Conditional discrimination learning in a male harbor seal (*Phoca vitulina*)

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Summary

Many animals are capable of complex problem solving that requires higher-order cognitive skills. Experiments using conditional discriminations have confirmed that animals such as some birds, primates, sea lions, and dolphins are capable of making associations between sample and comparison stimuli. Past findings on harbor seals, however, indicated that this species had difficulty with similar tasks, but methodology may have been a confounding factor. In this study, a male harbor seal was tested in a visual-visual conditional discrimination paradigm and results showed that he did not process information in the same manner as other species. Whereas sea lions, humans and probably other animals initially learn two sample/comparison relationships simultaneously and then are able to respond immediately to new relationships in the presence of either familiar one using an exclusion principle, this harbor seal learned only one relationship at a time. He responded correctly by excluding the known relationship but had difficulty responding to new stimuli. Only after intense training did he learn to make the necessary associations and even then he only learned the minimum required. The standard methods of training conditional discriminations, which are successful with sea lions, appear to be inappropriate for harbor seals. Perhaps researchers will have more success using methods that address the behavioral and ecological characteristics of this species.

Key words: harbor seal, conditional discrimination, learning, cognition

Introduction

Conditional discrimination paradigms have tested the cognitive abilities of animals in hundreds of experiments. Zentall, Hogan, and Edwards (1984) defined a conditional discrimination as follows: "in the presence of one or two (or more) conditional (or sample) stimuli an organism is given a choice between two (or more) choice or comparison stimuli. In the presence of one sample, one of the comparison stimuli is correct (i. e., reinforced); in the presence of the other sample, the other comparison stimulus is correct." Thus, a conditional discrimination is an "if .. then" model where a subject chooses the discriminative stimulus, B1, when it is presented with the conditional stimulus, A1 (if A1 then B1), and chooses B2 when shown A2 (if A2 then B2).

Conditional discriminations differ from simple discriminations in that there is always a second cue (or sample) which informs the subject as to which comparison to select. In a review of conditional discrimination learning, Carter and Werner (1978)

Sensory Systems of Aquatic Mammals (1995)
R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (editors)
De Spil Publishers, Woerden, The Netherlands ISBN 90-72743-05-9

pointed out that the second cue, or sample, controls the behavior of the subject such that it determines the choice of the comparison. This, however, should not imply that everything is simply contingent on the sample. Schusterman, Gisiner, Grimm, and Hanggi (1993) gave data which showed that California sea lions selected novel comparisons in the absence of familiar samples rather than use a novel sample to select the novel comparison. Through a process termed exclusion, these sea lions discounted the familiar comparison in the absence of the familiar sample and chose the novel comparison. As part of their match-to-sample testing, Schusterman *et al.* (1993) showed one of their sea lions, Rocky, an empty sample box (where normally a sample stimulus would appear) and then presented two comparisons. Rocky always chose the novel comparison instead of the familiar one whereas on control trials with two familiar comparisons her responses were random. This strongly suggests that the absence of the familiar sample, rather than the presence of the novel sample, controls which comparison is selected.

Match-to-sample (MTS) is generally a sequential form of the conditional discrimination in which a sample is presented first followed by two or more comparisons. For conditionality to exist, the discriminative functions must change so that the comparison stimuli occur as both correct and incorrect choices that are dependent on the sample stimuli (Dube, McIlvane, and Green, 1992). Stimuli may be visual, tactile or auditory and may be of one sensory modality or of a combination, i. e., an auditory sample and visual comparisons.

The MTS or conditional discrimination paradigm has been used with many different animals ranging from rats to dolphins. Primates, cetaceans and pinnipeds have been studied in experiments aimed at discovering whether they possess language- like capabilities. A simplified form of American Sign Language was taught to chimpanzees (*Pan troglodytes*) to signal actions, objects and other conditions (Gardner & Gardner, 1969) and other experiments included the use of plastic tokens or lexigrams to stand for objects (Premack, 1976; Savage- Rumbaugh, 1986). Schusterman & Gisiner (1988), using California sea lions (*Zalophus californianus*), and Herman (1986), using bottlenose dolphins (*Tursiops truncatus*), showed that both species can be taught a simplified language. The sea lions and dolphins were taught to associate hand/arm gestures with objects (balls, bats, rings, etc.), actions (flipper-touch, fetch, etc.), and modifiers (black, white, left, right, etc.) and were able to understand each signal separately, making possible the recombination of these elements into virtually thousands of different sequences. The results from the sea lion and dolphin data showed that a sequential conditional discrimination was a "key factor in the dolphin and sea lions being able to comprehend relationships encoded in gestural signs strung together to form sentence-like commands" (Schusterman & Gisiner, 1988).

Do other marine mammals have similar cognitive abilities? Prior to the 1980's, there was little cognitive research on harbor seals (*Phoca vitulina*). One exception was a study done on visual pattern discrimination and the establishment of learning sets (Schusterman, 1968). The results of that experiment indicated that harbor seals, like California sea lions, can discriminate between patterns and can rapidly form learning sets.

However, this harbor seal was only required to do a simple visual discrimination, not a conditional discrimination. The next attempt at determining the cognitive capabilities of harbor seals (*Phoca vitulina concolor*) came in the early 1980's with experiments that attempted to demonstrate identity matching- to-sample (sample and comparison are identical) and stimulus control in harbor seals (Constantine, 1981). In nine experiments using four harbor seals and one grey seal (*Halichoerus grypus*), Constantine could not show conclusively that these species were capable of identity matching-to-sample. She used different training techniques, including a two-key, Yes-No match-to-sample paradigm and the more standard three-key match-to-sample. When the seals were trained using the two-key, Yes-No set-up, they were able to respond correctly as to whether one sample/comparison pair was the same or different, but could not transfer this response to another set of stimuli or a different key location. Even though the seals did learn one set of stimuli, it often took an incredibly high number of trials, i. e., 16000. Results were similar for the three-key match-to-sample approach. Seals appeared to discriminate between black and white samples, but could not transfer the task to horizontal and vertical stimuli and analysis of data showed the seals were responding to the comparison stimuli depending on which side they were presented. Only after separate training of a left-side, then a right-side, two-key, Yes-No MTS, plus a three-key MTS did Constantine feel confident that one seal was controlled by all possible stimulus- response relationships.

A few years later, Renouf and Gaborko (1988) attempted to teach harbor seals to MTS using black and white squares. The seals did not learn the task, even after an additional textural cue was added to the stimuli. They also tried an auditory MTS with pup calls and pure tones as stimuli. After 32 weeks, the seals could not match-to- sample. Renouf and Gaborko (1988) rationalized that the tests may not have been appropriate for the natural history of this species. Therefore, they tested the animals using a spatial MTS paradigm in which comparison stimuli were located in either the same or different positions compared to the sample stimulus. The seals learned the tasks easily, but showed no evidence of concept formation. Renouf and Gaborko (1988) also tried to teach the seals a visual black/ white conditional discrimination, but gave up after 1800 trials when the animals remained at chance performance. Later, Renouf and Gaborko (1989) examined rule formation using a different experimental configuration. They reasoned that the harbor seals in the previous spatial experiment may have failed to grasp the MTS concept because of the greater amount of variation from one set of stimuli to another than what occurs in a comparable visual MTS. In a visual presentation, only the actual stimuli change on new tasks (not the apparatus nor the required response), but spatial conditional discrimination problems may change in other parameters such that what is relevant for one task, i. e., the animal's position, may be completely useless in another task and thus lead to a negative transfer. Subsequently, they used a simpler framework in which the seals were required to respond differently from one task to another while all other parameters were held the same. The seals learned the spatial discriminations easily and subsequent tasks were acquired quickly which is indicative of rule use. These results are interesting but may not have fully addressed the issue of conditional discrimination. Seals had only to make a physical response to a verbal/gestural cue; when told "Up" they performed an action on the object that was above water and when told "Down" they did the same action to the object under water. Seals, sea lions, dolphins and many other animals are easily trained to perform behaviors upon receiving verbal or gestural cues, but this is primarily a stimulus-response reaction rather than a cognitive association where a decision must be made between two or more stimuli.

Renouf and Gaborko (1988) did provide evidence that harbor seals could do spatial match-to-sample tasks which implies a higher level of cognitive capability. However, harbor seals failed on the visual MTS task, which corresponded to the results from the seals tested by Constantine (1981). These experiments, taken collectively, indicate that harbor seals seem unable to perform accurately in tasks which other animals such as chimpanzees, dolphins, pigeons and the more closely related sea lions can learn.

One consideration is that harbor seal vision may not be as good as other mammals that have been successful in such tasks. However, Renouf (1989) pointed out that the seal eye is well adapted for both underwater and land vision. Although the cornea is astigmatic in air, the eye compensates by having a stenopaic pupil. When light levels are sufficiently high, the pupil contracts to a narrow vertical slit which increases visual acuity and allows for sharp aerial vision.

According to Schusterman (1968), harbor seals were able to visually discriminate between stimuli in simple discrimination tests and improved with experience. It is only when the tasks become more cognitively challenging that the harbor seals' capabilities seem limited. This seems difficult to believe and there may have been constraints on learning in previous experiments. For example, both Renouf and Constantine used only a few stimuli in their attempts to teach visual conditional discriminations. Perhaps, their seals would have done better with more exemplars. In addition, Renouf and Gaborko gave up on the visual MTS testing after 1800 trials. In a similar experiment, two California sea lions took 1560 and 3440 trials before they reached criterion on their first two sample/comparisons (Schusterman *et al.*, 1993). Given additional training, perhaps the harbor seals also would have reached criterion.

Even though previous research with harbor seals did not always yield positive results, the success of sea lions, dolphins and primates in artificial sign language studies, which are, essentially, conditional discriminations, led to the hypothesis presented here that harbor seals should also be capable of performing similar tasks. Harbor seals have some unusual abilities for a mammal with regards to aerial vocalizations, including mimicry of human words (Ralls, Fiorelli, and Gish, 1985), and are very vocal under water during the breeding season (Hanggi & Schusterman, 1992; In press). During preliminary training, the harbor seal in this study, Sprouts, quickly learned to associate spoken commands with actions. Therefore, auditory stimuli should have been an ideal choice in a conditional discrimination test. Because auditory comparisons would have to be presented successively, which may be a more difficult task, visual comparisons with auditory samples were chosen for an initial experiment (Hanggi, 1992). This experiment showed that the harbor seal learned only to associate one sample tone with one visual comparison stimulus and responded correctly to the other sample/comparison because it was not the familiar one. When additional stimuli were presented, he was unable to respond correctly unless the first familiar comparison was available.

Following these results and finding some indications that dual modality tasks may be more difficult for some animals to learn (Birch & Belmont, 1964), the procedures were simplified to a traditional visual-visual arbitrary match-to-sample experiment (the term arbitrary indicates that the sample and comparison are different) which also allowed for direct comparisons with sea lion data (Schusterman *et al.*, 1993).

Materials and methods

Facilities

The visual-visual arbitrary match-to-sample experiment involved a 3-year-old male harbor seal (*Phoca vitulina richardsi*) named Sprouts who was housed along with two female California sea lions at Long Marine Laboratory, University of California, Santa Cruz. Training and testing were conducted in an 7.6 m diameter by 1.8 m deep circular concrete pool surrounded by a wooden deck. The pool was filled with minimally filtered sea water (approximately 15°C) via a flow-through system. During Sprouts' training and testing, the California sea lions were placed in an adjacent pool so that he was alone for all sessions. Sprouts was maintained on 2.5 to 3.0 kg of freshly thawed smelt or capelin and herring. Part of his daily fish was cut into bite-size pieces (approximately 15 g each) which served as a reward for correct responses. For incorrect responses, he was told 'no' and did not receive a fish reward.

Visual-visual matching-to-sample experiment

The apparatus used in this experiment consisted of three hinged wooden boards that, when attached to a wooden frame set on the pool deck, hung into the water (Fig. 1). The bottom of the apparatus was submerged by approximately five to ten cm. All three boards were 61 cm wide, 86.4 cm high and included a 30.5 cm square cut-out display, located 10.2 cm from the bottom and 15.2 cm on either side. Side boards were set at an angle of 40 degrees forward by two metal support bars. A 58.4 cm long PVC headstand (station) was attached perpendicular to the middle board 6.5 cm below the bottom of the cut-out display and floated at the water surface. Each cut-out display had a black, plastic door that could slide open vertically to reveal the stimuli. Movement of the doors was controlled by a hidden operator using a pulley system mounted on the back of the boards. The experimenter stood in a blind and, using two-way radios with headsets, instructed the operator and another assistant on which stimuli to use for each trial, when to employ a visual release signal, and when to give a fish reward. This person also gave commands for opening the doors and reinforced Sprouts' responses, blowing a whistle for a correct response and saying 'no' for an incorrect response.

Sprouts was trained to place his chin on the headstand prior to a trial. A trial began when the center door slid open to reveal a sample stimulus. Exposure times for the sample stimuli were always four seconds, after which the side doors opened to show the comparison stimuli. Following a 3- second delay, a visual release was given and Sprouts swam over to one of the two comparisons and touched his nose either directly onto the comparison or onto the wood below the comparison (Fig. 1).

Stimuli were two-dimensional, black computer drawings that were created using the MacDraw program on a Macintosh IIci computer and examples (350% reduction) with numeric coding are shown in Figure 2. These drawings were printed onto transparent adhesive-backed repro film (made by Rayven Inc.) using an Apple Laserwriter IINT and adhered onto 33 cm x 37 cm white plastic panels. The stimulus panels could be inserted into slots located behind the doors of the boards.

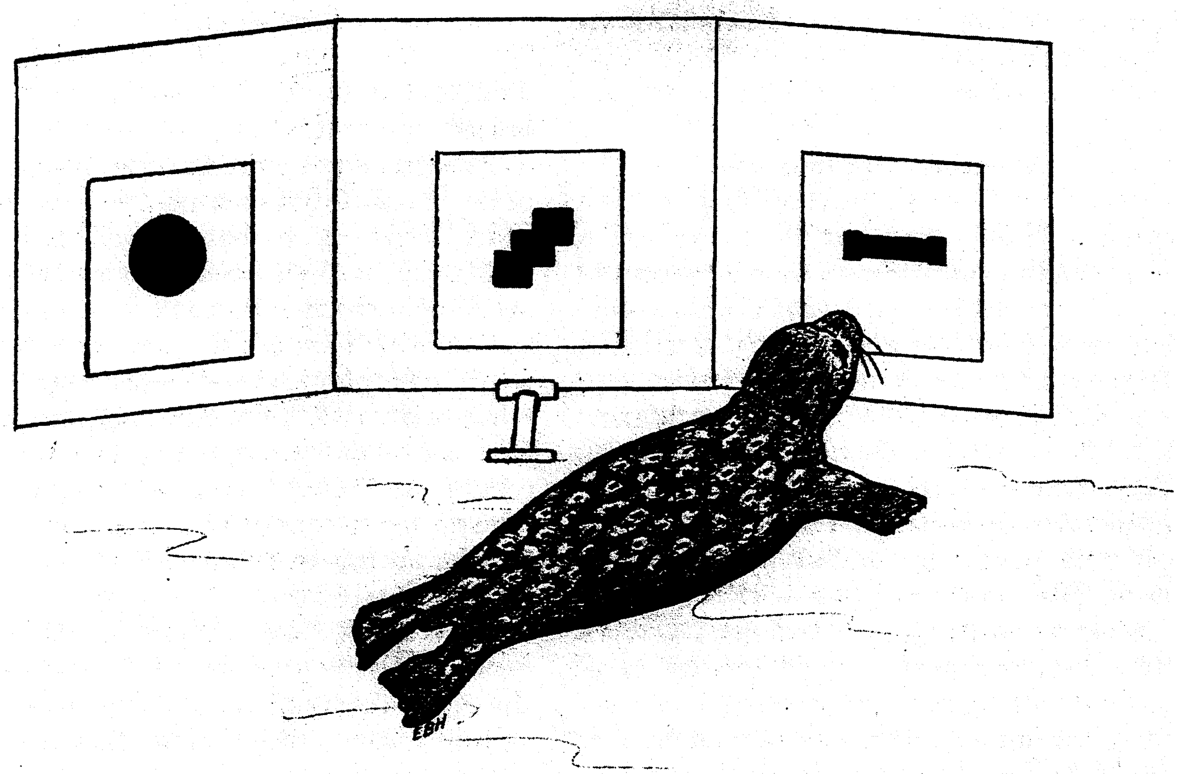


Figure 1. The conditional discrimination test apparatus. The sample stimulus (on center) and the comparison stimuli (on sides) have been presented, the harbor seal has been given a visual release (not shown), and has chosen the correct comparison stimulus.

Acquisition of the first two sample/comparison stimuli

Sessions consisted of 24 to approximately 60 trials, including No-Go's. No-Go's were trials for which Sprouts was not released so that he had to remain on station. This helped avoid anticipation problems and increased attentiveness to the stimuli. One 20- to 30-min session was run per day, generally five days per week. The initial training of the first two sample/comparison stimulus pairs was done by trial and error. The two-dimensional comparison stimuli were drawings of a black pipe and a black ball (Fig. 2). The sample stimuli, which also were black, two-dimensional drawings, are shown in Figure 2, the staircase serving as the sample for the pipe and the modified X serving as the sample for the ball. Trials of one pair of stimuli were run in blocks until Sprouts responded correctly for two or three trials in a row and then the other stimuli pair became the S+ (positive or reinforced stimulus) and so on. Once Sprouts responded correctly on several consecutive trials (about 75% correct responses), he was tested using a Gellerman random series for the rest of his acquisition phase. Testing continued until a third sample/comparison pair was added.

Introduction of a third sample/comparison

When Sprouts reached a criterion level of

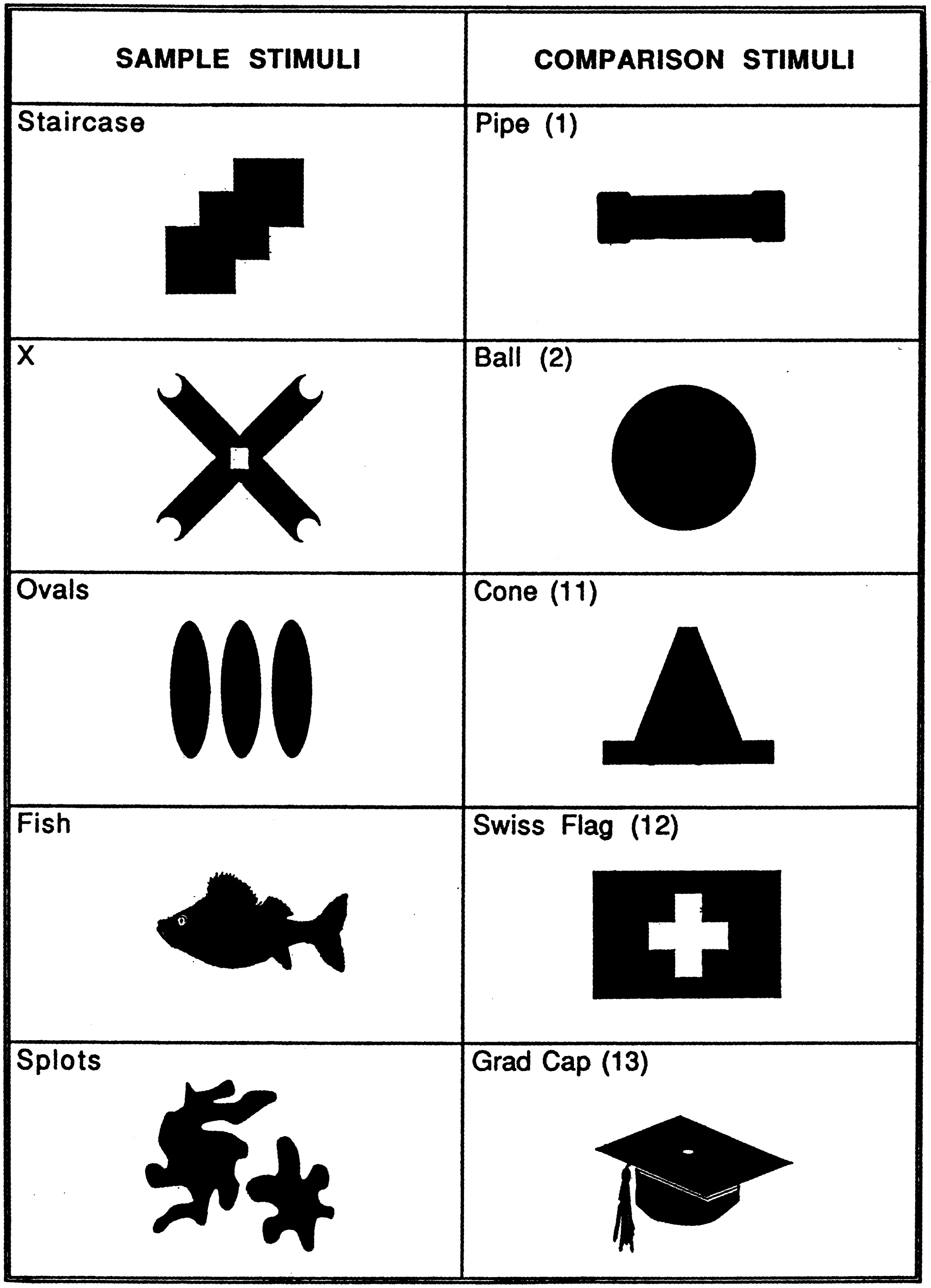


Figure 2. Two-dimensional black stimuli used in the visual-visual conditional discrimination experiment. Numeric codes for the comparison stimuli are given in parentheses.

85% over two consecutive sessions for the first two paired associates and after a practice (over-learning) period, a third sample and comparison was introduced. The new comparison was a two-dimensional drawing of a black cone and the sample was a triad of black ovals (Fig. 2). Using the exclusion technique developed with the sea lions, the novel comparison was run, as S+ and S- (negative stimulus), against a familiar comparison in four blocks of four to eight trials interspersed among the baseline that consisted of approximately 30 pipe and ball trials. After two sessions, blocks consisting of cone and pipe trials were omitted and only two blocks of cone and ball trials were run with the baseline per session. This continued for four sessions until Sprouts responded correctly to cone as the S+ and S- with ball on 8/8 trials for two blocks over two sessions after which cone trials (as the S+ and S- with ball) were added into the baseline and run randomly. After one such session, blocks of trials with cone and pipe were increased to give Sprouts greater exposure to these types of trials so that one part of a session consisted of 24 to 30 cone/pipe trials run semi-randomly and the other part consisted of baseline which was reduced to about 18 trials. After approximately 2.5 months, cone/pipe trials were incorporated into the random baseline and sessions consisted of 36 trials with three No-Go's.

It was necessary to keep the maximum number of trials from exceeding a certain amount because of motivational factors. Harbor seals, unlike California sea lions, do not appear to be very food motivated, and, at least with Sprouts, if the sessions ran too long he lost interest and made more errors. Loss of interest was exhibited by the lack of orientation to stimuli, increased swimming during inter-trial intervals, and distraction by any slight noise.

Introduction of two novel stimuli
After several weeks of over-learning, two novel sample/comparisons were introduced at the same time. The first novel comparison was a two-dimensional drawing of a Swiss flag with a fish drawing as the corresponding sample, and the second novel comparison was a graduation (grad) cap with splots as the corresponding sample (Fig. 2). Two sessions, each including 18 familiar- familiar (baseline) trials, 18 novel-familiar trials, 18 familiar-novel trials and two novel-novel trials were run. Of the novel-familiar trials, grad cap was the novel comparison stimulus for nine trials and Swiss flag was the novel comparison stimulus for the other nine trials. Novel-novel trials consisted of one trial each where grad cap was the S+ and Swiss flag the S- and one trial for the reverse. After two test days, an additional two days of baseline sessions were run to determine whether there was any carry-over effect from the novel stimuli testing.

Results

The acquisition curve for the first two sample/comparisons (pipe and ball) is illustrated in Figure 3. By 2720 trials, Sprouts reached and remained at or above criterion (90% correct responses) for three blocks of 40 trials. After this, he fluctuated between 80% and 92.5% for several blocks of 40 trials until at 3720 trials he tested consistently at 95% correct responses. Sprouts did equally well for both pipe and ball acquisition. It took 1959 trials to criterion when pipe was the S+ and 1919 trials when ball was the S+. There were periods of moderate biases to one stimulus followed by the reverse or from one side to another, but overall there was no appreciable difference. This acquisition curve was similar to those of sea lions (Schusterman *et al.*, 1993) and at this stage it was thought that Sprouts had acquired the

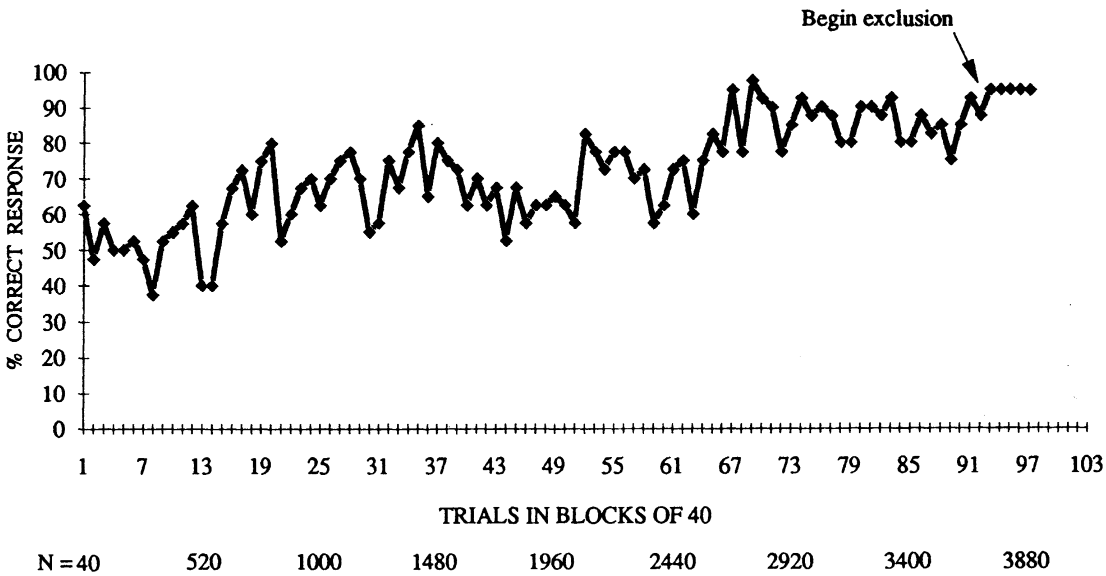


Figure 3. The Harbor seal's acquisition curve for the pipe and ball stimuli.

conditional discrimination between these two stimuli.

Introduction of the third comparison (cone) with its corresponding sample (a triad of ovals) yielded the following results: when cone was the S+ and ball the S-, Sprouts responded correctly on 11/12 trials (91.7%). When ball was the S+ and cone the S-, he responded correctly on 10/12 trials (83.3%); when pipe was the S+ and cone the S-, he was correct on 10/12 trials (83.3%); but when cone was the S+ and pipe the S-, he was correct on only 2/12 trials (16.7%). There was some indication of a right position bias (see Table 1, first six trials) but the primary problem was the stimulus choice. Sprouts did not use the exclusion principle for all stimuli. He had less difficulty when the conditional discrimination involved cone and ball, and on familiar-novel trials with pipe and cone. However, on novel- familiar cone/pipe trials, he biased to the more familiar stimulus. Sprouts had only acquired an association between the ball comparison and its sample X, not the association between the pipe comparison and its related staircase sample. Until now, he responded correctly when either pipe or ball was the S+ because he knew the association between the ball comparison and its sample so any trial that had a "not ball" sample must be pipe. He was able to choose correctly when the S+ was pipe and cone was the S-, but for these trials he may have just been responding to a previously seen comparison.

Because Sprouts should have improved if given more trials using the novel stimulus, blocks were increased to eight trials. This did not help and his performance with cone and ball began to deteriorate (Table 1, first 20 trials), therefore, several sessions of baseline, plus blocks with cone and ball as the comparison stimuli, were run. His performance quickly recovered and baseline remained high, between 93% and 100% correct responses. The acquisition curve for comparisons ball and cone in blocks of 40 trials is shown in Figure 4a. Sprouts was, for the most part, always above 90% for these two comparisons, with no biases towards either stimulus, and after 73 trials to ball as the S+

Table 1. The Harbor seal's initial performance on familiar-novel and novel-familiar trials when the third sample/comparison (cone) was added; R = right, L = left; 1 = pipe, 2 = ball, 11 = cone, CR = correct responses. First number after R or L indicates S+, number in parentheses indicates S-

Trials	Responses	R1(11)	L1(11)	R11(1)	L11(1)	R2(11)	L2(11)	R11(2)	L11(2)
First 6	CR/ TOTAL	6/6	4/6	2/6	0/6	5/6	5/6	6/6	5/6
	% CR	100.0	66.7	33.3	0.0	83.3	83.3	100.0	83.3
First ~20	CR/ TOTAL	14/19	13/20	6/20	3/21	16/18	15/17	13/18	9/17
	% CR	73.7	65.0	30.0	14.3	88.9	88.2	72.2	52.9

and 79 trials to cone as the S+ these stimuli were placed into the baseline in a random series.

The acquisition curve for pipe and cone was quite different (Fig. 4b). It started out at chance levels (50%) and gradually increased, but did not remain near 90% correct until approximately 1240 trials, which was also the point where these stimuli were added into the baseline (660 trials with pipe as the S+ and 589 trials with cone as the S+).

Baseline, which consisted of pipe and ball trials, remained high (about 95%) throughout this acquisition phase. Sprouts' overall performance broken down by stimulus and location during this period is shown in Figure 5. Performance on familiar-familiar (baseline) trials consistently was accurate as were the familiar-novel and novel-familiar trials when ball and cone were pitted against each other. However, when pipe and cone were the comparisons, Sprouts scored much lower regardless of whether the novel comparison was the S+ or S-. Only after intense training did his accuracy levels meet criterion requirements.

Sprouts' overall results were 505/546 or 92.5% correct responses and there were no position biases; correct responses to the right were 250/273 (91.6%) and correct responses to the left were 255/273 (93.4%). For trials involving ball as either an S+ or S-, he was well above 90%. He only dropped below 90% for trials where pipe and cone were the S+ and S-, but he still scored quite high for these (87.8% and 89.5%). So, there was every indication that Sprouts had finally formed associations for all the samples and their respective comparisons.

When the cone comparison was added initially, the intention was to run it against familiar stimuli, thereby giving Sprouts the opportunity to choose it by exclusion. To test whether he would consistently use this principle, two new sample/comparisons (fish/Swiss flag and splots/grad cap) were added for two sessions. These sessions consisted of familiar-familiar trials, familiar- novel trials, novel-familiar trials and novel-novel probes. For novel-familiar trials, he responded correctly on only 47% (8/17) of the Swiss flag trials and 33.3% (6/18) of the grad cap trials. He did better for the familiar-novel trials; 89.5% (17/19) for trials with Swiss flag as the S-, and 83.3% (15/18) when the S- was grad cap. Combining all novel-

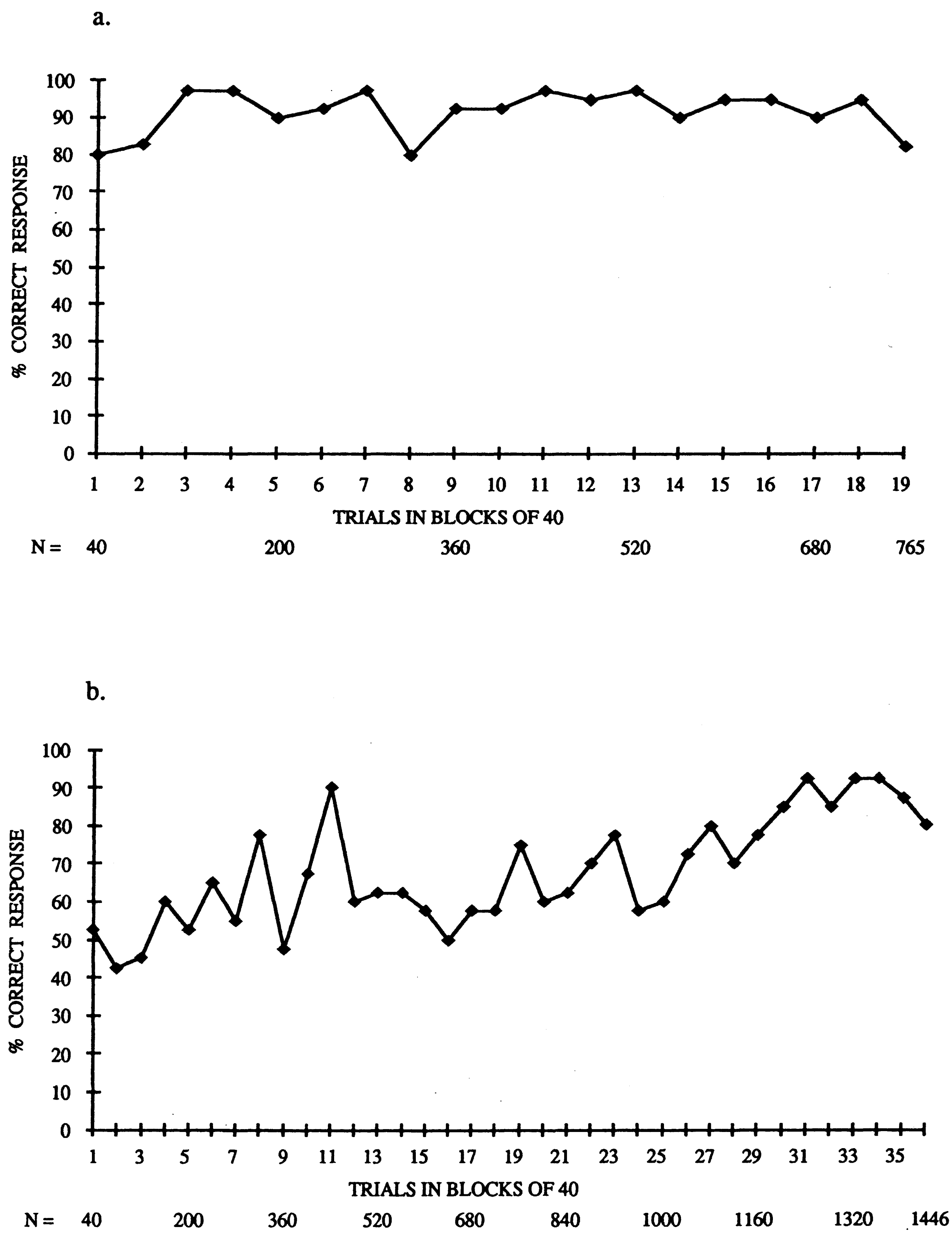
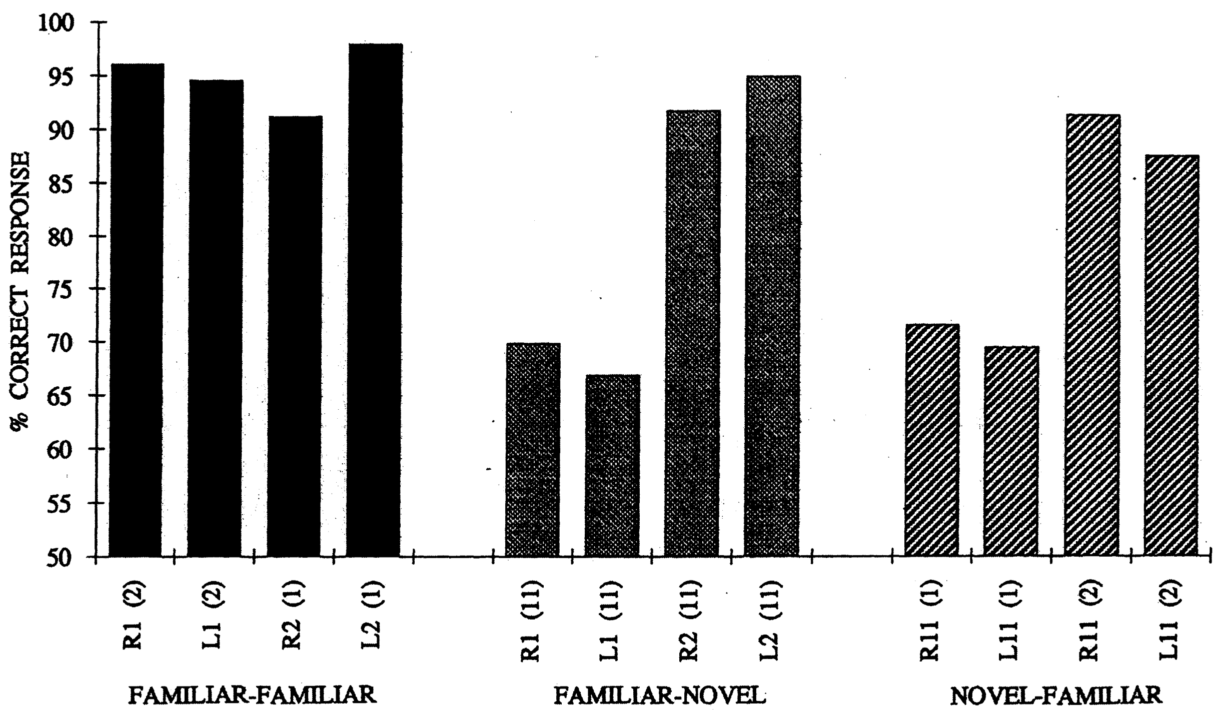


Figure 4. a. The Harbor seal's acquisition curve for the ball and cone stimuli. b. The Harbor seal's acquisition curve for the pipe and cone stimuli.



Note: R = right, L = left; 1 = pipe, 2 = ball, 11 = cone; First number after R or L indicates S+, number in ( ) indicates S-

Figure 5. The Harbor seal's performance during acquisition of the third sample/comparison (cone).

familiar trials, he only chose correctly on 40% (14/35) of the trials which was below chance (50%). For all familiar-novel trials, he responded correctly 86.5% (32/37), which was significantly above chance ($\chi^2 = 9.8$, df = 1, $p < 0.005$). He also showed an extreme left bias for the novel-familiar trials, with only 5.6% (1/18) correct responses to the right and 76.5% (13/17) correct responses to the left ($\chi^2 = 18.3$, df = 1, $p < 0.0001$). There was also a left bias, although not as strong ($\chi^2 = 4.7$, df = 1, $p < 0.05$), for familiar- novel trials; 72.2% (13/18) for correct responses to the right and 100% (19/19) for correct responses to the left. Novel-novel probe trials were at chance (50%, 2/4 trials). For trials involving novel stimuli as the S+, his primary response was to the left and for trials where the novel stimulus was the S- he responded to the more familiar comparison but still with a left bias. Baseline trials were affected, although insignificantly ($\chi^2 = 3.5$, df = 1, $p > 0.05$), falling to 83.3% (30/36), and showing a left bias which was again insignificant ($\chi^2 = 0.8$, df = 1, $p > 0.1$); correct responses to the right were at 77.8% (14/18) and those to the left were at 88.9% (16/18). Interestingly, five of the six baseline errors were on trials where cone was the S+ and pipe was the S- and the other error occurred on a trial where the S+ was again cone and the S- was ball.

Discussion and conclusions

Sprouts' acquisition curve for the first two sample-comparisons (pipe and ball) was typical and within range of acquisition learning of initial stimuli pairings for sea lions (Schusterman *et al.*, 1993). Sprouts did not show a bias toward one comparison and it appeared that this more controlled form of MTS was beneficial to learning. However, selection of one comparison in the presence of a certain sample does not necessarily preclude a relationship between the two. A one-sided association became apparent when a third sample/comparison (cone) was added. Only after intense pipe/cone training was Sprouts able to respond at high levels for all three stimulus pairings.

It was unclear whether Sprouts had truly learned associations among all three samples and all three comparisons. Theoretically, he could perform well by knowing only two associations since he could use exclusion to choose correctly the one he did not know. Additional testing then determined whether he could use exclusion for subsequent novel stimuli and thus, immediately respond accurately whenever one of the stimuli was novel. The results showed that: 1) although Sprouts could use exclusion when the ball was a comparison, he, unlike sea lions, was not consistent with this principle when subsequent stimuli were involved, and 2) although he responded poorly on all novel-familiar trials he did worse on trials where the S- was pipe indicating that he still did not have a firm grasp of the pipe sample/comparison association. For this test, a spatial aspect appeared which typically occurred whenever Sprouts was confronted with a new problem.

The conclusions from this experiment are: 1) Many animals are able to form associations between samples and comparisons. California sea lions, humans and probably other nonhuman species learn to discriminate between the initial two sample/comparisons by trial and error and then use the exclusion principle to facilitate the learning of new sample/comparison stimuli. Schusterman *et al.* (1993) demonstrated that sea lions respond almost errorlessly when a novel sample/comparison is pitted against a familiar one. However, sea lions do not form an immediate association. It requires a few hundred trials for such an association to become firmly established, yet they respond accurately to the novel stimuli by excluding familiar pairings.

Sprouts did not initially learn associations for both samples and their related comparisons. Instead, he learned only one relationship at a time and then only by intense training through trial and error. These results are consistent with past findings involving identity matching-to-sample tasks in harbor seals which, at early stages of learning, are no different than arbitrary matching-to-sample. Both paradigms begin as conditional discriminations, but unless one tests for generalized identity matching one cannot be sure that the subject has the concept of identity (Sidman *et al.*, 1982). The results of this experiment and those of past ones strongly suggest that the phenomenon of learning only one sample/comparison at a time is common to the species as a whole rather than in just one individual. Harbor seals do not consider the availability of two signals when they are first exposed to a conditional discrimination, rather they learn only one relationship and respond on the basis of whether or not the known sample is present. Only when additional stimuli are added do they learn another association but it takes hundreds to thousands of trials and, still, only the minimum required associations are formed. Because it was possible to teach Sprouts to discriminate conditionally between some stimuli, it is likely that his repertoire could have been built up with additional training but there was no indication that he would ever fully use exclusion to facilitate learning.

2) Sidman (1987) suggested that two choices are not enough and can result in false conclusions about what is learned. He reasoned that, with only two comparisons, results can often be interpreted erroneously. For example, a subject may score quite accurately (75% or greater) in an arbitrary MTS test and still not learn what the experimenter had intended. This high score could be attained not by choosing correctly on the basis of the appropriate stimuli but by biasing to either one stimulus or one key position. This problem may not emerge until the subject is confronted with another sample/comparison. False positives may occur simply because the subject correctly chooses one stimulus because it is the "other one." This is similar to the results obtained with Sprouts and perhaps the outcome would have been different if he had been given more than two choices.

3) Perhaps the standard methods used in teaching conditional discriminations are not appropriate for harbor seals. In a critical review of teaching discriminations to mentally retarded humans, McIlvane, Dube, Kledaras, Iennaco and Stoddard (1990) discussed a typical three-step method: 1) the subject is taught to discriminate between comparison A (S+) and comparison B (S-), 2) the discrimination is reversed and reinforcement histories are balanced, 3) the discrimination and its reversal are brought under instructional control (if A then A, not B; and if B then B, not A). These researchers suggested that problems may arise from this technique, namely it is assumed that the subject can discriminate samples A and B which have not actually been taught. Another possible problem is that the subject must suddenly be expected to observe two stimuli (the sample and the comparison) before responding and, finally, teaching discriminations between comparisons may encourage subjects to ignore the samples. Similar methods were used to teach conditional discriminations to Sprouts. It is quite possible that Sprouts reacted in the same manner as the subjects in the study by McIlvane *et al.* and therefore, did not initially learn what was expected. So, this is another indication that harbor seals may not solve problems the same way as do California sea lions, dolphins, and normal humans.

4) Like most animals, harbor seals are successful in spatial problem solving tasks. When harbor seals are confronted with an MTS test that requires a spatial discrimination they perform well (Renouf and Gaborko, 1988; Renouf and Gaborko, 1989). Sprouts showed an inclination to respond spatially whenever he was confronted with a new problem, although this was not the only factor involved in his behavior. Renouf and Gaborko (1988) suggested that harbor seals perform better in spatial experiments due to environmental factors including water pressure, temperature and illumination. Their underwater world is three-dimensional and seals probably use visual, kinesthetic, and vestibular cues to make decisions. We agree with their reasoning but question why this would be more important for seals than for sea lions or dolphins? We suggest that the tendency towards spatiality exists shortly after birth. Unlike many other phocids and otariids, harbor seal mothers do not vocalize to their pups, however, pups follow their mothers and mothers hold vigilance over pups during potentially adverse situations (Renouf, Lawson and Gaborko, 1983). Therefore, pups must locate their mothers not by recognition of vocalizations but by observing the mothers' visual fea-

tures and their locations (stationary or moving). This is different from the behavior of California sea lion pups who recognize their biological as well as human surrogate mothers through vocal cues (Schusterman, Hanggi and Gisiner, 1992). When harbor seal pups are left temporarily alone (as when the mothers leave to feed) they often remain or return to the same location they last were with their mothers (personal observation by EBH). Maintaining and re-establishing contact between mothers and pups thus appears to involve a spatial element. Perhaps this is one reason why harbor seals are more spatially inclined.

Although the mother is non-vocal (except for threats), the pup does vocalize, and Renouf (1985) demonstrated that a captive female harbor seal could discriminate between pup calls. It is suggested that this is also true in the wild. However, this only requires a female to recognize her own pup's call; again a single learned association.

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