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THE EFFECT OF VENTRAL RHINENCEPHALIC LESIONS ON AVOIDANCE THRESHOLDS IN MONKEYS[1]

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Some theoretical and clinical interest has been centered lately on lesions in the region of the amygdaloid complex, since they seem to affect emotional behavior drastically. A recent study (5) suggests that such effects in monkeys can be greatly augmented by making a more extensive lesion that includes the posterior orbital region, the anterior insula, and the anteromedial portions of the temporal lobe (including the amygdala)—areas which, together, form a unit as defined by strychnine neuronography (4). One of the purposes of the present study was to attempt to confirm this finding more satisfactorily by including both categories of lesions—amygdala and orbito-insulo-temporal—within the same experimental program. A second purpose was to examine the permanence or maintenance of changes effected by the lesions. This aspect of avoidance behavior was not studied in earlier experiments in which only learning and extinction relationships were examined. Concomitantly, it was thought valuable to vary the actual reinforcement contingencies and manipulanda as much as possible from those of the earlier studies, while retaining the basic study of avoidance behavior, for only by such variation can an inference be made that a lesion has an effect on emotional behavior independently of the response requirements specific to a given situation. The present situation is one in which there should have been much less interaction between avoidance and locomotor responses than in the earlier studies.

METHOD

Subjects

Nine rhesus monkeys (*Macaca mulatta*) were used. Three (AM-188, S-194, and IT-196) had previously been used in an experiment involving panel-pressing for food reward, and transferred quite readily to panel-pressing for shock avoidance. The others had to receive preliminary training in the lever-pressing situation.

Apparatus

Two similar sets of apparatus were employed, both consisting of small cages in which a single manipulandum was available. In one, the manipulandum was a small rectangular panel on the front wall of the cage. In the other, it was a protruding lever. Both cages were in soundproof chambers, with masking noises provided by air blowers.

Brief shock pulses could be delivered to the animal through a low-resistance chain[3] attached to an aluminum collar fixed to the animal. During experimental sessions, the animal's chain was attached to a beaded-chain swivel, which in turn connected to an insulated fixture on top of the cage. The cage itself provided one pole of the circuit. The intensity of the shock could be controlled by means of a circuit, described elsewhere (9), consisting of a high-ratio transformer fed by a direct-current input, with a variable resistor shunted across the primary coil. Six values of shock, arbitrarily designated 1 to 6 in order of increasing intensity, were used. These values gave nearly equal increments in total electrical charge, except for the interval between shocks 5 and 6 which was approximately one-third the size of the other intervals. Shock 1, to humans, felt like a very slight tingle. Shock 6, which was painful, would jump an air gap of just under ½ in.

Avoidance and Escape Contingencies

These were of the sort first described by Sidman (7). A push of the panel (or press of the lever) delayed the occurrence of a shock pulse by 10 sec. Regardless of when a response occurred, the next shock would not be delivered until 10 sec. after the last response. Hence, if an animal pushed the panel at least once every 10 sec., it would never receive a shock. If, however, a shock was permitted to occur, the next shock would occur, not 10 sec. later, but 2½ sec. later, until the animal responded again, thereby delaying the next shock by 10 sec. In Sidman's terminology, these contingencies consisted of an R-S interval of 10 sec., and an S-S interval of 2½ sec.

Procedure

Surgical

Three types of bilateral resections were performed: OIT—posterior orbital region, anterior insula, and

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[3] "Quarter-inch retinned steel universal chain," manufactured by Turner & Seymour Mfg. Co., Torrington, Conn.

anteromedial temporal lobe; AM—anteromedial temporal lobe; IT Control—inferior temporal region. One animal received a sham operation (S), which consisted of exposing the posterior orbital cortex and gently retracting it without removal of neural tissue.

All surgical procedures were performed aseptically in one stage; anesthesia was induced by the intraperitoneal injection of pentobarbital sodium, and tissue was removed by suction. In the case of OIT, AM, and S operates, the zygoma was removed prior to removal of temporal bone in order to obtain a better exposure.

Anatomical

Following experimentation, all *S*s were sacrificed, their brains embedded in celloidin, and the blocks serially sectioned at 25 mμ. Every twentieth section was stained with aniline thionin, and every fourth stained section was used to make an orthogonal projection onto graph paper. Sections were examined microscopically for evidence of damage.

Since large numbers of reconstructions of each type of lesion are now available in the literature (OIT—3, 5; AM—6, 8; IT—1, 2), only one reconstruction per surgical group is portrayed here (Fig. 1). Deviations within each surgical group were small, and were not felt to warrant detailed description.

Training

Preliminary training. Animals were taught to respond by an adaptation of the conventional "shaping-up" procedures. Shock pulses were delivered to the animal until it moved to the general vicinity of the panel (or lever), when a rest period of roughly 20 sec. was given. Next, the animal was required to make responses successively approximating the operation of the manipulandum. This "shaping-up" required from four days to three weeks, with approximately ½ hr. of training daily. Animals were then required to reach a criterion of receiving less than ten shocks in both of two consecutive 30-min. sessions (with Shock Intensity 6).

Preoperative avoidance threshold. After reaching the above criterion, each animal was given an extinction session until 3 min. elapsed without response.

Then, beginning with the weakest shock, animals were tested at each shock intensity until either (*a*) 200 shocks were received within both of two consecutive sessions, or (*b*) a stability criterion based upon shock and

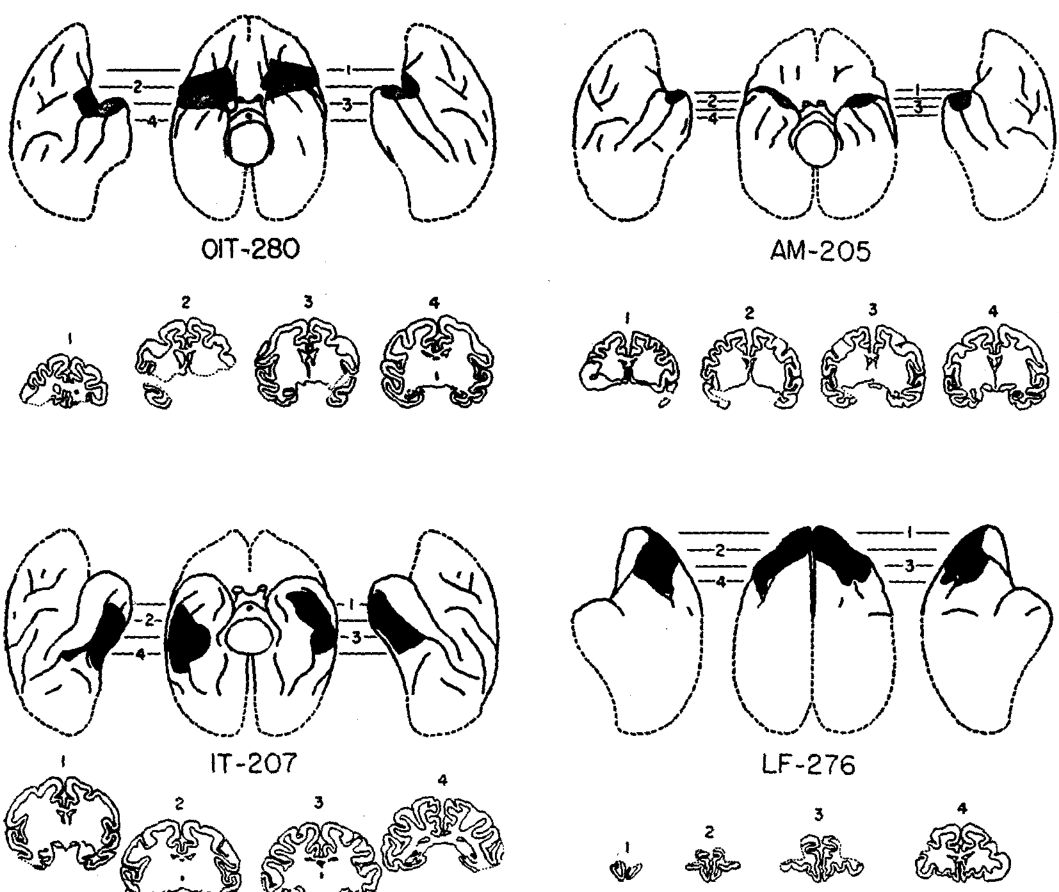

FIG. 1. Reconstructions and representative cross sections. One brain per operate group is shown.

response rate was achieved. In the event of *a*, the animal was tested at the next higher intensity. When the stability criterion was met, the intensity employed was defined as the animal's shock-avoidance threshold. The stability criterion required that out of five consecutive sessions, four of the five (including the first and the fifth) sessions had a response variation of no more than one-sixth *and* a shock-rate variation of no more than one-half.

Each session was 40 min. in duration, but the first 10 min. was ignored for purposes of calculation. This was done because it was found that the first few minutes consistently yielded a higher rate of response, which then sloped off to a slower and roughly steady rate of response for the duration of the session, as may be seen in illustrative curves published elsewhere (9). Each animal was tested twice daily.

Postoperative avoidance threshold. The *S*s were subjected to surgery after completion of the preoperative threshold procedure. Postoperatively, the same sequence was followed: an extinction session, followed by avoidance-threshold determination. Such testing began one week following surgery. Three animals were given only a single postoperative determination; the remainder were given four determinations, each preceded by an extinction run.

Other Procedures

All the animals participated in another brief experiment which consisted of the administration of reserpine, pentobarbital sodium, and isotonic sodium chloride (9). This procedure, which extended over a week's time, was carried out after completion of the preoperative threshold determination and after the first postoperative threshold.

RESULTS

First Postoperative Threshold

Figure 2 contains a representation of all the pre- and postoperative thresholds of each animal. The first postoperative threshold for both of the OIT operates, and for one of the three AM operates, were greater than their preoperative ones. All the controls had a *lowered* threshold, except for IT-208, whose preoperative threshold was already at the minimum value of "1." When our hypothesis that OIT > AM > Control is assessed with respect to these pre-post differences, Whitney's (10) three-sample test for ranks yields a significance of .01.

In order to deal with a more general measure of the animal's performance over the entire range of shock values given both preoperatively and on the first postoperative run, an index was computed for each animal for response rate and for shock rate. This index was defined as the ratio of the difference between the

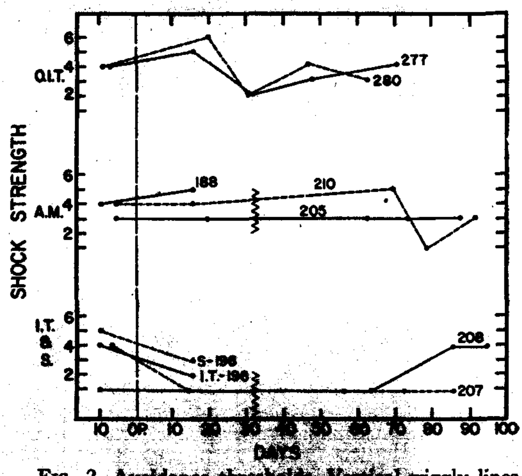

FIG. 2. Avoidance thresholds. Vertical wiggly lines through some of the AM and IT curves indicate occurrence of another brief experiment not reported here.

preoperative and the postoperative rates to the sum of these rates computed separately for each intensity and then averaged, or,

$$\text{R.I.} = \sum \frac{(\text{Postop Rate } S_i - \text{Preop Rate } S_i)}{(\text{Postop Rate } S_i + \text{Preop Rate } S_i)} \Big/ N_s$$

Using this measure, which is plotted in Figure 3, it is found that the OIT operates decreased greatly in response rate, the AMs decreased slightly, and all control operates increased in response rate. Similar indices based on shock rates show comparable results. The null hypothesis can be rejected at the .001 level either for response rate or shock rate.[4]

Subsequent Thresholds

The changes seen on the first postoperative run were not sustained. In particular, the OIT operates displayed a sharp reversal on the next run, having thresholds well below their

[4] Two additional animals, subjected to lesions of the lateral frontal cortex (as shown in Fig. 1) were run through the experimental procedure to test the suggestion (5) that the impairment of frontals in relearning to avoid shock in a shuttle box is due to their locomotor hyperactivity. On all measures these animals overlapped with the control group *and* the AM group. The results, particularly the response-rate indices (LF-276, +.399; LF-279, −.354), suggest that different changes follow for individual LF operates, depending on whether their hyperactivity happens to conflict or to summate with bar-pressing.

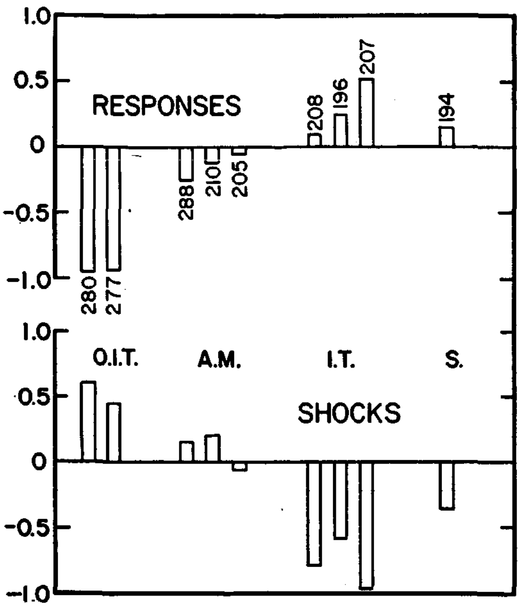

FIG. 3. Rate indices. Top graph is response rate, bottom is shock rate.

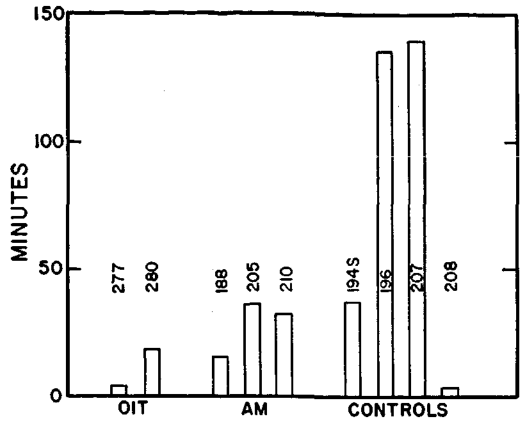

FIG. 4. Postoperative extinction to a criterion of 3 min. without response.

preoperative levels, which then increased on the final two runs. The other groups tended to remain at more or less the same level, although it is interesting to note the sudden drop in threshold for AM-210 on the third postoperative run.

Postoperative Extinction

Since earlier studies of ventral rhinencephalic lesions have found an increased rate of postoperative extinction for preoperatively acquired avoidance behavior (5, 8), it is of interest to examine the comparable extinction run in the present study, i.e., the first postoperative extinction session, which occurred prior to the threshold sessions. Figure 4 is a plot of these extinction times (including the criterion times). The general order of speed of extinction is in line with our hypothesis that OIT > AM > Control, and the null hypothesis may be rejected at the .05 level.

Attention is drawn to IT-208, which showed an extinction score of 3 min. (i.e., immediate extinction). When this animal was placed in the experimental cage for the extinction run, it appeared to be quite frantic, climbed up the side of the cage opposite the lever, and rocked the entire apparatus vigorously. This continued for the entire 3-min. period, without a single lever response. When tested the next day for shock, *S* showed an abnormally high rate of response after a similar sort of initial "fit" in the apparatus. If this behavior is interpreted as abnormally strong emotional behavior which interfered with integrated avoidance-responding, the extinction score misrepresents the behavior. The fact that extinction is sensitive to such influences as these lessens its value as an analytical tool.

DISCUSSION

Concerning the relationship between the relative effects of OIT and AM lesions, this study supports the inference from earlier studies that the OIT effects are more severe than the AM effects, which are distinguishable in turn from control performance. The question as to whether or not the relationship is simply one of mass action, however, cannot be resolved until a larger variety of subtotal lesions is made within the OIT unit.

The finding of an increased avoidance threshold for OIT operates on the first postoperative run, followed by a sharp reversal on the next run, raises an interesting problem of interpretation. It could be, of course, that avoidance threshold is simply a function of the interval following surgery. Equally plausible, however, is the assumption that the two successive thresholds are not independent, that the "flop" of the "flip-flop" occurred because of testing for the earlier "flip." Such an assumption might follow if it were assumed that the basic deficit produced by OIT lesions was a difficulty in the formation and maintenance of the association between secondary and primary reinforcing stimuli—a view forwarded elsewhere (8). In the present situation, the animal had to relearn (following extinction) that any behavior exclusive of lever-pressing was aversive. An impairment in such learning would result in a much higher shock rate (as was the case; Fig. 3, bottom), so that by the time learning had occurred, a much higher level of anxiety would have been generated to motivate subsequent behavior, with gradual subsiding to a control level. The explanation assumes that neither the animal's sensitivity to electric shock nor the aversive role of shock had altered—which appeared to be borne out by gross observations. But more sensitive experimental analysis of these points remains to be performed.

The explanation outlined would place less stress on "threshold of anger," "threshold of pleasure reaction," than is sometimes customary in referring to rhinencephalic lesions, although it would predict that an increased avoidance threshold would appear under most of the conditions prevailing when such descriptions are apt to be made. Only a rather careful experimental analysis could tease apart differential predictions for the "learning deficit" vs. "avoidance threshold" hypotheses, but such an analysis is essential for further elaboration of the role of the ventral rhinencephalic areas.

SUMMARY

Animals were trained in a Sidman avoidance situation, in which a lever-press delayed the occurrence of an electric shock. The intensity of the shock was varied to find the "avoidance threshold." The *S*s were then given bilateral lesions in the orbito-insulo-temporal region (OIT), the amygdaloid region (AM), or control inferotemporal or sham operations. After an extinction series, avoidance thresholds were again measured postoperatively. The following results were obtained.

1. Both in terms of the first postoperative avoidance threshold and in terms of a general index of response and shock rates, the OIT group showed less avoidance than the AM group, which in turn showed less than controls.

2. This order tended to be supported by the postoperative extinction results, but they did not achieve high statistical significance.

3. The OIT group, after demonstrating a raised threshold on the first run, showed a threshold even below the preoperative value on the second run. It is suggested that this reversal can be accounted for in terms of a relearning deficit.

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