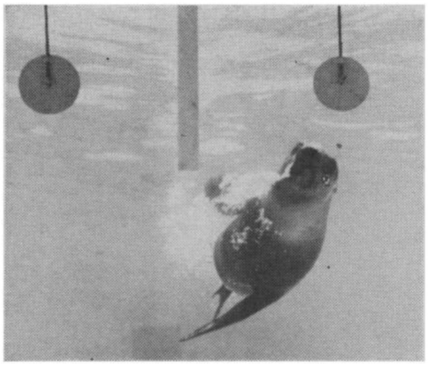

Fig. 2. A sea lion approaching the smaller of two targets. The size ratio of the larger to smaller target is 1.13:1.00.

tive trials and, generally, four pairs were presented at each test session for a total of 40 trials per session. Random sequences of paired presentations were given from session to session.

In the first experiment dealing with size threshold, black circular disks were used as the stimuli. The results of this experiment are presented in Table 2, which shows that, as the magnitude of the size-difference ratios decreases, there is a corresponding decrease in correct responses. The table also reveals that both animals were capable of discriminating a size-difference ratio as small as 1.06:1.

To appreciate the fineness of this discrimination, we compared our results with sea lions underwater to those results obtained by Klüver (*7*) with two Java monkeys. The monkeys were given a great number of size discrimination problems with two rectangles. On one problem, with one of the smallest difference ratios—on the order of 1.06:1—one animal got 70 percent correct in 420 trials and the other got 61 percent correct in 365 trials. Surprisingly, the scores were almost identical to the two sea lions at the same difference ratio. It should be noted that Klüver's monkeys were generally at a fixed distance of approximately 1.23 m from the stimuli, whereas the sea lions started their approach at approximately 5 to 6 m away and rarely got closer than 1 m before making a choice.

A second experiment dealing with size threshold was conducted with black triangular targets. In this experiment we forced the animal to make a decision at least 1.23 m prior to its giving the indicator response. This was accomplished by replacing the previously used perpendicular divider with one which projected 1.23 m outward from between the stimulus targets and all the way down to the floor of the tank. The data of this experiment were practically identical to those obtained with circular targets.

Our results suggest that under natural illumination (sunlight) the ability of the California sea lion to discriminate objects underwater on the basis of size may be as good as the ability of some monkeys to discriminate objects in air on the basis of size. Indeed, these behavioral data confirm the anatomical evidence (*4*) suggesting that pinnipeds have compensated for the loss of the refractive power of the cornea underwater by having a large spherical lens which produces enough accommodation to form a reasonably well-defined image on the retina.

Throughout these experiments (*8*) underwater monitoring revealed no sounds suggestive of pulses or clicks used for the purpose of echo-location. On infrequent occasions, we did obtain bubble sounds and underwater barks.

Upon completion of the experiments, sea lion B was presented with a size-discrimination task on moonless nights and did emit trains of pulses while swimming toward the targets. One tentative hypothesis concerning the click emission of sea lions seems to emerge from these investigations. Namely, that sea lions emit clicks primarily when visual cues are scarce or unavailable, but depend principally upon their visual sense for purposes of detecting and discriminating underwater objects.

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5. The following equipment was used for monitoring and recording underwater sounds. Hydrophones: (i) Channel Industries 275 (20 cy/sec to 150 kc); (ii) Fishphone (750 cy/sec to 6.5 kc). Recorders: (i) Vega at 60 inches per second (1.5 m/sec) (150 cy/sec to 150 kc); (ii) Ampex 601 at 7.5 inches per second (20 cm/sec) (30 cy/sec to 18 kc). Preamplifier: Burr-Brown Model 100. Amplifier and speaker: Webster-Chicago 66-1A.
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7 December 1964

Prenatal Auditory Sensitivity in Chickens and Ducks

Abstract. *Recordings from chick and duck fetuses inside the egg revealed an increase in the rate of bill-clapping and vocalization when the fetuses were aurally stimulated by the maternal call of their species on the day before hatching.*

Several days before hatching, the head of the fetal chick and of the fetal duck moves into the air space at the large end of the egg. At this time fetuses of both species begin uttering low-intensity peeps or cheeps (*1*). In at least one species of duck the incubating parent begins uttering a low-intensity call coincident with the pipping of her eggs, that is, before her young have hatched (*2*). In line with these findings and to expand our knowledge of prenatal sensory function, it seemed worthwhile to determine whether chicks and ducklings are capable of hearing prior to hatching. Workers in neurophysiology investigating the visual modality have demonstrated electrical changes of the eye and optic lobe of highly developed chick (*3*) and duck (*4*) fetuses upon stimulation by relatively intense flashes of white light from a source located several inches from the exposed heads of the fetuses. It is possible that the auditory system of the avian fetus develops at least as fast as (if not faster than) its visual system, partly because the fetus can stimulate itself aurally but is not normally subject to patterned visual stimulation until after hatching.

Though the present study is not parametric in any sense, the positive results concerning the presence of auditory sensitivity in highly developed chick and duck fetuses seem sufficiently clear-cut to warrant report now, pending completion of a more extensive examination of the various stimulative and developmental parameters which are involved.

Fifteen White Rock chicken eggs and 15 Peking duck eggs, which had been subjected to a preincubation chilling procedure to increase precision in aging (*5*), were candled on the day before hatching to determine the position of the fetuses in the air space (*6*). A small opening was made in the shell in the proximity of the bill or beak and then a sufficient amount of shell and inner membrane was removed to insert the needle electrodes, as shown in Fig. 1.

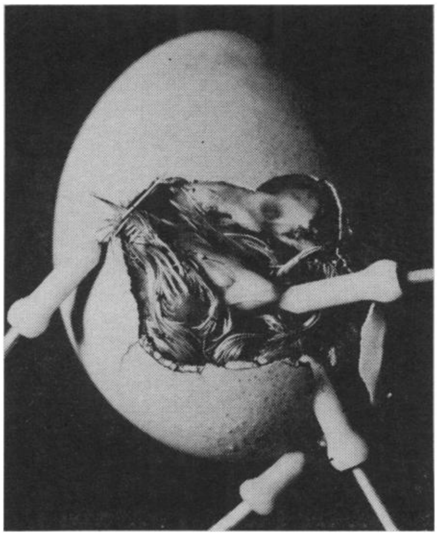

Fig. 1. A 20-day chick fetus with recording electrodes in lower mandible (for measurement of beak-clapping) and in skin on side beneath left wing (EKG). Indifferent electrode is in skin near spinal column (bottom of photo), and ground electrode is in loose fold of skin on top of the head (upper left of photo).

Beak- or bill-clapping was recorded from an electrode in the lower mandible, and an electrocardiogram (EKG) was obtained from a subdermal electrode under the left wing (Fig. 1). No anesthesia was used, and all 30 birds included in the study hatched without assistance within a day after the experiment. In this experiment the EKG was used only as a diagnostic tool—one duck and one chick were excluded from the experiment because, when they were at rest, their heart rates were consistently outside the normal range (180 to 290 beats/min for 19- to 20-day fetal chicks and 180 to 265 beats/min for 26- to 27-day fetal ducks). After insertion of the electrodes, the egg was placed on a tambour inside a transparent infant incubator ("Isolette") with the bill of the fetus about 2.5 cm from a highly sensitive directional microphone. Temperature and relative humidity in the incubator were 36° to 37°C and 46 to 59 percent, respectively. Bill-clapping, vocalization, EKG, and egg movement (tambour vibration) were recorded on an electroencephalograph. A portion of an actual record is shown in Fig. 2. Bill-clapping (beak-clapping) and vocalization occur independently. It is not necessary for the fetus to open its bill to emit vocalizations. In addition to the written record, the vocalizations were monitored by means of earphones, and the activity of the fetus was observed visually through the transparent plastic wall of the incubator.

After a 30-minute acclimation period, a 10-minute period of baseline recording was instituted under conditions of silence; this was followed by a 30-second period during which the fetus was aurally stimulated, and then by a final 4-minute period of baseline recording under silent conditions. During the 30-second period of aural stimulation the fetuses of each species were exposed to seven bursts of the prerecorded maternal call of their species with intervals of 1½ seconds between each burst (*7*). The sound source (tape recorder) was 109 cm from the egg. The sound level in the incubator (which was in a sound-attenuated chamber) was 48 to 52 db and the intensity of the calls was 68 to 74 db at the egg (*8*). Five fetuses of each species served as controls and did not receive aural stimulation during the above-mentioned 30-second period. The response measures were rate of bill- or beak-clapping and rate of vocalization during each of the three periods.

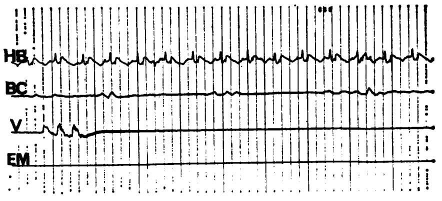

Fig. 2. Five-second record of heart beat (*HB*), bill-clapping (*BC*), vocalization (*V*), and egg movement (*EM*) from a 27-day duck fetus.

Table 1 (bottom line) shows that the average rate of both beak-clapping and vocalization increased markedly in the chick fetuses during the 30-second period of aural stimulation, and that beak-clapping and vocalization returned to the previous 10-minute baseline rate in the 4-minute period following stimulation. (The increases in rate of beak-clapping and vocalization are statistically reliable at $p < .05$ and $< .02$, respectively, according to the Wilcoxon paired replicates test.) Seven of the ten chick fetuses contributed to the increase in rate of beak-clapping and nine of the ten fetuses contributed to the increase in vocalization rate during the period of aural stimulation. The five control (unstimulated) chick fetuses did not show a change in rate of beak-clapping or vocalization during the 30-second control period. Their average rates per minute of beak-clapping and vocalization during the three consecutive periods were 35.94, 37.2,

Table 1. Increase in rate per minute of beak-clapping and vocalization in highly developed chick fetuses as a function of auditory stimulation for 30 seconds.

Developmental age	Pipped	10 min prior to call		30 sec during call		4 min after call	
		Beak-clapping	Vocalization	Beak-clapping	Vocalization	Beak-clapping	Vocalization
19 days, 22 hr	No	13.2	1.2	24	4.0	12.5	1.0
19 days, 22½ hr	Yes	35.5	5.6	96	0	34.0	2.5
19 days, 23 hr	No	36.0	9.0	18	20.0	34.0	0
20 days, 0 hr	No	41.3	0.4	146	10.0	35.2	0.7
20 days, 1 hr	Yes	67.4	2.1	68	8.0	66.7	.5
20 days, 2 hr	Yes	27.0	1.0	48	6.0	49.0	.5
20 days, 3½ hr	Yes	62.0	1.9	58	10.0	57.0	3.75
20 days, 5½ hr	No	43.6	1.8	78	4.0	26.5	3.0
20 days, 6½ hr	Yes	56.0	1.0	202	12.0	58.0	1.5
20 days, 11 hr	No	26.7	0.7	36	14.0	28.0	6.75
Chick group average		40.8	2.47	77.4	8.8	40.1	2.0

Table 2. Increase in rate per minute of bill-clapping and vocalization in highly developed duck fetuses as a function of auditory stimulation for 30 seconds.

Developmental age	Pipped	10 min prior to call		30 sec during call		4 min after call	
		Bill-clapping	Vocalization	Bill-clapping	Vocalization	Bill-clapping	Vocalization
26 days, 18 hr	No	51.7	0.6	114	6	99.2	0.5
26 days, 19 hr	No	74.0	.4	70	8	28.0	.25
26 days, 22 hr	No	39.6	2.5	66	4	45.0	.75
26 days, 22 hr	Yes	41.0	6.1	116	10	44.5	3.0
26 days, 23 hr	No	50.8	2.8	70	10	46.0	4.0
26 days, 23 hr	Yes	49.8	0.6	84	6	54.25	0.75
27 days, 0 hr	No	43.0	7.4	98	28	56.0	6.0
27 days, 6 hr	No	27.6	1.9	148	4	37.0	0.75
27 days, 7 hr	No	42.8	2.4	60	4	14.0	1.2
27 days, 7 hr	Yes	30.6	2.9	56	6	71.0	3.0
Duck group average		45.1	2.76	88.2	8.6	49.5	2.02

and 40.95 (beak-clapping) and 0.82, 1.20, and 1.08 (vocalization).

Table 2 (bottom line) shows that the ten duck fetuses also showed a marked increase in rate of bill-clapping and vocalization during the 30-second aural stimulation period. (The increases in rate of bill-clapping and vocalization are both statistically reliable at $p < .01$ according to the Wilcoxon paired replicates test.) Nine of the ten duck fetuses contributed to the increased rate of bill-clapping and all of the fetuses contributed to the increase in rate of vocalization during the aural stimulation period. The five unstimulated control fetuses did not show an increase in rate of bill-clapping or vocalization. Their average rates per minute for the three consecutive periods were 58.94, 42.80, and 53.54 for bill-clapping and 1.5, 2.0, and 2.6 for vocalization.

Both the chick and duck fetuses almost always vocalized between, but not during, each burst of their respective parental calls, as if they were responding to the offset of the auditory stimulation. On the other hand, beak- and bill-clapping occurred during, as well as between, bursts of the maternal calls.

Though this evidence indicates the presence of auditory sensitivity in highly developed chick and duck fetuses, further research is required to determine the limits of the sensitivity in terms of developmental age and type of auditory stimulation, and to answer the question of whether prenatal exposure to auditory stimulation actually affects the postnatal behavior of the fetus.

Shortly after hatching, naive chicks and ducklings can discriminate the maternal call of their own species in simultaneous discrimination tests involving the maternal calls of other species (*9*). Also, with reference to the postnatal elicitation of the following-response, naive ducklings and chicks are more reactive to the maternal call of their own species than to the maternal call of other species (*9*). The present results raise the interesting possibility that the auditory discriminative capacity of chicks and ducklings is operative prior to hatching.

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11 January 1965

Cesium-137 in Alaskans

The latest report from the Hanford group on cesium-137 body burdens in Alaska [H. E. Palmer, W. C. Hanson, B. I. Griffin, L. A. Braby, *Science* 147, 620 (1965)] is of the greatest interest; the more detailed publication of their studies should be still more so. The authors report that cesium-137 levels in Eskimos and Indians have continued to increase, as was expected, and will probably increase still further in the coming year. These increases have meaning only when compared to some bench-mark value, however, and the lack of such a standard in this report seems to be an important omission.

The Federal Radiation Council has established a Radiation Protection Guide for the average body burden of cesium-137 of a population at 1000 nanocuries. The RPG for individuals is 3000 nanocuries. One of the villages studied by the authors (Anaktuvuk Pass) has already exceeded the RPG for populations, and one person (not included in the average) was found in this village with a burden of 3000 nanocuries, the RPG for individuals. The comparison of the current measurements with FRC standards is particularly important in view of the authors' comment that "the amounts of Cs^{137} in caribou meat and Alaskan natives can be expected to increase next year."

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