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DISCRIMINATION ALONG A SIZE CONTINUUM FOLLOWING ABLATION OF THE INFERIOR TEMPORAL CONVEXITY IN MONKEYS[1]

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Several recent studies (reviewed in 3) have demonstrated marked impairment of visual discrimination in monkeys with temporal lobe lesions. This evidence presents difficulties for theory which accords an exclusive role in vision to the geniculo-striate system. One suggestion, made tenable by the absence of visual field defects in temporal operates, has been that damage to the temporal lobes interferes with an essential nonvisual function, termed a "comparison attitude" or "comprehension of the total training situation" (2), rather than with visual processes directly. In support of this hypothesis Lashley (2) has cited data, gathered by Chow (1), which demonstrate that monkeys trained postoperatively on new visual discriminations show recovery of other discriminations acquired prior to operation; without such training, reacquisition of the preoperative discriminations is retarded. Since the additional experience was provided on *new* tasks, the rapid recovery on the original tasks suggested transfer of a reacquired set—"perception" of the discriminanda, or "memory" for the rewarded stimulus, having been unaffected by the surgery.

Other evidence, however, opposes such an interpretation. Riopelle and Ades (7), and the senior author (4), have shown that temporal operates may learn or relearn an easy visual discrimination as quickly as controls, thereby demonstrating successful adaptation to the experimental procedure, yet subsequently show marked deficit in the learning or retention of a more difficult visual problem. These results were obtained in studies which employed a series of qualitatively different visual discriminations (of objects, hue, brightness, and pattern), and it might be argued that the training which the operates received in discriminating stimuli differing in a particular dimension did not provide the appropriate set for the discrimination of stimuli differing in another, perhaps more complex, dimension. The present experiment attempted to avoid this difficulty by providing preliminary training on a discrimination qualitatively *similar* to the test discriminations, the stimuli for all these tasks differing only along the dimension of size. Under such conditions, training to criterion on the first stimulus pair should, presumably, insure both adequate "comprehension" of the situation and the proper "comparison attitude" for discrimination of the other stimulus pairs in the series.

In an attempt to verify results obtained previously on transfer between qualitatively *different* discriminations, the animals were presented with a visual pattern discrimination after they had received the discriminations along the size continuum.

METHODS

Subjects

Six immature rhesus macaques, naive with respect to discrimination training, served as *S*s for the entire experiment. An additional group of 15 naive rhesus macaques was trained on the visual pattern discrimination only.

Apparatus

The apparatus has been described previously (5). It consisted essentially of an enclosure for the animal cage; a testing tray with two food wells, each 1¼ in. in diameter, spaced 18 in. apart; a vertical sliding panel which concealed the baiting of the food wells; and a one-way-vision screen which concealed *E*.

Size Discrimination

Initial training. Two animals with ablations of the inferior convexity of the temporal lobes (IT-55 and IT-58, "post-post" group) and four nonoperate controls (N-39, -56, -57, and -63) were trained to discriminate between discs 3 in. and 6 in. in diameter. (IT-55 and IT-58 were started on the problem 35 and 10 days after operation, respectively.) The incentive was a peanut concealed beneath the smaller disc. The

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two discs, cut from Beaverboard and painted flat black, were placed in random sequence over the two food wells. Thirty trials a day were presented until the animal attained a run of 25 consecutive successes.

First run. The 3-in. disc (consistently rewarded) was then paired successively with a 5-, 4-, 3½-, 3¼-, 3⅛-, 3$\frac{1}{16}$-in., and finally another 3-in. disc (consistently unrewarded), a single pairing being presented on two successive days for 25 trials a day. This procedure, beginning with the 3-in. vs. 5-in. discrimination, was then repeated so that each animal received a total of 100 trials on each of the seven pairings over a period of 28 days of testing. In order to prevent response to irrelevant aspects of the stimulus plaques, several discs of each size were prepared and frequently repainted so that no animal received the identical disc a second day.

Retraining and second run. The inferior convexity of the temporal lobes was ablated in two of the original controls (now IT-57 and IT-63, "pre-post" group), and after a ten-day recovery interval all six animals were retrained in a manner duplicating the initial-training and first-run procedures.

Pattern Discrimination

Following the second run on size discrimination all 6 animals were trained to discriminate a plus sign from an outline square. The discriminanda, each with an area of 3 sq. in., were painted yellow on 3-in. by 4-in. gray plaques. The animals received 30 trials a day on this task until they achieved a criterion score of 90 correct in 100 consecutive trials. Fifteen unoperated monkeys that had not had any previous discrimination training were presented with the same pattern discrimination. A comparison between the learning scores of these 15 naive animals and the scores of the 6 sophisticated animals permitted an evaluation of the effects of intensive size-discrimination training, with and without operation, on the formation of a qualitatively different discrimination.

Anatomy

General surgical and anatomical procedures were the same as those described previously (4), with the exception that the bilateral removals were performed in one stage instead of two. The lesions, shown in the

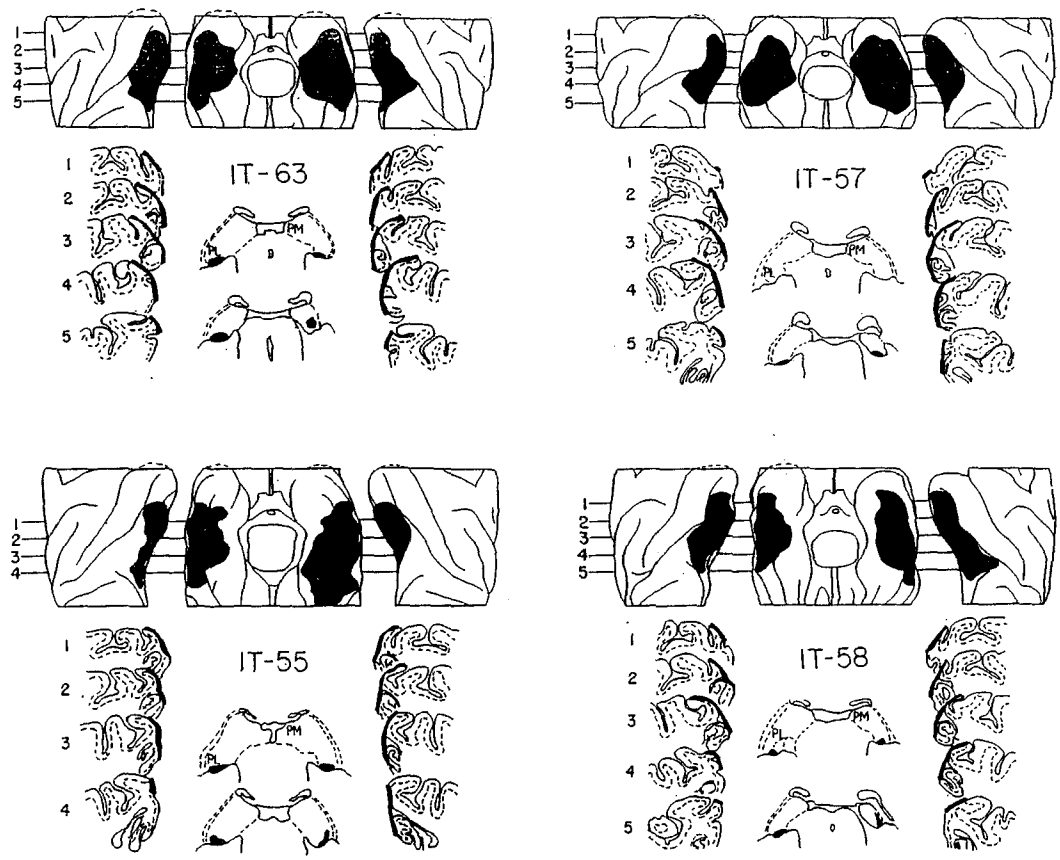

FIG. 1. Reconstructions of lesions. The ventral views are bounded by the lateral views of the corresponding hemispheres. Frontal and occipital lobes are not shown. The cross sections, numbered according to anterior-posterior position, are to be read from top to bottom, in reference to the lateral surface reconstructions placed directly above. The cross sections through the posterior thalamus are labeled *PL* for *pulvinaris lateralis* and *PM* or *pulvinaris medialis*. Black in the reconstructions and cross sections indicates damage; in the thalamus, degeneration.

reconstructions of Figure 1, are similar in locus and extent to those reported in the earlier study. To describe this locus, however, the term "inferior temporal convexity" is used in preference to the earlier designation "ventral surface," since both lateral *and* ventral views are necessary for a complete representation of the lesion. It can be seen from the reconstructions and cross sections that the pole, the banks of the superior temporal sulcus, and the hippocampal formation remained intact.

Retrograde thalamic degeneration is minimal and limited to the ventral portion of the posterior sections of the pulvinar. There is no evidence of degeneration in the lateral geniculate bodies.

RESULTS

Size Discrimination

Scores for initial learning of the 3-in. vs. 6-in. comparison are given in Table 1. Although the post-post operates made approximately twice as many errors as the controls, all the animals attained criterion rapidly. A comparison of these scores with the mean score of the 15 naive nonoperates on the plus-square discrimination (see Table 1) indicates that the discrimination of a 3-in. from a 6-in. disc is a relatively easy task. This conclusion is confirmed by the finding of perfect retention on this problem for the pre-post operates (as well as the post-post operates and nonoperates) after the ten-day recovery interval.

TABLE 1

Learning Scores on Size and Pattern Discriminations for All Groups

Group	Size Discrimination				Pattern Discrimination	
	Initial Training		Re-training		*Initial Training*	
	Trials	Errors	Trials	Errors	Trials	Errors
Nonoperates (pre-pre)						
N-56	78	20	0	0	150	68
N-39	89	28	0	0	120	61
Operates (pre-post)						
IT-63	58	23	0	0	520	210
IT-57	74	27	0	0	680	258
Operates (post-post)						
IT-55	107	46	0	0	220	92
IT-58	211	66	0	0	470	204
Naive nonoperates (N = 15)						
Mean					260	119
Range					130–510	51–245

Note.—Scores are trials and errors *preceding* criterion. For the 3-in. vs. 6-in. size discrimination the criterion was 25 correct in 25 consecutive trials; for the plus vs. square painted-pattern discrimination it was 90 correct in 100 consecutive trials.

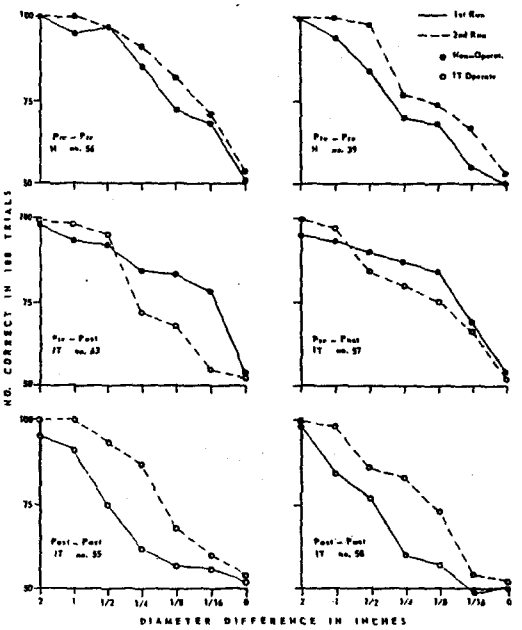

FIG. 2. Scores for each of six animals on first and second runs of size discrimination. The discrimination level *2* denotes the 3-in. vs. 5-in. pairing; *1*, the 3-in. vs. 4-in. pairing; etc.

Performance curves for each of the six animals on both the first and second runs are shown in Figure 2. It may be noted that the successive differences between the 3-in. disc and the others form a geometric progression; for convenience, the six levels of discrimination are plotted as equidistant, with the 3-in. vs. 3-in. pairings (designated as "0" difference in the figure) included for comparison. Performance on 3 in. vs. 3 in. was close to chance, suggesting that the experimental conditions were adequately controlled.

Figure 3 compares the first-run performance of each of the two post-post operates with that of the four controls. Both groups achieved nearly 100 per cent accuracy on 3 in. vs. 5 in., gradually diverged to a maximum separation at 3 in. vs. 3¼ in., and converged again to chance scores at 3 in. vs. 3 in. The inverse sine transformation was applied to the scores for each of the six discrimination levels, and these transformed data were entered in an analysis of variance. The results indicate that the difference between the operate and control groups (F = 3.78 with 1 and 4 df) and the differences

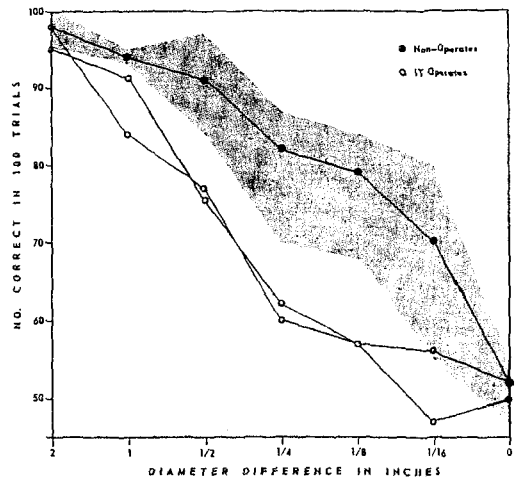

FIG. 3. Scores for two operates and four controls on the first run of size discrimination. Shaded area indicates the range of performance of the four nonoperate controls.

among the six discriminations (F = 37.60 with 5 and 20 df) are significant beyond the .01 level. The group-by-level interaction does not attain significance (F = .78 with 5 and 20 df), suggesting that the operates performed more poorly than controls throughout the range of discriminations studied. It should be noted that a significant interaction in the raw scores may have been eliminated as a result of the transformation.

Changes in performance from the first to the second run for the three groups—nonoperate controls, pre-post operates, and post-post operates—may be determined from an inspection of Figure 2. Whereas all groups showed gains in discriminating large differences, only the controls and post-post operates continued to improve as the difficulty of the discrimination increased; the pre-post operates, in contrast, showed a decrement in performance at the more difficult levels. An analysis of variance was performed on the differences between the transformed first-run and second-run scores, for each of the last five discrimination levels. (Inclusion of the first level—3 in. vs. 5 in.—would have biased the scores of the nonoperates in the direction of no change, since both animals attained 100 per cent correct on both runs.) The results of the analysis of variance indicate that the difference among the groups is significant beyond the .05 level (F = 24.87 with 2 and 3 df); t tests run for individual comparisons show that the difference between the post-post operate and control groups is not reliable, but that both groups differ reliably from the pre-post operates (t = 3.00 and 2.35, respectively, 3 df, one-tailed test; p = .05). The other comparison which attains significance is that among the discrimination levels (F = 4.70 with 8 and 12 df; p = .05), indicating that changes in performance varied with the difficulty of the tasks. The absence of significant interaction between groups and levels (F = .96 with 8 and 12 df), despite a suggestion of such interaction in the raw scores (see Fig. 2), may again be the result of the transformation.

Pattern Discrimination

Trial and error scores of the six animals on the plus-square pattern discrimination are presented in Table 1. It may be noted that there is no overlap among the scores for the three groups, the nonoperates learning most quickly, the post-post operates next, and the pre-post operates last. Comparisons between the performance of each of these groups and the performance of the 15 naive, unoperated animals show that the nonoperates fall at the lower extreme of the distribution of naive normals, the post-post operates are well within the range, and the pre-post operates are slightly retarded, falling at the upper extreme of the distribution for the naive control group. The probabilities of the nonoperates and pre-post operates obtaining such extreme trial scores by chance are .05 and .01, respectively (two-sample test [6]).

DISCUSSION

Results on the 3-in. vs. 6-in. size discrimination confirm an earlier observation (5) that temporal lobe damage may have no demonstrable effect on retention of an easy visual task, and yet produce impairment in the initial learning of that task. The learning deficit found in the present study was slight, however, and in both initial training and retraining all animals were brought quickly to a level of 100 per cent correct before they were presented with the discrimination continuum. To maximize the opportunity for positive transfer, the difference between the rewarded and unrewarded discs was reduced by a series of small

steps. The operates continued to discriminate throughout this series, their performance indicating a gradual, rather than an abrupt, transition from perfect scores to chance. Nevertheless, the performance of the post-post operates on the first run, and of the pre-post operates on the second run (as compared with their performance on the first), fell significantly below the equivalent measures for the nonoperate controls. This finding, which may be expressed as an increased difference limen for visual size, demonstrates that temporal operates may show impairment on a discrimination continuum even after they have been trained to discriminate stimuli differing in the relevant dimension.

The intensive training provided on the size discriminations did appear to facilitate the post-post operates' performance on the pattern discrimination, their learning scores falling well within the range of scores obtained by naive, *unoperated* animals. However, the two nonoperate controls learned significantly more rapidly than the naive animals, maintaining their superiority over the operates. Without the nonoperate controls the results might have led to the erroneous conclusion that training operated animals on one task produced complete recovery in their performance on another.

The implication of these results is not that the temporal operate's performance is permanently impaired (a more extended testing period would be required to clarify this point), but, rather, that a general readaptation to training is insufficient to overcome the deficit.

SUMMARY

The purpose of the study was to determine whether or not impairment in the visual discrimination performance of temporal operates could be overcome by preliminary training with stimuli qualitatively similar to the test stimuli. Two operated and four control monkeys were trained to discriminate a large difference in visual size and were then presented with a graded series in which this difference was gradually reduced. Following this training, two of the original controls were operated and all six animals were retrained on the largest difference before receiving the discrimination continuum a second time. Although the temporal operates rapidly attained the criterion of 100 per cent correct on the initial size discrimination, their scores on the subsequent size discriminations fell significantly below the scores achieved by the nonoperate controls. This impairment may be expressed as an increased difference limen for visual size. The results are interpreted as providing evidence against the view that a loss of a "comparison attitude" or of "comprehension" of the training situation accounts for the impairment in the visual discrimination performance of temporal operates.

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