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Reprinted from THE JOURNAL OF COMPARATIVE AND PHYSIOLOGICAL PSYCHOLOGY
Vol. 48, No. 3, June, 1955 *Printed in U.S.A.*

SIMULTANEOUS AND SUCCESSIVE VISUAL DISCRIMINATION BY MONKEYS WITH INFEROTEMPORAL LESIONS[1]

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Impairment in the performance of visual discriminations following inferotemporal cortical resections appears to be related to the parameter of "difficulty" (3, 5, 7), difficulty being defined in terms of the performance scores achieved by a control group on a given series of tasks. In a recent experiment (4) the difficulty of a discrimination was gradually increased by varying the physical dimensions (size) of the discriminanda: Although the animals with inferotemporal resections achieved perfect scores on the initial discrimination, they showed a decrement in performance (compared with controls) when the difference between the stimuli was reduced. The present experiments were designed to investigate whether such decrement occurs only when difficulty is a function of the physical dimensions of the discriminanda, or whether the impairment may be revealed, as well, when difficulty is a function of certain "situational" variables which determine the differential response. In the two experiments reported below all animals were first trained to criterion on a particular discrimination and then transferred to one or more variations of that discrimination using the *identical* discriminanda.

METHOD

Subjects

In the first experiment nine immature rhesus monkeys were used; in the second experiment six of these monkeys plus four others served as *S*s. All animals were trained in apparatus described previously (5).

Procedure

Experiment 1. The nine *S*s were divided into three groups of three animals each. All groups were trained, with the rerun correction technique, to a criterion of 90 correct in 100 consecutive trials, in the discrimination of a plus vs. a square each painted yellow on a gray background. To two of the groups (*S*s 4, 15, 26 and 2, 3, 5) the discriminanda were presented simultaneously: correct choice, rewarded with food, depended on opening that one of two containers covered by the plus sign. To the third group (*S*s 51, 52, 54), the discriminanda were presented successively: correct choice depended on *opening* the single centered cup (baited) when it was covered by the plus sign, and *not opening* the single cup (unbaited) when it was covered by the square ("go-no-go"). Animals were permitted 5 sec. in which to respond. The correct "no go" responses were not rewarded (except by termination of the correction trials). Following the training in the initial discrimination each group was given the other discrimination, i.e., the animals trained first in the simultaneous procedure were then trained in the successive, and conversely.

After the preoperative training had been completed all animals were subjected to bilateral one-stage cortical resections. The "successive-simultaneous" group and one of the "simultaneous-successive" groups received inferotemporal lesions; the other "simultaneous-successive" group received anterolateral-frontal lesions. The surgical and anatomical methods have been described elsewhere (3). Reconstructions of the temporal removals are shown as the first six diagrams in Figure 1. The figure also shows representative cross sections through the lesions and enlarged sections through the thalami. Reconstructions of the frontal lesions are reported separately (6).

Postoperatively, all groups were retested on both discriminations, presented in the preoperative order.

Experiment 2. The ten *S*s were divided into three groups. Four monkeys (*S*s 4, 15, 26, 37) had received bilateral inferotemporal resections; four (*S*s 2, 3, 5, 11) had received bilateral anterolateral-frontal resections; and two animals (*S*s 31, 36) served as nonoperated controls. (Three of the temporal and three of the frontal operates had comprised the two groups given identical training in Experiment 1.) Reconstructions of the lesions of the inferotemporal operates are shown as the last four diagrams in Figure 1. Those of the frontal controls are reported separately (6).

In the present experiment all groups were trained in the same manner. The discriminanda, a tobacco tin and an ash tray, were presented in three different situations: (*a*) simultaneously, choice consisting of opening one of two containers covered by the stimuli; (*b*) successively, choice consisting of opening or not opening a single centered cup covered by the single stimulus ("go-no-go"); and (*c*) successively, as heretofore, with a single stimulus presented in the center, but with opportunity for response the same as in the simultaneous procedure, i.e., opening the right or left of two simultaneously presented containers ("conditional").

Animals were trained with the rerun correction technique, and were permitted 5 sec. in which to respond.

[1] We wish to express our appreciation to Mrs. Marilyn Tucker and Miss Lila Rupp for their technical assistance and to the Department of the Army which, through grant No. DA 49 007-MD 401, made this study possible.

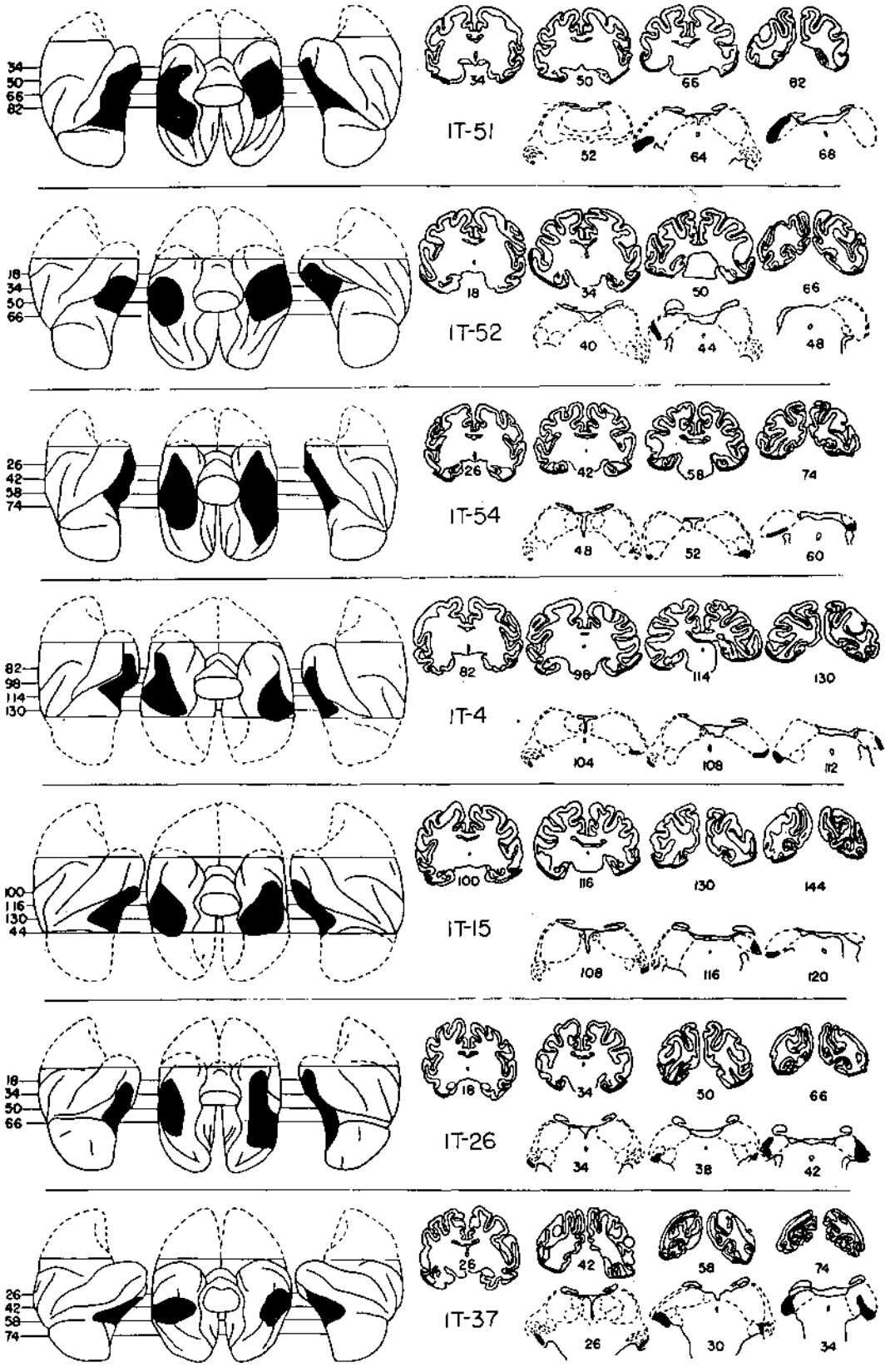

FIG. 1. Ventral and lateral reconstructions of inferotemporal lesions, with cross sections through the cerebrum showing the depth of the lesions, and sections through the thalami showing the retrograde degeneration. Black in the reconstructions and cross sections indicates damage; in the thalamus black indicates degeneration.

In both the simultaneous and "go-no-go" tasks each object was the positive stimulus for half the animals in each group, and, as before, only the correct "go" responses in the successive problem were rewarded with food. In the conditional successive task, however, both of the correct stimulus-response sequences (e.g., tobacco tin-go left; ash tray-go right) were rewarded. Order of training on the successive tasks was "conditional" followed by "go-no-go."

RESULTS

Experiment 1

The learning scores for the initial discrimination procedure of Experiment 1 are presented in Table 1. In all the studies reported in this paper, learning scores refer to the number of trials required to reach criterion; since error scores always paralleled scores based on trials to criterion, number of errors is not reported. Preoperatively, the six animals trained on the simultaneous problems learned somewhat more rapidly than the three animals trained on the successive problem. The probability of this difference occurring by chance is .012. (Throughout this report probability levels are based on Mann-Whitney U tests [2]).

Postoperatively all six inferotemporal animals took more trials in relearning the original problem than they had taken before operation; amounts of retardation varied widely and were not related to test procedure. The frontal operates, on the other hand, relearned the initial task in approximately the same number of trials as preoperatively. This difference, between the scores of the frontal group and those of the temporal group given identical training, is significant at the .05 level.

Results for the second discrimination of Experiment 1 are given in Table 2. Preoperatively, all animals showed saving in transferring from one task to the other. Indeed, transfer in one direction—from successive to simultaneous—was achieved without *any* further training, i.e., the three animals in this group attained the 90 per cent criterion in the first 100 trials; transfer in the reverse direction required from 20 to 150 trials preceding criterion, most of the errors occurring on the "no-go" stimulus presentations. The greater saving in favor of the successive-simultaneous sequence is significant at the .012 level.

TABLE 1

Pre- and Postoperative Learning Scores for Initial Discrimination Procedure of Experiment 1

Successive			Simultaneous			Simultaneous		
Animal	Pre	Post	Animal	Pre	Post	Animal	Pre	Post
IT 51	350	1530	IT 4	190	380	LF 2	130	100
IT 52	510	670	IT 15	250	2400	LF 3	200	130
IT 54	430	1470	IT 26	160	400	LF 5	130	150

Note.—Scores are number of trials (excluding corrections) required to attain criterion on the initial discrimination procedure of Experiment 1. *IT* denotes inferotemporal and *LF* anterolateral-frontal operates.

TABLE 2

Pre- and Postoperative Learning Scores for the Second Discrimination Procedure of Experiment 1

Simultaneous (After Successive)			Successive (After Simultaneous)			Successive (After Simultaneous)		
Animal	Pre	Post	Animal	Pre	Post	Animal	Pre	Post
IT 51	0	0	IT 4	80	400	LF 2	100	160
IT 52	0	0	IT 15	50	400	LF 3	150	0
IT 54	0	250	IT 26	50	420	LF 5	20	110

Note.—Scores are number of trials (excluding correction) required to attain criterion on the second discrimination procedure of Experiment 1 after having learned the first. *IT* denotes inferotemporal and *LF* anterolateral-frontal operates.

The *postoperative* results on the second discrimination show a consistent difference ($p = .05$) between the two groups of temporal operates; two temporal animals out of three again transferred immediately from the successive to the simultaneous task, whereas those trained in the opposite sequence required considerably more trials than they did preoperatively. Furthermore, the latter group of temporal operates was inferior ($p = .05$) to the frontal group which showed little or no retardation.

To summarize the results of Experiment 1: Prior to operation animals took longer in learning the successive discrimination, or in transferring to it, than in learning or in transferring to the simultaneous discrimination. Following operation, all the animals with inferotemporal lesions, in contrast with those with frontal lesions, were retarded in relearning their initial task, whether simultaneous or successive. Moreover, the inferotemporal operates which were then transferred in the more difficult direction, i.e., from simultaneous to successive, continued to show impairment on the second task, even after they had learned the first. These three animals, despite training on both problems preoperatively, and on one

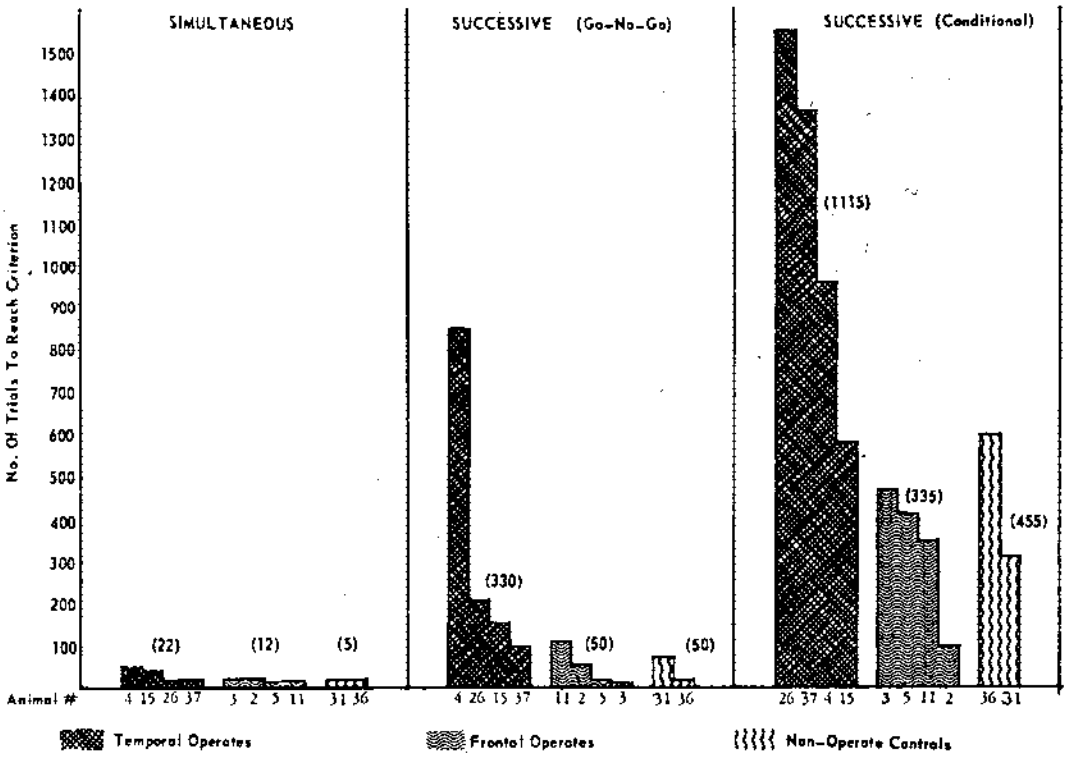

FIG. 2. Comparison of learning scores of three groups of animals in Experiment 2. The scores are number of trials preceding criterion on an object discrimination presented in three different ways. Correction trials are not included in the scores.

postoperatively, required approximately the same number of trials to attain criterion on the "go-no-go" discrimination as did the three animals which received this as the initial problem prior to surgery.

Experiment 2

The results of Experiment 2 are presented in Figure 2. All animals learned the simultaneous object discrimination quickly. The difference between the inferotemporal operates and the frontal and unoperated controls does not attain significance. (The scores of the frontal operates and nonoperates did not differ reliably in any of these procedures and so hereafter the two groups will be referred to together as controls.)

Nine of the ten animals required a greater number of trials to achieve criterion on the go-no-go discrimination than they had required on the simultaneous. On this more difficult task the temporal operates scored a significantly greater number of trials than did the controls ($p = .01$).

Finally, the performance of all animals on the conditional successive procedure was inferior to their performance on either of the other procedures, and here again, the inferior temporal operates took more trials in learning ($p = .01$). Although this finding is suggestive, it is not, by itself, sufficient evidence that the conditional task is more difficult than the go-no-go task; the training given in the first experiment and the order of presentation in the present experiment might tend to decrease the number of trials in the go-no-go situation.

It may be seen from Figure 2 that the impairment of the inferotemporal operates on these three tasks is roughly proportionate to the increasing number of trials taken by the controls.

DISCUSSION AND SUMMARY

Two experiments were conducted to determine whether or not animals with inferotemporal lesions, trained to discriminate between two stimuli in one situation, would subsequently show impairment in discriminating the

identical stimuli presented in a different situation.

In the first experiment six inferotemporal and three frontal (control) operates were tested for retention of a painted-pattern discrimination presented both as a simultaneous and as a successive (go-no-go) problem. For half the inferotemporal operates, and for all control operates, the sequence was simultaneous and then successive; for the remaining animals, the sequence was reversed. In the second experiment four inferotemporal operates, four frontal (control) operates, and two nonoperate controls were tested for initial relearning of an object discrimination. The objects were presented to all animals in the same order: simultaneously and then successively (both conditional and go-no-go). In both experiments the successive discriminations were more difficult than the simultaneous discriminations, and the deficit shown by the inferotemporal operates varied roughly in proportion to the difficulty of the tasks. The lack of impairment in the performance of the *anterofrontal* operates on these tasks should be noted. This finding is inconsistent with recent suggestions that loss of "act inhibition" (8) or difficulty with "conditionality" (1) are responsible for the changes in behavior produced by frontal ablations.

These data demonstrate that decrement in visual discrimination performance following inferotemporal lesions is a function of the situation determining the differential response, impairment being found on tasks which differed from others previously learned only in the manner in which the identical discriminanda were presented. Other data (4), however, have demonstrated that the deficit produced by inferotemporal lesions is a function also of the physical dimensions of the discriminanda, impairment being found when a task, previously learned, was changed only by gradually reducing the difference between the stimuli. Thus, no selective relationship between the visual discrimination impairment and either of these two classes of environmental variables is established. These studies bring into question the usefulness of the distinction between "agnosia" (which might account for the results of the present experiments) and "acuity loss" (which might account for the results found on varying the physical dimensions of the discriminanda) which has been traditionally employed to explain the disparate effects of lesions in "primary" and "association" cortex.

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Received June 7, 1954.