# Influence of Prefrontal Lobotomy on Social Interaction in a Monkey Group

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FREEMAN AND WATTS (4), Mettler (15), and Greenblatt (5), have reiterated the emphasis of earlier observers (3, 8, 16, 20), on the significance of social factors determining the outcome of prefrontal lobotomy in psychotic patients. The relative importance of the indirect effects of changed interpersonal relationships and of the direct effects of the surgery has not yet, however, been ascertained. Complex human groups do not lend themselves to the experimental manipulations necessary to define the significant social variables influencing the patient. The presence of cultural factors and the use of symbolic processes further obscure the problem. A monkey colony, on the other hand, with its relatively simple and apparent social interaction uncomplicated by cultural and symbolic factors, provides an opportunity for more direct examination of the influence of prefrontal lobotomy on the individual's relation to his social group.

The social relationships in infrahuman groups have been well described. Hamilton (6), Kempf (9), and Tinklepaugh (17) discussed the role of sexual behavior in establishing a dominance hierarchy. Alverdes (1), Harlow and Yudin (7), Zuckerman (21), Maslow (10, 11, 12, 13), Maslow and Flanzbaum (14), and Warden and Galt (19) described in detail the development of an order of dominance in monkey groups. Their studies indicate that the social structure of a primate colony is a rigid and powerful force in determining the social behavior of individual animals. The relative status of its members is determined early in the life of the group and the direction of aggression, primacy of food getting, and submission in sexual behavior is related to each individual's position in the social hierarchy.

That such well defined behavior patterns might be affected by damage to the frontal lobes was considered by previous workers. Bianchi (2), Warden and Galt (19), and Ward (18) reported conflicting results from their observations of the effects of insult to the frontal lobes on social behavior of monkeys. None of these investigators, however, studied a large group of animals over a long period of time both before and after frontal lobotomy specifically to determine the effect of the operation on the social dynamics of the group. The aim of the present investigation was first, to define changes in the social behavior of individual members of a monkey group after prefrontal lobotomy and the consequences of these changes in other group members. Second, to discover whether or not there occurred changes in the social organization and behavior of the group as a whole following changes in the behavior of its constituent members.

## Experimental Procedure

### Animals

Six young adult rhesus monkeys, 4 female and 2 male, ranging in weight from 3.5 Kg. to 4.5 Kg. were housed together in a large cage 8′ × 6′ × 12′. During a week the standard laboratory diet included bananas, peanuts, onions, potatoes, oranges, bread, and monkey biscuits. This was thrown into the cage while the animals were being observed.

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## Methods

One of us observed the group for one hour during the daily feeding situation, the other for one hour after 20 hours of food deprivation. Periodically the observers exchanged times of observation. Diary records were kept of group behavior, especially that demonstrating dominance, aggression, avoidance, and submission. Food was frequently offered to one or another of the animals, placed in barely attainable positions or between two monkeys of the group, or withheld for 48 hours to intensify social interaction.

After the group structure had been definitely established 3 outgroup monkeys, 1 a female in induced estrus, were introduced into the group at different times for periods of 72 hours each to provoke activity in the group as a whole in relation to new social stimuli. An additional aim was to observe the relation of ingroup status to the response to the stranger.

Following 3 months of observation 2 animals were subjected to prefrontal lobotomy. Another animal was operated on 3 months later. During the 3 weeks allowed for recovery all the animals were housed individually. The colony was then restored and the animals observed daily for 7 months. Two measures were taken to control for the effect of breaking up the colony for surgery. Once before the first two operations, and once after, the colony was disbanded and later restored. In these instances, as well as upon the introduction of outgroup animals, the order of dominance did not change.

## Operation

A prefrontal lobotomy limited to frontal granular cortex was performed on 3 of the animals.* Under sodium amytal anesthesia an osteoplastic Fulton full calvarium flap was reflected on the left temporal muscle through a linear incision extending from one temple over the vertex to the other. The dura was opened in a linear fashion, exposing the entire frontal lobe back to the central fissure. An incision was made between the limbs of the arcuate sulcus and the bulbs of the sulcus principalis on the left, the incision being about 2 cm. long. A brain spatula was inserted and manipulated so as to sever the fibers extending dorsally and medially to the cortex and then ventrally to the level of the sulcus principalis. A similar incision was made just below the sulcus principalis and the spatula inserted and moved to the floor of the skull and laterally as far as the cortex. Both incisions were then extended until they met. The line of the incision was then irrigated carefully and the same procedure repeated on the right side. No undue amount of bleeding ensued. The dura was closed. The bone flap was then replaced, the muscle sutured with interrupted silk technic, the scalp sutured in the same way with one layer of continuous subcuticular stitches finishing the closure. Though there were necessarily minor variations in the oper-

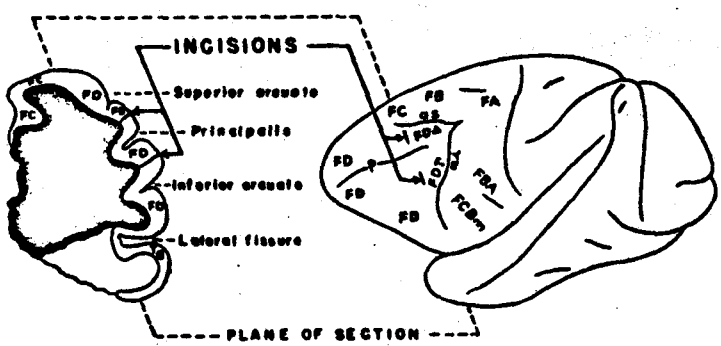


FIG. 1. Anterior frontal lobotomy in *Macaca mulatta*. This schematically portrays the plane and extent of the section.

* We are indebted to Dr. Karl Pribram for operating upon these animals when the authors could be present to discuss with him the location of the lesions and to assist with the operation.

ations all were intended to enter the brain at the same place and sever the same fibers.

Figure 1 shows schematically the extent of the lesion as planned. Histological examination of the brains is now in process. That functional prefrontal lobotomies were achieved is verified by the deficits in delayed response and delayed alternation which have been demonstrated in each animal when tested in the year following operation.

As a control for the operation those monkeys not operated upon were caught, anesthetized, had their heads shaved, and were isolated in the same way as the lobotomized animals.

## Results

### Social Structure of the Group: Establishment of the Hierarchy

Within a few days after the introduction of the 6 monkeys into the community cage a clear-cut social structure began developing on the basis of dominance-submission relationships. Dominance was expressed by primacy in food getting, and by aggressive behavior including glaring, growling, chasing, biting, and making threatening motions of the head and body. Aggression was common to all members of the group. It was an expression of dominance only in that it was directed downward in the hierarchy. Submission was expressed primarily in terms of avoidance. This included avoidance of the person of upper status animals, of preferred territory within the cage, and of situations likely to provoke attack. The single situation in which a low-status animal was most likely to be attacked was during feeding. Thus a lower-status animal rarely exhibited primacy in food getting, was cautious in obtaining food, and often carried it off to a safer place to eat. Behavior such as startle reaction, cringing, hiding, and haphazard running also occasionally characterized the low-hierarchy members. The social hierarchy which developed is portrayed in Fig. 2.

The time required for each individual monkey to find its niche in this social structure varied. *Back*, a 3.5 Kg. female, assumed the most dominant position on the first day, attacking any other animal with rare retaliation, and attacking other monkeys taking their food even though she did not eat it. She might then abandon this food and chase and bite still another animal.

*Head*, a 3.0 Kg. female, the second animal in order of dominance, continued to struggle for primacy for five days, but always retreated when attacked by No. 1.*

*Lefty*, a 3.6 Kg. female, was not definitely established as third in the hierarchy for approximately 2 weeks, although some degree of instability remained for a short time longer in that she occasionally displayed momentary aggression toward No. 2, and did not show as marked avoidance responses to No. 2 as to No. 1. Her No. 3 status was clearly demonstrated 16 days after the group was formed when she was the subject of a flurry of attacks, being bitten, chased, and grabbed around the head by No. 2. This attack was initiated by her attempts to get food before No. 2.

*Righty*, a 4.0 Kg. male, was No. 4 in the dominance hierarchy. He attacked No. 3 on several occasions during the first 10 days in the cage, but she always retaliated. He always retreated upon either a primary attack or retaliation from her.

*Alfred*, No. 5 in the hierarchy, was a 4.5 Kg. male, the largest animal in the group. On the first day he was aggressive, sexually active, and dominant in getting food, but he was quickly pushed down. By the fourth day No. 4 was attacking him frequently, demonstrated relative primacy in food getting, and drove him away from preferred locations. After a time food thrown to Alfred became a signal for No. 4 to glare at him, with Alfred then abandoning the food and cringing. This later reached the point where when the experimenter gestured toward him with a bit of food or a banana, he looked at No. 4, cringed, and

* The animal numbers designate the order in the original dominance hierarchy. The same numbers are retained after lobotomy even though the animals' order may change. Where an ordinal is used it designates the order at that time. For example, "Number 5 is sixth" would indicate that an animal originally in fifth place had dropped to sixth.

had. After 8 days he spent much of his time hiding or sitting alone in a corner. He exhibited hoarding behavior when a great deal of food was thrown in, but by the middle of the third week this had disappeared and when food was thrown in he avoided it and hid. He also retreated when there was other aggressive activity in the cage: for example, crawling under the radiator when No. 2 shrieked after having been bitten by No. 1.

The lowest and sixth position in the hierarchy was occupied by *Wizen*, a 3.0 Kg. female. From the first day she showed aggression only by growling toward monkeys in nearby cages, and on no occasion was ever observed in aggressive behavior toward any of her cagemates. By the fifth day she had been attacked by every other monkey without retaliating, and had become the "scapegoat" for the group. Thus, during the course of any general aggressive activity within the cage she was sure to be bitten by one or more of those involved. She was attacked by Nos. 4 and 5 more frequently than by the others. Within a week it was definitely established that in food getting she was a scavenger, that she was timid, avoiding all other monkeys, and seemed to relate more closely to the human observers than to her fellows.

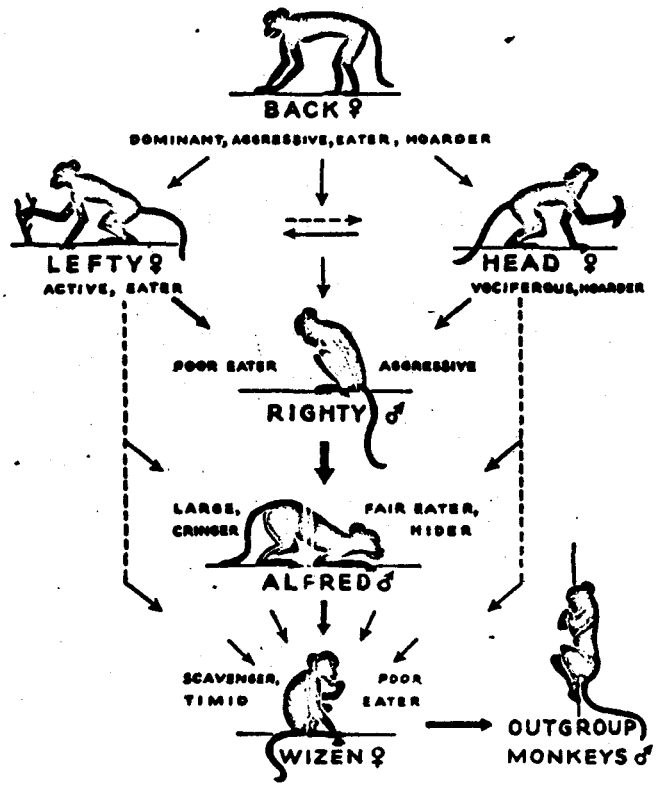


FIG. 2. The social structure of the monkey group. Arrows indicate the direction and intensity of aggressive behavior.

*Social Interaction Within the Group*

The general pattern of interaction within the group has been indicated above. In spite of occasional variability the social organization was relatively rigid, and once it had been established there were no changes in status during the preoperative period.

Aggression was always downward, as indi-

cated in Fig. 2. Such downward aggression was intensified by introducing frustrations, such as taunting an animal with a banana and finally withholding it. Such a situation predictably resulted in a violent attack by the taunted animal upon one or more lower status individuals, and would occasionally result in a "chain reaction" in which the aggression was transmitted from one to the other in a downward direction, for example from No. 1 to 4 to 5. Such a "chain" phenomenon was frequently observed when aggressive behavior was initiated by other stimuli. Downward "displacement" of aggression, associated with the inability of a lower status animal to retaliate against his higher status attacker, was the most prominent and constant characteristic of interaction within the group.

General aggressive behavior was stimulated by preferential treatment of low-hierarchy members by the experimenters, or occasionally by food taking by a low-status animal. For example, handing a banana to No. 6 stimulated an attack by 3 upon 4. Another illustration: when No. 6 was fed peanuts from the experimenter's hand she was attacked by No. 3 who chased her, clawed her, and pulled her hair. This stimulated an attack by No. 4 upon No. 5, and No. 3 was then attacked violently by No. 2. Except for attacks by the top animal on all the others, and by all upon the bottom scapegoat, the most intense and frequent attacks were upon victims immediately below the status position of the attacker.

The phenomenon of contagion or generalization of aggression or fear was observed on many occasions without obvious cause. For example, Head (No. 2) upon approaching the front of the cage was violently attacked by Back (No. 1). She shrieked loudly. When this happened Alfred (No. 5) crawled under the radiator and Lefty (No. 3) briefly attacked Wizen (No. 6). Thus each animal reacted in his own way: the submissive No. 5 hid, and the more aggressive No. 3 attacked the scapegoat No. 6.

*Responses to Introduction of Outgroup Monkeys*

On no occasion did any of the outgroupers fit into the structure of the ingroup. In two instances he was rapidly beaten into a position subordinate to all ingroup members, and in the third assumed complete dominance over the entire cage.

The first outgrouper, a normal 4.0 Kg. male, was introduced one month after the group had been formed. The most striking feature of the group response was that the most dominant animal ignored him, while the bottom animal who in the past had shown hostility only toward monkeys in other cages, acted as provoker, and was most active, screaming and nipping at him. No. 2, the noisiest and most curious of the ingroupers, first investigated but did not follow him when he retreated until No. 6 initiated the attack. No. 4 then joined. In a few minutes the outgrouper had ceased any kind of resistance, was bleeding and cowering in a corner with his back to the cage interior, and was completely unresponsive to the attacks of others even when Head chewed his tail. At this point No. 5, who had become increasingly excited, growling and mounting No. 1, attacked, biting him savagely around the loins. On the next day the outgrouper behaved skittishly and watchfully, staying away from the group high up on the cage sides. Nos. 4, 5, and 6 were actively aggressive toward him. He was not observed to eat at any time before his removal from the cage on the third day.

The response to the next outgrouper, a 4.0 Kg. lobotomized male, was very similar to that already described. Again No. 6 and eventually No. 5 were aggressive, and the others attacked him and took food away from him. Although he was definitely subdued he retreated less than the preceding outgrouper with an intact brain, and kept coming back for more punishment. He also was occasionally able to keep food long enough to eat it, although on the second day his taking food was the signal for a concerted growl by the entire ingroup, and any movement at all was the signal for some growls, especially from No. 6.

The third outgrouper was a 6.5 Kg. female in induced estrus, who was introduced one week later. She was considerably heavier than

ary of the ingroupers, and by the third day seemed to have the entire cage terrorized, Back, the top ingrouper, to the least degree. No. 6, the scapegoat, seemed to be her special target, and she, like the others except Back, retreated upon so much as a look from her.

### Behavior Following Prefrontal Lobotomy: Individual Primary Responses

Back, No. 1, and Alfred, No. 5, were operated on within a short time of each other in October, 1949, and Wizen, No. 6, was operated in the latter half of January, 1950. The major changes in the individual behavior of the three lobotomized animals are indicated in Table 1.

TABLE 1. INDIVIDUAL PRIMARY RESPONSES TO LOBOTOMY
Returned to community cage two and one-half weeks postoperatively

| *Subject* | *Preop. status* | *Motor activity* | *Transient increased aggression* | *Dominance status* | *Behavior change* |
|---|---|---|---|---|---|
| Back (Oct. 1949) | 1 | Increased | vs. Wizen (No. 6) (group "Scapegoat") | Unchanged. Food primacy unchanged. Social responses unchanged. | No significant change. |
| Alfred (Oct. 1949) | 5 | Increased | vs. Lefty (No. 3) and Righty (No. 4) (closest in hierarchy) | Unstable. Increased food getting and snatching attempts. Decreased response to threats of others. | Reversal of relationship with Righty and loss of cringing, phobic, "neurotic" behavior. |
| Wizen (Jan. 1950) | 6 | Increased | vs. Righty (No. 5) (closest in hierarchy) | Unstable. Increased food getting and snatching attempts. Decreased response to threats of others. | Initiation of chattering, grimacing, and more "normal macaque behavior. |

Back, the top animal in the social hierarchy, showed the least marked change after operation. Her level of motor activity was increased and she paid more aggressive attention to Wizen, the group scapegoat, than prior to surgery. She remained the most dominant animal, retained her primacy in food getting, and showed no new patterns of response to the others.

The behavior of the two low-status animals was definitely different after lobotomy than it had been before. Both showed increased motor activity, and exhibited increased food-getting attempts, sometimes snatching food from under the noses of higher status monkeys. They exhibited a decreased response to the threats of others, and showed transient aggressive behavior against the animals immediately above them in the dominance hierarchy. Alfred's (No. 5) behavior was most striking in this respect. His cringing, submissive behavior disappeared and he attacked Righty (No. 4) several times on the first day he was returned to the cage. Within two days it was apparent that a reversal in their relationship had occurred. He also attacked No. 3 on several occasions during the first week and did not withdraw when No. 2 growled at him. By the time Wizen (No. 6) was operated on the number 5 position was occupied by Righty. She was observed to attack him on at least one occasion at the end of the first week after return to the cage, and judging from his behavior may well have done so at other times when she was not observed. This was especially striking since she had never before been seen to exhibit any aggression toward her cagemates. In addition, she showed fewer

timid avoidance responses, and showed the macacus characteristic chattering and grimacing which had not been observed in her prior to surgery.

*Social Interaction Following Lobotomy*

The primary behavior change in the individual monkey following lobotomy was the beginning of a chain of events returning to impinge upon him, and in turn stimulating him to new behavior. It is possible to analyze the social interaction with regard to all of the combinations that might occur: one animal versus the entire group, animal versus animal, and so forth. Figure 3 shows in a schematic way the social interaction following Alfred's (No. 5) lobotomy with special reference to Lefty (No. 3). This illustrates the change occurring in the group structure.

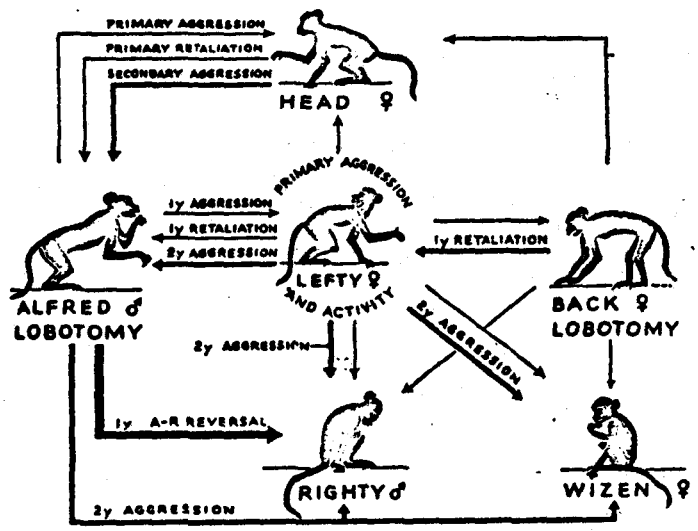


FIG. 3. Social interaction following lobotomy of Alfred (originally No. 5) with special reference to Lefty (No. 3).

After lobotomy Alfred displaced No. 4 and for a short time was able to attack Lefty, No. 3, without retaliation. Thus, in effect, he moved up to the number three position. Both Lefty (No. 3) and Head (No. 2), toward whom he had also shown transient aggression and with whom he competed in food getting, soon began to retaliate, attacking him with increasing frequency and intensity, pushing him back to the number four position. He in turn then displayed intensified "secondary" aggression against the two lower-status animals. This was very marked by the end of the second week after re-entering the cage, especially when one of them was fed directly by the experimenter or when he himself was attacked or had food taken away by Nos. 1, 2 or 3. While he was never seen to attack No. 1 after his operation, he showed less fear and avoidance upon being threatened, bitten, or chased by her, and occasionally attempted to snatch food directly from her. This stimulated increased retaliatory aggressive activity against him on her part and again contributed to the downwardly directed "secondary" aggression. With the increased downward push on both Nos. 5 and 6 they reached a position of relative equality where attacks by No. 5 on 6 practically disappeared. Righty's (No. 5) anomalous position might be accounted for by his low tolerance for conflict which was demonstrated in later testing.

Alfred's changed behavior not only stimulated No. 3 to retaliation against him but also resulted in his temporarily showing greater activity toward and decreased avoidance of all other cage members. The two bottom animals showed no response to this except to

...ecame more firmly established in their posi... Number 2 did not retaliate but displayed ...ore aggression toward Alfred. Number 1, ...wever, retaliated actively, with the effect of ...rther intensifying No. 3's attacks upon Al...red. This is designated in Fig. 3 as secondary ...gression. Number 1 at this time also showed ...creased aggressive activity against the other ...ge members, who became more active down...ard in the hierarchy except for the bottom ...o who responded with increased avoidance. Thus, the lobotomy of a single animal had ...percussions throughout the social system. Increased upward aggressive or food-getting activity resulted in increased retaliative activity, with consequent intensification of downward aggression, and at the bottom of the scale with increased avoidance.

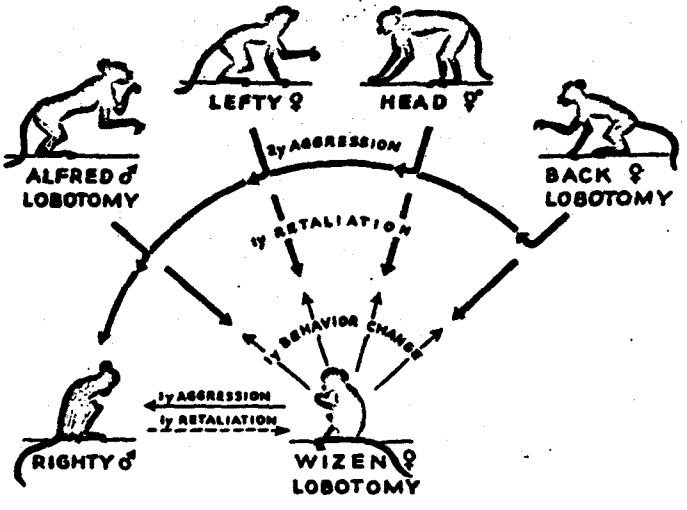


FIG. 4. Social interaction following lobotomy of Wizen (No. 6).

Responses to the reintroduction of the outgroup animals during this period were essentially as before. The major individual changes were that Alfred, apparently in association with his upward movement, attacked more rapidly than before, and No. 6 (who bore the brunt of even more intense aggression than before) no longer participated. The general characteristics of the group in relation to the outgrouper remained unchanged.

After the new social pattern had reached some degree of stability No. 6 was lobotomized, approximately 2 months after the reconstitution of the group. The general pattern of social interaction following her return to the community cage is schematized in Fig. 4. Her primary response to operation—increased motor activity, food-snatching attempts, and decreased avoidance behavior—resulted in an intensification of attacks upon her by the four higher status monkeys. Her direct assault upon Righty, who was now in a position of relative equality, was followed by rare, mild, transient retaliation. After the first week, however, he showed avoidance behavior, and was the subject of increasingly frequent attacks by the others. He had already taken over to some degree the function of group scapegoat after the reversal of his relationship with Alfred. This new intensification, which is referred to in Fig. 4 as secondary aggression, since it does not represent direct retaliation because of his new behavior, seemed to be a consequence both of the attack upon him by No. 6 and of the activity stimulated by her in the others.

In addition to retaliation against her, No. 6's increased activity also stimulated aggressive behavior by No. 1 against No. 2. When this occurred Alfred was seen to join the attack although he would not carry out such behavior independently. Following the attack on No. 2 by No. 1 in unison with Alfred, now in

fourth place, both Nos. 2 and 3 began to display increased concerted aggression against Righty and Wizen, now equal in the 5-6 position. These last two after this displayed no aggression toward each other for 3½ months, and sometimes would huddle together in the face of attack. During this time Alfred continued to show occasional upward aggression and at the end of 3½ months began once more to climb in the hierarchy, attacking both Nos. 2 and 3. Back retained her top position throughout the observation period. Wizen, on the other hand, began to exhibit increased avoidance behavior after 3½ months, the first sign being cowering and hiding when Righty was attacked by others. This foreshadowed Righty's resumption of dominance over her, and by the end of 4 months after her lobotomy she was again in the bottom position.

## Discussion

The present investigation was designed to observe the effects of lobotomy on an individual's relationship to his social group and the responses of other group members to his postoperative behavior.

Aggressive attack was a universal characteristic of the constituent members of the group. Before lobotomy the difference between animals was in the direction of their attack, and this appeared to be a function of learned avoidance responses. The behavior of a high-status animal toward lower-status animals was characterized by attack and absence of avoidance responses. The behavior of low-status animals was characterized by avoidance of the person of the higher status animal itself as well as of situations associated with attack by a higher status animal. When the low animal was attacked it did not retaliate, but retreated or attacked in a downward direction. The learned avoidance response was the basis upon which the social structure of the colony was built.

The most evident effect of lobotomizing 3 members of this group was to reduce the rigidity and stability of the social structure. This apparently occurred because of the disappearance or marked diminution of learned avoidance responses in the low-status animals. With the disappearance of the avoidance response in the lobotomized monkeys there appeared aggressive behavior, especially directed at the animal immediately above in the hierarchy. The upward aggression by low-status members resulted in violent retaliatory attacks, the ultimate effect of which was to increase the intensity of downward aggressive action throughout the social structure, and to decrease the animal's postlobotomy tendency to upward mobility in the hierarchy. The lobotomized animals soon abandoned direct attacks on upper-status monkeys, although they continued to enter situations such as food snatching which invited attack upon them. In spite of the intensification of the downward aggression which tended to restore the original social order the structure of the colony was not reconstituted in its original form. This was partly because of the impaired ability of low-status animals after lobotomy to relearn avoidance responses appropriate to their relative position in the hierarchy, and partly because of the secondary changes in other group members which followed this.

On the basis of these data it might be predicted that the effect of lobotomy on a human social group, for example a family, would be to change the avoidance-aggression relationships. The lobotomized person should theoretically lose the avoidance responses which he had learned as a way of dealing with the aggression of his fellows. With the disappearance of these avoidance responses he might then be expected to express previously inhibited aggression directly, or in symbolic terms. The response of the group should then be in the direction of intensified retaliation. The differences in reaction between human and monkey populations would be attributable to (1) the greater number of possible responses on the part of the human group; (2) the complexity of reaction introduced by symbolic behavior, and (3) related cultural factors.

## Summary

1. A colony of 6 *Macaca mulatta* monkeys was observed for 3 months before prefrontal

...tomy of 3 of its members and for 7 months ...er.

2. Before lobotomy a rigid dominance hier...hy was established on the basis of learned ...dance responses. After lobotomy the sta...y of the hierarchy was lost because of the ...ked diminution of the learned avoidance ...ponses in operated low status animals, with ... increase in upwardly directed aggression, ...d a tendency to upward mobility in the ...rarchy. This stimulated retaliation by ...eatened upper status animals, with the ...mate effect of increasing downwardly di...cted aggression throughout the group. The ...ial structure was not reconstituted in its ...ginal form, because of the impaired ability ...low status animals after lobotomy to relearn ...oidance responses appropriate to their rela...ve position in the hierarchy.

3. Implications of this finding for human groups are pointed out.

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