come 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.
4. D. Brown, *J. Mammal.* **41**, 342 (1960).
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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 of the optokinetic reflex is equivocal (*8*). We decided to work with the guppy (*Lesbistes reticulatus*), and, to test the reaction of this species, we placed newborn guppies one at a time in a petri dish at the center of a rotating drum. Within a few seconds they swam in the direction of rotation. We therefore submit this evidence as of interest in its own right. The optokinetic reflex is present at birth in this species.

We constructed a drum, 40 cm in diameter and 20 cm high (*9*), in which lights were arranged in columnar fashion, each column being illuminated by three small neon bulbs. The light within each column was diffused by means of adhesive tape, but each column of light was separated from the next by opaque tape so as to yield sharp columns 0.6 cm in width. These columns of light were 1.8 cm apart. At any one moment every third column around the inside of the drum was simultaneously lit for a set period of time. To give an impression of movement, as the lights in these columns went out, the columns adjacent to them, after an equal period of darkness, in, say, the clockwise direction, went on, and so on. Each column remained illuminated for the same period.

By spacing the columns which flashed together three apart there could be no ambiguity as to the direction of movement. Based on the factor of proximity, the perceived movement (for humans at least) is always in the direction of the adjacent columns to light up rather than in the direction of those separated by one column. By means of a rotating switch the arrays of columns could be lit up successively. The speed of flashing was a function of the speed of the rotating switch. Another switch was used to reverse the direction of apparent motion or to produce a stationary flashing effect. Although stroboscopic stimulation has been shown to elicit the optokinetic reflex in animals, the method previously used was to illuminate intermittently a truly rotating drum. In the method that was utilized here, there is no movement whatsoever.

In the first experiment pregnant guppies were placed individually in plastic breeding tanks. The tanks were constructed so that the offspring could escape from the female by dropping through a horizontal divider separating the top and bottom of the tank. To exclude light, the tanks were enclosed in cardboard containers and placed in a light-tight cabinet. As a further precaution the room in which the experiments were conducted was also kept completely dark. These conditions ensured that the young were maintained under conditions precluding the possibility of visual learning. The containers were checked daily with a momentary flash of light, and, if parturition had occurred, a single newborn fish was poured into a petri dish containing just enough water to allow the fish to swim. The petri dish was placed on a platform in the center of the drum; we found it helped to elevate the dish slightly so that the columns extended somewhat below the eye level of the fish. The ages of the fish tested ranged from a few minutes to 24 hours.

After a short period of adaptation to the dish with one series of columns illuminated, the rotational flashing was started. The speed was such that if the columns had actually been moving they would have made about 18 rotations per minute. The fish was observed for about 2 minutes (by two of us), and then the direction of apparent motion was reversed. The room was dark except for a dim lamp some distance away.

All of the ten fish tested circled in the direction of apparent rotation, and all reversed when the direction of apparent rotation was reversed. An interesting finding was that of an inertial tendency in the fish; they would continue swimming in one direction for several seconds after the direction of stroboscopic movement was reversed or the apparent motion stopped altogether. This effect is similar to what others have called "after-nystagmus" to a truly rotating drum (*10*).

The second experiment was identical to the first except that the subjects were newly hatched praying mantids (*Tenodera sinensis*) (*11*). The egg casings were kept under a glass jar which in turn was kept inside a light-proof bag in a darkened room. Occasional brief probes with a flashlight established when the eggs had hatched. The recently hatched mantids were placed one at a time on the floor of the drum. In some cases they were covered by a transparent celluloid dish, but in others they were allowed complete freedom of movement inside the drum.

The results for ten mantids were identical with those for the fish. Every mantid circled rapidly in the direction of apparent rotation. Following reversal of direction the insect would stop, bend its body in the new direction of the "moving" stripes, and then circle in that direction. Some circled without changing their location in space while others circled in a fairly wide arc.

It might be argued that the optokinetic reflex to stroboscopically flashing columns may be based on a tendency to follow stimuli which are seen successively in different locations even though they may not be seen to move from one location to another. This argument would be refuted if it were possible to show that circling occurs only for a middle range of speeds of successive flashing. At too slow a speed perhaps only successive flashes would be seen, not movement; at too fast a speed, simultaneous flashes would be seen, not movement. However, since the optokinetic reflex itself might not occur at speeds which are too slow or too fast, the absence of circling at such speeds cannot be taken as evidence that apparent movement was not perceived. Hence, the design of the third experiment was as follows. Separate groups of five guppies each were tested with the drum truly rotating at one of three speeds, namely 3.3, 18.7, and 41.5 rev/min. Three additional groups of five guppies each were subjected to stroboscopic "rotation" at apparent speeds which were identical with those of the groups that were subjected to true rotation.

The drum used in the preceding experiments was also used in this experiment to produce apparent motion, but since it was not suitable for actual rotation, we constructed an exact replica, except that in this case the columns remained permanently lit, and mounted it on a shaft to permit rotation. In this experiment no attempt was made to work with fish deprived of prior visual experience.

All the guppies circled under conditions of *actual* rotation regardless of speed. This means the optokinetic reflex could be elicited at all speeds tested. However, under conditions of stroboscopically induced motion only the five guppies in the group subjected to the intermediate speed (18.7 rev/min) circled.

We conclude that, as with humans, apparent movement is seen by the guppy only at certain speeds, and that change of location of stimuli is insufficient to elicit the optomotor reflex; unless movement is perceived, circling will not occur. Our results indicate that there are two stages in the optokinetic reflex, namely (i) the perception of rotation of the stripes and (ii) the circling or pursuit of such phenomenally moving stripes. If the conditions are not right in (i), (ii) will not occur.

We believe that the response to apparent movement will also prove to be innate in human infants. It does not follow, however, that experience cannot also play a role in the mature organism; the two factors are not mutually exclusive.

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2. J. Orlansky, *Arch. Psychol. N.Y.* **32**, 222 (1938).
3. H. E. Toch and W. H. Ittelson, *Brit. J. Psychol.* **47**, 195 (1956).
4. I. Rock and S. Ebenholtz, *Am. J. Psychol.* **75**, 193 (1962).
5. P. v. Schiller, *Z. Vergleich Physiol.* **20**, 454 (1934).
6. Although the term optokinetic nystagmus is often used for the response to a rotating pattern, it refers in particular to the eye movements involved in this response. A more general term is needed to encompass other modes of response such as circling behavior.
7. It has been shown that *adult* animals (for example, fish and guinea pigs) display the optokinetic response to a stroboscopically "rotating" drum [M. Gaffron, *Z. Vergleich Physiol.* **20**, 299 (1934); K. U. Smith, *J. Exptl. Psychol.* **26**, 443 (1940)].
8. O. H. Mowrer found that visually deprived pigeons reared to 6 weeks of age displayed a normal vestibular nystagmus but not an optokinetic nystagmus. [*J. Genet. Psychol.* **48**, 383 (1963)]. On the other hand, optokinetic nystagmus has been demonstrated in recently born human infants and newborn chicks [J. M. McGinnis, *Genet. Psychol. Monogr.* **7**, 321 (1930); J. J. Gorman, D. G. Cogan, S. S. Gellis, *Pediatrics* **19**, 1088 (1957); G. Birukow and M. E. Simon, *Naturwissenschaften* **41**, 45 (1954)]. The contradiction may be due to the fact that rearing under visual deprivation as in Mowrer's experiment has deleterious effects on functions which otherwise do not require experience to be evidenced. This issue is discussed in C. B. Zuckerman and I. Rock, *Psychol. Bull.* **54**, 269 (1957). Evidence supporting this conclusion now exists. Contrast R. Fantz, *J. Comp. Physiol. Psychol.* **50**, 422 (1957) with A. Riesen, in *Biological and Biochemical Bases of Behavior*, H. F. Harlow and C. N. Woolsey, Eds. (University of Wisconsin Press, Madison, 1958) in the area of form perception.
9. We acknowledge the help of John Gianutsos in constructing the stroboscopic optokinetic reflex apparatus and the replica of it used in the final experiment.
10. K. U. Smith and S. Bojar, *Psychol. Bull.* **35**, 193 (1938).
11. The mantis egg casings were provided by Miss Alice Gray of the Department of Entomology, Museum of Natural History, New York.

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Geological Interpretation of Aeromagnetic Profiles

In "Genesis of the Arctic Ocean Basin" (*1*) King, Zietz, and Alldredge relied upon aeromagnetic data to arrive at their main conclusion, "that at least one part of the Arctic Basin is underlain by continental rocks. . . ." The method used to interpret these data was to compare segments of magnetic profiles over the Arctic Ocean with magnetic profiles obtained over oceanic and continental crustal sections. If a magnetic profile from a region of the Arctic Basin was more similar to a profile over a continental crustal section than to one over an ocean basin, they concluded that that region of the Arctic Ocean was continental in geological structure, and vice versa. The bases for these comparisons were grouping and frequency of occurrence and amplitude of anomalies. Apparently comparisons were made by visual inspection.

One of the examples given is a comparison of a "typical low-level profile over [the] Central Magnetic Zone" with a "typical profile off Cape Mendocino, California." With reference to the latter magnetic profile the authors say: "These true oceanic profiles all look much alike, except over isolated features such as seamounts, and over regions of probable thick sedimentary accumulation near the continental margins." It is concluded that these two magnetic profiles do not compare favorably, whereas another profile, flown at 30,000 feet (9000 m) above the Alpha Rise, resembles profiles flown at 500 feet above a Precambrian shield and 10,000 feet above basement over the United States stable region. They therefore say that the "Central Magnetic Zone" is "underlain by continental rocks."

Can a conclusion of such sweeping geologic importance be justified by the presented evidence? The answer to this question can be approached in three ways: First, do the profiles being compared differ and, if so, in what respect? Second, are the differences real or apparent? Third, do the differences have any geologic relevance and, if so, to what extent?

The only very convincing dissimilarity between the compared profiles over the "Central Magnetic Zone" and off Cape Mendocino is the difference in overall amplitude, that of the Cape Mendocino profile being approximately one-half that of the "Central Magnetic Zone." The difference in amplitude of anomalies between these two profiles could be explained in a number of ways, such as by differences in susceptibility of the rocks, differences in depth of burial, and remanent magnetism.

It is not necessarily diagnostic of geologic differences contrasting continental and oceanic crustal structure. For instance, the Geophysical and Polar Research Center, University of Wisconsin, has completed more than 20 aeromagnetic flights over the "Central Magnetic Zone." The profile shown in King, Zietz, and Alldredge's Fig. 4 is from one of the earlier flights (*2*). Many of the profiles show amplitudes no greater than those observed over the Pacific Ocean off Cape Mendocino. The similarity among the three flights shown in their Fig. 5 cannot be very convincingly envisioned at elevations ranging from 500 feet to 30,000 feet above the sources of the anomalies.

However, accepting for the sake of argument that the similarities or dissimilarities of the profiles have been positively established, consider now the second aspect of the problem: whether the profile differences are real or apparent. Take for example the region off Cape Mendocino itself, which has been surveyed in great detail by the U.S. Coast and Geodetic Survey (*3*). A contour map of the residual total magnetic field, after Raff (*4*), is shown in Fig. 1.

The most obvious feature of this map is the lineation of magnetic anomalies. The strike of the profile used by King, Zietz, and Alldredge across this area is unknown. However, it is obvious that the character of magnetic profiles constructed across the region will vary appreciably with both azimuth and location. To illustrate this point graphically, three profiles are shown below the contour map. Profiles 1 and 2 were constructed along the 41°N and 40°N parallels, respectively; profile 3 was constructed along the 128°W meridian. The difference in character among these, resulting solely from variations in orientation and location, is striking.

One might then logically question whether such geometric ambiguity can be avoided by comparing contoured sections rather than individual profiles. In answer to this one need but con-