EFFECT OF ABLATION OF "SENSORY ASSOCIATION" CORTEX
ON SENSORY PRECONDITIONING IN CAT.

by

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A THESIS

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INTRODUCTION

Since the time of Aristotle (33) the peripheral sensory pathways have been thought to have both common and independent cortical projections. Recently experimental evidence of such cortical areas has been presented (3, 5, 14, 40). Utilizing either chloralose or curarized cat preparations these authors were able to record cortical responses to auditory, visual or tactile stimulation within one response field. Recently the distribution to responses from all three modalities stimulated has been shown to be equal and undifferentiated in four cortical fields, two on the middle suprasylvian, one on the anterior lateral, and one around the pericruciate sulcus (48). These fields are well differentiated anatomically and may be termed sensory association areas. In a recent series of papers (48, 49) Thompson has demonstrated that the:

"1. Topographical distribution of association response amplitudes in all cortical association fields is identical for all stimulus modalities, and for different receptive fields of a given modality. Thus it is not possible to identify modality of stimulation from cortical distribution of responses.

2. Association response waveform is the same in all cortical association fields to all modalities of stimulation: a relatively broad long latency (15-40 msec.) initial positivity followed by a more variable negativity.

3. The minimal onset latencies for association responses have the same cortical distribution for all stimulus modalities, corresponding exactly with the foci of maximal response amplitudes.

4. In a given preparation, the minimal onset latencies for a given stimulus are identical in all four association fields.

5. Two successive stimuli to any two modalities result in the identically long relatively and absolutely unresponsive periods for the second of two association responses that result when the same stimulus is delivered twice. This could result only if the different stimuli activated one and the same central system.

6. Association response amplitude variability is large and essentially the same for all cortical association response fields and for all modalities of stimulation. The standard deviation for association response amplitudes is 50% or more of the mean response amplitude, in contrast to primary responses, where response amplitude standard deviation is usually about 10% of mean amplitude.

7. The correlation of response amplitudes in any two of the association fields is essentially perfect with repeated stimulation of any modality. This perfect correlation obtains in spite of the considerable variability of association response amplitudes and could result only if the two recording channels were measuring activity of one and the same system at two points.

8. Correlations of association response amplitudes from all association fields with corresponding primary responses are zero for all stimulus modalities, thus demonstrating that the variability of association responses is independent of the variability of primary sensory systems. These results further demonstrate that the perfect correlations of association response amplitudes in the association fields cannot be due to any general cortical condition such as

fluctuating level of excitation or depression.

9. Responses in all cortical association fields to all modalities of stimulation are normal in appearance and distribution after removal of all other cortex, thus demonstrating that they result from subcortical activation and can be independent of all other cortical activity.

10. The intracortical depth distribution of association response potentials is identical in all four association fields for all modalities of stimulation. In all cases the deep initial negativity reaches a maximum at a depth of about 1.6-1.8 mm., suggesting that surface association responses result from a potential sink located deep in the cortex.

11. Single-unit activity in all association fields of the cortex for all modalities of stimulation is always encountered at the same depth, 1.4-1.8 mm., corresponding to the region of maximal deep initial negativity of the evoked response. Unit discharges always occurred at and immediately following the peak of the deep initial negativity.

12. When patterns of unitary discharge were seen for one stimulus modality, the same patterns were found for the other modalities of stimulation. Amassian (4) reported units in the anterior lateral area that respond equally to auditory and tactile stimuli (the only stimuli used), and Buser and Imbert (14) reported units of the anterior sigmoid gyrus that respond equally to auditory, somatic, and visual stimuli."

Bental and Bihari (8) have done single unit recording from the suprasylvian sensory association areas in unrestrained, unanesthetized cats and were able to elicit single cell responses to both visual and auditory stimuli. They suggested that the . . ."association cortex units show less modality specificity and more interaction between modalities than do primary sensory units". Recent evidence suggests that the sensory association system has both reticular and mid-thalamic relays (1, 2,)[1]. Hicks and Thompson[2] have demonstrated cortical association responses using electrical stimulation of the mesencephalic reticular formation.

Although previous attempts to demonstrate behavioral deficits following association cortex ablation have been made (16, 17, 18, 21, 32, 34), it is notable that the term association refers to those areas where primary responses are not seen (39) rather than the previously described electrophysiologic polymodal fields.

However Neff, et al. (36) was unable to demonstrate a difference, in pre-operatively trained and post-operatively test cats, in ability to localize tone with suprasylvian gyrus ablations. Hara (22) reported no difference in brightness thresholds, a transient change in size discrimination and a marked loss of form discrimination in pre-operatively trained and post-operatively tested cats with the pre-striate (middle suprasylvian) ablated.

Using the same animals post-operatively Warren (50) found they were unable to solve umweg (detour) problems in a Hebb-Williams maze.

Johnson (28) did both partial and total ablations of the sensory association areas in cats. He then presented them with a problem which required them to run if a light and tone were presented simul-

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[1] W. Prescott. Personal Communication. 1962

[2] L. Hicks and R. F. Thompson. Personal Communication. 1962.

simultaneously but to remain motionless if the stimuli were presented independently. He found that the partially ablated animals were able to learn the task but it took them significantly longer than normal or somatic cortex ablated controls. The totally ablated animals were unable to learn to his (Johnson's) established criteria. They did show responses to the simultaneous stimuli but did not inhibit responses to the independent presentations. However they did show some, statistically significant, tendency toward differential responses in the direction of learning. He did mention that perhaps the total ablated group had some difficulty in connecting the conditioning stimuli with the shock, but that the only valid conclusion that might be drawn was the necessity for total ablation for the demonstration of behavioral differences.

While most of the behavioral studies cited have confined themselves primarily to some intra-modal task, there are paradigms which rely, operationally, upon inter-modal stimuli. A rather interesting, if somewhat controversial (Seidel), method is sensory pre-conditioning. This phenomena, first noted by Brogden (11), consists in a) the presentation of paired stimuli (the pre-conditioning phase) followed by b) the conditioning of one of the stimuli to an unconditioned stimulus (the aquisition phase) until some arbitrary criteria of frequency of conditioned responses is attained and then c) experimental extinction to the previously unreinforced stimulus (the test phase). The number of responses made in this phase compared to responses of control subjects is a measurement of pre-conditioning, and the responses themselves are termed pre-conditioned responses.

At present the phenomena has been demonstrated in dogs (11), pigeons (40), rabbits[1], cats (30), rats (6), monkeys (12), and humans (10, 19, 20).

The method of training has included food reward (12, 39), shock avoidance (25, 26, 30, 34, 43, 46) and GSR response (15, 19, 33, 51). While Bregden originally utilized the number of responses during experimental extinction to the previously unreinforced stimulus as the test for sensory pre-conditioning, others (35, 43) have preferred the "savings" or positive transfer measure. They trained the animals to respond to light, then instead of extinguishing them, they trained them to tone. They noted the pre-conditioned animals required less trials than did the non-pre-conditioned controls. Brown (12) using monkeys first trained the subjects to press one lever if a yellow light flashed, and another lever if a white light flashed. After the animals had acquired this habit, they were placed in a separate cage and the yellow light was followed by a green light and the white by a red for some 20 repetitions. They were then placed back in the conditioning box, and for one half the animals green replaced yellow and red replaced white as a conditioning stimulus. For the other half the reverse (i. e. red for yellow and green for white) was true. The reversal group showed random lever pressing, but the non-reversed group showed no loss of habit. Bahrick using the traditional sequence (pre-conditioning prior to aquisition) also pre-conditioned rats in their home cages with light and tone, and showed a significant amount

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[1] W. J. Bregden. Personal Communication. 1961.

of pre-conditioning.

Brogden, Hoffeld, Thompson, and Kendall (25, 26, 30, 47) have done several parametric studies on cats using the Brogden-Culler wheel (10) to condition running responses to shock with aquisition conditioning to light. The absolute number of responses during experimental extinction to tone was the test of pre-conditioning. They (26) showed that a 4 second of tone prior to the onset of a 2 second light tone combination gave significantly greater pre-conditioning than did shorter or no tonal precedence. They showed also that four pre-conditioning trials gave a greater amount of pre-conditioning than did any other amount ranging from 1 to 800 pre-conditioning presentations of tone and light (26). This study failed to establish any mathematical relationship between the number of presentations and the number of pre-conditioned responses. Thompson (47) showed that cats without pre-conditioning training but conditioned to the 55% acquisition level to light showed a significant number of responses to tone, but a group brought to 90% acquisition showed no responses to tone. Kendall and Thompson (30) have shown that sensory pre-conditioning exists within one mode. They pre-conditioned one group of cats with combinations of 2000 cps and 250 cps tone and trained them to 250 cps. They found a significantly greater number of responses to the test stimulus (2000 cps) in the experimental groups than in a non pre-conditioned control group. However, they were unable to obtain a gradient in response strength to other test tones similar to gradients found in tests of stimulus generalization. From this and from the previous finding of a lack of relation between trials to acquisition to light and pre-conditioned responses to tone (26), they suggested that pre-conditioning may be an "all or none" phenomena. This question of generalization gradient from the pre-conditioning stimulus was studied in humans by Karn (29) who found no responses to a red light if pre-conditioning was done with a white light.

Silver and Meyers (45), using rats and the savings method to test the presence of the pre-conditioning effect, found that animals presented with, tone followed by light pretraining, and tested to tone showed the effect while animals with simultaneous or light then tone pretraining did not. They felt that this was analogous to forward versus backward conditioning, and the results were further evidence that sensory pre-conditioning followed the laws of classical conditioning.

Coppock (19) using human subjects and the GSR as a test for pre-conditioning pre-extinguished one group to tone during pretraining and found they gave less responses during testing than did a normally preconditioned group. He also used a random sequence of light and tone for a non pre-conditioned control.

Cherinkov and Brogden using human subjects (15) with GSR gave different instructions to each group. In groups where the possibility of tone occurrence, without any reference to its significance, was mentioned there was no pre-conditioning effect.

The theoretical implications of the phenomena have been reviewed recently by Seidel, who feels the evidence for its existence is sufficient but that its relation to classical learning theory is as yet unsettled. For example, Dalos and Wickens (51) using finger shock avoidance in humans as the test found that if the subjects were required to make different verbal responses to each of the two pre-conditioning stimuli, there was a decrease in the number of pre-conditioned responses compared to controls. They used this as evidence to imply the effect is in actuality mediated stimulus generalization.

However Lovibond (33) doing practically the same thing, but using GSR as a measurement, found that the pre-conditioning was independent of the response during pretraining.

Seidel (44) preconditioned rats under conditions of food fast, water deprivation and satiation, then using shock avoidance training under food fast for all groups, found that there was no significant difference in the test phase. He concluded that if mediated transfer was to account for the effect, the autonomic nervous system response did not seem critical.

However, Bahrick (6) ran two groups of rats, one 14 hours food deprived and the other one hour food deprived. He showed that the 14 hour group gave significantly more responses. He concluded that his results were compatible with the hypothesis of a mediated response as an explanation for the phenomena.

While the cited studies differ widely regarding interpretation and in some cases seemingly conflict, the following factors would seem mutually evident.

1) The phenomena does exist.
2) There is at present no variable which has been shown to be proportional to the amount of pre-conditioning.

3) There is no obvious reinforcement to the test stimulus which accounts for the performance.

4) There is no obvious response to the test stimulus which, if mediated, would account for the performance.

5) It differs from stimulus generalization, both in the requirement of prior exposure to the test stimulus and the lack of a generalization gradient.

6) The phenomena is most stable if regarded as either all or none.

The above summary suggests that the paradigm does differ from classical learning types of problems and probably relies upon different behavioral mechanisms. The findings regarding response and reinforcement coupled with the parametric studies along with its "all or none" characteristic would strongly suggest "attention".

From the previous discussion it would appear that while the electrophysiology of the sensory association system is rather well delineated, however, little has been done to correlate these findings with a behavioral task. Although the system does respond to polymodal stimuli, it also is relayed through the reticular formation. This latter finding would suggest that perhaps the system is in some way involved in "attention", a previously suggested function of the reticular formation (24, 27, 42). Prior discussion has pointed out the paradigm of sensory pre-conditioning seems to be partially a function of "attention", as well as necessitating responses to two modes of conditioning stimuli.

If the assumptions regarding "attention" are posited, animals with association cortical ablations should show a predictable performance if presented with a sensory pre-conditioning problem. These predictions would include:

1) There will be no significant difference in the number of sensory pre-conditioned responses in ablated animals that have had pretraining and ablated animals that have not had pretraining.
2) Ablated animals will not show a significant amount of pre-conditioning if compared to normal animals.
3) Animals with a comparable amount of non-association cortex removed will not show a significant difference when compared to normal animals.
4) Sensory association cortically ablated animals will not show a significant difference, compared to normals, in ability to learn a response to light.

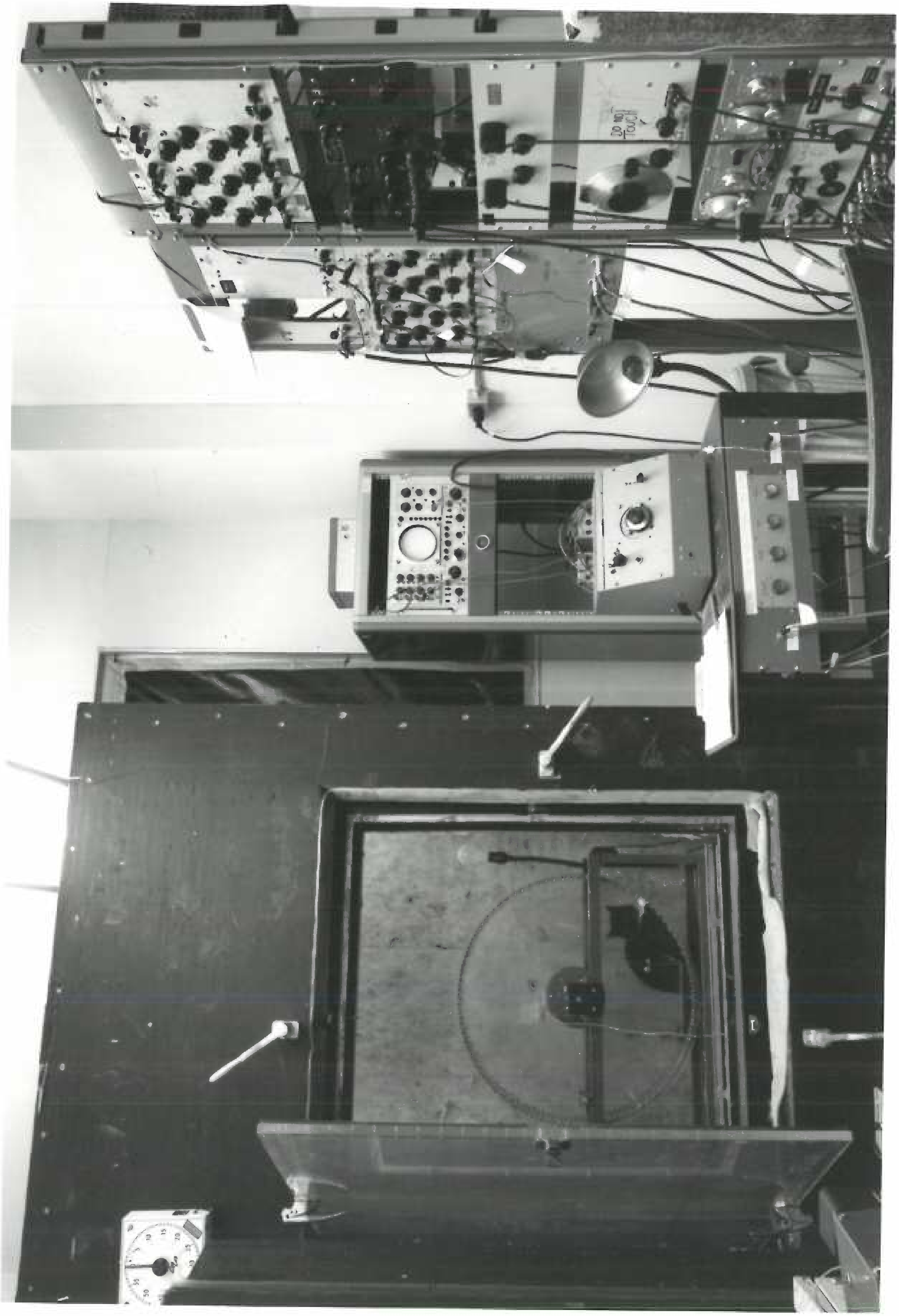
Prediction number two, coupled with prediction number four, hypothesizes the loss to be predominately in the area of attention rather than intra-modal discrimination.

This study is an attempt to determine the effect of the sensory pre-conditioning paradigm upon cats with sensory association cortex ablations.

FIGURE 1

Photograph of actual conditioning apparatus.

FIGURE 1



MATERIAL AND METHODS

Apparatus

The animals used in the present study were adult cats provided by the University of Oregon Medical School animal quarters. Criteria for selection were weights greater than 2 kilo, residence in the animal quarters for 30 days, and healthy appearance prior to conditioning. No attempt at selection based on sex, genetic or behavioral type was made. With the exception of the immediate post-operative period, the animals recieved routine care provided by the animal quarters.

The apparatus was a modified Brogden-Culler rotating cage (10) as previously described by Johnson (28).

The rotating cage (See Fig. 1) was constructed of two plexiglass sides, 30 inches in diameter, set 6 inches apart. The sides were connected at their circumference by 3/16 inch brass rods placed 1/2 inch apart. Through these rods a shock, produced by an amplifier-transformer system designed to automatically maintain a constant current, could be delivered. The rotating cage was provided with a tension adjustment which allowed ease of turning to be roughly equated for cats of different weights.

The cage was placed over a metal pan, covered with paper towels to catch urine and fecal material, which was in turn placed on a small table inside of a fiberglass-lined box with internal dimensions of 29 by 69 inches. This box was fitted with a plexiglass door and was inside another box, the outside dimensions of which were 7 1/2 by 3 1/2 feet. The two boxes were separated by a three inch dead air space. The outside box had three inch thick plywood walls and a door provided with one way glass. The inner box was dimly illuminated by two 60 watt light bulbs placed in the ceiling and enclosed in frosted glass. The operator sat in front of the box with a control panel and a record sheet in a darkened room illuminated only by a 7 1/2 watt red light on the instrument panel. A small microphone was placed in the inner box and the operator was thus allowed full view of the animal and cage, with the ability to hear the animal and the onset of shock or auditory stimuli.

The box provided a sound attenuation of 40-55 db and human subjects placed inside were unable to discern visual stimuli outside the box. The auditory stimulus was a pure 1000 cps tone, generated by a Hewlett-Packard wide range oscillator and filtered high and low by a Spencer-Kennedy variable electronic filter. The level of tone was adjusted to 60 db above .0002 dyne/cm^2 by means of a Hewlett Packard attenuator set. A Grason-Stadler electronic switch provided a rise fall time of 100 milliseconds. The tone was delivered into the conditioning box through a speaker set in the ceiling of the inside box placed two feet above the rotating cage.

The visual stimulus was provided by two 100 watt uncovered bulbs, one of which was placed at a distance of 4 inches from either end of the rotating cage. The subject was always facing one of the two bulbs.

The shock current did not exceed 10 ma. and was usually less than 5 ma. The regulation of stimuli was provided by means of Tektronix 162 waveform generators and 161 pulse generators, which were connected to a control panel. The operator was able to elect tone and/or light as a CS and a shock of a variable current as UCS. The UCS occurred as a 100 msec. pulse at the termination of the CS. It was also possible to produce recurrent shock if the animal did not respond to the first pulse of the UCS.

Behavior

A response was defined as any movement by the animal which produced rotation of the cage and occurred after the onset of the CS and prior to the onset of the UCS. The CS was presented if and only if the animal was motionless and had been so for at least 5 sec. Inter-stimulus times were varied from 5 sec. to 30 sec. of motionless behavior to avoid temporal conditioning.

The conditioning paradigm was broken into five basic periods (See Fig. 2). 1) Environmental adaptation: The subjects were placed in the apparatus for a 20 minute period on two separate days without presentation of stimuli. 2) The pre-conditioning period: The experimental subjects underwent sensory pre-conditioning (SPC) which consisted of four presentations of a 6 sec. tone with a light overlapping the last two seconds, within a 20 minute period. The control subjects underwent random pre-conditioning (RPC) which consisted of eight random presentation of either a 6 sec. tone or a 2 sec. light. There were a total of four tones and four visual stimuli for each animal (See Fig. 2 and Table #1). 3) Acquisition phase: The animals were conditioned in an escape avoidance paradigm to a 2 sec. light. They were given a set of 20 trials daily, with no more than 36 hours and no less than 12 hours between sessions, until a criteria of 18 out of 20 presentations resulted in a conditioned response. 4) Experimental extinction to tone: The animals were presented with a 2 sec. tone without a UCS for 20 trials daily until two or less responses to tone were elicited. 5) Experimental extinction to light: The animals were presented with a 2 sec. light flash without a UCS for 20 trials daily until two or less responses were elicited.

All animals who gave less than two responses to tone during experimental extinction were later conditioned to tone until there were at least three responses. This was referred to as the critical test.

One group of animals labeled normal no pre-conditioning received no stimuli in the pre-conditioning period.

During the training periods the subjects were allowed to respond freely, and no attempt was made to hinder hyper-active behavior other than increasing the tension on the cage prior to a given session. S's were left in the cage continuously for the total of twenty trials unless they defecated, in which case they were removed, while the apparatus was cleaned, and then returned to the cage.

No attempt was made to schedule training for an exact time, but once the animals were removed from the animal quarters they occupied the same transport cages and were trained in the same order. The author was responsible for the bulk of the training. Mr. Hilton Smith pre-conditioned all operated animals.

Daily records of the amount of current, whether it was pulsed or repetitive, and whether a response occurred, were kept.

Although it has previously been noted that "the naming of cats is a difficult matter..." (38), an attempt has been made to code the S's according to both their operative and conditioning status without regard to thier actual order of procurement from the animal quarters. Thus the first letter refers to their operative treatment:

N = Normal

A = Association Ablation

S = Sensory Ablation

The final letters refer to the conditioning paradigm

NPC = No Pre-conditioning

RPC = Random Pre-conditioning

SPC = Sensory Pre-conditioning

A total of six groups of five animals each are included in this study.

1) Normal animals who were sensory pre-conditioned (N-SPC).
2) Normal animals who were randomly pre-conditioned (N-RPC).
3) Normal animals who were not pre-conditioned (N-NPC).
4) Sensory association cortex ablated animals who were sensory pre-conditioned (A-SPC).
5) Sensory association cortex ablated animals who were randomly pre-conditioned (A-RPC).
6) Sensory somatic cortex ablated animals who were sensory pre-conditioned (S-SPC).

All training on ablated animals began at least 30 days following operation. All subjects were experimentally naive.

Operations.

Prior to operation the animals were anesthetized with pentobarbital sodium (40 mg./kg.) intra-peritoneally. After anesthesia was obtained, atropine (.04 mg./kg.) was injected intra-muscularly, and the head was shaved to remove all scalp hair. The animal was placed in a head holder, which did not traumatize the tympanic membrane or infra-orbital nerves. The scalp was then prepped.

Under sterile conditions the animal was draped; and the midline scalp, from the nasion to the occipital ridge, was incised. The scalp was retracted laterally and the temporalis muscle freed from its anterior and midline facial attachments. The muscle was then retracted and the bone scraped free of periostium. Bilateral trephine holes were placed over the frontal sinuses and the bone removed with rongeurs to the posterior frontal sinus wall. The sinus membrane was freed and removed, and the sinus was dried with the aid of suction. Hemostasis was obtained with bone wax. A small piece of dry gelfoam was placed in each nasal sinus foramena, this was then covered with acrylic resin cement which was allowed to harden. The sinus was then bathed in zephrin (1:1000) for 20 minutes and the instruments re-sterilized.

For the SAC ablations, bilateral trephine holes were placed in the tempro-parietal areas and the bone removed with rongeurs, exposing dura posteriorly to the occipital area, anteriorly to include the posterior wall of the frontal sinus, medially to within 2 mm. of the midline and laterally to the ectosylvian gyrus. For the SSC ablation the bone was removed anteriorly and medially to the same extent but laterally to the zygomatic-temporal suture and posteriorly to the apex of the zygoma.

The dura was incised and retracted, and the pia opened. A number 19 needle with a blunted end was used to gently aspirate the cortex. Brain hemostasis was obtained with the aid of oxidized cellulose and tamponade or gelfoam. In some instances gelfoam was left in situ. The dura was then reapproximated and sutured with 6-0 silk and an atraumatic curved needle. Following reapproximation a saline soaked piece of compressed cotton was placed over the dura and the contralateral hemisphere treated in the same manner. The wound was then closed in anatomical layers, and sprayed with a plastic bandage.

Following operation 300,000 units of bicillen was administered I.M., and the animal was allowed to regain consciousness, a period varying from 4 to 18 hours, under an infra-red heat lamp. The animals were then fed milk by hand using a rubber syringe, until they could eat without aid (a period of 1 to 2 days). They were then returned to the animal quarters.

Lesions. (See Fig. 3).

The sensory association cortex was ablated in two groups (A-SPC and A-RPC). Anatomically this attempted to include:

1) The total of the middle suprasylvian gyrus.
2) The anterior one fourth of the lateral gyrus.
3) The posterior third of the anterior supersigmoid and the and the anterior third of the posterior supersigmoid, the medial third of the coronal gyrus, and the superficial bank of the singulate gyrus.

The total lesion included approximately three hundred square millimeters of cortex.

The sensory somatic cortex was ablated in one group of animals (S-SPC). Anatomically this attempted to include: The posterioral lateral three quarters of the posterior supersigmoid gyrus, the posterior one half of the coronal gyrus, the total anterior suprasylvian gyrus, the total anterior ectosylvian gyrus and the anterior two thirds of the anterior sylvian gyrus. The total area ablated included approximately three hundred square millimeters of cortex.

Following completion of training, six of the sensory association lesion animals and the five somatic sensory lesion animals were sacrificed and profused. The brains were then removed and photographed.

The remaining four animals are to be utilized for further behavioral experimentation. The sacrificed sensory association ablated animals were utilized in acute electrophysiologic studies which included the removal of dura and the placement of electrodes on the cortex. These experiments did not interrupt the anatomy of the cortex.

FIGURE 2

A. Phases

1. N St. 2 days no CS or UCS
2. 1 day i NPC: no CS or UCS
   ii SPC: paired light and tone
   iii RPC: random light and tone
3. CL: condition shock avoidance to light to 90% acquisition level
4. Ex-T: experimental extinction to tone to 10% response level
5. Ex-L: experimental extinction to light to 10% response level

B. Presentation schedules (see Table I)

SPC: Sensory pre-conditioning
RPC: Random pre-conditioning

light 2 sec. tone 6 sec.

FIGURE 2

CONDITIONING PARADIGM

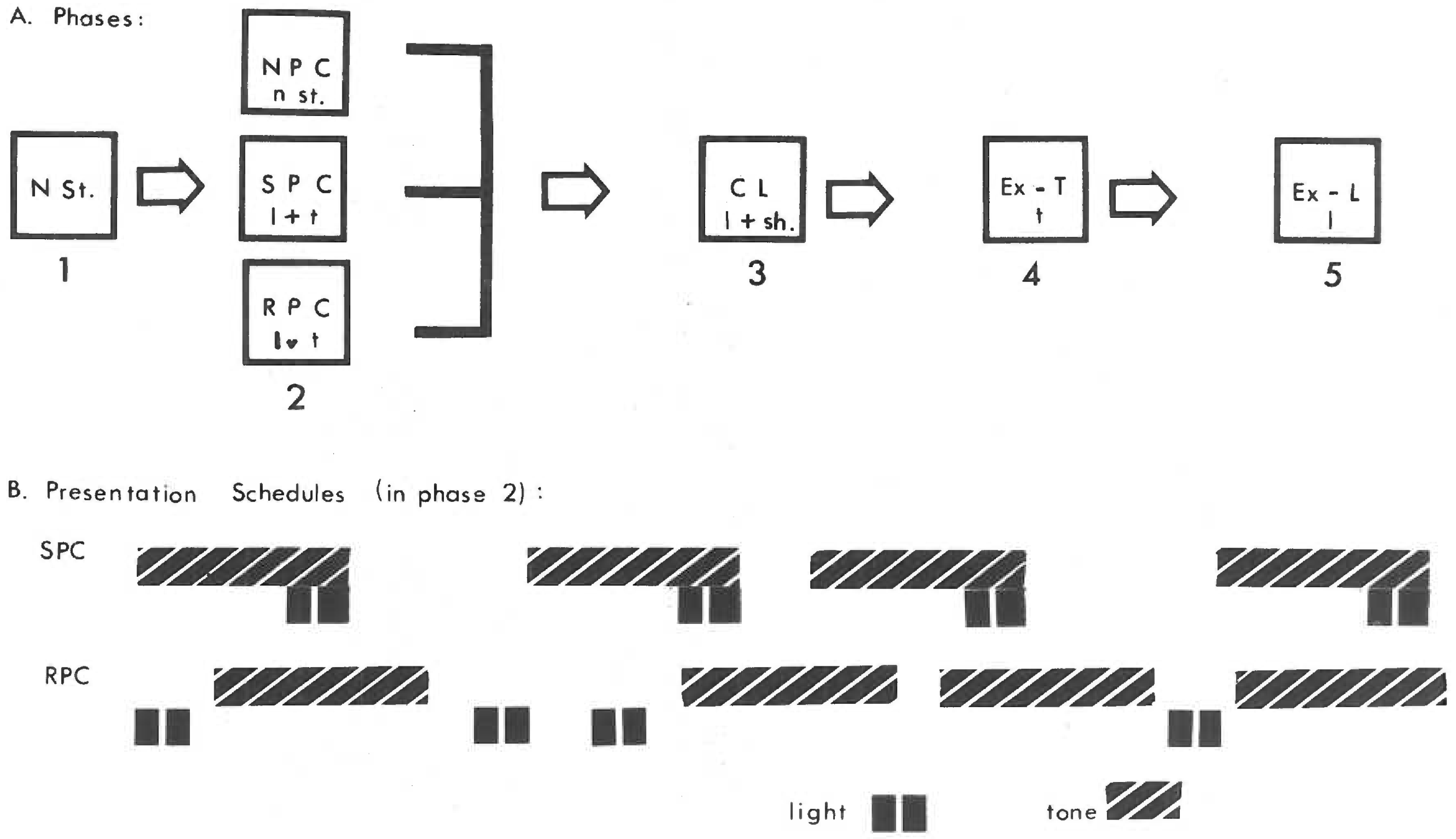


TABLE I

Random Pre-Conditioning Schedule

Schedule number:	1	2	3	4	5
Time and mode	2_L	1_T	1_T	1_L	1_T
	3_T	2_L	2_L	2_T	2_L
	5_L	4_T	3_L	3_L	4_T
	6_L	5_T	4_T	4_T	5_L
	7_T	6_T	7_L	6_T	6_T
	8_T	9_T	8_L	9_L	8_T
	9_L	12_L	10_T	12_T	11_L
	14_T	13_L	11_T	14_L	13_L

T = Tone

L = Light

The cats were placed in the apparatus for a 15-minute period. Stimuli were delivered at the times noted or as close to it as possible. No stimuli were delivered if the animals eyes were closed or if it was moving. No stimuli were delivered at intervals closer than 60 seconds.

FIGURE 3

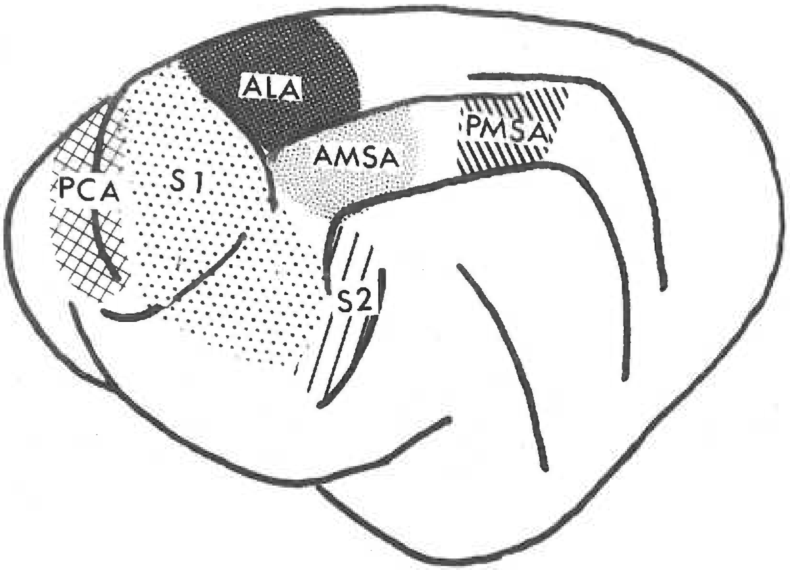
Schematic:

A. Anatomical distribution of sensory association and somatic cortex
    1. PCA = Pericruciate Association Area
    2. ALA = Anterior Lateral Association Area
    3. AMSA = Anterior Middle Suprasylvian Association Area
    4. PMSA = Posterior Middle Suprasylvain Association Area
    5. S_1 = Somatic Sensory I Area
    6. S_2 = Somatic Sensory II Area

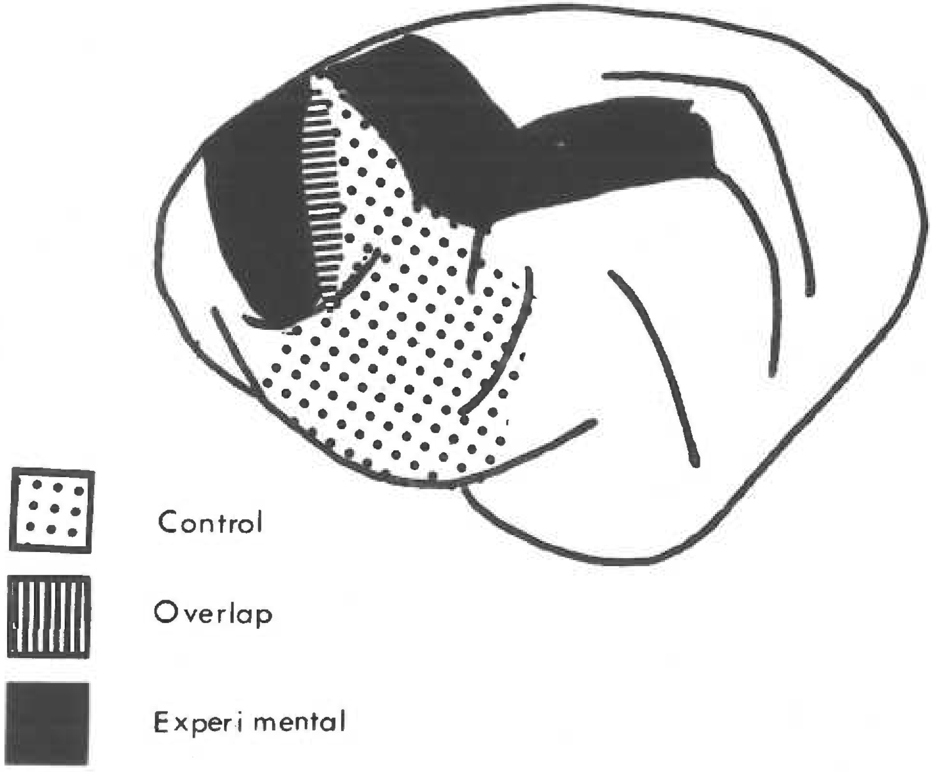
B. Intended Lesions

FIGURE 3

Sensory Association & Somatic Cortex



Intended Lesions



RESULTS

Behavior.

The results are illustrated in both tabular and graphic form, with the total number of responses to light, during the acquisition phase, in Figure 4, and the total number of responses during experimental extinction to tone, the crucial test of pre-conditioning, in Figure 5. The tables show the mean and total number of responses, or days to criteria, in each of the phases for individual animals and groups.

A Bartlett test (52) for homogeneity of variance, performed on the number of days for response acquisition to light, yielded a chi square of 2.57 (chi square .05 = 9.49 for 4 df) implying the variation around each of the group means was essentially the same for all groups. A simple between-within analysis on the group means failed to show a significant difference at the .05 level (Table IV). Figure 4, a graph of the total number of responses for each animal in each group does not suggest a difference for this measure of acquisition. Table III is an attempt to present acquisition data independent of both the total number of days and total number of responses. In the first section the total number of trials for each animal was divided into 10% segments and cumulative responses for each segment were calculated and averaged for each group. The second portion of the Table is the cumulative averaged percentage of total responses for each group. A graph was drawn representing the second portion of the Table but the overlapping of lines made distinction of individual groups extremely difficult. It was noted that group A-SPC seemed to follow the general curve but was consistently somewhat lower on the ordinate. Visual inspection of the data might suggest a somewhat different learning curve for the operated animals, however, in light of statistical analysis of other measure during this phase, these differences are probably spurious.

Analysis of the total number of responses to light during extinction was done. The Bartlett test (52) again failed to reveal significant differences between group variations with a chi square of 7.41 (chi square .05 = 9.47 for 4 df). The between-within analysis yield an F of 0.48 ($F_{.05}$ = 2.62 for 5 and 24 df) and was not significant at the .05 level (Table IV). Again the results failed to discriminate between groups, this time in relation to the number of responses during experimental extinction to light.

Analysis of response data for the experimental extinction to tone, the crucial test for pre-conditioning, did reveal significant differences between the groups. This data was analysed both in terms of the total number and the number on the first day, of responses during experimental extinction. Both measures failed to meet the assumption of homogeneity of variance, the chi squares were 93 for the former and 53 for the latter. Although the F ratio is fairly robust with respect to the assumption of homogeneity of variance (52), the a'priori significance level was raised from .05 to .01 for the between-within analysis. Both measures showed significant differences of group means at this level with respective F's of 4.7 and 5.3 ($F_{.01}$ = 3.90 for 5 and 24 df) (Table IV). A Kruskal-Wallis H test

(52), a non-parametric analysis of variance which depends on rank ordering of data, yielded a chi square of 12.9 (chi square .05 = 9.49 for 4 df). The rank ordering of responses for the first day did not differ, over groups, from that of the total number of responses. Since the non-parametric measure substantiated the results of the between-within analysis of variance, a Duncan (20) test for ranking means was performed utilizing the error term from the parametric analysis of variance. This showed that the normal sensory pre-conditioned group and the somatic ablated, sensory pre-conditioned group were not significantly different from each other in terms of mean responses to tone but were both significantly different from the rest of the groups. This test failed to elicit differences between the sensory pre-conditioned and the randomly pre-conditioned sensory association ablated groups. Neither of these groups were significantly different from the non-sensory pre-conditioned or randomly pre-conditioned normal control groups.

The only significant difference demonstrated, in the behavioral data, was in the responses to tone, the crucial test for pre-conditioning. Animals with association cortex ablations fail to show significant pre-conditioning, while animals with non-association cortex removed did not differ from normal non-operated animals. The other behavioral measures, in this paradigm, did not differentiate sensory association cortex ablated animals from normals.

Observations.

Observation of the convalescent animals failed to show any striking differences between the association operates and normal cats. It was noted that the sensory association ablated animals showed some hind paw spasticity, probably the result of ablation of motor area around the pericruciate sulcus. Immediately following operation, however, there were some rather striking differences between the association and somatic ablated animals. The association animals were unable to detour about obstacles in their path and would face into corners, standing for as long as an hour, for the first four or five days following operation. During hand feeding association ablated animals demonstrated opisthotonic paroxysms with a rigid dorsal flexion of the head and extensor rigidity. This would typically last less than one minute, did not appear to interfere with consciousness, and had no associated post-ictal spasticity. The somatic lesion group failed to show either of these abnormalities.

The association lesion group, during the acquisition phase to light, had a tendency to stare directly at the stimulus and then failed to respond, seeming as though they had "forgotten why they were looking". Neither the normal nor the somatic lesion group demonstrated this phenomenon.

Anatomical.

Although histological reconstructions of the lesions have not as yet been prepared, photographs of the brains with gross descriptions are shown in Figures 6 to 15. Most lesions, both in the association and somatic groups, erred in the direction of sparing too much cortex. The lesions did seem to be approximately equal in size and in variability. While the sensory association lesions did not include as much of the anterior lateral gyrus as intended, gross examination indicates that the electrophysiologic polymodal response fields were, in all probability, totally destroyed.

TABLE II

Acquisition of Light

Total number of days

	N-NPC	N-SPC	N-RPC	A-SPC	A-RPC	S-SPC	
Cat 1	8	13	5	21	16	13	
2	6	8	24	18	10	14	
3	12	14	22	12	13	12	
4	10	6	23	22	16	7	
5	18	2	16	15	5	11	
Average:	10.8	8.6	18	17.6	12	11.4	13.07

Total number of responses

	N-NPC	N-SPC	N-RPC	A-SPC	A-RPC	S-SPC	
Cat 1	71	102	60	203	128	124	
2	51	97	236	156	80	85	
3	122	131	176	83	133	124	
4	121	81	179	199	166	85	
5	198	20	182	100	50	102	
Average:	112.6	82.8	165.8	168.2	111.4	104	124.13

TABLE XXI

Average Cumulative Responses for Percent Total Trials

	10*	20	30	40	50	60	70	80	90	100
N-NPC	1.2**	6.2	14.6	27.6	39.4	49.6	62	76.4	93.8	112.6
N-SPC	1.4	5.8	11.4	17.4	25.2	34.6	45.8	57	68.8	82.8
N-RPC	1.4	2.4	18	33.4	50.4	68.6	90.2	115.4	137.4	165.8
A-SPC	0.8	2	6.6	14.6	27.4	43.6	66	92.4	119.2	168.2
A-RPC	1.2	6.4	10.6	17.4	32.6	36.2	53.8	72	90.4	111.4
S-SPC	3.0	6.2	10.4	17.4	27.4	38.8	50.2	65	83.2	104

* Percent Total Trials
** Average Cumulative Responses

Average Cumulative Percent Total Responses for Percent Total Trials

	10*	20	30	40	50	60	70	80	90
N-NPC	1.1**	5.5	13	24.5	35	44.1	55.1	67.9	83.3
N-SPC	1.7	7	13.8	21	30.4	41.8	55.3	68.8	83.1
N-RPC	0.8	1.4	10.8	20.1	30.3	41.3	54.4	69.6	82.8
A-SPC	0.5	1.2	3.9	8.7	16.3	25.9	39.2	54.9	70.9
A-RPC	1	5.7	9.5	15.6	29.2	32.4	48.2	64.6	81.8
S-SPC	2.8	5.96	10	16.7	26.3	37.3	48.3	62.5	80

* Percent Total Trials
** Average Cumulative Percent of Total Responses

FIGURE 4

Total responses to light in acquisition phase.

FIGURE 4

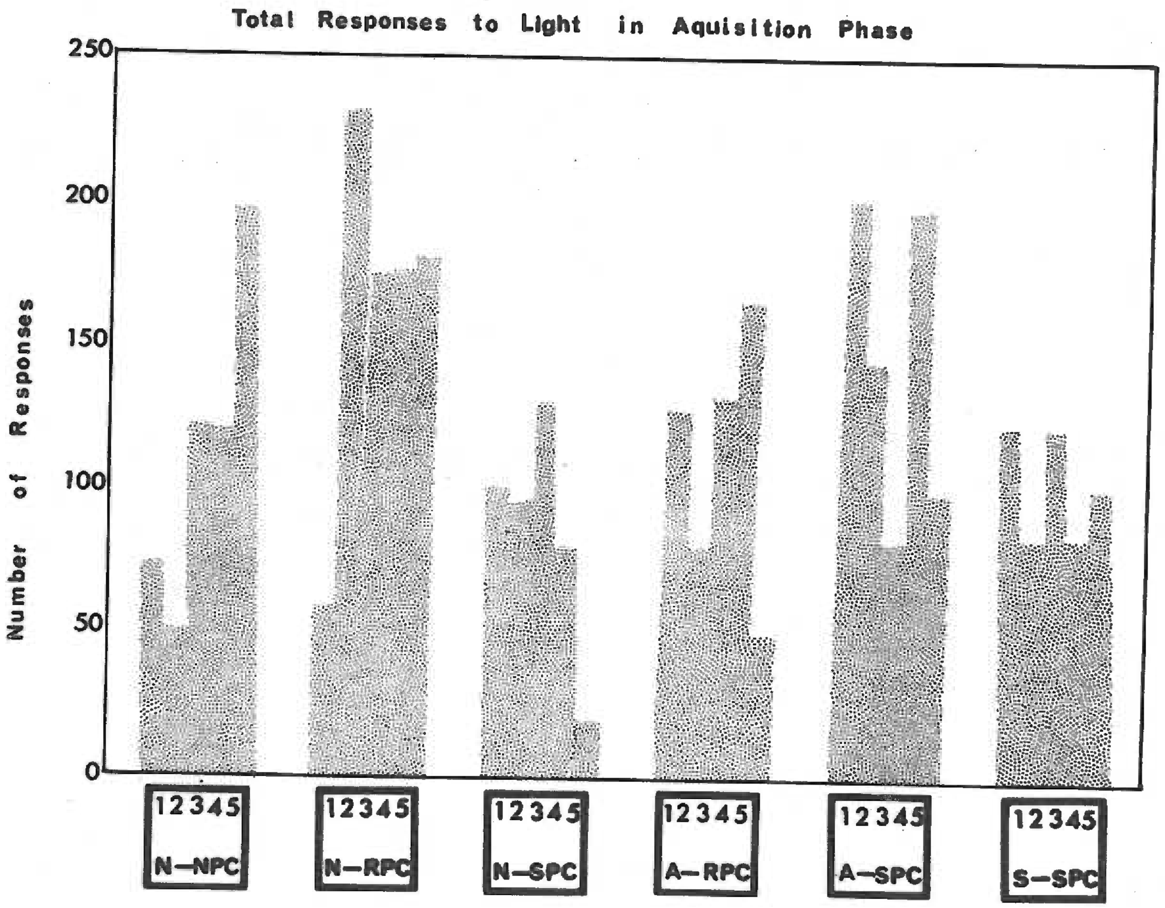

Total Responses to Light in Aquisition Phase
Number of Responses
250
200
150
100
50
0
12345
N—NPC
12345
N—RPC
12345
N—SPC
12345
A—RPC
12345
A—SPC
12345
S—SPC

TABLE IV

Summary of analysis of variance

A

Aquisition to Light: Total days

Source	df	SS	MS	F
Between	[illegible]	353	70.60	2.51
Within	24	676	28.17	
Total	29			

B

Extinction to Tone: Total Responses

Source	df	SS	MS	F
Between	5	733.77	146.75	4.70**
Within	24	749.60	31.23	
Total	29			

C

Extinction to Light: Total Responses

Source	df	SS	MS	F
Between	5	135.47	27.09	0.48
Within	24	13298.4	554.10	
Total	29			

F05 = 2.62
F01 = 3.90

TABLE V

Extinction to Light

Total number of days

	N-NPC	N-SPC	N-RPC	A-SPC	A-RPC	S-SPC	
Cat 1	2	4	5	7	4	1	
2	4	3	2	8	4	6	
3	3	5	3	1	3	6	
4	5	5	5	1	5	5	
5	5	4	5	2	5	1	
Average:	3.5	4.2	4	3.8	4.2	3.8	3.96

Total number of responses

	N-NPC	N-SPC	N-RPC	A-SPC	A-RPC	S-SPC	
Cat 1	9	16	52	61	18	2	
2	38	20	11	83	32	41	
3	19	20	14	1	16	38	
4	27	39	40	2	60	67	
5	39	47	47	6	33	0	
Average:	26.4	28.4	32.8	30.6	31.8	29.6	29.93

FIGURE 5

Total responses to tone in extinction phase.

TABLE VI

Extinction to Tone

Total number of days

	N-NPC	N-SPC	N-RPC	A-SPC	A-RPC	S-SPC	
Cat 1	1	3	1	1	1	2	
2	1	3	1	1	1	4	
3	1	1	1	1	1	4	
4	1	2	1	1	1	4	
5	1	4	1	1	1	2	
Average:	1	2.6	1	1	1	3.2	16.33

Total number of responses

	N-NPC	N-SPC	N-RPC	A-SPC	A-RPC	S-SPC	
Cat 1	1	8	0	0	4	5	
2	0	11	1	1	2	14	
3	0	1	1	0	1	14	
4	1	5	0	0	1	18	
5	1	32	1	0	0	4	
Average:	0.6	11.4	0.6	0.2	1.6	11	4.26

TABLE VII

Responses for first 20 Trials

	N-RPC	N-SPC	N-RPC	A-SPC	A-RPC	S-SPC	
Cat 1	1	4	0	0	3	4	
2	0	6	1	1	2	6	
3	0	1	1	0	1	8	
4	1	5	0	0	1	5	
5	1	17	1	0	0	3	
Average:	0.6	6.6	0.6	0.2	1.2	5.2	2.88

TABLE VIII

Response to Experimental Extinction to Tone

Summary: Duncan Test

Order:	1	2	3	4	5	6
Groups:	A-SPC	N-NPC	N-RPC	A-RPC	S-SPC	N-SPC
ΣX	1	3	3	8	55	57
$\bar{X}$	.2	.6	.6	1.6	11.6	11.4

Mean Scores

	A-SPC	N-NPC	N-RPC	A-RPC	S-SPC	N-SPC
A-SPC	--	.4*	.4*	1.4*	10.8	11.2
N-NPC		--	0*	1.0*	10.4	10.8
N-RPC			--	1.0*	10.4	10.8
A-RPC				--	9.4	9.8
S-SPC					--	.4*
N-SPC						--

Ranked Groups

M_1	N-SPC
M_2	S-SPC
M_3	A-RPC
M_4	N-RPC
M_5	N-NPC
M_6	A-SPC

N-SPC and S-SPC do not differ from each other, but significantly differ from the other four groups. (No significant differences between A-RPC, N-RPC, N-NPC and A-SPC.

DISCUSSION

The data suggests certain parametric conclusions. The necessity for particular combinations of tone and light is evident from the unoperated cats. The N-NPC and N-RPC groups do not differ in response in experimental extinction to tone from each other but do differ from the N-SPC group. The only difference in pretraining between the N-SPC and N-RPC groups is the combination of light and tone. The statistical measures of response to tone support the hypothesis that under certain conditions the phenomena is best considered all or none. The lack of difference in ranked means for response to tone in the first 20 trials vs total trials to extinction would imply that the former is as acceptable as the latter. The efficacy of this measure in assessing functionally related experimental variables in the SPC conditioning paradigm could well be a matter for future investigation. The previous findings of Brogden, et al., regarding the stability of the paradigm and the failure of acquisition or extinction variables to affect the number of responses in the experimental extinction to tone phase in any systematic fashion is substantiated.

The previous predictions (see Chapter 1, page 11) are born out in their entirety for this experiment. Although the statistical significance of the data speaks for itself, relevance to an understanding of brain mechanisms and behavior is not clear cut. Aside from possible procedural criticisms (which will be discussed later), the very cogent question of meaningfulness must be raised. It would seem that cortical ablation does have a differential effect on sensory pre-conditioning; but since the variables of the sensory pre-conditioning phenomena are not well understood, the specific effects of cortical ablation are difficult to assess. Although the possibility of "behavioral association" in a literal sense (i.e., the connection of "sensory traces" 24, 31) as a function is not totally rejected, it would not appear as the most economical hypothesis. If the coupling of heterogenous stimuli requires intact association cortex, then why did the sensory association ablated groups show no differential ability in the acquisition phase? Obviously a "coupling" between the unconditioned stimulus (a tactile stimulus) and the conditioning stimuli must take place. There is no reason to believe that this type of "coupling" is qualitatively different from the supposed light and tone "association". However, there are obvious subjective intensity differences. The animals would occasionally orient to the conditioning stimuli, but the shock tended to bring out a more intense response. Since efforts to maintain a control on shock threshold would interfere with the conditioning paradigm, which demanded one hundred per cent avoidance reinforcement, no comparison with normal animals can be attempted.

While the concept of "attention" is perhaps fuzzy at best it is seemingly pertinent in regard to this experiment. Previous discussion attempted to point out its apparent influence in this conditioning paradigm. Perhaps it might be studied operationally with respect to intensities of conditioning stimuli necessary to elicit pre-conditioned responses. It would be speculated that large increases in the intensity of the pre-conditioning stimuli might result in pre-conditioned responses in animals with sensory association cortex ablations.

Although the data does not merit a conclusion regarding the functional behavioral relationship of the sensory association cortex it might be speculated that such concepts as "attention", "vigilance", "alterness" or "arousal" could well apply.

This experiment was not designed to investigate the theoretical questions involving S-S bond linkages versus the response mediation hypothesis in sensory pre-conditioning. It is doubtful that the evidence presented will be of crucial value to either interpretation. It does suggest, however, that there are qualitatively different mechanisms involved in response acquisition to traditional conditioning procedures and sensory pre-conditioning, since operative intervention interrupts the latter with no obvious effect on the former.

The conditioning procedure itself may be open to some criticism. Certainly with a minimum of automation in the programming of stimulus presentation and response assessment there is the obvious problem of experimental bias. It was for this reason that data collection was limited to the presence or absence of response. The criteria for response is clear enough to enable mutual agreement among observers. Yet it is unfortunate that this experiment was unable to assess such measures as response latency or random activity.

Anatomically the lesions, although somewhat varied in extent, appear to have fulfilled their purpose. It is interesting to note that a pilot study[1] on two of the association operated cats shows no association responses in the cortex and diminished association responses in

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[1] Personal communication. William Prescott. 1963.

both the reticular and central thalamic association systems. It was also noted that the areas of response seemed both diminished in total extent and increased in variability in comparison with normal animals. It must be emphasized that the correlations of individual cat behavior with lesion size cannot be attempted without adequate histological examination, and then only if the vast amount of intra-animal variability is kept closely in mind.

While certain behavioral hypotheses have been experimentally supported, the studies should certainly suggest future investigation. The following points might enhance the general approach: a) It would be wise to utilize a purebred cat stock in order to reduce biological variability. b) It would increase the efficiency of the experiment to use more automated behavioral apparatus in order to obtain increased amounts of information. Certainly the previously mentioned response measures may be assessed in such apparatus as might the differential effects of positive and negative reinforcement.

Actual studies that would seemingly stem immediately from this experiment would include:

1) Studies of intramodal sensory pre-conditioning.
2) Studies of variation of pre-conditioning stimuli intensity.
3) Studies aimed more directly at the phenomena of "attention": such as EEG assessment with regard to both alpha blocking and arousal patterns, habituation studies and vigilance tasks.

SUMMARY

The effect of total sensory association cortex ablation on sensory pre-conditioning was investigated in cat. A total of six groups of five animals each were studied. Three normal groups, one having no pre-conditioning, one having random pre-conditioning, and one having sensory pre-conditioning, were compared with three groups of cortically operated cats. The operates included one group which had sensory association cortical ablations and sensory pre-conditioning, one group which had sensory association cortical ablations and random pre-conditioning, and one group with somatic sensory lesions and sensory pre-conditioning.

The pre-conditioning procedure was divided into five phases. The first phase consisted with acquainting the animals with the apparatus, the second with pretraining, the third with the shock avoidance conditioning of a running response, the fourth with experimental extinction to tone, the fifth with experimental extinction to light. During the pretraining phase animals were either given paired light and tone or random light and tone or no light and no tone. The number of responses during the experimental extinction to tone phase was considered the measure of sensory pre-conditioning. The results showed effective pre-conditioning only in the normal sensory pre-conditioned and the somatic sensory cortex ablated sensory pre-conditioned groups. Analysis of response data failed to demonstrate any other statistical significant differences between groups. The following conclusions were drawn:

1) The sensory association cortex in cat plays some role in sensory pre-conditioning, since the phenomena is not demonstrable in cats with this lesion but is demonstrable in cats with comparable amounts of somatic sensory cortical ablation.
2) Ablation of the sensory association cortex does not appear to have a significant effect on the acquisition of a shock avoidance running response to light.
3) Particular temporal combinations of light and tone seem necessary to obtain pre-conditioning.
4) The number of responses during the first 20 trials of experimental extinction to tone appear as efficient in demonstrating the presence of the phenomena as do the total number of responses to an arbitrary experimental extinction criteria.
5) Secondary extinction does not appear to have a differential effect on the number of pre-conditioned responses.

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APPENDIX

Photographs and Gross Descriptions of the brains

Figures 6 through 16

Figure 6

Animal: A-RFC #1

Operated: 10-1-62 Sacrificed: 4-8-63 Trained: 12-13-62 to 1-4-63

Days for acquisition to light: 16

Responses to extinction: Tone 4 . Light 19

Description of Lesion:

Left Hemisphere: The middle suprasylvian gyrus appears narrowed and depressed. There is loss of normal contour, both at the anterior lateral sulcus and the middle suprasylvian sulcus. There is loss of cortical substance at the anterior 5th of the anterior lateral gyrus, this loss of substance extends superficially to the midline. The anterior cingular gyrus seems to maintain its normal anatomical shape. The pericruciate area appears destroyed in an area 2 mm. about its sulcus. There is minimal loss of substance about the cingulate gyrus anteriorly.

Right Hemisphere: The middle suprasylvian gyrus shows total loss of cortex. The lateral gyrus seems ablated to its anterior 1/3th. There is loss of substance about the lateral aspects of the pericruciate sulcus. The medial 3 mm. of the pericruciate areas do not seem disrupted.

Comment:

The darkened areas about the left hemisphere of this brain are the result of an electrophysiological experiment which did not alter the anatomy of the cortex. This lesion appears incomplete both in the anterior lateral and the pericruciate areas.

FIGURE 6

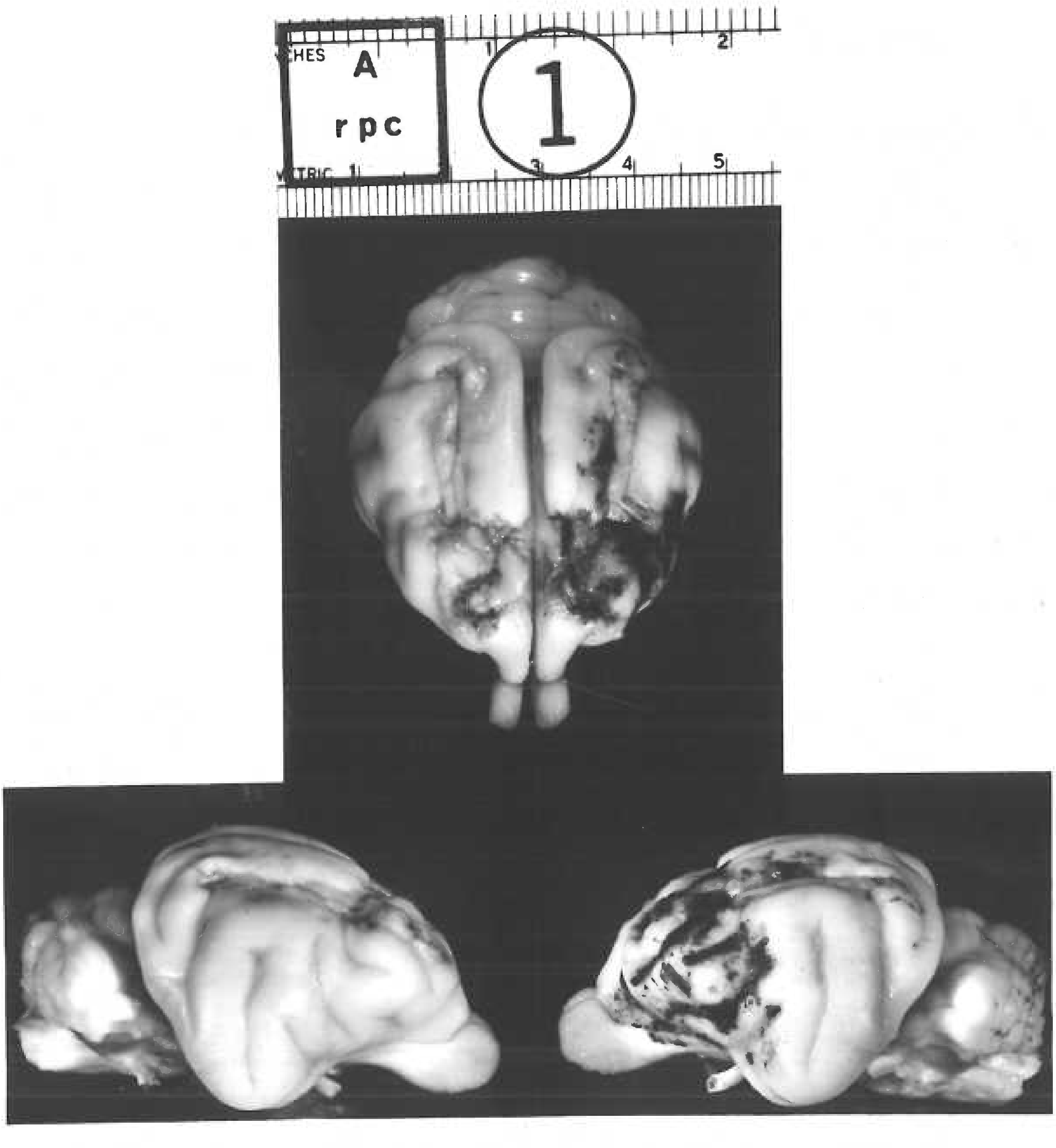

Figure 7

Animal: A-RPC #3

Operated: 11-7-62 Sacrificed: 4-17-63 Trained: 12-13-62 to 12-30-62

Days for acquisition to light: 13

Responses to extinction: Tone 1 Light 16

Description of Lesion:

Left Hemisphere: There is loss of substance and contour about the middle suprasylvian gyrus. Both the lateral and middle suprasylvian sulci appear disturbed with loss of substance from their suprasylvian banks. The lateral gyrus seems disturbed in its anterior 1/4th, this disruption extends to and includes part of the cingulate gyrus. The pericruciate areas appear totally ablated, this ablation extends anteriorly and inferiorly to include at least 4 mm. of cingulate gyrus. Right Hemisphere: The middle suprasylvian gyrus appears to have lost substance and contour. The anterior lateral gyrus is seemingly crowded down upon the middle suprasylvian. The lateral gyrus has lost substance in its anterior 1/4th. This loss extends to and includes part of the cingulate gyrus. The pericruciate areas appear totally disrupted. This disruption extends to and includes part of the anterior cingulate gyrus in a semicircular area extending about 2 mm. in its total diameter.

Comment:

Blackened areas about the anterior pole and cerebellum are the result of an acute neurophysiological experiment which did not alter the anatomy of the cortex. The lesion seems complete with the exception of the ablation of the left hemisphere's anterior lateral gyrus which does not extend medially or posteriorly in a complete fashion.

FIGURE 7

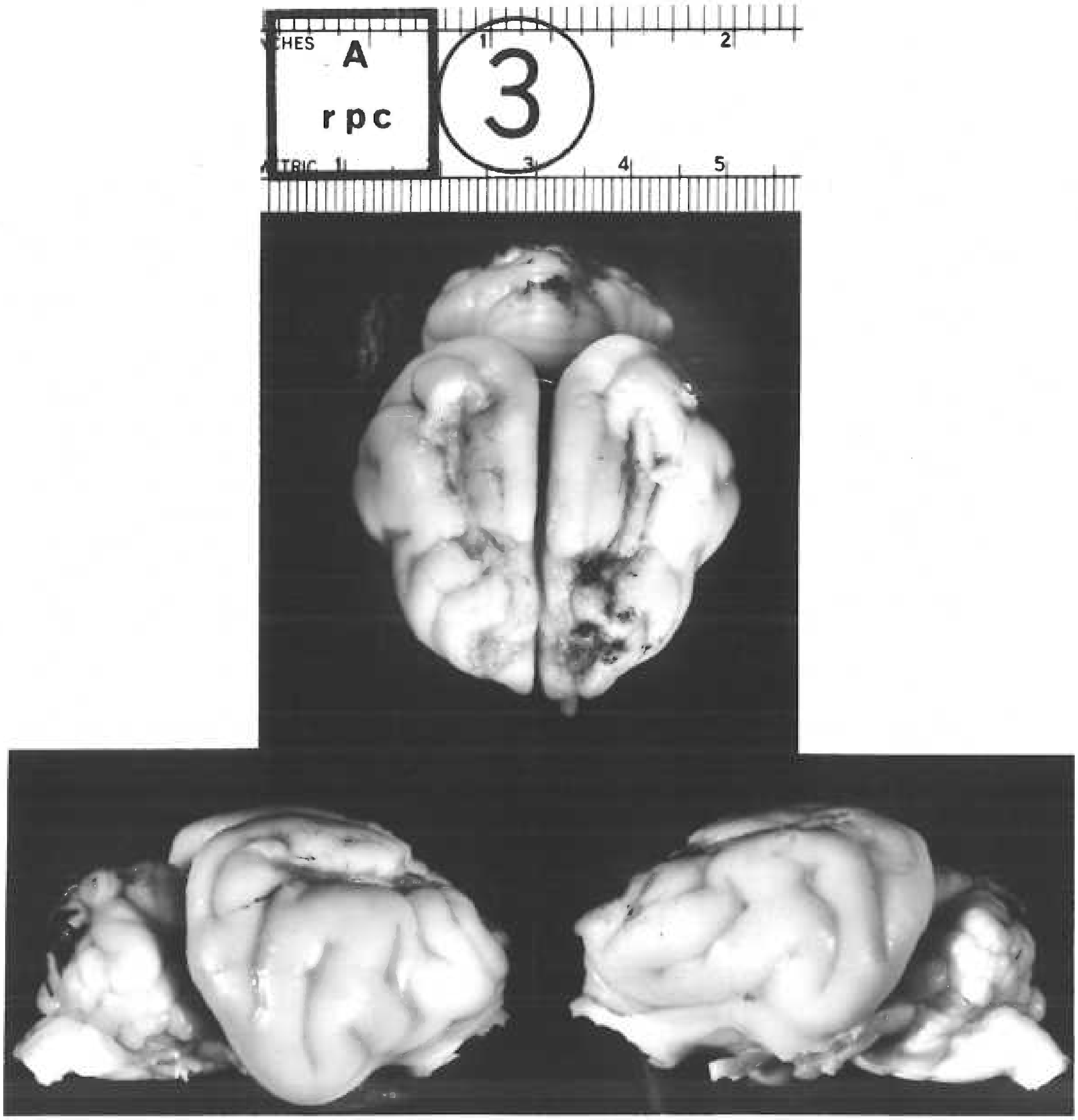

Figure 8

Animal: A-RPC #4

Operated: 11-16-62 Sacrificed: 4-19-63 Trained: 2-28-63 to 3-25-63

Days for acquisition to light: 16

Responses to extinction: Tone 1 Light 60

Description of Lesion:

Left Hemisphere: There appears to be total loss of all substance in the middle suprasylvian gyrus. The lateral gyrus shows loss of structure and content in its anterior 1/5th extending medially to include part of the cingulate gyrus. There is total loss of substance surrounding the pericruciate areas. There is no evidence of the anterior or posterior thirds of the anterior and posterior suprasigmoid gyrus. The lesion extends to include part of the cingulate gyrus anteriorly for about 4 mm.

Right Hemisphere: There is total loss of substance of the middle suprasylvian gyrus. The lateral gyrus shows loss of substance in its anterior 1/5th which extends medially to include the cingulate gyrus. There is total loss of substance about the pericruciate areas matching that of its contralateral hemisphere.

Comment:

The darkened areas about the left hemisphere are the result of a electrophysiological experiment which did not disrupt the anatomy of the cortex. The lesions seem to cover its intended extent.

FIGURE 8

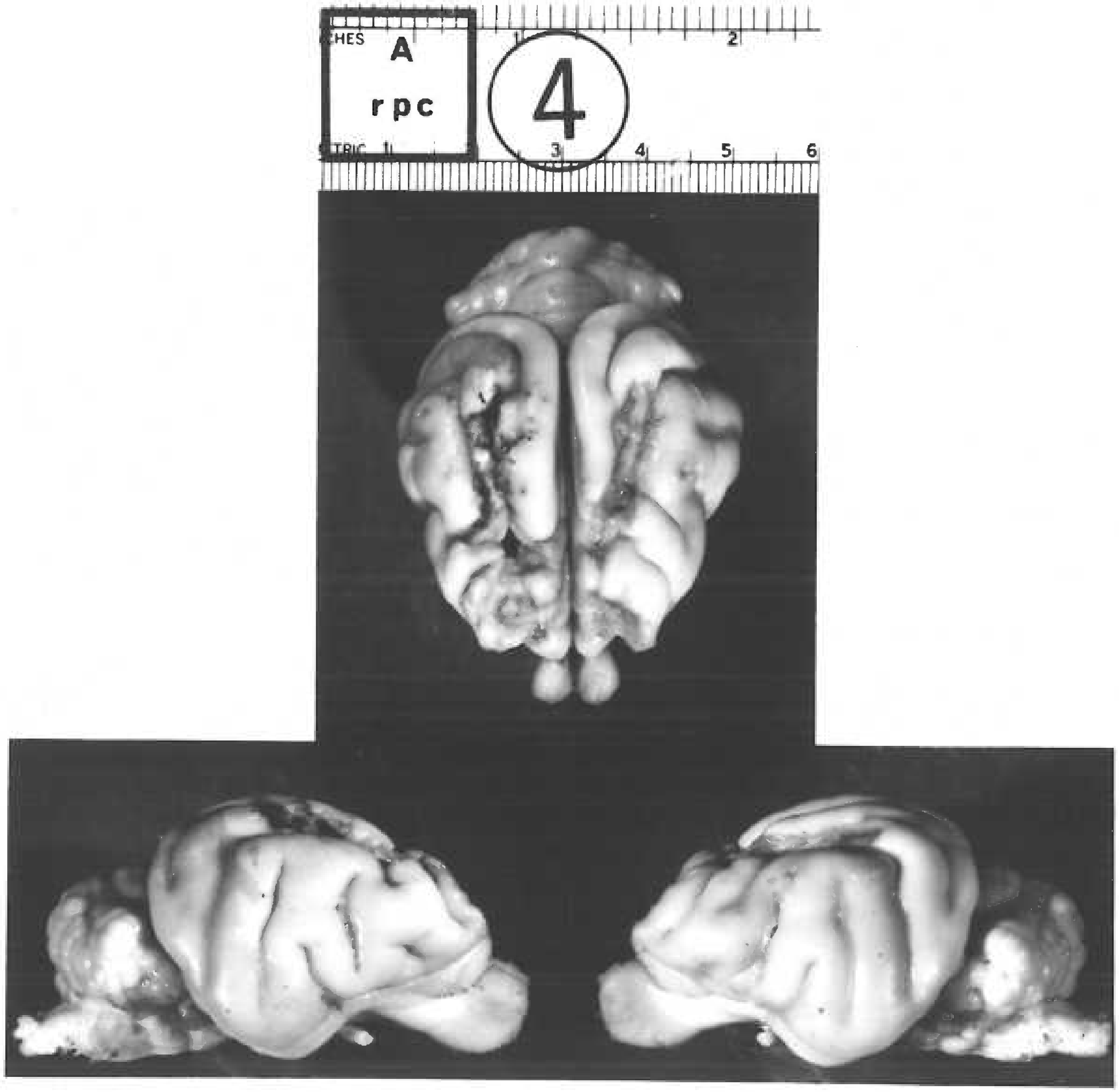

Figure 9

Animal: A-RPC #5

Operated: 12-10-62 Sacrificed: 4-19-63 Trained: 3-28-63 to 3-10-63

Days for acquisition to light: 5

Responses to extinction: Tone 0 Light 33

Description of Lesion:

Left Hemisphere: There is total loss of substance of the middle suprasylvian gyrus which extends across the lateral sulcus to involve the lateral 1/4th of the lateral gyrus. There is total loss of the lateral gyrus in its anterior 1/4th which extends to, but does not include, the medial aspects of the cingulate gyrus. The pericruciate areas seem totally ablated extending to and including the anterior cingulate gyrus.

Right Hemisphere: The middle suprasylvian gyrus appears ablated with the exception of its posterior 1/5th. The anterior 1/5th of the anterior lateral gyrus seems totally ablated. There is total loss of cortical substance around the pericruciate areas and the cruciate sulcus can not be identified. There appears to be loss of substance at the anterior portions of the cingulate gyrus.

Comment:

The darkened areas about the right hemisphere are the result of an acute neurophysiological experiment which did not disrupt the anatomy of the cortex. With the exception of the posterior middle suprasylvian gyrus on the right hemisphere the lesion seems to have fulfilled its intent.

FIGURE 9

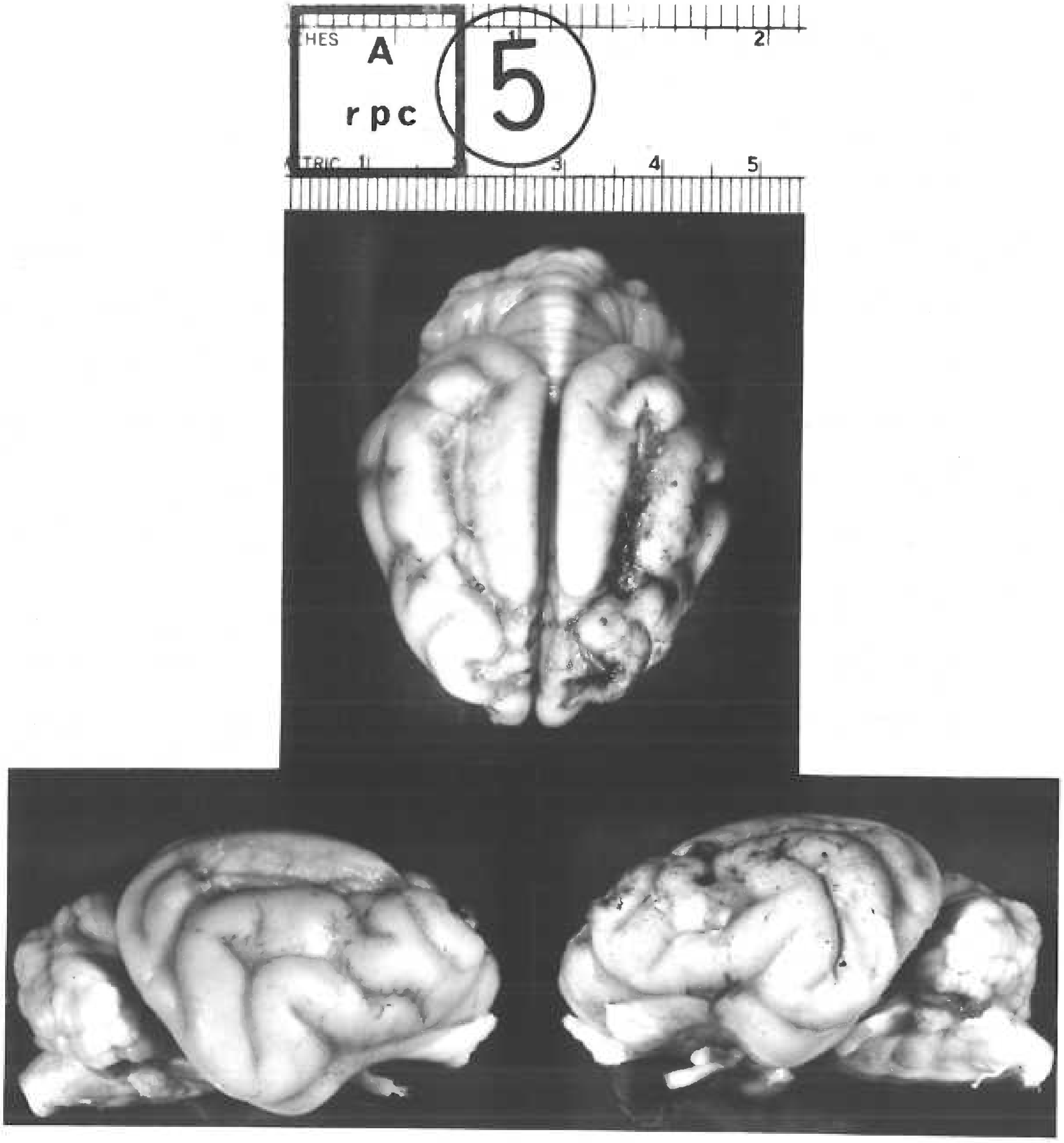

Figure 10

Animal: A-SPC #2

Operated: 9-14-62 Sacrificed: 4-2-63 Trained: 12-13-62 to 1-9-63

Days for acquisition to light: 21

Responses to extinction: Tone 1 Light 83

Description of Lesion:

Left Hemisphere: The middle suprasylvian gyrus shows loss of contour and substance. The lateral gyrus appears almost totally intact with the exception of the anterior 1/5th of its more lateral extent. The pericruciate areas seem totally ablated extending to and including the anterior cingulate gyrus.

Right Hemisphere: The middle suprasylvian gyrus shows loss of contour and substance. The lateral gyrus seems almost totally intact, again with the exception of its more medial extent. The pericruciate areas seem totally ablated down to and including the superior lip of anterior cingulate gyrus.

Comment:

The darkened portion of the left hemisphere is a result of an electrophysiological experiment which did not destroy the anatomy of the cortex. The lesion seems adequate with the exception of its lack of destruction of the anterior lateral sensory association areas.

FIGURE 10

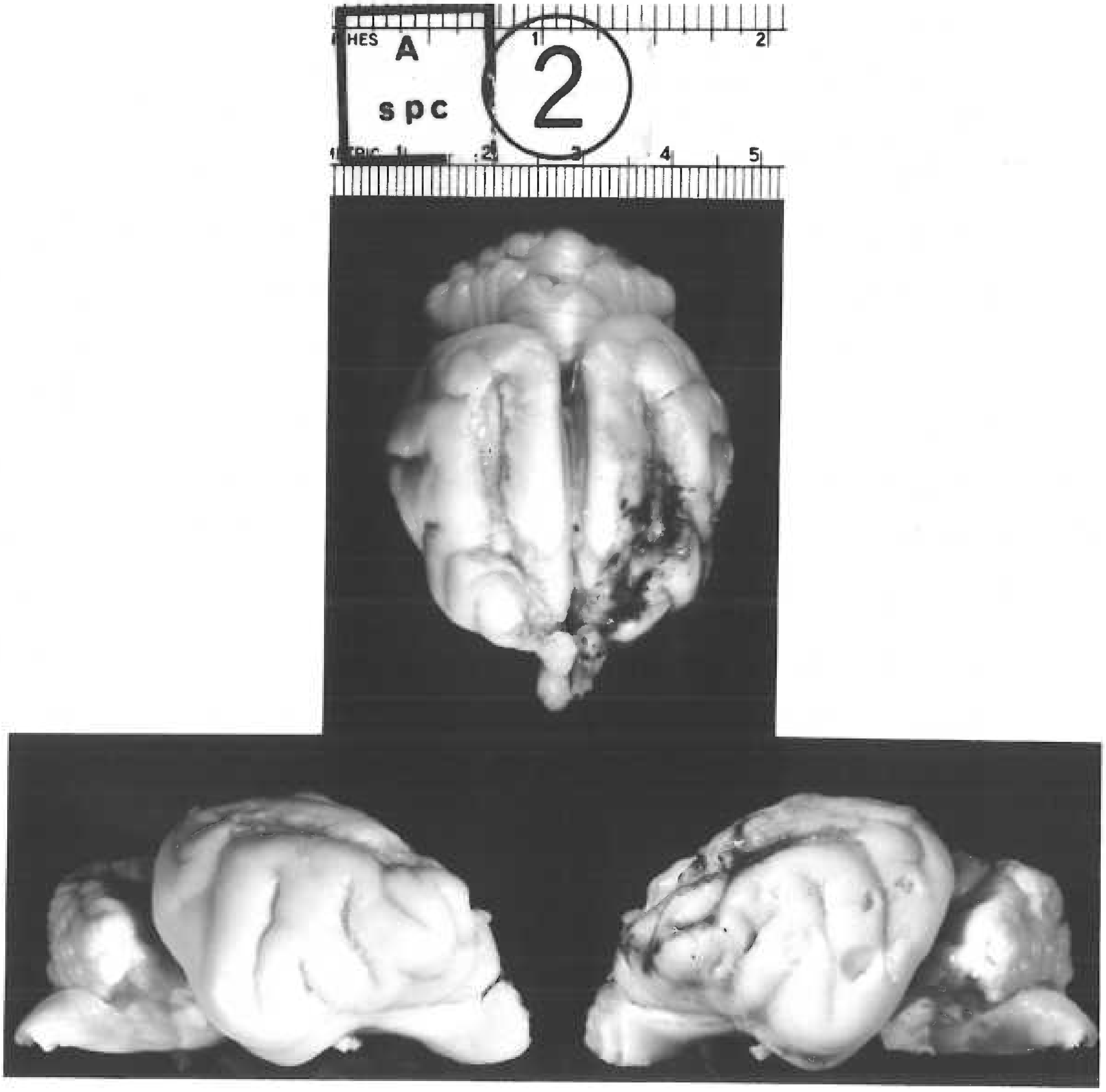

Figure 11

Animal: A-SPC #5

Operated: 1-2-63 Sacrificed: 4-18-63 Trained: 2-28-63 to 3-18-63

Days for acquisition to light: 15

Responses to extinction: Tone 1 Light 6

Description of Lesion:

Left Hemisphere: There is total loss of substance of the middle suprasylvian gyrus. There is total loss of substance of the anterior half of the anterior lateral gyrus extending to the midline and including the superior lip of cingulate gyrus. The pericruciate areas are totally ablated and include the anterior portion of the superior lip of cingulate gyrus.

Right Hemisphere: The middle suprasylvian gyrus is totally ablated with the exception of its posterior 1/4th. The lateral gyrus shows loss of substance in its anterior 1/5th. There is loss of the pericruciate areas medially to include both anterior and posterior aspects of the anterior cingulate gyrus.

Comment:

The darkened areas on the right hemisphere are the result of an acute electrophysiological experiment which did not disrupt the anatomy of the cortex. The lesion appears adequate with the exception of the right hemisphere sparring of the posterior 1/3rd of the middle suprasylvian gyrus.

FIGURE 11

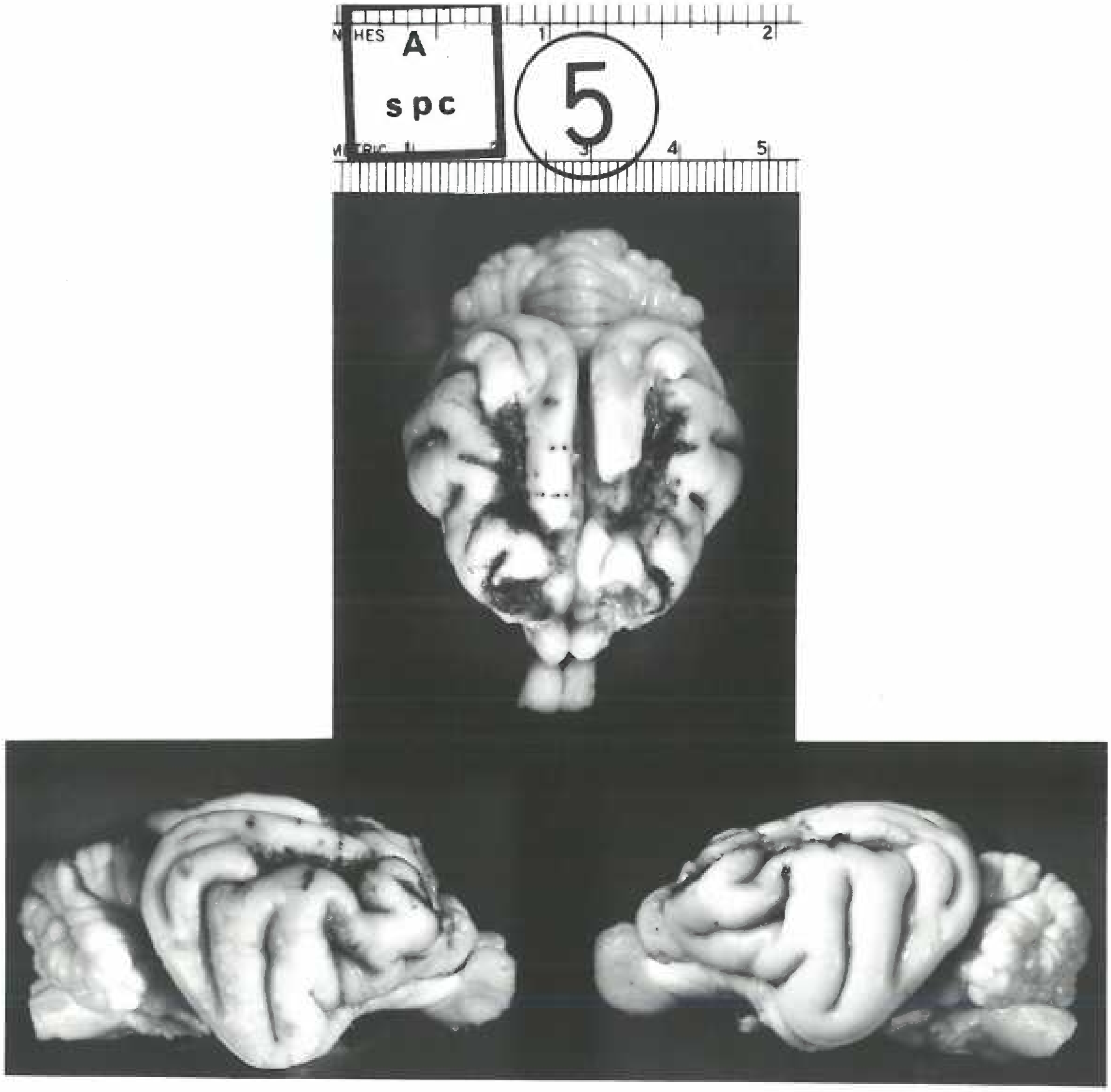

Figure 12

Animal: S-SPC #1

Operated: 1-10-63 Sacrificed: 4-15-63 Trained: 3-29-63 to 4-14-63

Days for acquisition to light: 13

Responses to extinction: Tone 5 Light 2

Description of Lesion:

Left Hemisphere: There appears to be loss of form and substance of the cortex in the following areas: Posterior suprasigmoid gyrus in its posterior 1/2 and medially to within 3 mm. of the midline; the anterior suprasylvian, anterior ectosylvian, and anterior sylvian gyri seem totally ablated, the lesion extends posterior-ventrally to the rhinal sulcus, and anteriorly to an imagined perpendicular from the middle of the coronal gyrus.

Right Hemisphere: The lesion extends medially to the midline, anteriorly to the cruciate sulcus, posteriorly to include the anterior half of the posterior suprasigmoid. The anterior suprasylvian, anterior ectosylvian, and anterior sylvian gyri appear ablated in total. The lesion does not extend ventrally beyond a horizontal perpendicular with the rhinal sulcus. Anteriorly the lesion does not extend beyond the midline of the coronal gyrus.

Comment:

The lesion appears to fulfill its intended extent with the exception of the more ventral portions of the right hemisphere.

FIGURE 12

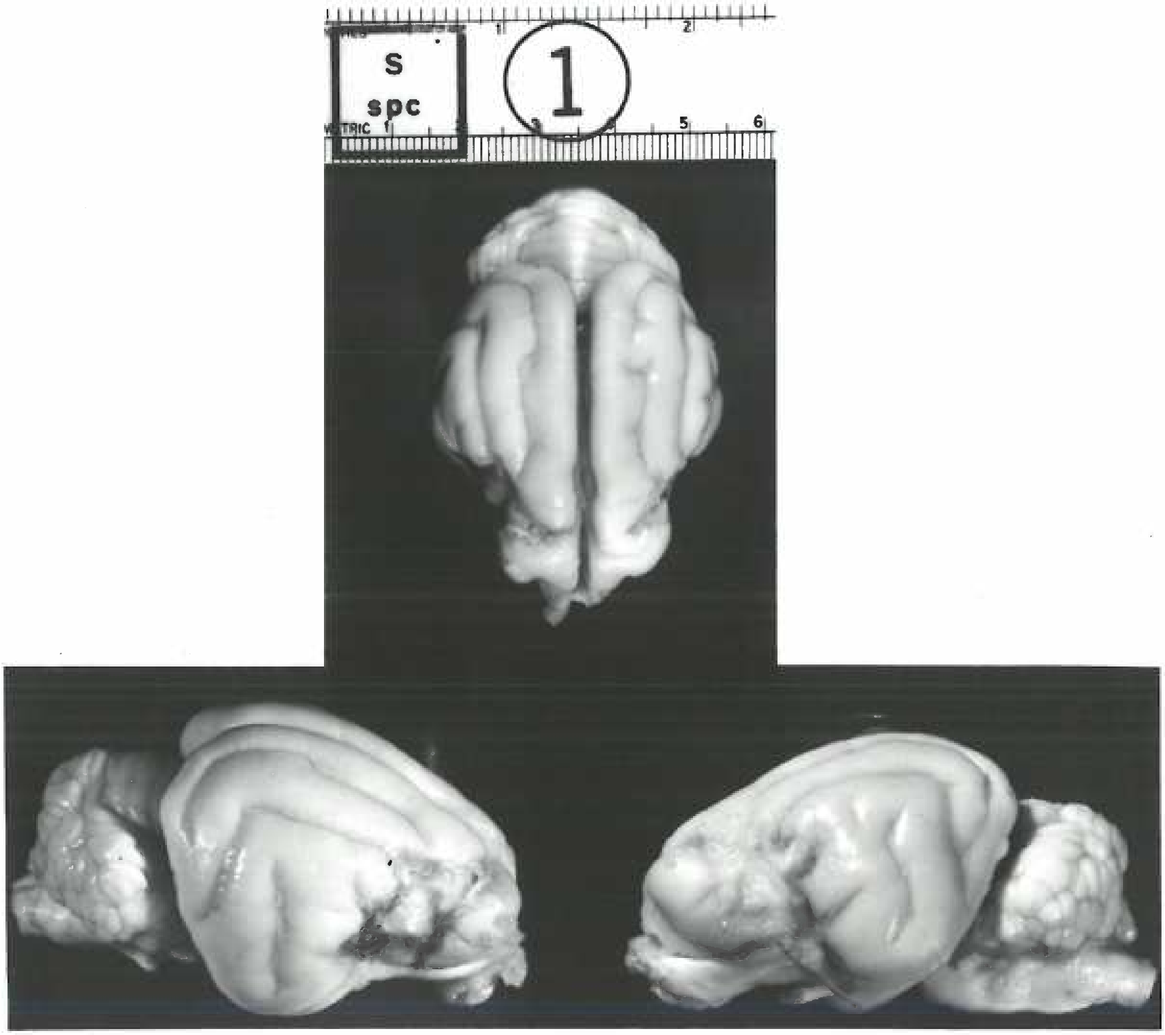

Figure 13

Animal: S-SPC #2

Operated: 1-11-63 Sacrificed: 4-2-63 Trained: 3-29-63 to 4-21-63

Days for acquisition to light: 14

Responses to extinction: Tone 14 Light 41

Description of Lesion:

Left Hemisphere: The posterior suprasigmoid gyrus appears involved in its posterior lateral 1/4th. There is loss of substance up to and including the anterior 1/6th of the lateral portion of the middle suprasylvian, the anterior suprasylvian, the anterior ectosylvian, and anterior sylvian gyri seem totally ablated. The ventral portion of the lesion extends to and 3 mm. below an imagined horizontal perpendicular across the rhinal sulcus and is anteriorly bounded by the posterior 1/3rd of the coronal gyrus.

Right Hemisphere: There appears to be loss of cortical substance to the posterior sigmoid gyrus which extends medially to within 3 mm. of the midline. There is total loss of the anterior suprasylvian, anterior ectosylvian, and anterior sylvian gyri. The lesion extends ventrally to and some 4 or 5 mm. below an imagined horizontal run across the rhinal sulcus anteriorly, the lesion extends to the anterior 1/3rd of the coronal gyrus.

Comment:

At operation this animal showed total ablation of the frontal synuses. The left hemisphere lesion shows some invasion of the middle suprasylvian gyrus. It also fails to extend anteriorly to the intended degree. The lesion of the right hemisphere seems adequate in extent.

FIGURE 13

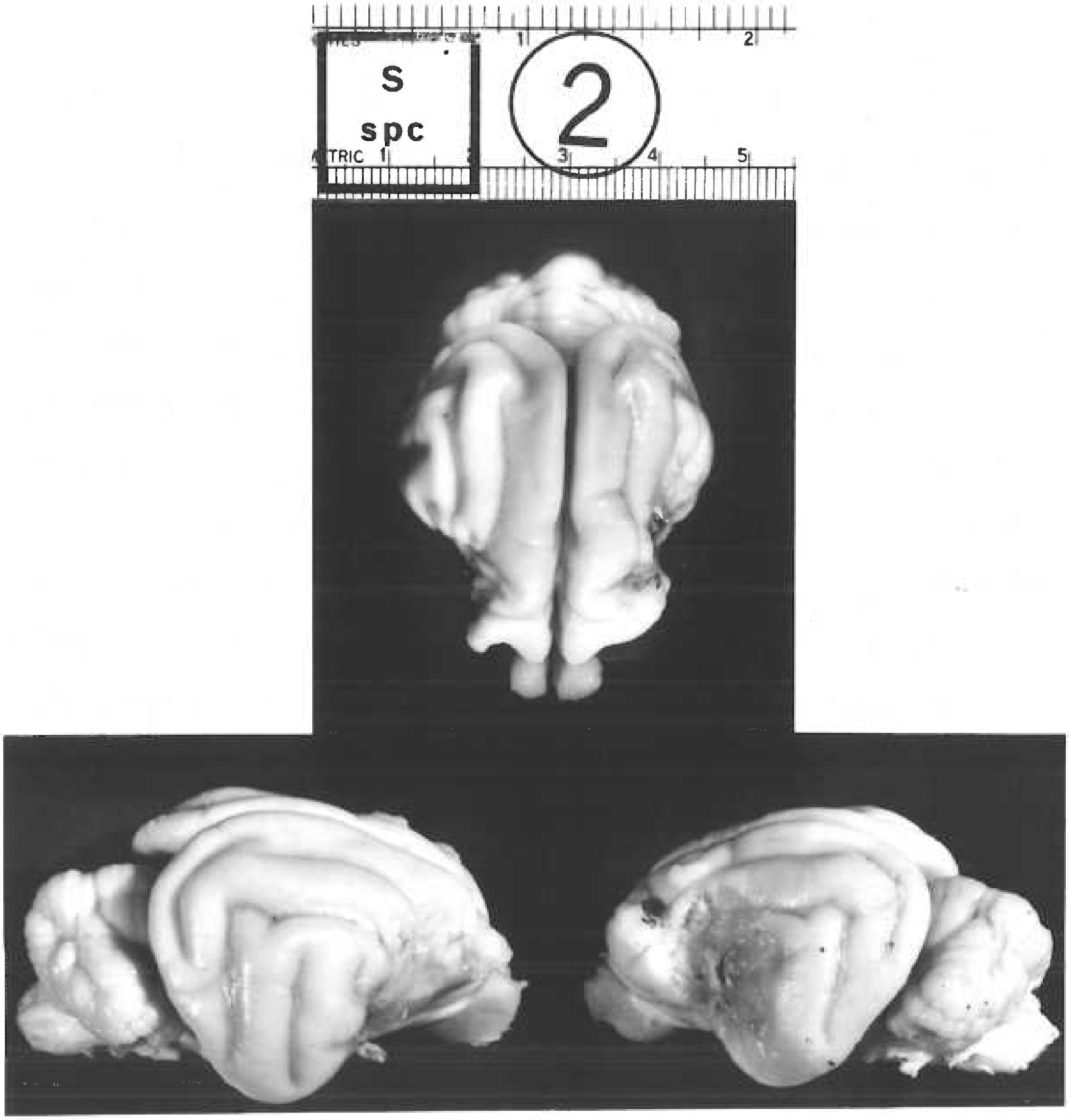

Figure 14

Animal: S-SPC #3

Operated: 1-15-63 Sacrificed: 4-20-63 Trained: 3-29-63 to 4-20-63

Days for acquisition to light: 12

Responses to extinction: Tone 14 Light 38

Description of Lesion:

Left Hemisphere: The anterior-medial area of the posterior supresigmoid gyrus appears ablated in its posterior 2/3rds. There is total loss of the anterior suprasylvian, anterior ectosylvian, and anterior sylvian gyri. The lesion extends ventrally to the tip of the temporal horn and anteriorly to a perpendicular from the boundary of the middle and posterior thirds of the coronal gyrus.

Right Hemisphere: There is loss of cortical substance to the lateral 2/3rds of the posterior supresigmoid gyrus. The anterior middle suprasylvian, and the anterior ectosylvian gyri are totally lost. The lesion extends ventrally across the rhinal sulcus. Anteriorly it is bounded by the posterior third of the coronal sulcus, posteriorly it invades the middle sylvian and middle ectosylvian gyri.

Comment:

The left hemisphere lesion appears adequate. The right hemispheric lesion appears to have invaded portions of the auditory cortex and does not extend to its intended degree anteriorly.

FIGURE 14

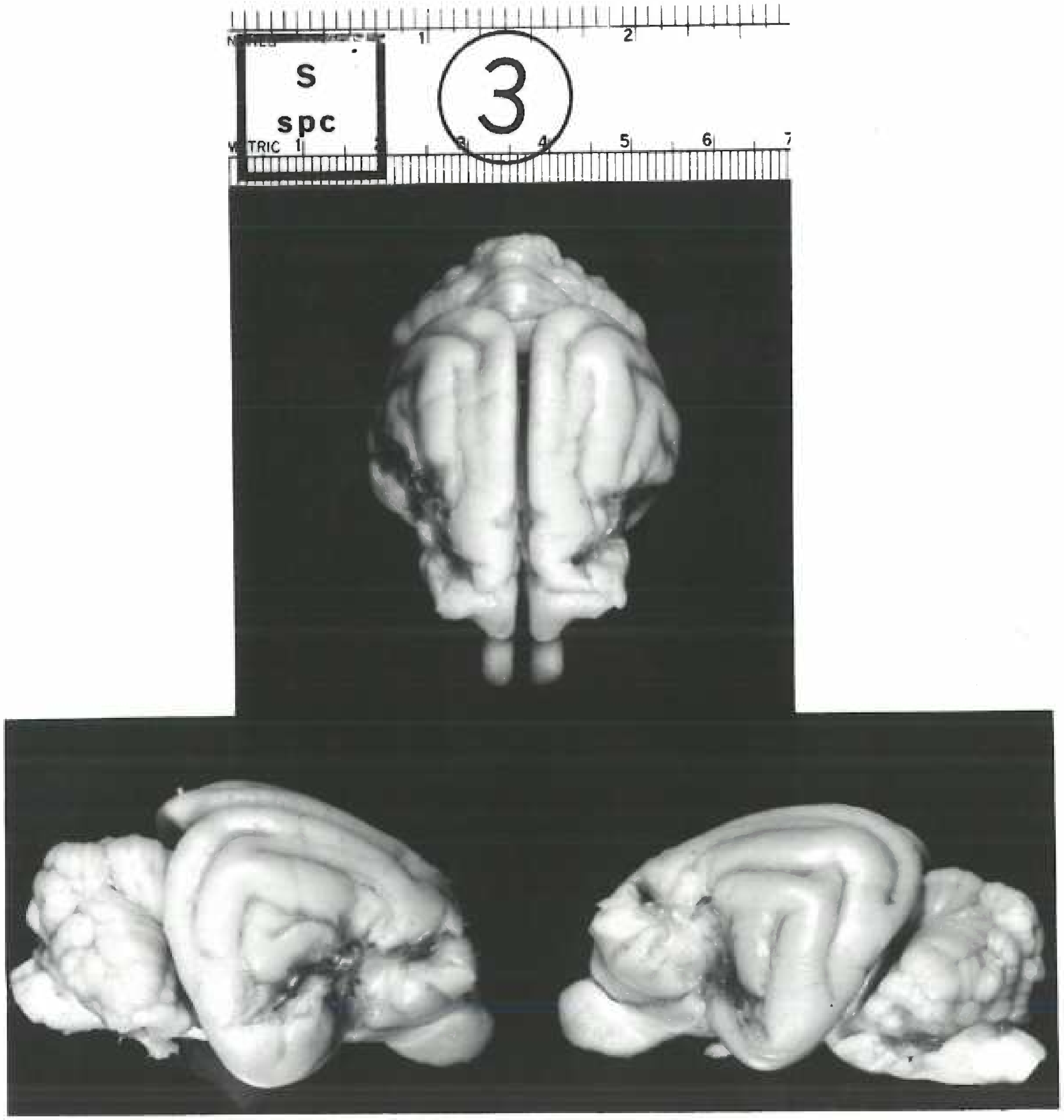

Figure 15

Animal: S-SPC #4

Operated: 2-4-63 Sacrificed: 4-15-63 Trained: 3-29-63 to 4-15-63

Days for acquisition to light: 7

Responses to extinction: Tone 18 Light 67

Description of Lesion:

Left Hemisphere: There is loss of substance at the lateral 1/4th of the posterior sigmoid. The anterior suprasylvian and anterior ectosylvian gyri are totally lost. Loss of substance extends down to but does not cross the rhinal sulcus. Anteriorly the loss of substance is bound by a perpendicular drawn from the middle portion of the coronal gyrus.

Right Hemisphere: There is loss of cortical substance on the lateral 1/5th of the posterior sigmoid gyrus, the anterior suprasylvian and and anterior ectosylvian gyri seem totally lost. This extends ventrally to but does not cross the rhinal sulvus. Anteriorly this loss is bounded by a line drawn at the perpendicular to the meeting of the posterior third and middle third of the coronal sulcus.

Comment:

The lesion seems somewhat inadequate in medial extent bilaterally. There is a questionable inadequacy of ventral extension of the lesion bilaterally.

FIGURE 15

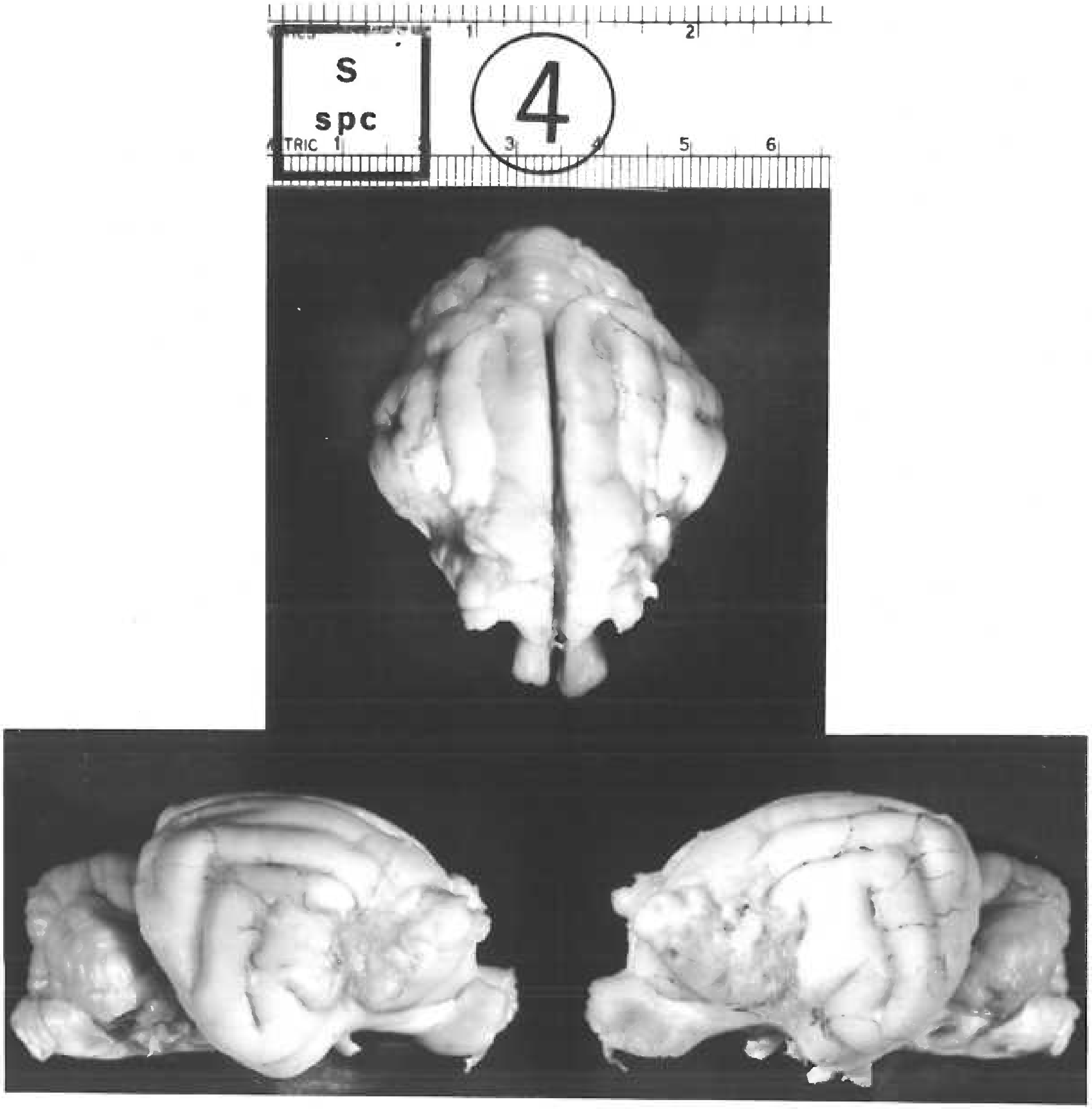

Figure 16

Animal: S-SPC #5

Operated: 2-5-63 Sacrificed: 4-20-63 Trained: 3-29-63 to 4-20-63

Days for acquisition to light: 20

Responses to extinction: Tone 4 Light 0

Description of Lesion:

Left Hemisphere: The posterior sigmoid gyrus seems involved in its lateral 1/5th. There is loss of substance to the anterior middle suprasylvian, anterior ectosylvian, anterior sylvian gyri. This extends ventrally to and some 3 mm across the rhinal sulcus. Anteriorly the lesion is bounded by a perpendicular drawn between the middle and posterior 1/3rd of the coronal gyrus.

Right Hemisphere: The posterior suprasigmoid seems to have lost substance in its lateral 1/5th. This loss of substance extends to the anterior suprasylvian, anterior ectosylvian, anterior sylvian gyri. Cortical destruction does not extend beyond the rhinal sulcus. Anteriorly this area does not cross the hypothetical perpendicular drawn between the posterior 1/4 and the anterior 3/4 of the coronal gyrus.

Comment:

The lesion seems adequate on the left hemisphere. The right hemisphere does not have the intended anterior destruction.

FIGURE 16