pipe to the black ball." This suggests that, by using a sequence rule, both marine mammals perceived that modifier categories depend on the object category while object categories remain distinct from one another except when followed by the relational term FETCH. Nevertheless, by using the relational sequence rule the sea lion Rocky was even capable of correctly carrying out novel commands containing as many as six or seven signs (e.g. BLACK SMALL FOOTBALL, LARGE BLACK CUBE FETCH; glossed as "take the large black cube to the black small football.")

We believe that sea lions, like dolphins, that have been conditioned to associate signs and objects, code things and dimensions imaginally and not in words or "grammatical terms". The grammatical thinking of animals is in the eye of the beholder. It is an error due to our own thinking in a formal grammar and therefore expressing the phenomena in such terms. The sea lion Rocky, like the dolphin Ake, apparently learned two rules and was able to apply them quite effectively under a variety of circumstances.

In one experiment we showed that if relational instructions between two objects were reversed immediately following a successful response then the likelihood of correct responses was higher on the reversals than on the original relational instructions. Thus Rocky was more likely to take the ball to the pipe when given the sequence PIPE, BALL FETCH than she was to take the pipe to the ball when she was given the immediately preceding instruction BALL, PIPE FETCH. We attribute better performance on *reversed* relationals than on *original* relationals to a *priming* effect. That is, since the first signed object is sometimes either ignored or forgotten, we believe that presentation of signs designating the same objects on successive trials (despite their reversed order) enables the sea lion to think actively about the signs and their associated referents.

Further experiments have corroborated the idea that a California sea lion can be trained to be as sensitive to the sequentiality of signs as dolphins. For example, if the standard sequence (Modifier) + Object + Action was changed to Object + (Modifier) + Action the sea lion Rocky would not even leave station. And when given a series of commands like PERSON, DISC MOUTH, Rocky, like the dolphin Akeakamai, mouthed the disc and ignored the person. These responses to unfamiliar, novel sequences are explicable in terms of just two learned rules:

1. If an object is designated by one, two or three signs (an object sign and up to two modifiers), then perform the designated action to that object.
2. If two objects are designated (again, by one to three signs each) and the action is FETCH, then take the second designated object to the first.

The animals' responses do not require the ability to treat the signs as syntactic elements in the full grammatical sense of that term.

What, then, are some of the mental tools needed for a simplified language? We conclude that the precursors of language are likely to be found in animals that are at least capable of combining the following learning and cognitive skills:

1. Paired associate learning or higher order conditioning.
2. Perceiving and categorizing objects and events into class and relational concepts -- each with their own subcategories (Thomas, 1980).
3. Acquiring conditional sequential discriminations.

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