more errors on the jigsaw problem, than those in the Unnamed condition. This interaction between effect of names and type of problem is highly reliable (2 × 2 analysis of variance, $F = 15.19$, $df = 1/28$, $p < .001$). The Named-Unnamed difference is reliable both on the jigsaw problem (overall within-groups mean square used as error estimate, $t = 2.91$, $df = 28$, $p < .01$) and, in the opposite direction, on the memory task ($t = -2.66$, $p < .05$). The only reliable effect on solution times is the overall difference between jigsaw and order problems ($F = 100.17$, $df = 1/28$, $p < .001$). The fact that solution time for the jigsaw problem was slightly longer for the Unnamed than for the Named group raises the question whether the Unnamed group made fewer errors simply because they spent more time on the problem. When the effect of this difference in working time is removed by means of covariance analysis, however, there is still a reliable difference in errors in favor of the Unnamed condition ($F = 7.62$, $df = 1/27$, $p < .05$).

The assumption that the Unnamed group would form representations which encoded more information about figural properties of the shapes than the representations used by the Named group was tested directly by having all subjects draw the shapes from memory, in their positions in the ring, at the end of the experiment. An error was scored for each of the eight line segments of each shape that was omitted, drawn slanting in the wrong direction, or connected to the wrong end of an adjacent segment. The mean number of such errors was 20.2 in the Named condition and 14.8 in the Unnamed condition ($t = 3.10$, $df = 30$, $p < .01$).

The results are consistent with the assumption that the Named and Unnamed conditions induced the formation of verbal and imaginal representations, whose relative merits depend on the problem to be solved. An alternative possibility is that subjects in the Unnamed condition verbalized the figural properties of the shapes, or the relations between them, and that these verbalizations facilitated the jigsaw and drawing tasks. Analysis of post-experimental reports does not support this interpretation. Those subjects in the Unnamed condition who reported doing the most verbalizing made more errors in the jigsaw problem and fewer in the memory task than those reporting less verbalizing. Subjects who reported that they did not notice during training that any of the shapes fitted together showed as strong an interaction between naming and type of problem as those who reported noticing such relations. These findings support the interpretation that the interaction reflects a difference in the properties of nominal and imaginal representations (*6*).

HOWARD B. RANKEN
*Department of Psychology,*
*Northwestern University,*
*Evanston, Illinois*

### References and Notes

1. C. C. Spiker, *J. Exptl. Psychol.* **52**, 107 (1956).
2. E. Saltz and S. E. Newman, *Am. J. Psychol.* **73**, 91 (1960).
3. H. B. Ranken, *Psychol. Repts.*, in press.
4. L. Carmichael, H. P. Hogan, A. A. Walter, *J. Exptl. Psychol.* **15**, 73 (1932).
5. W. C. H. Prentice, *Am. J. Psychol.* **67**, 315 (1954).
6. Supported in part by a research grant (MH-7115) and a special research fellowship (MF-10506) from the National Institute of Mental Health. Robert W. Lissitz collected the data.

1 April 1963

## Underwater Sounds of Pinnipeds

Abstract. *Descriptions and analyses are presented of underwater sounds made by six species of seals in captivity,* Zalophus californianus, Phoca vitulina, P. (Pusa) hispida, P. (Pagophilus) groenlandica, Halichoerus grypus, *and* Cystophora cristata. *The suitability of these very faint sounds for echolocation is discussed.*

Many observers of seals have felt, from the success of these animals at making a living in dark and turbid waters, that acoustics must play an important part in their lives. From Scheffer's recent review of the pinnipeds (*1*) we learn that their olfactory apparatus is reduced (no great loss to a submerged air-breather), that not much is known of their hearing, and that while the eyes are normally well-developed and adapted to water and darkness, "individuals totally blind but in good health have been reported." This certainly suggests at least expert passive use of sound (listening), if not active use (echolocation). For a long time no underwater sounds were detected, although a number of people listened for them (of course, the familiar raucous above-surface calls, particularly of the otariids, have often been heard underwater). Thomas C. Poulter was the first to record underwater calls of pinnipeds. He described pulsed signals of captive *Zalophus californianus* and mentioned similar sounds of two or three other otariids and two phocids (*2*). In the meantime one of us (C.R.) had been eager to test his long-standing feeling that seals must use active underwater sound, and had arranged for us to investigate the seals exhibited by the New York Zoological Society at their Aquarium and Zoological Park. This we did in January 1963, listening and recording in the presence of three species of otariids, *Zoalophus californianus, Eumetopias jubata*, and *Callorhinus ursinus*, a walrus (*Odobenus rosmarus*), and five species of phocids, *Phoca vitulina, P.* (*Pusa*) *hispida, P.* (*Pagophilus*) *groenlandica, Halichoerus grypus*, and *Cystophora cristata*. We were unable to attribute exclusively underwater sounds with certainty to *Eumetopias, Callorhinus*, or *Odobenus*. It was soon apparent why we had failed to hear seals in the field. The only underwater sounds which we now heard were impulses (or clicks) so faint that they were not detected unless the seal was within about 3 meters of the hydrophone. In this and other ways they differed from

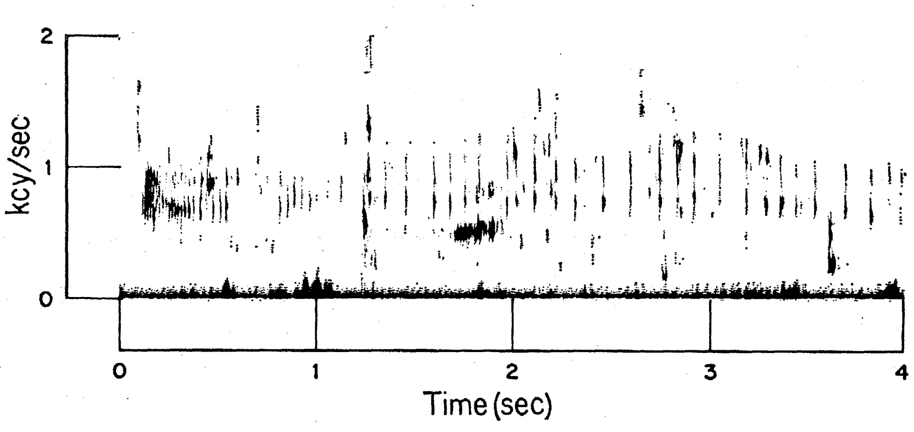

Fig. 1. Underwater clicks of a *Zalophus californianus* searching the bottom of its pool at the feeding station; 100-cy/sec bandwidth analyzing filter. (A 300-cy/sec high-pass filter reduced some of the tank background.)

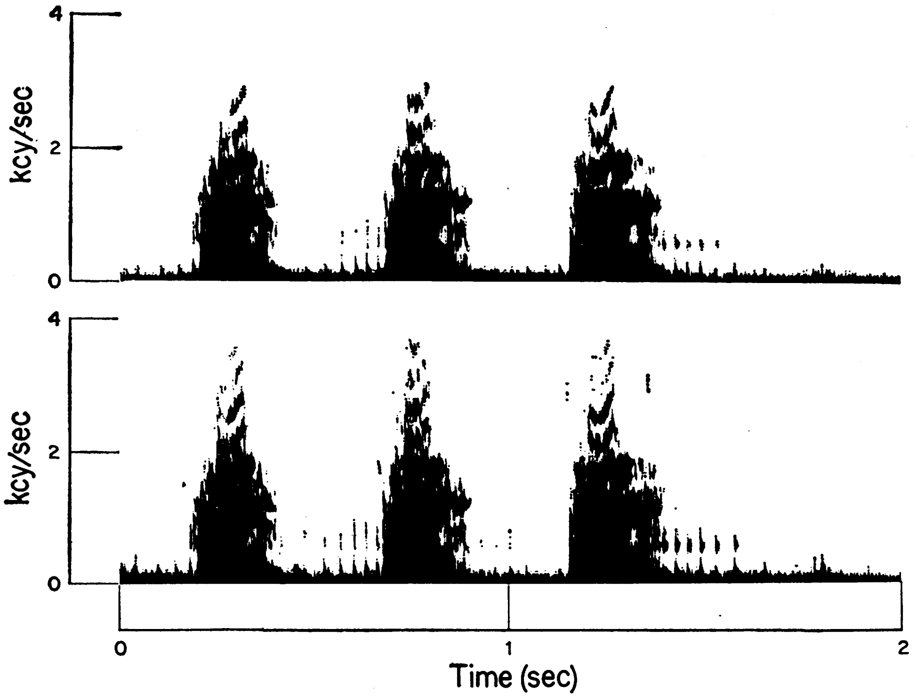

Fig. 2. Simultaneous barks and clicks of a *Zalophus californianus* with head out of water, as heard in air (top) and in water (bottom); 200-cy/sec bandwidth analyzing filter.

the better known clicks of toothed whales (*3*) which are often loud enough to be heard at much greater distances and that characteristically exhibit a continuous frequency spectrum. The seal sounds, although they too had a sharp front, emphasized particular frequencies, sometimes several at once, but not necessarily harmonic; *Cystophora* was an exception, for it uttered clicks that were continuous from about 0.1 to 3 kcy/sec, and even to 16 kcy/sec.

Our few hours of listening to each species in captivity probably only sampled their repertoire and surely afforded no proof that the sounds heard and recorded were used in echolocation. We can only say that they were almost always related to the last stages of a search for food dropped in the water and, since our observations were made in the daytime, the food must have been visible. We did not ordinarily hear the sounds when a seal passed the hydrophone on a routine circuit of the pool and we evidently could not have heard them if uttered at greater distances, such as across the pool. Whether the seals could have made louder sounds of this nature we do not know. In our very limited experience the sounds of the seals were conspicuously less loud than the porpoise clicks and they were often very hard to distinguish against the high background noise which is normal in aquaria.

If these clicks are utilized in echolocation, their faintness would seem to confine their usefulness to even shorter ranges than porpoise sonar. Thus, while the sounds may help in the last critical stages of catching the prey, they would not seem to be of much service in preliminary location at a distance. Both the low level and rather low frequency would make them especially hard to distinguish from the background. The faintness of these sounds might be a response to captivity in reverberating concrete pools, and perhaps they would be louder in darkness. However, the seals do not appear to soften their in-air calls under these conditions.

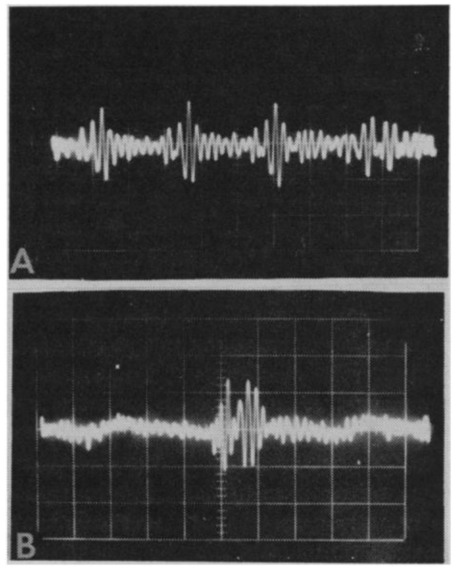

Fig. 3. Oscilloscope photographs of underwater clicks of a *Zalophus californianus*. These clicks are from the sequence shown in Fig. 1; Fig. 3*A* shows the first few, Fig. 3*B* is from the middle. Horizontal divisions are 5 msec, vertical divisions are 0.05 v; Allison 2-AR bandpass filter, passing 600 to 1500 cy/sec.

In this report we have used the word "click" for all of the short-impulse sounds recorded, regardless of their frequency structure or whether they were made in air or underwater. We found, in the course of our experiment, that the sea lion can make clicks both in air and underwater.

Both underwater and air sounds were recorded on 6.3-mm magnetic tape at 38.1 cm/sec on separate tracks simultaneously. The underwater recordings were made with a battery-powered AX 58 hydrophone (Brush Development Corp.), a transistor amplifier (Woods Hole), and a Crown (B 822) tape recorder (Woods Hole modification). The frequency response of this entire system was essentially flat from 30 to 10,000 cy/sec and usable to 30,000 cy/sec; the hydrophone response is not smooth above 10,000 cy/sec. The air sounds of the seals were recorded on the second channel of the tape with a microphone (Electrovoice 635) which, according to the manufacturer, responds from 40 to 15,000 cy/sec. The sound spectrograms were made on a Kay electric vibralizer, with analyzing filter, set "wide," to give increased time resolution at the expense of frequency resolution. The analyzing filter bandwidth is indicated for each spectrogram; thus "200 cy/sec bandwidth" means that resolution is no finer than 200 cy/sec.

Three *Zalophus californianus* (Lesson) California sea lions in the New York Zoological Park (Bronx Zoo), shared a pool with two *Eumetopias jubata*. For the most part, the latter were kept at the far end of the pool, while the *Zalophus* were lured, one at a time when possible, to a second feeding station at the hydrophone.

The *Zalophus* calls were short, sharp bursts of clicks of several frequencies at rates up to 50 per second. Figure 1 shows a characteristic series ranging from 600 to 1000 or more cy/sec, made by the animal searching the feeding area. The raucous barks in air were loud at the hydrophone when the seal was in the water. Figure 2 shows simultaneous barks and clicks recorded for one sea lion. The animal was two meters

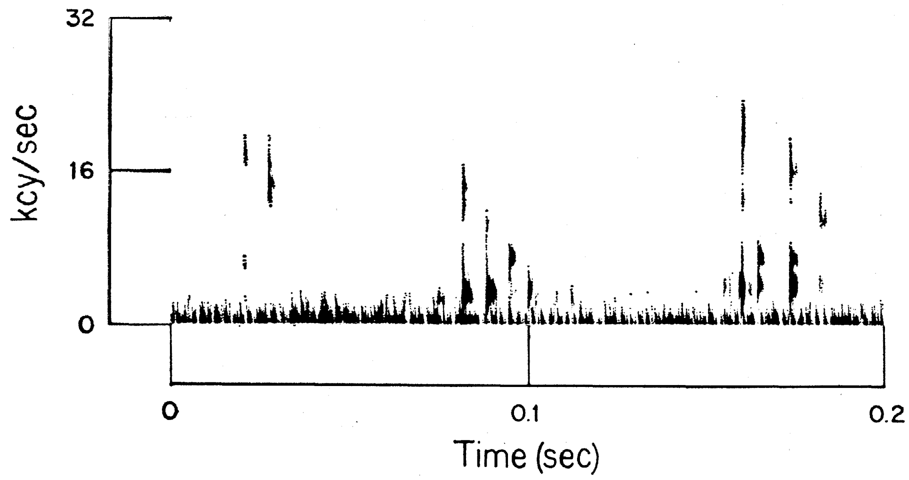

Fig. 4. Underwater clicks of *Phoca (Pusa) hispida*. Note the varying harmonic emphasis; 1600-cy/sec bandwidth analyzing filter.

in front of us with its head well out of the water and, as it addressed these barks to us we could hear the clicks issuing from its open mouth. The figure shows that at this short range there is no conspicuous difference in the structure of the sounds heard through air or through water.

It is puzzling to compare Poulter's results with ours. We have spent less time than he has with sea lions. He must have made excellent recordings to give him the resolution he has obtained. We occasionally found paired or interrupted clicks, which suggest but do not particularly agree with Poulter's "double pulses." Our records (Fig. 3) do not show the consistent frequency shift which he described, with both parts of the double click being about the same frequency. In most of the few we found, the second part of the click was about twice as long as the first, while in others both parts were about equal. We found none with as great a difference in duration or as great a separation as suggested by Poulter's diagram (*2*). We point out, with some perplexity, that our *Zalophus* frequencies are much lower than his, even at the low end, by about a factor of four.

In the case of two *Phoca vitulina* Linnaeus harbor seals, a 5-year-old male *P. v. concolor* from Maine and a 4-year-old female *P. v. largha* from the Bering Sea, in captivity since infancy, the clicks were not only hard to hear and harder to analyze, but the sounds from each subspecies were very much alike. Each has a major component near 12 kcy/sec, and the Atlantic *concolor* also emphasized 6 to 8 kcy/sec in other pulses. Our data are insufficient to show whether this last feature is distinctive. Three *P. (Pagophilus) groenlandica* seals were in the pool, but distant at the time of these recordings.

One 2-year-old male *Phoca (Pusa) hispida* Schreber ringed seal, captive since infancy, in a quiet tank, emitted clicks that were often in pairs, spaced 2 to 20 msec apart. Whether paired or not, the clicks usually had a fundamental frequency near 4 kcy/sec with varying harmonic emphasis up to the sixth harmonic (Fig. 4).

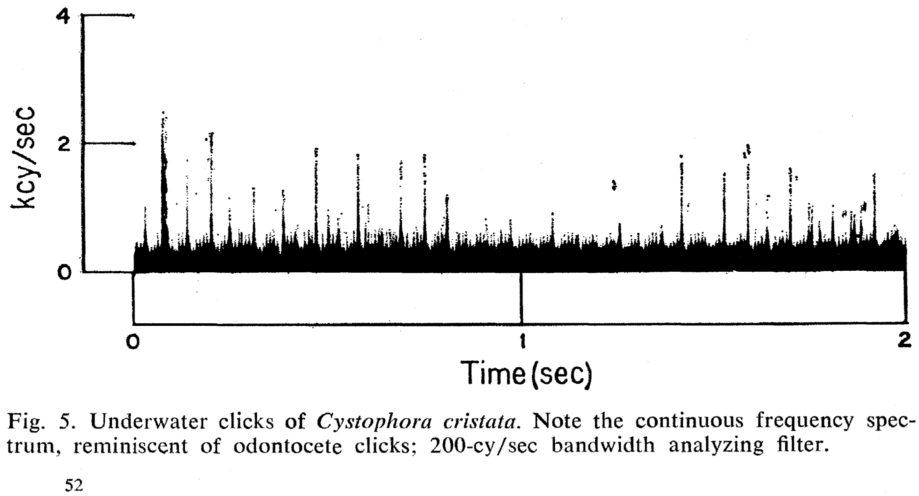

Fig. 5. Underwater clicks of *Cystophora cristata*. Note the continuous frequency spectrum, reminiscent of odontocete clicks; 200-cy/sec bandwidth analyzing filter.

A mature female *Phoca (Pagophilus) groenlandica* Erxleben harp seal, captured on the sea ice in the Gulf of St. Lawrence in March 1962, uttered clicks exhibiting varying harmonic emphasis on a fundamental of 2 kcy/sec. In general structure the calls resemble those of *P. (Pusa) hispida.* Repetition rates up to about 130 per second were noted.

Three *Halichoerus grypus* (Fabricius) gray seals, two 5-year-old females and one 4-year-old male, captured as pups in the St. Lawrence region, Canada, were recorded. They were in a large pool; a single young *Callorhinus ursinus* was in a small pool separated by a barred gate. The noise level was high, partly from the brisk activity of the *Halichoerus,* so that the clicks were hard to detect. They were sometimes in pairs spaced about 0.01 to 0.02 second apart, sometimes apparently random, and occasionally in series at about 60 per second. Frequencies near 6 to 12 kcy/sec are predominant in some clicks, while others emphasize several frequencies, sometimes as high as 30 kcy/sec. Possibly the *Callorhinus* may also be represented here, but we have considered only those sounds recorded when a *Halichoerus* was near the hydrophone.

Two *Cystophora cristata* (Erxleben) hooded seals, a mother and her half-grown son, captured on the Gulf of St. Lawrence sea ice in March 1962, were in a quiet tank. Such sounds as we heard were made by the youngster, for his mother remained suspiciously aloof, and kept away from the hydrophone. Two types of clicks were noted, one a rather narrow band pulse with an emphasis in the neighborhood of 4 kcy/sec at times, and more often 16 kcy/sec. The other type of click was unlike any of the other pinnipeds', broad band, and rather like those of odontocetes, although usually not reaching higher than 3 kcy/sec, but sometimes reaching as high as 16 kcy/sec. Below this frequency, however, the click was continuous down into the background at about 100 kcy/sec (Fig. 5). The highest repetition rate was about 20 per second (*4*).

William E. Schevill
William A. Watkins
Carleton Ray
*Woods Hole Oceanographic Institution, Woods Hole, Massachusetts,* and
*New York Aquarium, New York Zoological Society, Brooklyn 24*

### References and Notes

1. V. C. Scheffer, *Seals, Sea Lions, and Walruses: A Review of the Pinnipedia.* (Stanford Univ. Press, Stanford, Calif., 1958), pp. 14–15.
2. T. C. Poulter, *Science* **139**, 753 (1963).

→ W. N. Kellogg, R. Kohler, H. N. Morris, *ibid.* **117**, 239 (195 → J. C. Lilly and A. M. Miller, *ibid.* **133**, 1689 (1961); W. E. Evans and J. H. Prescott, *Zoologica* **47**, 121 (1962); W. E. Schevill, R. H. Backus, J. B. Hersey, in *The Sea*, M. S. Hill, Ed. (Interscience, New York, 1962), vol. 1, *Physical Oceanography*, chap. 14, pp. 556–57; W. E. Schevill and W. A. Watkins, "Whale and porpoise voices." A phonograph record (Woods Hole Oceanographic Institution, Woods Hole, Mass., 1962).

4. Supported by U.S. Navy Bureau of Ships, contract NObsr 72521. We thank the New York Zoological Society for making the seals available and for local support. Contribution No. 1376 from the Woods Hole Oceanographic Institution.

6 May 1963 ■

## Influence of Methodology on Electroencephalographic Sleep and Arousal: Studies with Reserpine and Etryptamine in Rabbits

Abstract. *In studies with reserpine and with etryptamine, quite opposite electroencephalographic effects were obtained when either of these two drugs was administered to rabbits prior to surgical preparation for EEG recording as opposed to the drug being given after the rabbits had been fully prepared for EEG recording. With the one method, EEG rhythms indicative of sleep were obtained, while with the other method, EEG rhythms indicative of central nervous system stimulation were obtained, although with both methods, the amount of drug, duration of drug in animal, and type of acute preparation were identical for both sets of findings. The presurgical injection procedure produced EEG results more in accordance with behavioral and biochemical findings, even though the conventional procedure is to administer the experimental drug after the animal has been prepared for EEG recording.*

In most electroencephalographic (EEG) drug studies involving an acute animal preparation, the animal does not receive the experimental drug until after it has been fully prepared for EEG recording. While the technical details vary from laboratory to laboratory, this type of preparation generally involves a temporary period of general anesthesia as well as a prolonged period of local anesthesia, the implantation of several recording electrodes either to the surface of the brain or directly within the brain tissue, and, in many experiments, artificial respiration with its consequent tracheotomy and curarization. Each of these procedures produces its own physiological consequences and, in this sense, all acute animal experiments of this type are unphysiologic. Within limits, these procedures do not vitiate the experimental results, since the acute preparation is, itself, a major condition of the experiment. This assumes, however, that the procedures utilized in the preparation of the animal for EEG recording exert a constant influence throughout the experiment and also that they do not interact in some unique way with the pharmacological actions of the drug under investigation.

Our laboratory has found in studies with reserpine and with etryptamine that quite opposite EEG effects were obtained in rabbits when the experimental drug was administered to the animal prior to the preparation for EEG recording as opposed to the drug being given after the animal had been fully prepared for EEG recording, even though with both methods the amount of drug, duration of drug in animal, and type of acute preparation were identical for both sets of findings. With either reserpine or etryptamine, with one method EEG rhythms indicative of sleep were obtained, while with the other method, EEG rhythms indicative of central nervous system stimulation were obtained. These differing EEG effects of sleep and arousal generally lead to opposite kinds of interpretation of drug action.

We have studied etryptamine (alpha-ethyltryptamine), which is a weak inhibitor of the enzyme system monoamine oxidase. While its mechanism of action is not fully understood, it exhibits central nervous system stimulatory properties, an action shared by other and stronger inhibitors of monoamine oxidase. Our laboratory undertook an EEG, behavioral, and neurochemical analysis of the action of this chemical agent (*1*). New Zealand male albino rabbits were tracheotomized under ether and local pontocaine anesthesia, curarized and artifically respired. Five coaxial electrodes were implanted directly into brain tissue through trephined holes in the exposed skull. A control EEG recording was taken to assess the initial responsiveness of the animal, 5.0 mg/kg of etryptamine was then administered by femoral vein, and the rabbits were sacrificed at intervals varying from 15 to 360 minutes after injection for determination of brain serotonin. Electroencephalographic recordings were taken throughout the drug period. Activation of the EEG was usually apparent by 30 to 40 minutes after the administration of etryptamine in those animals which were studied for the longer time periods. The stimulatory effects, as evidenced by sustained EEG alerting, persisted unabated until the sacrifice of the animal. While brain serotonin levels were not found to be significantly elevated as compared to the usual findings for the stronger inhibitors of monoamine oxidase, it was apparent from the increasing and decreasing levels across time that this brain amine could not be associated with any EEG activation beyond about 3 hours of drug time. The rabbits studied for 6 hours, however, were still displaying EEG arousal at the time of sacrifice.

Because of the biochemical findings, a second set of animals was studied with the same surgical procedures and electrode implantation but under a method whereby the drug was administered prior to the preparation of the animal for EEG recording. In this second group, 5.0 mg/kg of etryptamine was given by marginal ear vein and the animals were placed back in their boxes until a period 2 hours prior to the time the animals were to be sacrificed for serotonin determinations. At 2 hours before sacrifice, the animals were then prepared for EEG recording in the same manner as described above for the postsurgical injection method. The surgical procedures required approximately 30 minutes, thus giving 90 minutes of EEG recording prior to sacrifice. With this second method of drug study, it was determined that the drug-induced EEG alerting usually subsided by 3 to 4 hours after injection, a duration bearing closer correspondence with the return of brain serotonin to control levels.

Figure 1, *A* and *B*, presents EEG tracings from each of two animals studied with the differing presurgical and postsurgical procedures for administration of etryptamine. Each recording was taken just before the sacrifice of the animals for serotonin determinations. As can be seen from Fig. 1, tracings *A* and *B* depict quite opposite EEG states. In Fig. 1*A*, the EEG rhythms are characteristic of the