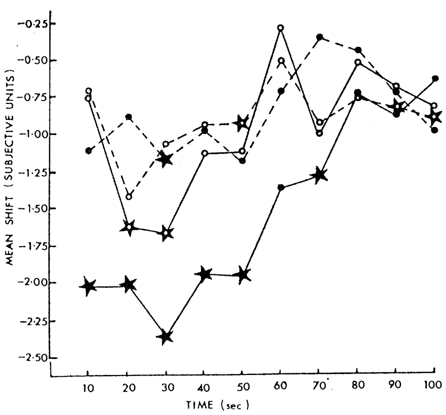

Fig. 1. Mean shift in itch intensity from initial level produced by vibrator application at different body sites. The value at each point is corrected for the slow, spontaneous decrease in itch intensity in the absence of vibration observed in the control group. ●——●, Group I, same wrist; ●- - - -●, group II, same lower arm; ○——○, group III, opposite wrist; ○- - - -○, group IV, opposite lower arm. *Star*, associated $p \leqq .05$

inputs during afferent transmission (*7*).

An explanation of this interaction may be that the light tactile stimulation produced by vibration, like that produced by scratching, triggers impulses in the large A "touch" fibers which inhibit the C-fiber "itch" impulses at the thalamus or cortex (*8*). However, there is no physiological evidence for this mechanism. Moreover, this mechanism does not account for the enhancement of itch intensity after vibration or prolonged scratching.

The results may be explained more satisfactorily as being due to physiological activities occurring at the early stages of information transmission. Mendell and Wall (*9*) have shown that the largest A fibers produce activity in the substantia gelatinosa and that this activity inhibits subsequent transmission of nerve impulses from peripheral sensory fibers to the first central cell. Conversely, C fibers facilitate transmission of sensory input. Since light tactile stimulation produces firing in some C fibers (*10*) as well as in the largest A fibers (*11*), vibration would have opposing inhibitory and facilitatory effects on the input evoked by cowage. However, the number of active C fibers would be small compared with the large number of low-threshold A fibers that would be fired by the vibrator (*11*); thus the overall effect would be inhibitory. This mechanism could account for the decrease in itch intensity produced by vibration.

After cessation of vibration, the balance would shift in favor of a greater after-discharge in C fibers than in A fibers. After-discharge is unlikely to continue more than a few milliseconds in A fibers (*11*) but has been observed to persist in C fibers for as long as 10 seconds after brief stimulation of the skin (*12*). This facilitation of the afferent pattern by the C-fiber after-discharge could therefore account for the enhancement of itch intensity that frequently occurs after scratching or vibration. The transformation of severe itch into frank pain by vibration observed in three subjects is comparable to the observation (*7*) that vibration enhances perception of intense, painful shock although it masks low-intensity shock. At high itch intensities the massive C-fiber input evoked by the itch-producing substance apparently combines with the C-fiber input activated by vibration (and overcomes the inhibitory A-fiber effect) to produce an increased frequency in central firing that gives rise to pain rather than itch.

That the intensity of itch felt at the wrist is decreased significantly by vibration applied to the opposite wrist is also consistent with this hypothesis. Activity in the substantia gelatinosa is influenced by fibers from both sides in the body, so that vibration of either wrist should have comparable effects (*13*).

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Trained Porpoise Released in the Open Sea

Abstract. *A Pacific bottlenose porpoise,* Tursiops gilli, *was trained for a period of 10 weeks to swim at high speed on command and return to an underwater speaker when a specific sound cue was played. This animal was released in the open sea off Oahu, Hawaii, and worked each day for 7 days. At night it was held in an anchored floating pen. The trainer's control over the animal was probably associated with the controlled feeding of the porpoise, the development of social ties between the porpoise and trainer, and the animal's fear of unknown situations.*

On 23 August 1964, near Coconut Island, Kaneohe Bay, Oahu, Hawaii, a trained subadult male Pacific bottlenose porpoise (*Tursiops gilli*) was escorted into the open sea and its movements controlled by use of underwater sound signals (*1*). A week later the same animal was placed in a floating chain-link cage, 9.3 by 9.3 by 3.1 m, anchored in the open sea in the lee of Manana Island, 1.5 km off the Oahu coast. Daily releases of the unfettered animal were made for 7 days in the course of attempts to determine its top swimming speed (*2*). The animal could be controlled easily by the use of the sound signals and standard food rewards.

The experimental porpoise, named Keiki (Hawaiian for "child"), was caught on 24 March 1964 on Penguin Bank 45 km from the Oahu coast. The animal was taken from a school of approximately 80 animals, including at least four other young.

When the porpoise was feeding well, after a few days of captivity at the Oceanic Institute, trainers established the sound of a police whistle as a conditioned reinforcing stimulus by pairing the stimulus with the presentation of food. The conditioned stimulus, followed by food, was used to establish some simple conditioned behavior, including stopping in front of the trainer. No further training was undertaken until 15 June 1964, when a variety of trained behaviors related to the projected speed tests were shaped by standard conditioned-response techniques. Throughout the tests behavior desired by the experimenter was reinforced first by the use of a police whistle, which had become a strong conditioned reinforcing stimulus, then by a reward of whole fish. No food was given the animal except as a reward for correct behavior. The multiple approximation technique was used to shape most behavior patterns—that is, if a complicated pattern was desired, the simplest approximation of it was developed first, with the ultimate complexity being developed gradually through prolonged training. Thus, the first approximation of response to the recall signal consisted of requiring the stationary porpoise to touch the speaker held very close to its rostrum when the sound signal was turned on. Gradually, the speaker was taken farther and farther from the animal, thus requiring the porpoise to move toward it. Ultimately, in the open sea, the animal responded to the loud underwater sound signal by swimming toward the submerged speaker and stopping directly in front of it. The signal, a train of intense, pulsed, broad-band clicks, with maximum energy between 2 kc/sec and 4 kc/sec, was designed to cut through normal oceanic background noise, to allow long-distance transmission, and to avoid the accommodation of the ear that can occur rapidly with continuous pure tones. The signal was produced by a transistorized oscillator circuit from a battery-operated console and was transmitted into the water through a University MM 2F underwater speaker mounted on a 1.8-m metal hanger that could be hooked over the gunwale of a small boat (*3*).

Punishment consisted of moving away from the animal after an erroneous performance, for a time period set approximately 1 minute longer than the animal required, on the average, to station himself spontaneously in front of the trainer in anticipation of further work.

The majority of training was performed in the semi-enclosed lagoon, 300 m in length, that fronts the University of Hawaii Marine Laboratory at Coconut Island. Here the cage was set up and half the length of the lagoon was blocked off by a net barrier. After the porpoise had spent 2 days within the cage, one side was let down. The animal at first refused to leave the cage and had to be escorted by swimmers into the lagoon. These swimmers led the animal the full length of the netted lagoon. The porpoise refused to enter the cage again and was finally forced back into the cage by the use of a crowder net. This behavior was repeated three times and then the porpoise began, voluntarily, to return to his cage upon command of the recall signal. After that the porpoise was given full run of the blocked lagoon, but seldom ventured beyond the immediate area within which his swimming speed was being timed (about one-third the area available). Keiki's entire food intake consisted of approximately 6.75 kg per day of frozen surf smelt (daily intake was varied somewhat according to the requirements of training), except that the porpoise was seen, on two occasions, swallowing masses of colonial hydroids found floating in the lagoon. The animal's dependence upon us to provide food obviously continued into the open sea situation; he was not observed to make any attempt to catch the numerous fish available in the lagoon. Furthermore, the requirements of the speed tests at sea allowed the porpoise little free time in which to hunt.

During the first 3 weeks of August daily training sessions were carried out in which the animal was required to leave the cage on cue (a 3-kc/sec constant tone), swim a 60-m course at high speed, and return to his cage upon hearing the recall signal. At the end of each daily session the animal was recalled, the gate closed, and the animal left in confinement overnight.

On 20 August, restraining nets were removed so that Keiki had easy access to the open sea, but he never attempted to venture out alone. On 23 August the recall signal speaker and instrument console were placed in a skiff powered by a small outboard motor, and the animal was led by periodic recalls into all parts of the lagoon, and finally into the open waters of Kaneohe Bay. The porpoise at first hung behind the boat and seemed reluctant to leave the lagoon. Once we had ventured past the entrance and into the deep channel the animal became visibly nervous, exhibiting jaw chattering and tail slapping, and showing the whites of the eyes, behavior patterns which have been associated with agitation in cetaceans (*4*). After several recalls had been performed in the open water Keiki disappeared momentarily and when next seen was plunging very rapidly away from our skiff, along the edge of the reef that fringes Coconut Island. When the animal was an estimated 195 m away the recall was switched on. The animal stopped at once and returned directly to the speaker. After several more recalls were performed Keiki was led back into the lagoon and caged.

On 25 August the porpoise was moved to the floating pen in the lee of Manana Island. A week-long series of speed trials was performed in which the porpoise spent an average of 3 hours a day swimming unfettered in open water. Keiki was required to follow a fast skiff that towed a surfboard with a streamlined speaker pod suspended beneath, through which the recall signal could be transmitted. The tests were performed along a 320-m calibrated buoy line. Throughout these tests the porpoise remained near one of the small craft, even in the absence of the recall signal, and never strayed away farther than about 90 meters. The operation became quite routine after the first day, and little attention was given to holding the animal close to the skiff with the recall signal. The porpoise re-entered the floating cage upon hearing the recall signal (with the portable speaker hooked over the rear of the cage) and allowed us to close the door without any attempt to rush from the cage. To assist this behavior the animal was held at the rear of the cage by a trainer who reinforced the behavior of "stationing" by presenting the animal with the signal (preconditioned) to rise halfway from the water to take a fish, during and after the period while the gate was being closed. Initially, we were quite concerned about the animal's reaction to wave wash inside the cage, but in spite of large swells and even breaking white water within the cage, Keiki was able to maneuver easily away from the walls.

The exact components of our control over the porpoise cannot be listed categorically. It seems probable that the trainer's control has multiple bases, among which are controlled feeding, social ties between the scientist and the porpoise, the porpoise's fear of unknown waters or situations, coupled with the porpoise's isolation as an individual, and the formal conditioning process through which the animal was led.

Captive cetaceans in general are notable for the ease with which they become habituated to a single kind of food, which may be wholly foreign to them in nature, often to the exclusion of all others. This may assume ridiculous proportions, such as occurred with the captive beluga that would eat nothing but tiny killifish (*5*). Captive cetaceans may often be kept in the same tank with living fish of various varieties, and often may completely ignore them.

In nature most porpoise species form tightly knit schools. The social structure of such schools is complex (*6*) and may involve much dependence of young upon adults. Young bottlenose porpoises orient to their mothers, or to "auntie" porpoises, for an extraordinarily long time (as long as 6 years), particularly in times of stress. To remove a young animal from such a social order and to place it in captive isolation may induce starvation. In some oceanariums a docile well-tamed animal is maintained that can be held with such a newcomer until the new animal is tamed and feeding. Even after a porpoise is tamed, isolation is stress-producing, and extended periods may cause a decline in health (*5*). For these reasons, during the training described here, about an hour a day was devoted to swimming with the isolated animal. Keiki quickly became very tame and solicited bodily contact of various sorts from the swimmer. Porpoises frequently stroke each other with their flippers. The members of the investigating team often responded to Keiki's solicitations by stroking and patting him during and after work sessions. It is possible that this bodily contact constitutes a reward for which the presence of human beings becomes a conditioned reinforcing stimulus, increasing the probability that the animal will stay near people under most circumstances. Keiki's high degree of tameness allowed us to perform many manipulations, such as transport, that otherwise would have frightened him severely. Whether we did more than develop a high degree of tolerance, and whether we pressed into the realm of dependence is a moot point.

Fear is expressed in porpoises by the visible signals mentioned before, and may also be indicated by abrupt cessation of feeding and a sudden lack of clear response to learned signals. All of these things suggest that from time to time Keiki was frightened. Such fright occurred whenever the animal was led into a new situation, such as when the porpoise was taken for the first time beyond the limits of the measured course, or when he was led out of the cage for the first time. Bottlenose porpoises in captivity are notable for refusing to go through gates where they cannot see, or for refusing to pass under unfamiliar objects above water or over newly placed obstacles on the bottom. Before an animal can be induced to do these things it may literally have to be driven by force once or twice (*5*). This marked fear of new situations may also have been an important part of our control over the lone animal in the open sea.

The development of a trained porpoise that can be manipulated in the open sea opens the way to a variety of experimental possibilities. Several captive porpoises have been broken to harnesses, which not only allows an additional degree of control, but allows the attachment of a variety of instruments to the animal that can record physiological parameters, such as heart rate, lung configuration, and blood pressure. It may prove possible to insinuate a trained animal in schools of wild animals and to observe and record various kinds of behavior. Such animals could also be used to perform a variety of human-directed tasks in the sea.

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References and Notes

1. Another somewhat similar release was made on 13 August 1964 by R. Bailey of Point Mugu Naval Missile Center, in which a harnessed and buoyed Atlantic bottlenose porpoise was allowed to swim briefly in Hueneme Harbor, California.
2. I thank those who helped with these tests, especially Karen Pryor, Dorothy Samson, Phyllis and Susan Norris, and Dr. Ronald Turner for their help with training, Taylor Pryor for organizational help, the staff of the Hawaii Marine Laboratory for many courtesies, and Georges Gilbert and Leo Kama for their constant support in building and maintaining the offshore gear. This work was performed under ONR grant G-0007 64. (Contribution No. 2, The Oceanic Institute, Makapuu Point, Oahu, Hawaii.)
3. A 3-kc/sec sine wave was modulated by a 1-cy/sec sawtooth generator, producing the "chirp train" used as a recall signal. Amplification was achieved through two Fannon 37-watt amplifiers, each hooked to separate underwater speakers.
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Perception of Stroboscopic Movement: Evidence for Its Innate Basis

Abstract. *Newborn guppies and newly hatched praying mantids were placed inside a stationary cylinder containing a columnar pattern such as is used to elicit the optokinetic reflex. By illuminating columns in sequence, the pattern was made to appear to rotate. All of the animals tested circled in the direction of apparent movement. As with humans, movement was only perceived at intermediate rates of flashing.*

The fact that apparent movement is seen only at certain speeds and spatial separations, that it can be seen by a variety of species, as well as by decorticated animals (*1*), has suggested to many that the effect is innate. Nevertheless, it is possible that such perception of movement is learned on the basis of experience with real movement. This argument is supported by the fact that stroboscopic movement is optimum if the stimuli in the two locations are identical or quite similar (*2*), by the fact that the direction of perceived movement is affected by the meaningful content of the stimulus object (*3*), and by the recent finding that the necessary stimulus conditions entail alternate flashing of two regions in phenomenal space, not in two separate retinal-cortical regions (*4*).

However, logical considerations and indirect tests are no substitute for a direct empirical test of the question. To eliminate exposure to real movement, as would occur in a transfer-type of design (*5*), we sought a method which would tap an innate response to real movement. The one we chose, because of its reliability, was the optokinetic reflex (*6*). With the assumption that the species we wanted to test would react at birth to a truly rotating striped pattern (either with turning movements of the eyes, head, or total body), the question was: Would it react at birth to a pattern which flashed stroboscopically in such a way as to simulate true rotation (*7*)?

For convenience and reliability we wanted a species that would respond to the perceived rotation of a drum by movement of its entire body. Fish are known to swim in the direction of a rotating drum, but we did not know if newborn fish would do this. The evidence in general for the innateness