Orality, Preference Behavior, and Reinforcement Value of Nonfood Object in Monkeys with Orbital Frontal Lesions

Abstract. *Monkeys with orbital frontal ablation, compared with sham-operated controls, showed enhancement of oral tendencies toward nonfood items. Further, unlike the controls, they persistently performed an instrumental response for one of these nonfood items. On the other hand, the lesioned monkeys did not show altered preferences for food versus nonfood items. These findings suggest that reinforcement value and preferential ordering are dissociated by orbital frontal ablation.*

In the course of testing monkeys with orbital frontal ablations for emotional behavior and learning (*1*), we have noted heightened oral tendencies toward nonfood objects in these animals, similar to those described in monkeys with amygdala lesions (*2*). In the present experiment we investigated systematically these oral tendencies and obtained evidence that they are associated with increases in the reinforcement value of nonfood objects.

Eight adolescent, male rhesus monkeys (*Macaca mulatta*) served as subjects. Four had bilateral removals of orbital frontal cortex, and the remaining four were sham-operated controls that underwent the same operative procedures except for the removal of cortical tissue. Surgery, which had been performed 6 to 8 months prior to this experiment, is described elsewhere (*3*). Briefly, cortical removals were performed by subpial aspiration under Diabutal anesthesia with aseptic precautions (*4*). Gross inspection of the brains at autopsy reveals that orbital frontal cortex was completely removed in three subjects, while the fourth showed sparing of the posteromedial portion unilaterally. Prior to this experiment, subjects had been tested for emotional reactions in various situations, both before and after surgery. During food preference testing the subjects were maintained at a full diet of 45 calories per kilogram of body weight per day (Purina Monkey Chow); in subsequent reinforcement tests diet was restricted to approximately 30 cal kg^{-1} day^{-1}.

All testing was conducted in a Wisconsin General Test Apparatus, described elsewhere (*5*). In preference testing three food items (a piece of apple, banana, and a 0.75-g whole-diet pellet) and three nonfood objects (a small cork, an empty drug capsule, and a small metal bolt) were presented simultaneously in six food wells of a test board 21 inches (53 cm) wide. The six items were presented 15 times on each of three successive sessions, and on each trial the spatial position of each item was randomized. An opaque screen was interposed between a subject's test cage and the test board after the subject picked up all the items or after 2 minutes had elapsed since its last choice.

Following preference testing, subjects were trained to displace a 3-$in.^2$ (7.6-cm^2) metal plaque from a single, centered food well in a test board in order to obtain a whole-diet pellet, identical to those used in preference testing. Fifteen reinforced trials were administered daily for 5 days; on each trial the screen separating a subject's cage from the test board remained open for 1 minute, irrespective of subject's response latency. Response latencies were measured to the nearest second with a stopwatch. On the sixth session the food pellet was replaced by a drug capsule identical to those in prior preference testing, and a total of five sessions were administered with the capsule as a reinforcer. In all other respects, the procedure was the same as used in food-reinforcement testing.

In preference testing, oral tendencies might be manifested in preference behavior (the order in which items are chosen) or in selection (the number of trials on which items are chosen irrespective of order of choice within trials). To evaluate preferences of food and nonfood items, subjects' order of choice was averaged for each of the six items over the total number of trials on which they chose the item. As seen in Table 1, both the control and lesioned monkeys tended to prefer food to nonfood items, although one of the four controls preferred the cork and capsule to the pellet, and one of the four lesioned monkeys preferred the cork most.

Moreover, subjects in both groups varied considerably in their relative preferences for each of the three foods. Further, the lesioned subjects, like the controls, preferred the cork to the capsule and the capsule to the bolt. Thus there were no marked group differences in preferences for food and nonfood items, although the lesioned group showed slightly weaker preferences for apple and bolt than did the control group (see Table 1). On the other hand, there were striking group differences in the selection of nonfood items. As seen in Table 1, the control group's lower preferences for nonfood as compared with food items was accompanied by reduced selection of nonfood items; on the average, these subjects selected nonfood items only 10 times in the 45 trials. On the other hand, the lesioned subjects selected the nonfood items much more frequently, on the average 30 times in 45 trials, and this group difference in the number of times nonfood items were selected is significant ($t = 4.92$; d.f. $= 6$; $P < .01$).

In reinforcement testing, all subjects readily learned to displace the metal plaque in order to obtain the food pellet, and all but one control (S-3) performed consistently on the five sessions; S-3 required eight additional sessions for consistent plaque displacement. As seen in Fig. 1, the control group showed an abrupt drop in frequency of plaque displacement when the capsule was substituted for the food pellet, and their performance remained at a low level in subsequent sessions. Three of the control monkeys

Table 1. Mean order of choice of food and nonfood items and frequency of selection (parentheses) of items in sham-operated controls (S) and monkeys with orbital frontal lesions (OF).

Subject	Apple	Banana	Pellet	Cork	Capsule	Bolt
S–1	2.1 (45)	2.1 (45)	1.8 (45)	4.0 (10)	3.8 (4)	4.8 (3)
S–2	2.1 (42)	1.8 (45)	2.0 (42)	3.6 (7)	4.0 (3)	4.7 (2)
S–3	2.1 (44)	1.9 (45)	3.5 (17)	2.9 (18)	3.0 (30)	4.5 (2)
S–4	1.9 (42)	1.9 (34)	2.1 (44)	3.2 (20)	3.8 (12)	3.3 (10)
Mean	2.0 (43.3)	1.9 (42.3)	2.4 (37.0)	3.4 (13.8)	3.7 (12.3)	4.3 (4.2)
OF–1	2.3 (45)	2.0 (45)	2.8 (45)	3.6 (41)	4.6 (36)	4.8 (26)
OF–2	2.7 (45)	2.4 (43)	4.1 (39)	2.3 (43)	3.7 (41)	4.9 (28)
OF–3	2.0 (45)	2.0 (45)	2.8 (35)	3.3 (33)	4.4 (22)	4.8 (16)
OF–4	2.2 (45)	1.9 (45)	3.1 (45)	3.2 (28)	4.1 (41)	5.4 (20)
Mean	2.3 (45.0)	2.1 (44.5)	3.2 (41.0)	3.1 (36.3)	4.2 (35.0)	5.0 (22.5)

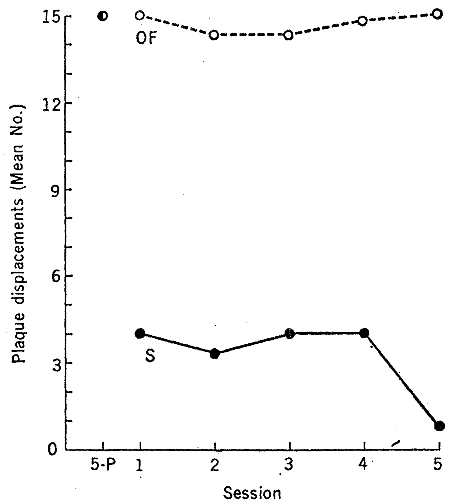

Fig. 1. Mean number of plaque displacements of the sham-operated (S) and orbital-frontal lesioned (OF) groups of monkeys in the last session with food pellets as reinforcement (5-P) and in the subsequent five sessions with capsules as reinforcement.

responded no more than twice on each of the five sessions, while the fourth showed only a slight drop in performance on the first four sessions and then responded only three times on the fifth session. All the lesioned subjects, on the other hand, consistently maintained a high level of responding during all tests with the capsule as reinforcement, and the group difference in frequency of plaque displacement was significant ($F = 17.42$; d.f. $= 1/6$; $P < .01$). Moreover, the lesioned subjects' response latencies were not consistently altered by changing the reinforcement from pellet to capsule.

These findings indicate that orbital frontal ablation, like amygdalectomy (*2*), produced increased oral tendencies; however, these oral tendencies were manifested in increased selection of nonfood items, while preference behavior was not affected. This dissociation argues against the view that the increased orality was due to impaired recognition of food versus nonfood, as has been suggested with reference to amygdalectomy (*2*). Moreover, the lesioned subjects' abnormally heightened selection of nonfood items was not due to increased manipulative tendencies per se, for these animals put into their mouths the nonfood items they picked up. Further, palatability was apparently a factor in the lesioned subjects' selection of nonfood items, since they preferred the cork and the capsule to the bolt.

The lesioned subjects' heightened oral tendencies were also accompanied by an apparent increase in reinforcement value of one nonfood item; these subjects, unlike the control animals, performed instrumental responses to obtain capsules as readily and as consistently as they had previously to obtain pellets. This persistence in instrumental responding was not due simply to increased resistance to extinction found following orbital frontal ablation (*3*), for the lesioned monkeys ate the capsules for which they worked so diligently. Moreover, it does not appear that their consumption of capsules was due to increased hunger, for the latencies of their instrumental responses for food pellets were not different from those of the control subjects; nor does orbital frontal ablation increase rates of instrumental responding for food (*3*).

The finding that lesioned subjects show both heightened selection and heightened reinforcement value of a nonfood item but no alteration in preference behavior suggests that orbital frontal ablation selectively affects control of certain motivational processes while sparing processes involved in discriminative-preference behavior. In other words, it would appear that the suppressive control normally exerted over oral tendencies is impaired and the *value* of nonfood items is enhanced, whereas the recognition of food-nonfood differences and preferential ordering is spared following orbital frontal removal. This interpretation is consistent with the view that orbital frontal cortex exerts suppressive control over hypothalamic appetitive mechanisms (*6*). Whether the preferential aspect of oral behavior is controlled by other forebrain structures or is a property of the hypothalamic appetitive mechanism remains to be determined. Finally, the unexpected dissociation between selection of nonfood items and preference following orbital frontal lesions has a parallel in the problem-solving behavior of such lesioned subjects: here, too, the suppression of a variety of response tendencies is impaired, but not the preferential ordering of response tendencies (*7*).

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Dark Adaptation: An Interocular Light-Adaptation Effect

Abstract. *Presentation of light to the left eye simultaneously with adaptation of the right eye to light may accelerate dark adaptation in the right eye. The result is that the rod-cone-break and the final threshold of the rods are achieved earlier than when the right eye alone is adapted to light.*

The usual procedure in dark-adaptation studies is to adapt the eye to be tested to light for several minutes. During this period, the other eye is adapted to dark. Consequently, for the greater portion of the dark-adaptation session the adaptation states of the eyes are different. If dark adaptation is completely a peripheral process, as is most frequently supposed (*1*), then this difference in adaptation state is of no consequence. If, however, the adaptation state involves other processes in which the eyes are not independent, differences in adaptation states may affect the threshold values that form a dark-adaptation curve.

Since Piper (*2*) first opened the question, it has been debated whether interocular effects exist in dark adaptation. Even when such effects have been supported, they have usually been described as sensitivity losses (*3*). We have found a situation now in which light adaptation in one eye appears to increase the rate of subsequent dark adaptation in the other eye.

Preliminary light adaptation was for 5 minutes. The left eye saw a circular field subtending a visual angle of 12° and a retinal illuminance of 5.6 log trolands, but saw it only during light adaptation. The right eye was the test eye. During light adaptation it saw a