

SIGNAL PROBABILITY AND RESPONSE BIAS IN CALIFORNIA SEA LIONS¹

RONALD J. SCHUSTERMAN and BRIAN W. JOHNSON
California State University *University of Alaska*

Frequently, marine mammals in a variety of signal-detection tasks maintain a low level of false alarms while attempting to maximize their correct detections or hits. In the present experiment it was shown that variations in the probability of visual or acoustical underwater signals generated isosensitivity curves in sea lions.

The behavior of marine mammals has fascinated comparative psychologists for the past two decades. Particular interest has been focused on the sensory perception of several different species. Fundamental research with the aim of determining the sensory capabilities of whales, porpoises, sea lions, seals, and sea otters is of critical importance if we are to fully understand the nature of their socially communicative signalling, feeding orientation, and navigation skills (Schusterman, in press). Recently, it was pointed out that the strategy of seals, sea lions, and porpoises in a variety of psychophysical tasks with several different indicator responses and a variety of reinforcement contingencies was to maximize the proportion of correct detections or hits while holding the proportion of false alarms at a constant low value (Schusterman, 1974). It has been suggested that experiments concerned with the relationship between stimulus control and traditional psychophysical tasks be conducted with marine mammals (Schusterman, 1974). The present experiment studied the simultaneous variation of response bias and sensitivity in two California sea lions (*Zalophus californianus*) in auditory and visual tasks which very much parallel the yes-no signal detection paradigm.

METHOD

The training and testing conditions, as well as the equipment, have been fully described for both the auditory (Schusterman, Balliet, & Nixon, 1972) and visual tasks (Schusterman & Balliet, 1970). Vocal emission by the sea lions, which consisted of a burst of short-duration sound pulses or clicks (Schusterman, 1966) served as an objective index of signal detection in both auditory and visual tasks. The Ss had been trained to vocalize when specific signals were presented and to remain silent when they were not presented and to

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perform these acts while maintaining their heads in a fixed position on a head stand under water in an oval-shaped redwood tank. In a yes-no signal detection paradigm, vocalization was considered the "yes" response, and silence for a given interval of time was considered the "no" response.

Subjects

The experimental Ss were an 8-year-old female *Zalophus* (Bibi) and a 6-7-year-old male (Sam). Both sea lions were wild born and had been in captivity since the age of 1 or 2. Both Ss had had intensive training in emitting underwater click bursts in the presence of a wide-striped target and in remaining silent in the presence of a narrow-striped target (Schusterman & Balliet, 1970). Prior to the present experiment, Sam was trained to emit a burst of underwater clicks in the presence of a pure tone and to remain silent in the absence of such a signal (Schusterman et al., 1972). Bibi was given the visual task and Sam the auditory task.

Visual Task

A visual acuity test was used with successive presentation of the *standard* target (catch trial), consisting of 300 lines per inch, and the *comparison* target (signal trial) with stripes of much greater width. "Yes" in the presence of the comparison is a "hit" (Y/sn), and in the presence of the standard it is a "false alarm" (Y/n). "No" in the presence of the standard is a "correct rejection," and in the presence of the comparison it is a "miss." Hits and correct rejections were reinforced with a piece of herring.

The S's head was approximately 4.9 m from a target which was presented for approximately a 3-sec. duration. If the comparison target was presented, S was required to emit a burst of clicks within 3 sec. ("yes") in order to receive one piece of herring. If the standard target was presented, S had to remain silent for 3 sec. ("no") in order to receive one piece of herring. Regardless of S's response or the reinforcement contingencies, the intertrial interval was usually about 15 sec. Usually vocalization occurred immediately following target submersion (see below). Angles subtended by the stripes of the comparison targets are shown in Table 1.

Targets were attached to a board which made a loud noise when lowered into the water. This noise served as a warning signal that either the comparison or standard target would be presented. To help

TABLE 1
Signal Intensity Values

Signal Strength	Acoustic dB re 1 μ B (in water)	Visual Visual Angle (min.)
Strong	+36	7.3
Moderate	+30	6.1
Weak	+26	4.4

ensure that S would not report "yes" (vocalize) before a target was completely submerged, sometimes the board was lowered only to water level. This procedure tended to minimize "yes" responses to the warning signal.

Acoustic Task

Schusterman et al. (1972) provide a full description of the equipment controlling the experimental contingencies, and producing, amplifying, attenuating, monitoring, and measuring acoustic signals; ambient noise measurements are also given. A lead zirconate titanate transducer (F-41) was used to project a 48-kHz tone into the testing tank for the acoustic task. This high-frequency tone was initially chosen because when acoustic testing was begun, bird vocalizations were being picked up in the tank, and the frequency spectrum of several of these vocalizations were in the general range of the best hearing sensitivity of the California sea lion (1 kHz to 28 kHz). Therefore, *Es* chose a tonal signal considerably higher in frequency than any known noise that could enter the tank.

In the acoustic task a light was used as a warning signal, sometimes followed by a tone (signal trials) and sometimes not (catch trials). A single trial consisted either of the presentation of a light for 2.5 sec. or the presentation of a light with a 48-kHz tone turned on during the last 0.5 sec. of the 2.5-sec. light duration. If a tone was presented, *S* was required to emit a burst of underwater clicks within 1.5 sec. of tone onset ("yes") in order to receive one piece of herring. If a tone was not presented, *S* had to remain silent for 3.5 sec. after light onset ("no") in order to receive one piece of herring. The intertrial interval was about 15 sec.

The *S*'s head was positioned 2 m from the sides of the tank, 0.7 m from the surface of the water, and 1 m from the projector. The intensities of the acoustic signals are shown in Table 1.

Signal Probability

Signal probability was varied as follows: 0.50, 0.70, and 0.30. Three different signal strengths (strong or "suprathreshold," moderate or "threshold," and weak or "subthreshold") were presented daily in a modified psychophysical method of constant stimuli. Each of the three different signal strengths was mixed on a quasi-random basis from session to session with catch trials for a total of 10 consecutive trials and then repeated four times within each session, for a total of 120 trials per test session. In the sequence of signal strengths, each daily session initially went from strong to weak. Following the first block of 30 trials, each block of 10 trials containing a given signal strength was presented randomly.

The 0.50 probability of signal presentation was used as a constant baseline, which was returned to following the introduction and termination of each of the other two signal probabilities. Changes in the signal probabilities were introduced when *Ss* had reached a relatively steady state in their emission of false alarms and hits at the constant baseline (10 or 14 days). The baseline probability of 0.50 was returned to only when a relatively steady state was attained at each of the other two signal probabilities.

RESULTS AND DISCUSSION

Figures 1 and 2 not only show the main results on a daily basis but also show the sequence of the signal probabilities for both acoustic and visual conditions. At an initial signal probability of 0.50 (first panel of Figure 1), hits increased directly as a function of signal

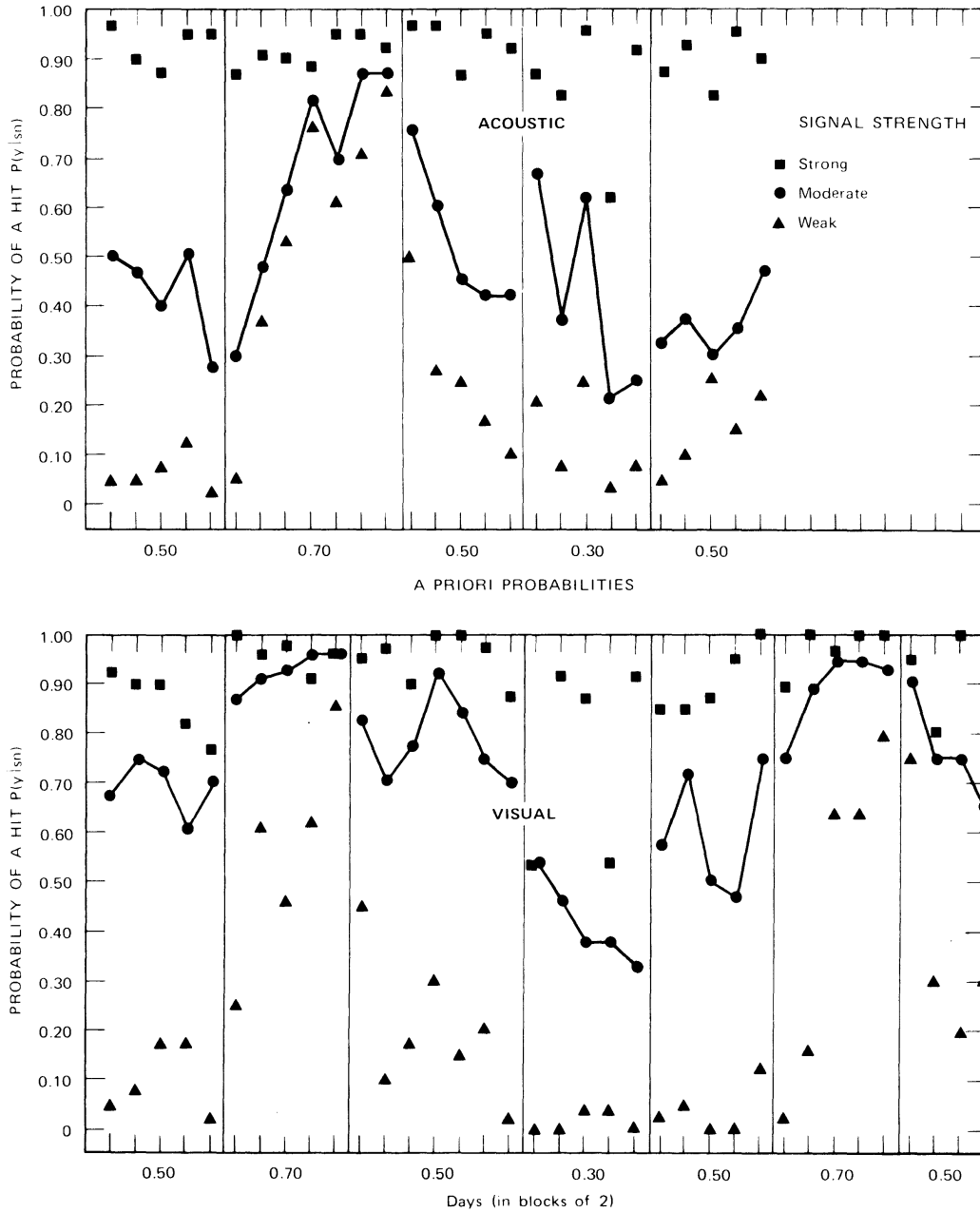


Fig. 1. Acquisition of correct detections or hits by sea lions as a function of signal strength and changes in the a priori probabilities.

magnitude for both acoustic and visual conditions, and they remained relatively stable at each of the signal strengths over the 10-day period. Hits and false alarms changed systemically when the signal

probabilities were varied. The *Ss*' only cues were the change in the ratio of signal to catch trials (i.e., a priori or signal probabilities) and the reinforcement patterns associated with the consequences of responding. Generally, the greatest changes from baseline (a priori

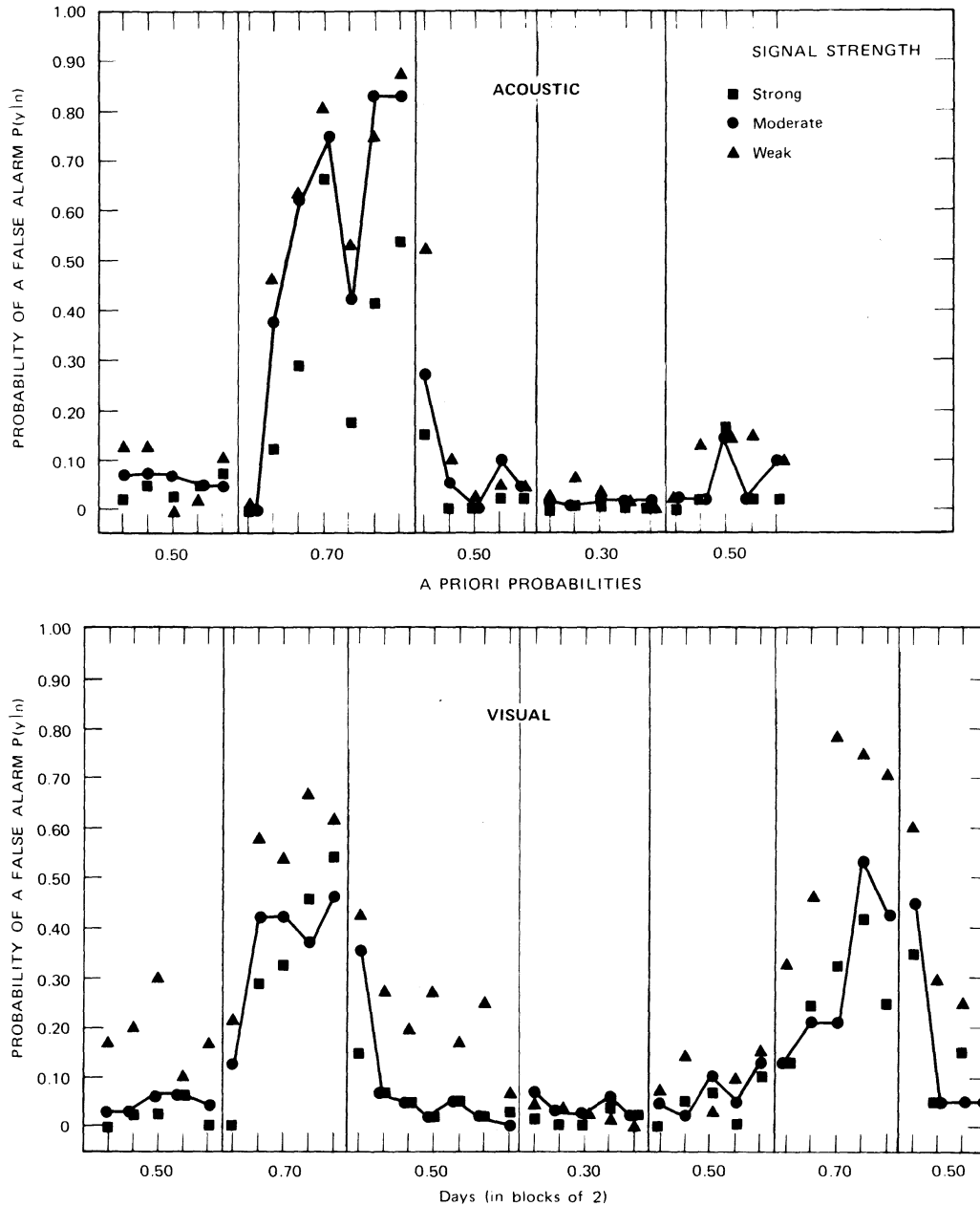


Fig. 2. Acquisition of false alarms as a function of signal strength and changes in the a priori probabilities.

probability of 0.50) detection performances occurred when the a priori probabilities were shifted to 0.70. In both acoustic and visual conditions, shifts in the a priori probabilities had only slight effects on the hit rate when a strong signal was used, but they had great effects

on the hit rates of weak and moderate signals. Since the hit rate for the weak signals during baseline in both modalities was approximately between 0.00 and 0.20 (quite similar to the false-alarm rate), the dramatic increase in hits and false alarms must be interpreted as an optimal strategy for maximizing fish reinforcements. In contrast to the negligible effects of an a priori probability of 0.70 on the hit rate of strong signals, a 0.70 probability of signal presentation significantly increased the false-alarm rates of all signals, even the strongest. An a priori probability of 0.30 had some depressing effect on the hit rate of both strong and moderate signals in both modalities and tended to reduce the false-alarm probability to nearly 0.00 for signals of all magnitudes.

Figure 3 shows a group of isosensitivity curves for the Ss. All data points are based on the last 4 days (160 trials) of signal detection performance for each signal probability (the values for 0.50 are based on all replications). The figure shows that the conservative response criterion, adopted by Ss in both acoustic and visual tasks at all levels

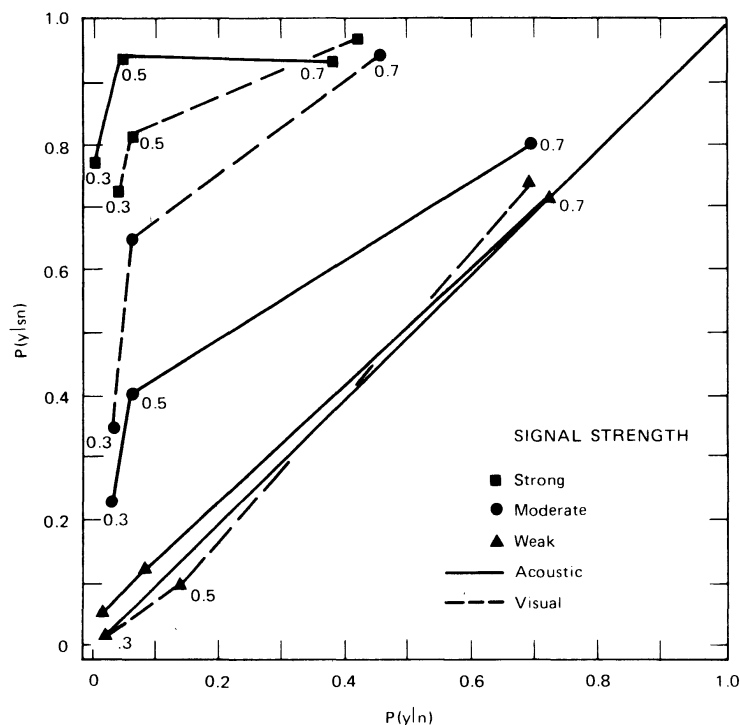


Fig. 3. Isosensitivity curves for sea lions. Numbers refer to a priori probabilities.

of signal strength, can be dramatically changed by varying the signal probability. However, as Figures 1 and 2 have shown, both Ss responded with a low probability of false alarms soon after returning to a signal probability of 0.50. Furthermore, these figures suggest that the probability of 0.50 clearly controls the response criterion to the same extent it did prior to changes in signal probabilities and consequent changes in response criterion. It would appear, therefore, that the original stimulus and reinforcement contingencies under which Ss were trained to emit low rates of false alarms continued to

exert stimulus control despite repeated shifts in signal probabilities. The question of whether such stability would be maintained if other variables which may control response criterion (e.g., magnitude of reward and schedules of reinforcement) were systematically varied remains to be studied.

In Figure 3 the data point representing the acoustic signal of moderate strength at signal probability of 0.70 is quite close to the major diagonal indicating near chance detection ability. Thus although under this condition the hit rate was about 0.80, the false-alarm rate was almost as high—about 0.70. This same phenomenon is reflected in the steepness and relatively high asymptotic level of the hit and false-alarm curves when *S* in the acoustic task was shifted from a signal probability of 0.50 to a signal probability of 0.70. This result suggests that *S* in the acoustic task may have learned to ignore the so-called signal of moderate intensity and reported the presence of signals primarily because of the reinforcement pattern associated with weak signals at an a priori probability of 0.70. The latter is the equivalent of receiving substantial reinforcement for responding "yes" in the absence of a signal. A similar result was obtained by Terman and Terman (1972) with rats in an acoustic intensity discrimination task. Nevertheless, one may conclude that, in general, the variations in the probability of visual or acoustical underwater signals generated reasonable isosensitivity functions in sea lions.

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