

**Shaping and Discriminative Control of Underwater  
Click Vocalizations in a California Sea Lion**

Ronald J. Schusterman

Stephen H. Feinstein

## Shaping and Discriminative Control of Underwater Click Vocalizations in a California Sea Lion

**Abstract.** *A captive sea lion (Zalophus californianus) which had never before produced clicking sounds in the laboratory was first conditioned to vocalize in air and subsequently learned to emit underwater clicks. Clicking was brought under control by differential reinforcement procedures. Vocalization as an indicator response may be useful in the comparative study of discriminative behavior.*

In recent research with two captive female sea lions (*Zalophus californianus*), clicking sounds underwater, which may be used for echolocation (1), were produced by only one of the animals (Bibi)—primarily under conditions of poor visibility. Furthermore, the sea lion (Cathy) that did not make clicking sounds underwater was also found to be less vocal in air (2). When both animals were placed together in an experimental tank and were trained to make an instrumental response (each striking simultaneously presented targets of different size) for food reinforcement, both animals were highly aroused, as evidenced by their raucous play and aggressiveness between trials, but Bibi alone produced barks and clicks. On the assumption that the production of underwater clicking sounds may be related to the vocalness of a sea lion, we proposed to condition Cathy to vocalize in air and to determine whether, in its attempt to vocalize under water, the animal would begin to emit clicking sounds. Accordingly, a series of experiments was initiated with the aim of shaping (3) an underwater clicking vocalization by Cathy and then gaining discriminative control over the vocalization.

A piece of fish was held in front of the sea lion in air until it made a vocalization, which was promptly reinforced. Conditioning of vocalization was quite rapid. The vocalization was not a bark, but a hoarse sound which we have noted that females make when they are placed in situations considered frustrating. Figure 1a is a sonogram of the vocalization (4).

Immediately after a session of conditioned airborne vocalizations, Cathy was placed in an outdoor tank (Fig. 2). The testing conditions and apparatus were similar to those previously described in detail (5). As soon as the animal positioned itself approximately 6 m in front of the testing platform, it began to vocalize with its head out of water as it waited for a target to be presented. Initially

this behavior was maintained by lowering a single circular target (16.1 cm<sup>2</sup> in area) into the water and allowing the animal to strike the target in order to obtain a piece of herring. The animal's behavior was then gradually shaped so that it had to duck its head under water and vocalize prior to target presentation and subsequent food reinforcement. Much of the time we did not hear a vocalization. Apparently, in attempting to vocalize, Cathy primarily blew bubbles with only a slightly audible vocal sound. During this initial phase of conditioning, we differentially reinforced those bubbling sounds that had vocal components, barks, and clicking sounds. An initial click train occurred within the first 5 minutes and the animal acquired consistent click emission within approximately 30 minutes. The acquisition of

underwater clicking is depicted in Fig. 3 (6). Typically, on any given trial the animal would duck its head under water, begin a series of clicks, swim toward the target area slowly while clicking continuously, and terminate clicking as soon as the target was lowered. In other words, the animal learned to emit clicks in order to produce the target which was associated with food reinforcement.

During operant conditioning, the discriminative stimulus gradually acquires secondary reinforcing properties (7). As has already been indicated, in our first experiment the target, which had acted as a discriminative stimulus as well as a manipulandum in previous experiments (5), served as a secondary reinforcer during the shaping of clicking sounds. In order to gain discriminative control over Cathy's vocalizations, a procedure had to be developed whereby the target could be presented prior to click emission. As anticipated, if the target was lowered before the animal ducked its head under water, no clicking sounds were produced. Rather, the target merely served as a signal for the animal to swim forward rapidly. Since Cathy would emit clicking sounds prior to target presentation while slowly

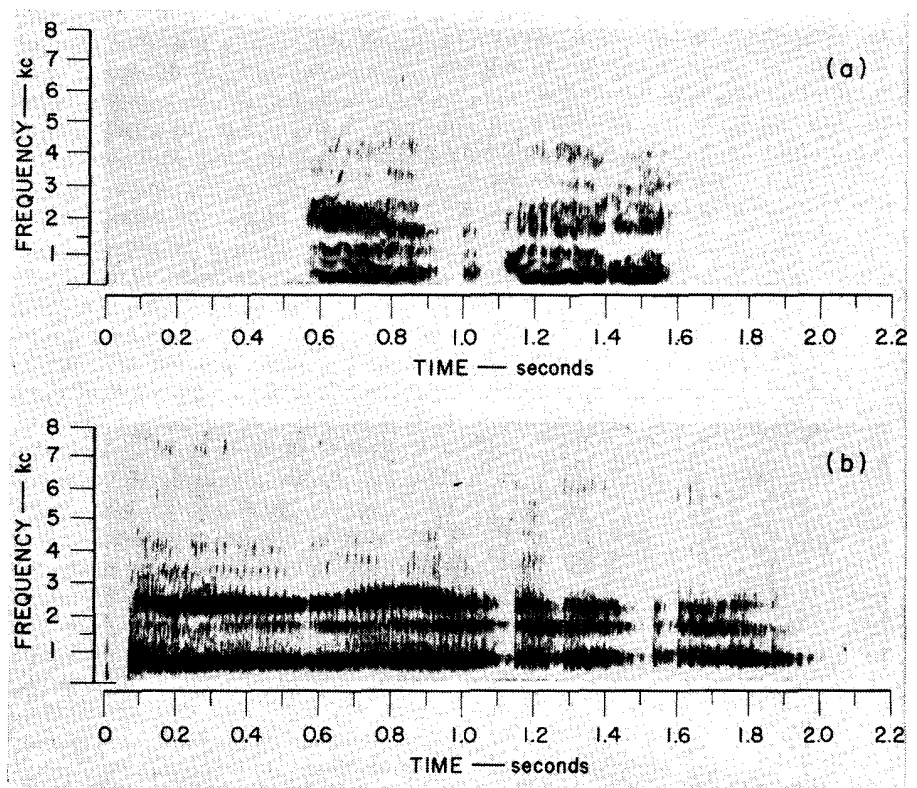


Fig. 1. (a) Sonogram of a conditioned airborne vocalization by *Zalophus californianus*. (b) Sonogram of a conditioned underwater clicking vocalization by *Zalophus californianus*. Operant reinforcement techniques were used to shape this vocalization.

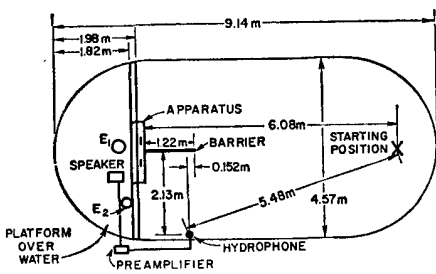


Fig. 2. Plan of the experimental tank, showing test apparatus, recording equipment, and location of the sea lion at the beginning of each trial.

swimming forward, we began reinforcing such behavior directly, without lowering the target. Subsequently, we lowered the target in a gradual manner. Although we had to backtrack on a number of occasions, the animal learned to continue its vocalization even after the target was fully lowered into the water. This is not to say that the target signalled the animal to make a clicking vocalization. On the contrary, there were several occasions when, even though the target was not present, the sea lion swam forward while continually clicking until it reached the display area. Discriminative control over this underwater vocal behavior was demonstrated in the next experiment.

Using a counter-conditioning paradigm, fish reinforcement was made contingent on either clicking or not clicking depending upon the size of the target presented. More specifically, a clicking vocalization in the presence of a large (736.1 cm<sup>2</sup>) circular target was reinforced, whereas *not* clicking in the presence of a small (16.1 cm<sup>2</sup>) circular target (the one that the animal had originally been trained with) was reinforced. The targets were presented successively in a random se-

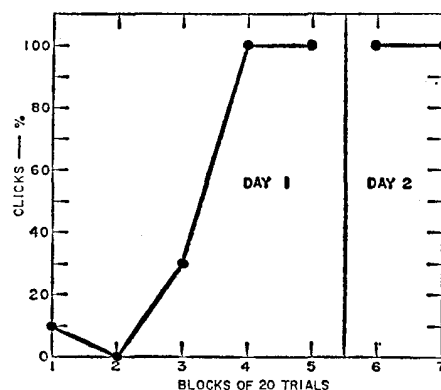


Fig. 3. Initial acquisition of underwater clicks.

quence within blocks of 100 trials, with each being presented on 50 occasions at each test session. There were two test sessions on each of the first three days, and thereafter one test per day.

Figure 4 presents the main results of this experiment; it shows that virtually complete discriminative control over Cathy's underwater clicking was accomplished within 3 days or after 600 trials. Invariably, when the large target was presented, the animal would dive under water and immediately produce a series of clicks at a distance of 6 m from the display area; the animal continued clicking as it swam forward until it pushed against the target. The time between emission of the first pulsed sounds and target presentation was usually less than 0.25 second. Although the animal initially showed signs of rapidly extinguishing its vocalization in the presence of the small target while maintaining its vocalization in the presence of the large one, during the latter half of the fourth session, it stopped clicking altogether. For the next two sessions, each target was presented in alternating blocks of 10 and 20 trials, returning to random presentation throughout sessions 7 to 15.

In a further experiment, Cathy was confronted with 100 successive presentations of a large (736.1 cm<sup>2</sup>) and a small (16.1 cm<sup>2</sup>) triangle. Despite the change in the form of the stimuli, Cathy continued to perform virtually without errors—that is, the animal correctly indicated "large" by vocalizing and "small" by not vocalizing.

Lilly and others (8) have stated that, because of their relatively large brain, dolphins are superior to most, if not all, nonhuman mammals in their ability to learn vocal responses. However, as has been pointed out (9), it seems premature to take such a position without considering alternative hypotheses such as the possibility that the operant control of vocalization may be ecologically determined. The present results demonstrate the ease with which *Zalophus* may be shaped to make a very specific underwater vocalization, in addition to the relative ease of gaining discriminative control over such behavior. The results suggest that *Zalophus*, despite its relatively smaller brain, may be capable of modifying its vocalizations to a degree which rivals that of *Tursiops*. Indeed, operant conditioning procedures have proved highly successful in

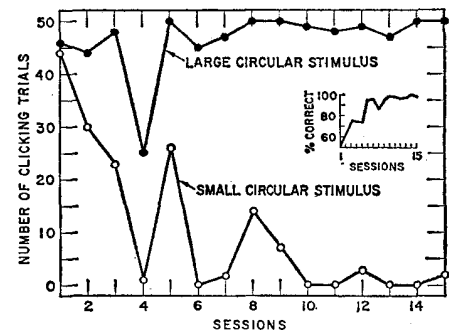


Fig. 4. Acquiring and maintaining discriminative control of underwater click vocalizations. The sea lion was reinforced for clicking in the presence of a large circular stimulus and for not clicking in the presence of a small circular stimulus. Inset shows acquisition of correct indicator responses (vocalizing or not vocalizing).

modifying the barking of dogs and the meowing of cats. (10).

One particular implication of the present results deserves special comment—namely, that the use of animal vocalizations as an indicator or choice response should prove to be a useful tool for those researchers interested in the comparative study of discriminative behavior.

RONALD J. SCHUSTERMAN

STEPHEN H. FEINSTEIN

Stanford Research Institute,  
Menlo Park, California 94205

#### References and Notes

- W. E. Evans and R. Haugen, *Bull. S. Calif. Acad. Sci.* **62**, 165 (1963); T. C. Poulter, *Science* **139**, 753 (1963); W. E. Schevill, W. A. Watkins, C. Ray, *ibid.* **141**, 50 (1963).
- R. J. Schusterman, *Amer. Zoologist*, in press.
- Shaping refers to the modification of behavior (in this case vocalization) by reinforcing successive approximations of the ultimately desired behavior.
- The following equipment was used for monitoring and recording underwater sounds: hydrophone, Channel Industries 275 (20 cy/sec to 150 kcy/sec); amplifier-speaker, Ampex 2044 (65 cy/sec to 13 kcy/sec); and recorder, Uher 4000-S at 7.5 inches per second (20 cm/sec) (40 cy/sec to 20 kcy/sec).
- R. J. Schusterman, W. N. Kellogg, C. E. Rice, *Science* **147**, 1594 (1965); R. J. Schusterman, *Proc. Amer. Psychol. Assoc.* **1**, 139 (1965).
- Although shaping of an instrumental response does not often lend itself to a discrete-trial analysis, such analysis was possible because the sea lion returned to its starting position after each approach toward the target area.
- F. S. Keller and W. N. Schoenfeld, *Principles of Psychology* (Appleton-Century-Crofts, New York, 1950).
- J. C. Lilly, *Man and Dolphin* (Doubleday, New York, 1961); — and A. Miller, *J. Comp. Physiol. Psychol.* **55**, 73 (1962).
- R. J. Andrew, *Science* **137**, 585 (1962); J. M. Warren, in *Annual Review of Psychology* (Stanford Univ. Press, Stanford, Calif., 1965).
- K. Salzinger and M. B. Waller, *J. Exp. Anal. Behav.* **5**, 383 (1962); M. E. Molliver, *ibid.* **6**, 197 (1963).
- Supported by NSF grant GB-1437. We gratefully acknowledge the assistance of Roger Gentry and Garth Rader, who helped in testing the animal.

8 October 1965