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BRIEF COMMUNICATION

Impairment in Sampling Visual Stimuli in Monkeys with Inferotemporal Lesions[1]

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BUTTER, C. M. AND M. HIRTZEL. *Impairment in sampling visual stimuli in monkeys with inferotemporal lesions*. PHYSIOL. BEHAV. 5 (3) 369–370, 1970.—Monkeys with inferotemporal (IT) lesions and their controls, monkeys with partial removal of striate cortex (LS) and unoperated monkeys, were trained to discriminate between two stimulus compounds differing in brightness near the response site and in hue, distant from the response site. In subsequent discrimination testing, only the distant cue (hue) was available. All animals learned the original discrimination rapidly. However, in the discrimination test, the IT monkeys made significantly more errors than did the unoperated monkeys, while the LS monkeys were unimpaired. These findings support the view that IT lesions impair visual search. Once the IT monkeys learned the test discrimination, they were not impaired in a series of subsequent tests in which the area of the distant cue was successively reduced.

Rhesus monkey Visual search Striate cortex Inferotemporal cortex Hue discrimination Brightness discrimination

MONKEYS with inferotemporal (IT) lesions are impaired in discriminating between visual patterns [11]. Moreover, after mastering pattern discriminations, IT monkeys, unlike control animals, behave in equivalence testing as though they had utilized only one part of the patterns and not the whole form in discrimination learning [1, 3]. This alteration in equivalence behavior suggested that IT monkeys are deficient in searching or sampling visual features. The present study was undertaken to test this hypothesis. Initially in discrimination learning, monkeys attend to visual features at or very near the response site [7, 9] and apparently later utilize distant cues by searching [13]. Thus, we predicted that IT monkeys, unlike those with partial striate cortex lesions, would be deficient in transferring from discrimination training, in which cues near and distant from the response site were present, to testing in which only the latter cue was available. We also predicted that once the IT monkeys had successfully completed searching for the distant cue, they would no longer be impaired when task difficulty was increased by successively reducing the area of the distant cue.

METHODS

Subjects

Subjects were 12 adult rhesus monkeys (*Macaca mulatta*) of both sexes which had prior pattern discrimination experience [1, 2]. Four had one-stage, bilateral removals of IT cortex, which included all cortex on the middle and inferior temporal gyri, sparing subcortical structures and temporal polar cortex and only minimally invading ventral prestriate cortex. Four animals had one-stage bilateral removals of all striate cortex on the lateral surface of the hemispheres (LS), and the remaining four were unoperated controls (N). The details of surgery, performed approximately eight months prior to this study, and of histology are described elsewhere [2]. Throughout testing, animals were maintained on Purina Monkey Chow (30 cal/kg/day).

Apparatus and Procedure

Animals were trained and tested in a two-choice Wisconsin General Test Apparatus [1]. The form board had runners and backstops into which stimulus plaques fitted so that the monkeys had to push the near edge of the plaques to uncover the food-well. Animals were first trained to discriminate between two 4.5-in. square plaques, the near halves of which differed in brightness (two shades of gray) and the far halves of which differed in hue (red vs. blue). For half of the animals in each group the positive stimulus was dark-gray/red, for the other half it was dark-gray/blue. Correct choices were rewarded with one-half a peanut. Spatial position of the plaques was varied according to a Gellermann series [8]. Thirty trials were administered daily until animals made 90 correct responses in 100 consecutive trials. The monkeys were

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then required to discriminate between plaques the distant halves of which had the same hues used in training, but the near halves of which were identical grays intermediate in brightness to the two grays used in training. Following reattainment of the discrimination learning criterion, the area of the plaques occupied by the hues was successively reduced by one-half in three additional tests; the remainder of the plaques was the same intermediate gray used in the first test. Except for the changes in stimulus area, the procedures in the four tests were identical to those used in training.

RESULTS AND DISCUSSION

As seen in Fig. 1, the initial discrimination problem was easily mastered by all groups, which did not differ from each other in mean errors. However, in the first test discrimination, in which the near (brightness) cue was no longer available, the IT group made on the average more than four times as many errors as did the N group, and the mean errors of these two groups were significantly different ($t = 2.62$; $df = 6$; $p < 0.025$). The IT group was also significantly impaired relative to the LS group ($t = 2.11$; $df = 6$; $p < 0.05$), which did not differ from the N group. While the N group on the average made fewer errors in the first test than in training, in fact only two of the four N monkeys (and two LS monkeys) showed evidence of positive transfer; they made fewer errors in this test than they did in training. On the other hand, all the IT monkeys committed more errors in this test than in training. While the IT monkeys were impaired in the first test, as seen in Fig. 1 their performance in the subsequent tests was not deficient. In fact, the average errors of the IT group were consistently, although not significantly, less than those of the N group, despite the increasing difficulty of the task for the N group in successive tests. Moreover, no other group differences in the last three tests were significant.

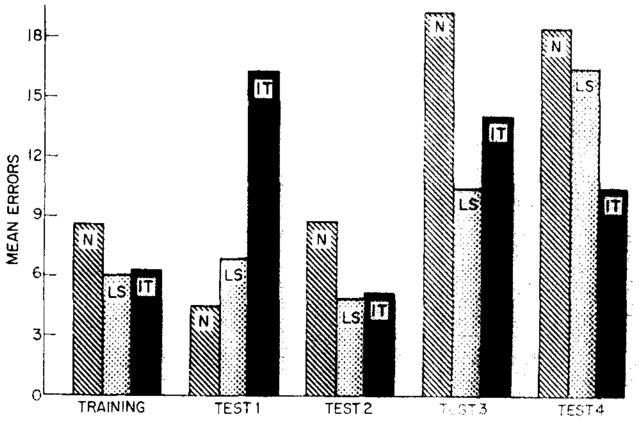

FIG. 1. Mean errors of the unoperated (N), lateral striate (LS) and inferotemporal (IT) groups in discrimination training and in each of the four test discriminations.

It is unlikely that the IT monkeys' impairment in the first test discrimination was due to a deficiency in ability to transfer, independent of the particular stimulus changes from training to testing, since IT monkeys do not show generalized transfer deficits [1, 2, 4]. Further, in interpreting the IT monkeys' deficit in the first test, it should be noted that they were not impaired in initial discrimination training, which for the control animals, was no less difficult than the first test. The first test differed from training in two respects: the only cue was color and there was no cue where animals touched the plaques. It is unlikely that the first difference could account for the IT monkeys' impairment, since monkeys with lesions limited to IT cortex do not show deficits in easy color discrimination tasks like the one used here [5, 6, 10, 12]. It would seem more likely, then, that the IT monkeys' deficit was related to the absence of a cue at the response site. According to this interpretation, the IT monkeys' deficit was due to an impairment in searching for the only relevant cue (i.e. the hues distant from the response site), a task which the control animals more readily mastered in training or in the test itself. Moreover, the IT monkeys' unimpaired performance in the last three tests indicates that once they had successfully completed searching for the relevant cue, they were still able to utilize this cue normally, despite the increasing difficulty of the task. These findings are consistent with the view [1] that visual discrimination deficits produced by IT lesions are due, at least in part, to an impairment in visual search.

REFERENCES

1. Butter, C. M. The effect of discrimination training on pattern equivalence in monkeys with inferotemporal and lateral striate lesions. *Neuropsychologia* **6**: 27–40, 1968.
2. Butter, C. M. Impairments in selective attention to visual stimuli in monkeys with inferotemporal and lateral striate lesions. *Brain Res.* **12**: 374–383, 1969.
3. Butter, C. M. and W. L. Gekoski. Alterations in pattern equivalence following infertemporal and lateral striate lesions in rhesus monkeys. *J. comp. physiol. Psychol.* **61**: 309–312, 1966.
4. Butter, C. M., M. Mishkin and H. E. Rosvold. Stimulus generalization in monkeys with inferotemporal lesions and lateral occipital lesions. In: *Stimulus Generalization*, edited by D. I. Mostofsky. Stanford: Stanford University Press, 1965.
5. Chow, K. L. Effects of partial extirpations of the posterior association cortex on visually mediated behavior in monkeys. *Comp. Psychol. Monogr.* **20**: 187–218, 1951.
6. Chow, K. L. Further studies on selective ablation of associative cortex in relation to visually mediated behavior. *J. comp. physiol. Psychol.* **45**: 109–118, 1952.
7. Cowey, A. Discrimination. In: *Analysis of Behavioral Change*, edited by L. Weiskrantz. New York: Harper and Row, 1968.
8. Gellermann, L. W. Chance orders of alternating stimuli in visual discrimination experiments. *J. genet. Psychol.* **42**: 207–208, 1933.
9. Meyer, D. R., F. R. Treichler and P. M. Meyer. Discrete-trial training techniques and stimulus variables. In: *Behavior of Nonhuman Primates*, Vol. 1, edited by A. M. Schrier, H. F. Harlow and F. Stollnitz. New York: Academic Press, 1965.
10. Mishkin, M. Visual discrimination performance following partial ablations of the temporal lobe: II. Ventral surface vs. hippocampus. *J. comp. physiol. Psychol.* **47**: 187–193, 1954.
11. Mishkin, M. Visual mechanisms beyond striate cortex. In: *Frontiers of Physiological Psychology*, edited by R. Russell. New York: Academic Press, 1966.
12. Mishkin, M. and K. H. Pribram. Visual discrimination performance following partial ablations of the temporal lobe: I. Ventral vs. lateral. *J. comp. physiol. Psychol.* **47**: 14–20, 1954.
13. Polidora, V. J. and W. J. Thompson. Orienting behavior and the S–R spatial discontiguity effect in monkeys. *J. comp. physiol. Psychol.* **59**: 240–245, 1965.