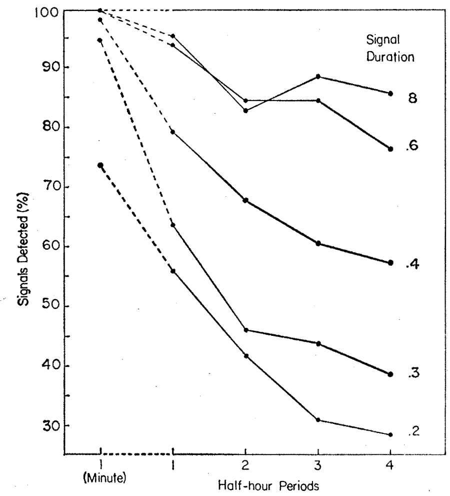

Fig. 1. The percentage of signals detected during the 1-minute task and during each half-hour of the 2-hour task, for signals of five different durations.

nals were brief stoppages of the hand. The viewing distance was 2.5 m.

On the first occasion, vigilance performance was determined over a number of 1-minute periods by having the subjects verbally indicate, after each single rotation of the clock-hand, in which of four marked and numbered 30-degree segments of the circumference the signal had occurred. Signals were stoppages of the hand for 0.2, 0.3, 0.4, 0.6, or 0.8 second. Each duration was used 10 times, 50 durations being given to each subject in random order. On the second occasion, performance was determined over a period of 2 hours with the marked segments of the clock deleted. Signals of the same durations occurred in random order and location. Signals of each duration occurred once each 15 minutes, the signal rate being 20 per hour. Subjects responded to signals by depressing a microswitch held in the hand. Some of the results are shown in Fig. 1. Since there are no "unwanted signals" in such a task, there were no false reports of signals and the problem of discriminating between true signals and unwanted signals did not arise.

Analysis of variance showed, for the 2-hour task, a significant decrement and a significant difference between signal durations (both at the 0.01 level of confidence). The signal duration times the decrement interaction was not significant. A second analysis showed detection performance on the 1-minute task differed significantly (at the 0.001 level of confidence) with signal duration. In a final analysis in which the data from both tasks were considered as having been generated in a single task, the signal duration times the tasks interaction was found to be significant at the 0.001 level of confidence—that is, there was a differential degree of decrement between performance on the first task and mean performance on the second.

These data are interpreted as being in support of the hypotheses (*2*).

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References and Notes

1. C. H. Baker, in *Vigilance, A Symposium*, D. Buckner and J. McGrath, Eds. (McGraw-Hill New York, 1963).
2. These data were collected when I was at the Defense Research Medical Laboratories, Toronto, Canada, and constitute DRML Report No. 234-12, PPC No. 277-94-20-42, H.R. No. 215.

29 July 1963 ■

Auditory Discrimination by the Cat after Neonatal Ablation of Temporal Cortex

Abstract. *Some auditory discriminations cannot be acquired by the cat after large bilateral ablations of auditory cortex at maturity. However, if such ablations are sustained during infancy, these discriminations are readily learned. The function of the cortex in auditory discrimination depends on the age of the nervous system at the time of injury.*

Cats in which auditory cortex has been removed are able to discriminate the onset of a sound (*1*), changes in the intensity (*2*), or changes in the frequency (*3*) of a tone. On the other hand, after similar cortical damage animals are unable to distinguish between two different sound patterns (*4*) or between two sounds of different duration (*5*). These findings are based on experiments in which the animals were mature at the time of ablation. They indicate that some auditory discriminations are not cortically bound but that others are. It was the purpose of the work reported here to explore further

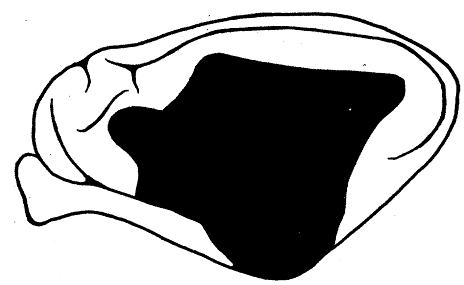

Fig. 1. Schematic representation of the lateral cortical surface of the cat brain showing the intended size and location of the lesion.

the relationship between cortical structures and auditory discrimination by removing such structures during infancy rather than at maturity.

Large bilateral lesions were made in the brains of nine infant cats between the seventh and tenth postnatal days. Surgery was carried out under dilute Nembutal anesthesia and cortical tissue was removed by aspiration. The intended area of ablation is shown in Fig. 1 and includes at least the total cortical projection field of the medial geniculate body (*6*). Littermates of these animals were used as nonoperated controls. All 18 animals were reared in the laboratory until 6 months of age, at which time discrimination training was initiated. Lesions were made in another group of seven mature animals ranging in age from 6 to 9 months. In four of these cats the ablations were comparable to those made in the infant group. In the remaining three, the lesions were intentionally smaller. Training of these animals began 6 months after this surgery, as did that of a group of five nonoperated controls of the same age.

All cats were trained to avoid shock by crossing from one side to the other in a typical two-compartment shuttle box, after a change in the duration of a pulsing tone. The avoidance signal consisted of a sequence of 800-cy/sec tone pulses, each pulse lasting 1 second, with a 1 second silent interval between successive pulses. The neutral signal was an identical sequence of pulses. However, the duration of each pulse in this sequence was 4 seconds. The animal was required to cross within a 10-second period after a shift from neutral to avoidance signal if shock were to be averted. Accordingly, the learning of the avoidance response depended on the cat's ability to distinguish between two sounds of different duration. Intertrial intervals were

Table 1. Trials to criterion for cats learning a duration discrimination.

Infant-operated		Controls		Adult-operated		Controls	
Cat	Trials	Cat	Trials	Cat	Trials	Cat	Trials
3A*	175	3B	120	2A†	140	2B	195
11A	125	11B	95	4†	160	7	275
12A	160	12B	150	6†	170	16	230
35A*	140	35B	115	54A‡	>500	38	150
37A*	90	37B	120	57‡	>500	54B	185
47A	130	47B	110	59‡	>500		
48A	145	48B	120	60‡	>500		
49A*	220	49B	§				
72A	100	72B	175				
Median	140		120				195

* Lesion large, but not reaching rhinal fissure. † Small lesion confined essentially to AI, AII, and Ep. ‡ Animal failed to reach criterion in over 500 trials. § Died.

varied in a random fashion from 60 to 180 seconds. During these intervals "mock" trials were given as a control for possible sensitization. On such a trial the avoidance signal was not presented. However, records were kept of the frequency with which the animal crossed from one compartment to the other during randomly selected 10-second periods within the intertrial interval. During the intertrial interval the neutral signal was sounded continuously. Animals were given five trials a day and trained to a criterion of three successive days at 100-percent conditioned response or until they failed to reach criterion in 500 or more trials. If an animal could not learn the duration discrimination, an attempt was made to condition the response to an 800-cy/sec tone. Failure to obtain conditioning under these simpler stimulus circumstances might indicate that motivational factors rather than loss of sensory cortex per se were responsible for the animal's inability to acquire the discrimination.

Three of the infant-operated animals, in addition to being trained on the duration problem, were subsequently trained on a pattern discrimination. In the pattern problem the animal was conditioned to make the avoidance response within 15 seconds after the temporal pattern of a repetitively sounding group of three frequencies was changed from a neutral signal of low-high-low to an avoidance signal of high-low-high, that is, when the pattern was shifted from 800-1000-800 to 1000-800-1000 cy/sec. These animals were given ten trials a day and trained to a criterion of two successive days at 90-percent conditioned response or better. At the conclusion of training, operated animals were sacrificed and their brains prepared for histological examination. Surface lesions were reconstructed and the thalamus was studied for retrograde degeneration.

The behavioral results of this study are summarized in Table 1. All nine of the infant-operated cats were able to learn the discrimination 6 months after surgery, requiring on the average 140 trials to reach criterion. They did not differ in any significant way from their littermate controls who required an average of 120 trials to learn the problem. On the other hand the four adult animals sustaining comparable large lesions were unable to learn the discrimination 6 months after surgery in over 500 trials. In spite of the fact that they were unable to learn the duration problem, three of these animals readily acquired the avoidance response to a simple tone. Cat No. 59, however, could not be so conditioned. In the remaining three animals of the adult group, Nos. 2A, 4, and 6, the lesions were intentionally smaller and did not include the total projection field of the medial geniculate. These animals were able to learn, as were all of the adult controls, who required on the average about 195 trials (*7*).

It will be recalled that three of the infant-operated cats were given training on a pattern problem after they had been trained on the duration problem. These were cats 35A, 37A, and 72A. Cats 35A and 37A learned in 180 and 510 trials respectively (*8*). Cat 72A had to be sacrificed after 80 trials, but evidenced significant learning during this period.

Postmortem examination of the brains of the operated animals revealed that the location and magnitude of central nervous damage in the auditory system of five out of the nine infant-operated animals was at least as extensive as that seen in the four adult-operated cats who were unable to learn the duration problem. In these animals the intended area of ablation had been removed and the entire medial geniculate had degenerated bilaterally. The remaining four animals in the infant-operated group were found to have less cortical damage than was intended. In each case the ablation was insufficiently extended into the ventral cortex either on one or both sides, that is, it failed to reach the rhinal fissure in the temporal-insular region. In these brains, the posterior portions of the medial geniculate were largely preserved.

These results are in essential agreement with those reported elsewhere to the effect that large bilateral lesions of auditory cortex prevent the acquisition of a duration discrimination if the lesions are made at maturity. On the other hand, comparable damage sustained during infancy has no effect on the acquisition of this discrimination at maturity. Similarly, pattern discrimination can be acquired by the cat in the absence of auditory cortex if the cortex is removed during infancy. It would appear that the role of cortical structures in auditory discrimination is dependent on the age of the nervous system at the time of experimental injury. Neonatal damage to the auditory system seems to have less impairing effects than damage sustained at maturity (*9*).

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References and Notes

1. K. D. Kryter and W. H. Ades, *Am. J. Psychol.* **56**, 501 (1943).
2. M. Rosenzweig, *ibid.* **59**, 127 (1946).
3. J. M. Goldberg and W. D. Neff, *J. Neurophysiol.* **24**, 119 (1961).
4. I. T. Diamond and W. D. Neff, *ibid.* **20**, 300 (1957).
5. D. P. Scharlock and W. D. Neff, "The role of the cortex in the discrimination of sounds of different duration" (paper presented at Midwestern Psychological Association Meetings, Chicago, 1959).
6. The intended area of ablation included auditory areas AI, AII, and Ep, somatic area II, and the cortex of the insular-temporal region.
7. No statistically significant evidence was found supporting the notion that avoidance conditioning is more difficult with older than with younger animals.
8. D. P. Scharlock and A. J. Yarmat [*J. Comp. Physiol. Psychol.* **55**, 455 (1962)] present evidence indicating that doubling the number of daily trials doubles the total number of trials to criterion. On the pattern problem, animals were given ten rather than five trials per day.
9. Supported by grant NB-02848-03 from NIH.

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