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NOTE

DETECTION OF MASKED PATTERNS IN MONKEYS WITH INFEROTEMPORAL, STRIATE OR DORSOLATERAL FRONTAL LESIONS*

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Abstract—Monkeys with lateral striate (LS) lesions, inferotemporal (IT) lesions or dorsolateral frontal (DLF) lesions were trained to discriminate between two visual patterns before and after the patterns were masked with irrelevant stimuli (rings enclosing the patterns). Compared to the DLF monkeys, the IT monkeys and one monkey with LS lesions were retarded in discriminating between the unmasked patterns. Irrespective of their performance with unmasked patterns, the IT and LS monkeys were impaired in discriminating the masked patterns, compared to the DLF monkeys. Analysis of performance in testing suggests that both LS and IT lesions produce an impairment in selective attention to visual stimuli.

INTRODUCTION

FINDINGS from stimulus generalization [1] and pattern equivalence [2] tests suggested that monkeys with inferotemporal (IT) lesions are impaired in selectively attending to visual stimuli. Results consistent with this view were obtained in a subsequent experiment: Monkeys with IT lesions, relative to control animals, were retarded in discriminating between forms masked with irrelevant stimuli after they had discriminated between the same forms without masking [3]. Moreover, monkeys with partial lesions of striate cortex were equally impaired in discriminating between masked forms. However, since the masking partially obliterated the borders of the discriminanda, the striate-lesioned monkeys' impairment may have been due to an acuity loss rather than an impairment in selective attention. In the present experiment, acuity difficulties were avoided by testing monkeys with partial striate lesions, IT lesions, or prefrontal lesions for pattern discrimination before and after the patterns were masked by enclosing them in rings.

METHODS

Nine rhesus monkeys served as subjects: Bilateral removals of lateral striate (LS) cortex ($N=3$), of IT cortex ($N=3$) or of dorsolateral frontal (DLF) cortex, excluding the frontal eye fields (area 8) ($N=3$), were performed approximately six months prior to this study. Details of the surgical procedures are described elsewhere [3]. All animals had been tested for pattern discrimination prior to this study, both before and after surgery. Following the completion of testing, the animals were sacrificed, and their brains prepared for histological examination [3]. The lesions were placed as intended except for IT-3, which showed a large area of softening in the left superior temporal gyrus.

The monkeys were first trained in a Wisconsin General Test Apparatus to discriminate between two patterns, Z (rewarded) and E (unrewarded), constructed of black paper pasted on white 3-in. square plaques (see Fig. 1). Thirty trials were administered daily, and the position of the two stimuli was varied by a Gellermann series [4]. Responses to the positive stimulus were rewarded with half a peanut. Following the attainment of 90 correct responses in 100 trials, the same patterns were presented with black rings surrounding them (see Fig. 1), and the monkeys were required to reattain the same criterion of learning used in prior training. Except for the addition of the rings, testing conditions were identical to those used in training.

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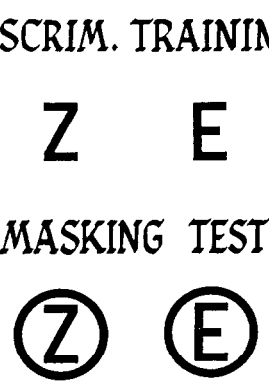

FIG. 1. Patterns used in discrimination training (above) and masked patterns used in testing (below).

RESULTS AND DISCUSSION

The IT monkeys, compared to those with DLF lesions, were consistently impaired in learning to discriminate between the two patterns without masking, as seen in the left hand column of Table 1. On the other hand, the scores of two of the monkeys with LS lesions (LS-2 and LS-3) were in the range of the DLF monkeys, while the third LS monkey (LS-1) was severely retarded in learning.

Table 1. Trials to criterion in discrimination learning (DT) and masking test (MT) by lateral striate (LS), inferotemporal (IT) and dorsolateral frontal (DLF) monkeys

Groups	DT	MT	Savings*
LS-1	1025	1064	−0.02
LS-2	283	432	−0.21
LS-3	237	772	−0.53
IT-1	987	940	+0.02
IT-2	776	898	−0.07
IT-3	872	1048	−0.09
DLF-1	308	141	+0.37
DLF-2	321	99	+0.53
DLF-3	81	10	+0.78

* $\frac{\text{(Trials to criterion in DT)} - \text{(Trials to criterion in MT)}}{\text{(Trials to criterion in DT)} + \text{(Trials to criterion in MT)}}$

In subsequent tests in which the patterns were masked with rings, both the LS and IT monkeys were retarded in reattaining the discrimination criterion compared to the DLF monkeys, which all showed positive savings scores (see right hand column of Table 1). Moreover, the monkeys with LS lesions showed even less savings than did the IT monkeys; in fact, the two LS monkeys that were most severely retarded (LS-2 and LS-3) in relearning with masked patterns were unimpaired in initial learning compared to the DLF monkeys. Further analysis of test performance reveals that the LS and IT monkeys had little or no difficulty in reattaining 75 per cent correct performance in masking tests. LS-1 and LS-2, like the frontal monkeys, reattained 75 per cent correct performance in the first 100 trials, while LS-3 required only 88 additional

trials (out of a total of 772 test trials) to reach the 75 per cent level. With regard to the IT monkeys, two of them (IT-1 and IT-3) reattained 75 per cent correct performance in the first 100 trials, and IT-2 required only 64 additional trials (out of a total of 898 test trials) to reattain the 75 per cent level. The impairment of the monkeys with IT or LS lesions in the masking test was thus due largely, and in some cases completely, to difficulty in reattaining higher levels of performance, between 75 and 90 per cent correct.

These results, then, clearly indicate that LS lesions, like IT lesions, produce deficits in discriminating between patterns masked in such a way that acuity is not a critical factor in test performance. Moreover, it appears that a deficit in pattern learning is not a necessary condition for retarded performance in masking tests, since two of the LS monkeys (LS-2 and LS-3) showed no impairment in pattern learning relative to the DLF animals.

Since masking tests were conducted only after the animals had already learned to discriminate between the patterns without masks, pattern learning was not confounded with the effects of the masking stimuli. However, it is possible that the deficits found in masking tests simply reflect an impairment in learning a new, difficult discrimination, rather than an impairment in selective attention. Contrary to this interpretation, the LS and IT monkeys had little or no difficulty in reattaining 75 per cent correct performance in the masking test. Their impairment only became evident in reattaining more stringent criteria (between 75 and 90 per cent), which is just the kind of impairment that would be expected from animals deficient in maintaining selective attention through a long series of trials.

These findings, then, support the view that LS lesions, as well as IT lesions, produce a deficit in selective attention to visual stimuli [3]. It should be noted that GROSS, COWEY and MANNING [5] have recently described similar deficits in monkeys with ventral prestriate lesions, as well as in IT monkeys, when irrelevant stimuli were added to pattern discriminanda. Apparently, then, many cortical regions implicated in vision, including striate cortex, contribute to processes involved in selective attention to visual stimuli. In addition, the finding that the monkeys with DLF lesions showed better performance in the masking test than did the LS or IT monkeys is at variance with the view that damage to any cortical area produces equivalent deficits in detecting masked patterns [6].

REFERENCES

1. BUTTER, C. M., MISHKIN, M. and ROSVOLD, H. E. Stimulus generalization in monkeys with inferotemporal and lateral striate lesions. In *Stimulus Generalization*, D. J. MOSTOFSKY (Editor), Stanford University Press, Stanford, California, 1965.
2. BUTTER, C. M. The effect of discrimination training on pattern equivalence in monkeys with inferotemporal and lateral striate lesions. *Neuropsychologia*, **6**, 27–40, 1968.
3. BUTTER, C. M. Impairment in selective attention to visual stimuli in monkeys with inferotemporal and lateral striate lesions. *Brain Res.* **12**, 374–383, 1969.
4. GELLERMANN, L. W. Chance order of alternating stimuli in visual discrimination experiments. *J. genet. Psychol.* **42**, 207–208, 1933.
5. GROSS, C. G., COWEY, A. and MANNING, F. J. Further analysis of visual discrimination deficits following foveal prestriate and inferotemporal lesions in rhesus monkeys. *J. comp. physiol. Psychol.* **76**, 1–7, 1971.
6. TEUBER, H.-L. and WEINSTEIN, S. Ability to discover hidden figures after cerebral lesions. *Archs Neurol. Psychiat. Chicago*, **76**, 369–379, 1956.

Résumé—Des singes avec lésions striées latérales (SL), des singes avec lésions inférotemporales (IT) et des singes avec des lésions frontales dorsolatérales (FDL) étaient entrainés sur une discrimination de deux patterns visuels, avant et après le masquage de ces patterns par des stimulus non pertinents (cercles entourant le patterns). Par comparaison avec les singes FDL, les singes IT et un singe SL montraient un retard de la discrimination des patterns non masqués. Quelles que soient leurs performances sur les patterns non masqués, les singes IT et SL étaient déficitaires dans la discrimination des patterns masqués si on les compare aux singes FDL. L'analyse des performances à ces tests suggère que les lésions SL et IT produisent un trouble de l'attention sélective aux stimulus visuels.

Zusammenfassungen—Affen mit laterostriaeren (LS), temporobasalen (IT) und frontodorsolateralen (DLF) Läsionen wurden daraufhin trainiert, zwei optische Gestalten zu unterscheiden, welche vorher und hinterher mit uncharakteristischen Reizelementen verändert wurden. Die IT-lädierten Affen und ein Affe mit einer LS-Läsion zeigten den DLF-geschädigten Tieren gegenüber eine Verlangsamung beim Erkennen unveränderter Figuren. Unabhängig von der Wahrnehmungsleistung unveränderter Figuren zeigten sich IT- und LS-geschädigte Tiere unfähig, maskierte Figuren zu unterscheiden, auch im Vergleich zu DLF-Affen. Eine Analyse der Testergebnisse spricht dafür, daß sowohl laterostriaere als auch temporobasale Läsionen eine Leistungsminderung für das Wahrnehmen optischer Reize bewirken.