

## EFFECT OF DEPRIVATION ON DELAYED RESPONSE AND DELAYED ALTERNATION PERFORMANCE BY NORMAL AND BRAIN OPERATED MONKEYS<sup>1</sup>

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3 monkeys impaired on delayed response and delayed alternation after mid-lateral frontal lesions, 3 monkeys unimpaired on these tasks after control lesions, and 3 unoperated monkeys were tested on spatial delayed response (with direct baiting) and spatial delayed alternation following 2, 26, and 50 hr. of food deprivation. Increased deprivation improved delayed response performance by all groups to a similar extent. Increased deprivation had no effect on delayed alternation performance by any group.

Pribram (1950) has reported food deprivation to improve delayed response performance of frontal monkeys. In the present study, the effect of deprivation on performance of spatial delayed response (with direct baiting) and spatial delayed alternation by normal monkeys and by monkeys with partial frontal lesions was investigated for two reasons. The first was to determine whether Pribram's (1950) results on the effect of fasting could be attributed to an increase in cueing value or to an increase in incentive or reinforcing value of the bait. The bait serves as a cue in delayed response, but not in delayed alternation. Thus, if the effect of deprivation was only on the cueing value of the bait, increased deprivation would be expected to improve delayed response performance, but not delayed alternation performance. On the other hand, if the effect of deprivation was on the incentive value, increased deprivation would be expected to improve performance of both tasks.

The second reason was to compare the effect of deprivation on the performance of unoperated monkeys, control operated monkeys, and monkeys deficient on delayed response tests following frontal lesions. The impairment of frontal monkeys might be related to a motivational change. This might be reflected in a change in the effect of deprivation. However, *failure* to find an effect of deprivation on frontal performance different from that on normal performance would neither support nor deny the possi-

bility of a change in motivational processes after lateral frontal ablations.

Harlow and his colleagues have repeatedly demonstrated that *deprivation* per se does not affect performance in discrimination testing (Harlow, 1953; Meyer, 1951b; Miles, 1959) although *size and amount of reward* does (Meyer, 1951a; Schrier & Harlow, 1956). This suggests that, at least in normal monkeys during discrimination testing, incentive is not increased by deprivation. If the same were true in delayed response testing it would argue strongly against the second hypothesis, viz. that deprivation increases the incentive value of the bait. It would also argue indirectly against the first hypothesis, viz. that deprivation increases the apparent size or stimulus value of the bait.

### METHOD

#### *Subjects*

The Ss were nine immature *Macaca mulatta*. Three (No. 10, 30, and 38) had received ablations of the banks and depths of *sulcus principalis* (the P group);<sup>2</sup> three (No. 1, 7, and 32) had received ablations of the depths and anterior bank of the arcuate sulcus and of rostral cortex on the lateral surface excluding *sulcus principalis* (the nonprincipal or NP group); three (No. 6, 8, and 31) served as unoperated controls (the U group). All Ss had received identical testing experience in

<sup>2</sup> *Sulcus principalis* is the cortical "focus" of the delayed response-type test deficit in *Macaca mulatta*, i.e., its removal results in a greater specific impairment on delayed response and delayed alternation than that produced by cortical lesions elsewhere (Gross, 1963a; Gross & Weiskrantz, 1962; Mishkin, 1957).

<sup>1</sup> See Footnote 1 of Gross (1963a).

delayed alternation, delayed response, auditory discrimination, visual discrimination, discrimination reversal and locomotor activity studies (Gross, 1963a, 1963b, 1963c). At the time of the present study (about 4 mo. after operation), the delayed alternation and delayed response performance of the P group was severely impaired but that of the U and NP groups did not differ; thus the NP group served as an operated control group. The surgical methods<sup>8</sup> and reconstructions of the lesions are reported elsewhere (Gross, 1963a).

### *Apparatus and Test Procedure*

The apparatus, a modified Wisconsin General Test Apparatus (WGTA), and the test procedures are described elsewhere (Gross, 1963a, Gross & Weiskrantz, 1962). On every trial the bait was a raisin.

### *Deprivation Levels*

The levels of deprivation used were 2 hr., 26 hr., and 50 hr. For 1 week prior to the start of the experiment, Ss had food available only between 9:30 and 10:30 A.M. Each day throughout the experiment, on days on which Ss were fed, the feeding time remained 9:30-10:30 A.M. On days Ss were tested, the testing time was always within the period 12:30-1:30 P.M.

### *Delay Times*

The use of a common intratrial delay for all the groups would have made it difficult to compare the effects of deprivation on their performance. For example, if operated Ss were performing a task at a level of 50% correct responses and control Ss at 90%, and if a treatment caused significantly greater improvement in the operated group, inferences about the interaction of the operation and the treatment might not be justified. A more parsimonious explanation of such a result is that the treatment makes the problem simpler for both groups and the operated group has greater room for improvement. Therefore in the present study, the delay time for each S was individually determined on the basis of its performance before the start of each phase of the experiment. The effect of deprivation on delayed alternation was studied in the first phase and the effect on delayed response in the second. Before the first phase Ss were tested on a 3 sec. delayed alternation test (Gross, 1961) and on the basis of their performance the delays in the alternation phase were set as follows: P group—3 sec., NP and U groups—5 sec. After the first phase and before the second, Ss were tested on a 1 sec. delayed response (Gross, 1961) and on the basis of their performance the delays in the delayed response phase were set as follows: P group, all—1 sec.; NP group, No. 7

and No. 32—5 sec., No. 1—1 sec.; U group, No. 6—1 sec., No. 8—5 sec., No. 31—20 sec.

### *Design*

A serially balanced design was used which permitted the measurement of "carry-over" effects from the previous level of deprivation (Sampford, 1957) unlike the Greco-Latin square design usually employed in deprivation experiments (Grant, 1948; Meyer, 1951b). In order to prevent confounding of treatment effects and days-since-last-tested effects, Ss were tested every 4 days regardless of whether they were being deprived for 2 hr., 26 hr., or 50 hr. Fifty trials per test session were given.

In addition to performance scores (percentage of correct trials), total time required for each delayed alternation session was measured in order to provide a measure of latency of response. Since a longer latency might have effects similar to a longer delay, a finding of improved performance with increased deprivation might be due to a shorter latency of response.

## RESULTS

The carry-over effect did not approach significance as a source of variation in either phase. Therefore variation due to carry-over effects was pooled with the error term and the analyses recalculated.

### *Delayed Alternation*

*Latency of response.* Since the intratrial delay was not the same for all groups, three parallel analyses were performed. Neither Treatments nor Sessions were significant sources of variance, indicating that deprivation did not affect latency of response (Treatments:  $F < 2$ ,  $df = 2/8$  in all groups; Sessions:  $F < 2$ ,  $df = 5/8$  in all groups). Furthermore, latency and performance were not significantly correlated in any S.

*Performance.* Neither Treatments nor Treatments  $\times$  Groups were significant sources of variance, indicating that performance was not affected by changes in level of deprivation (Treatments:  $F < 1$ ,  $df = 2/24$ ; Treatments  $\times$  Groups:  $F < 1$ ,  $df = 4/24$ ). The Sessions effect was significant, reflecting the fact that Ss improved their performance within the six sessions ( $F < 3.43$ ,  $df = 5/24$ ,  $p < .05$ ). The Sessions  $\times$  Groups interaction failed to approach significance indicating that there was no difference among the groups in this improvement ( $F < 1$ ,  $df = 10/24$ ). The Groups

<sup>8</sup> L. Weiskrantz performed all the surgery except that on No. 38.

TABLE 1  
MEAN PERCENTAGE OF CORRECT PERFORMANCE ON  
DELAYED ALTERNATION AND DELAYED RE-  
SPONSE UNDER THREE LEVELS  
OF FOOD DEPRIVATION

| Deprivation Level | Delayed Alternation |        |        | Delayed Response |        |        |
|-------------------|---------------------|--------|--------|------------------|--------|--------|
|                   | 2 hr.               | 26 hr. | 50 hr. | 2 hr.            | 26 hr. | 50 hr. |
| P group           | 69.0                | 74.0   | 78.0   | 80.0             | 89.7   | 89.0   |
| NP group          | 78.7                | 82.3   | 85.3   | 75.0             | 88.3   | 88.3   |
| U group           | 79.0                | 78.3   | 74.0   | 72.3             | 89.7   | 96.0   |

effect was significant, demonstrating that the attempt to equate the performance of the groups was not completely successful ( $F = 4.98$ ,  $df = 2/24$ ,  $p < .05$ ). As indicated in Table 1, the NP group was superior to the other two, but the U and P groups overlapped.

In summary, hunger did not affect alternation performance.

#### Delayed Response

Observation during delayed response testing suggested again that latency varied independently of both deprivation and performance.

Treatments were a significant source of variance, reflecting an improvement in performance with increasing deprivation ( $F = 17.00$ ,  $df = 2/24$ ,  $p < .001$ ). As indicated in Table 1 this variance is attributable primarily to the difference between the 2 hr. level of deprivation and the other two levels. The Groups  $\times$  Treatments interaction did not reach significance indicating that there was no difference in the effect of deprivation among the three groups ( $F = 1.73$ ,  $df = 4/24$ ). A significant Sessions effect reflected the increase in performance over the six sessions ( $F = 3.14$ ,  $df = 5/24$ ,  $p < .05$ ). The Sessions  $\times$  Groups interaction failed to reach significance, demonstrating that all the groups improved by about the same amount ( $F < 1$ ,  $df = 10/24$ ). The variance due to Groups failed to approach significance, indicating that the manipulation of the intratrial delays was successful in equating the performance of the groups ( $F < 1$ ,  $df = 2/24$ ).

In summary, all of the groups improved

their delayed response performance to equal extents when hungry.

#### COMMENT

Deprivation improved Ss' performance of delayed response but not of delayed alternation. This result suggests that the effect of deprivation was to enhance the stimulus value of the food at the time of baiting (as Pribram, 1950 had suggested).

The results indicate that although food deprivation may not affect WGTA discrimination testing, it does affect delayed response performance in a WGTA. The absence of any "carry-over" effect from one level of deprivation to the next indicates the adequacy of using Latin square designs in studying the behavioral effects of deprivation in monkeys.

The finding that frontal operates improved their delayed response performance when hungry does not reveal anything about their deficit, since hunger improved the delayed response performance of operated and unoperated controls to a similar extent.

The different effect of food deprivation on performance of delayed response and delayed alternation indicates that measures of performance on these two tasks are not equivalent dependent variables.

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