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EFFECTS OF CINGULECTOMY ON SOCIAL BEHAVIOR IN MONKEYS[1]

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WARD (9), GLEES *et al.* (1) AND KENNARD (2) have reported that lesions in the anterior cingular gyrus (area 24 of Brodmann) produce profound changes in the social behavior of monkeys. These changes have been characterized by Ward as loss of "social conscience," the animals behaving as though they had lost all social responsiveness, walking and sitting on their cage mates as though they were inanimate objects, and openly taking food from them. However, "this never led to a fight, for it was neither pugnacious nor even aggressive" (9, p. 15). In addition, both Ward and Glees *et al.* confirm the observation of Smith (8) that cingulectomized animals lose their preoperative shyness or fear of man and approach the human more readily to take food. Kennard has reported that the cingulate area ablations she has performed "reproduce in detail the patterns of behavior previously described by Smith and Ward" (2, p. 37). In contrast with these reports of behavioral change, Pribram and Fulton (5) have reported that anterior cingulate lesions had little or no effect on social behavior in three animals.

The majority of the previous investigators therefore agree that cingulectomy alters social and emotional behavior in monkeys. However, previous investigators have been, for the most part, only incidentally interested in social behavior and their observational techniques have consisted almost invariably of recording of gross impressions. The present investigation was undertaken as a rigorous and systematic study of the effects of this lesion, with techniques for observing and recording inter-animal social behavior and individual-cage behavior towards man. With the more complete information gathered in a systematic manner, the change in behavior following cingulectomy will be easier to specify. Further, the information can then be compared with similar information gathered in a study of the effects of amygdalectomy (7) on social behavior.

METHOD

Subjects. The subjects of this investigation consisted of four groups of five young rhesus monkeys (*Macaca mulatta*). Group 3 was composed of five immature males; the other groups contained ovariectemized females. One animal (Barbara) was a member of each of the three female groups; two animals (Sheila and Marlene) were members of two female groups. Each female group, however, was constituted at a different time, so that no animal served simultaneously as a member of more than one group. The animals in each group were housed alternately either together in a large cage of dimensions 8 $\times$4.5

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×7 ft. or separately in smaller individual cages of dimensions 2×2.5×2.5 ft. The periods of group- and individual-cage living are reported in Table 1.

Group-cage observation. When housed in the group cages, each group was observed daily at a regular time. *E* sat in front of the cage and introduced a quantity of peanuts one at a time (75 peanuts in groups 1 and 2, 50 peanuts in groups 3 and 4) through the wire mesh of the cage front by means of a feeding device which consisted of a length of 1.5 in. pipe mounted obliquely on a stand so as to extend 1 ft. into the large cage. *E* recorded which animal got each peanut as well as the dominant-subordinate interaction that occurred. At the end of the observation session, Rockland monkey pellets were thrown into the cage in amounts sufficient to make up the daily total ration of 80 cal./kg. body weight per animal (exclusive of peanuts). This diet was supplemented three times a week with one-half orange per animal. The animals were fed the same diet when housed individually.

Three categories of behavior were recorded during the daily session: peanut-getting acts; dominant acts (including both inter-animal aggressive acts such as biting, chasing and threatening and non-interactional acts such as stealing food and mounting the feeding pipe), and subordinate acts (including cringing, fleeing and failing to get food). Each animal received a tally of 1 for each dominant, subordinate and peanut act in which he engaged. The daily total of peanut acts for an animal, not including unsuccessful attempts, constituted his *Peanut Score* (P Score). The daily total of all dominant acts and unsuccessful peanut attempts constituted his *Other Dominance Score* (O Score). The sum of these two scores made up his *Total Dominance Score* (D Score) and sum of all subordinate acts made up an animal's *Subordination Score* (S Score). In addition to these scores, changes in an animal's rank in the group hierarchy, *i.e.*, a measure based solely on the direction of the dominant-subordinate interaction, were used to evaluate the effects of surgery. These scoring procedures have been described in detail by Mirsky (4).

Individual-cage observation. During the individual-cage periods, *E* observed each monkey daily while offering it five pellets of food and rated the ensuing behavior for aggressiveness (or fearlessness) according to a scoring scheme described by Rosvold *et al.* (8). The more aggressive (or fearless) an animal appears, the higher the score he receives; behavior such as vocalization, the distance of the animal from the front of the cage, the number of pellets taken and threatening behavior are rated and assigned a scoring weight. A high positive score (*i.e.*, +12) indicates that the animal is quite aggressive and/or unafraid in his behavior toward a human observer. A low or zero score indicates that the animal is quite unaggressive and fearful in his behavior toward a human observer.

Surgical and anatomical procedures. The surgical and anatomical procedures were the same as those described by Pribram and Fulton (5) except that Nembutal anesthesia was employed.

Design. The design of the study is summarized in Table 1. Two successive baseline measures were obtained preoperatively of the behavior of the animals in groups and in the individual cages. These served to provide control measures of both the characteristic individual-cage and group-cage behavior of the animal against which to evaluate the effects of surgery. Following the second preoperative period, the animal that was number one in the hierarchy of each group was subjected to bilateral cingulectomy. Postoperatively there were three measures each of group-cage behavior and of individual-cage behavior. The first individual-cage test was usually begun within one week after surgery, and the first group-cage test about two weeks after surgery. After the postoperative measures had been obtained on the number one animal in the hierarchy of Group 1, the number five (lowest) animal in the hierarchy of that group was operated upon and studied over three individual-cage and three group-cage periods. This schedule is summarized in Table 1.

Results

Anatomical. The reconstruction of the lesions is illustrated in Fig. 1. All five operated animals had at least 75% destruction of the anterior cingulate gyrus, although the lesion was probably most complete in Dot. Unlike the others, Dot had little or no sparing of the subcallosal portion of the anterior cingulate. Laura sustained most damage to the cingulate gyrus as a whole (*i.e.*, including both anterior and posterior portions) although she differed little from Roseann and Bobby in this respect. The corpus callosum was damaged in all animals, although more extensively in Laura and Roseann than in the others, particularly in the left anterior portion. Medial frontal and polar cortex was damaged extensively in all operated animals and most in Laura, although again the damage was not markedly different from that in Roseann and Bobby. Ventral orbital cortex was invaded in all animals, with Roseann sustaining the greatest loss. In each case, the overall damage

Table 1. Design of study according to temporal sequence of observation periods

Period description	Length (Days)	Cage situation
Preoperative 1	5	I[1]
	10	G[2]
Preoperative 2	5	I
	10[3]	G
SURGERY ON NO. 1 ANIMAL		
Postoperative 1	5	I
	10	G
Postoperative 2	5	I
	10	G
Postoperative 3	5	I
	10[4]	G
SURGERY ON NO. 5 ANIMAL (GROUP 1 ONLY)		
Postoperative 1	5	I
	10	G
Postoperative 2	5	I
	10	G
Postoperative 3	5	I
	10	G

[1] Individual cage.
[2] Group cage.
[3] Nine days for group 1.
[4] Seven days for group 1.

was rather more extensive on the right. In terms of total damage to both sides, in order of most to least, the animals rank: 1, Roseann; 2, Laura; 3, Dot; 4, Bobby; 5, Sally.

Group-cage behavior. The effects of cingulectomy were evaluated in two ways: on the scores of the five operated animals taken as a group, and on each operated animal's scores considered separately. To determine the immediate group effect, the mean of each operated animal's scores during the second preoperative period was used as a single score in computing an overall mean for each dominance or subordination measure and this was contrasted with the corresponding overall mean during the first postoperative period. To determine the delayed group effect, the overall second preoperative period mean was contrasted with the corresponding mean during the third postoperative period. Both immediate and delayed postoperative group

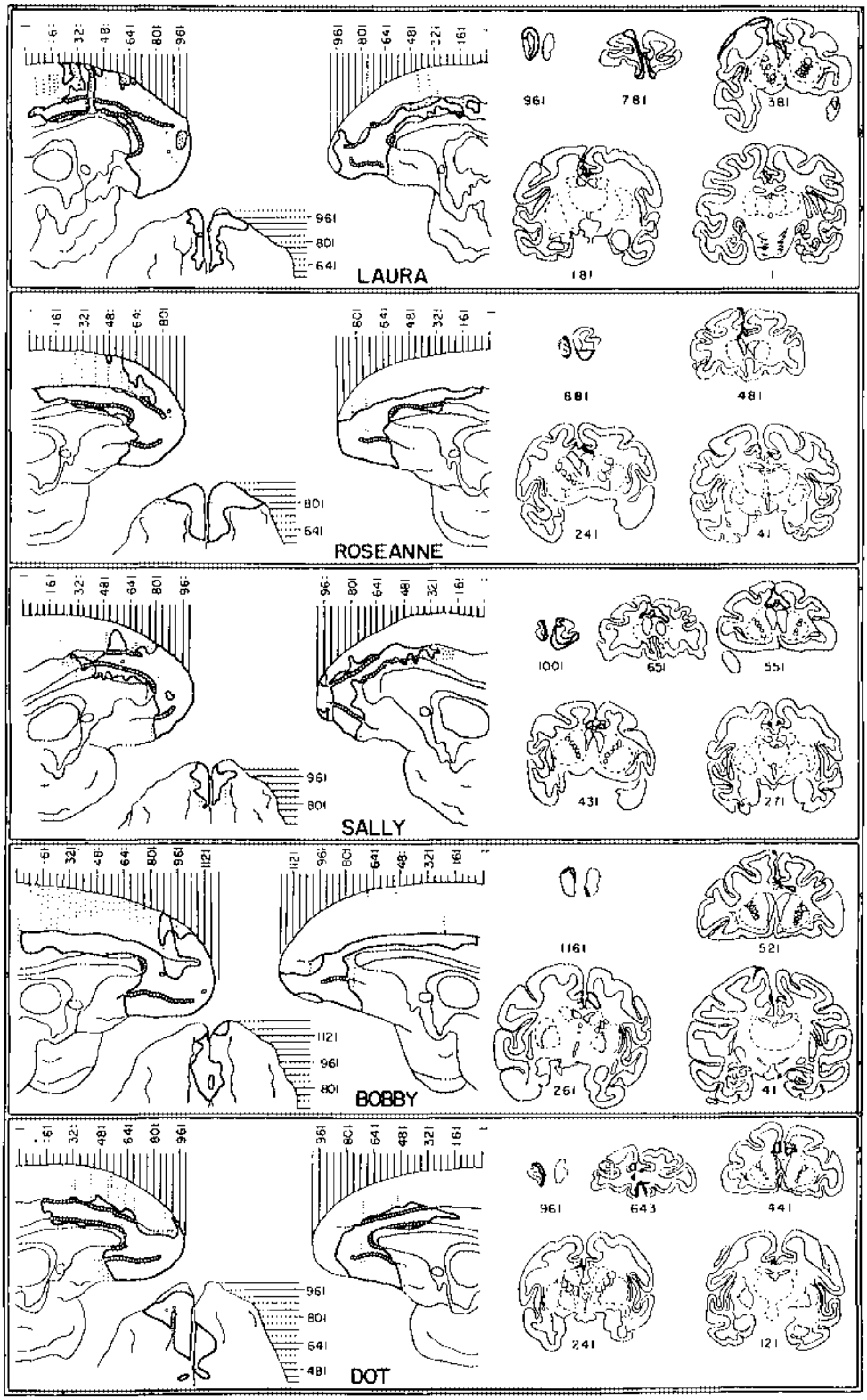

FIG. 1. Reconstructions of brains and representative cross sections showing lesions in five operated animals. Black indicates complete destruction, dotted lines indicate partial damage.

effects were measured using Peanut (P), Other Dominance (O), Total Dominance (D), and Subordination (S) Scores. None of these eight comparisons revealed a difference significant at $p < 0.05$ (t test for matched groups).

Lest the nonsignificant group comparisons conceal some significant individual differences, individual comparisons were made between the means of each operated animal's scores (here used as means) during the periods specified above. Table 2 summarizes the individual comparisons of P, O, D, and S Scores. The significance of these differences was evaluated by the Mann-

Table 2. Summary of immediate and delayed effects of cingulectomy on measures of group-cage behavior; all operated animals

Group		1	1	2	3	4
Operated animal		Laura	Roseann	Sally	Bobby	Dot
Comparison	Measure					
2nd preop. test	P	decrease[1]	—	—	—	—
	O	increase	—	—	—	—
vs.						
	D	increase	—	—	—	—
1st postop. test	S	—[3]	—	—	—	—
(Immediate)	Rank in Hierar.					
2nd preop. test	P	DECREASE[2]	—	—	increase	—
	O	DECREASE	—	DECREASE	—	—
vs.						
	D	DECREASE	—	—	INCREASE	—
3rd postop. test	S	INCREASE	decrease	—	—	—
(Delayed)	Rank in Hierar.	Fall to No. 3	—	—	—	—

[1] A change significant at $p < 0.05$ is indicated by lower case letters.
[2] A change significant at $p < 0.01$ is indicated by upper case letters.
[3] — indicates no significant change.

Whitney U test (3). Only one of the five operated animals (Laura) showed any significant immediate postoperative differences; on the whole, these were in the direction of increased dominance. Four of the five operated animals show some significant score change in the delayed comparison, but again the most marked are those occurring in Laura. The various changes will be discussed in detail in relation to each group.

Group 1. Figure 2 presents the mean Total Dominance (D) Scores and mean Subordination (S) Scores of the animals in Group 1 for the several group-cage periods in which the group was observed. Preoperatively, the dominance hierarchy was as follows: 1, Laura; 2, Harriet; 3, Barbara; 4, Sheila; 5, Roseann. In the first postoperative group-cage period Laura showed a slight but significant decrease in her Peanut (P) score and a significant increase in her Other Dominance (O) Score. The latter was reflected in a significant increase in her D Score. There was no change in her position in the hierarchy; she remained number one, and, as would be expected, continued to show a zero S Score (Fig. 2). Interpretation of the delayed effects of surgery in Laura is complicated by the fact that the number two animal, Harriet, died between postoperative periods 1 and 2. When the group was reconstituted in postoperative period 2 (after Harriet's death) Laura remained dominant for one day and then fell sharply in dominance to the number three position in the group of four animals. Barbara, formerly number three, now assumed the number one position and Sheila, formerly number four, now became number two. Roseann remained the least dominant

Table 3. Summary of individual-cage observation; operated animals and hierarchy controls

Pair	Animal	Individual-Cage period				
		Preop 1	Preop 2	Postop 1	Postop 2	Postop 3
1	Laura[1]	—[3]	30[4]	52	48	46
	Harriet[2]	—	30	40	46	—
2	Roseann[1]	46	49	48	55	52
	Marlene[2]	56	59	53	50	57
3	Dot[1]	30	10	52	48	24
	Jean[2]	40	33	47	46	42
4	Bobby[1]	31	48	·	46	43
	Max[2]	7	9	·	9	17
5	Sally[1]	14	20	33	38	35
	Esther[2]	38	40	31	20	31

[1] Operate.
[2] Hierarchy Control.
[3] Data unavailable.
[4] Represents the sum of five individual-cage observation scores.

animal in the group. Laura's fall in the hierarchy was reflected in significant decreases in her P, O, and D Scores and a significant increase in her S Score. These changes are apparent in Fig. 2 which also shows that Laura retained this subordinate position for as long as Group 1 was studied.

Roseann, the least dominant animal in the group, was operated upon after Laura's postoperative period 3. As can be seen in Table 3, she showed no significant immediate postoperative score change and a delayed postoperative change only in that her S Score decreased significantly. However, her S Score had been decreasing steadily since the first postoperative period after Laura's operation (Fig. 2).

Group 2. Figure 3 presents the mean D and S Scores of the animals in Group 2 over the five group-cage periods. Preoperatively, the dominance hierarchy was as follows: 1, Sally; 2, Esther; 3, Barbara; 4, Sheila; 5, Marlene. The hierarchy remained unchanged for as long as Group 2 was observed and there were no changes in any of Sally's scores in the immediate postoperative comparison. She did show a significant decrease in her O Score in the delayed postoperative comparison (Table 2) but this was not reflected in her D Score (see Table 2; also Fig. 3).

Group 3. Figure 4 presents the mean D and S Scores of the animals in Group 3 over the five group-cage periods. Preoperatively the dominance hierarchy was as follows: 1, Bobby; 2, Max; 3, Ralph; 4, Oswald; 5, Tim. The

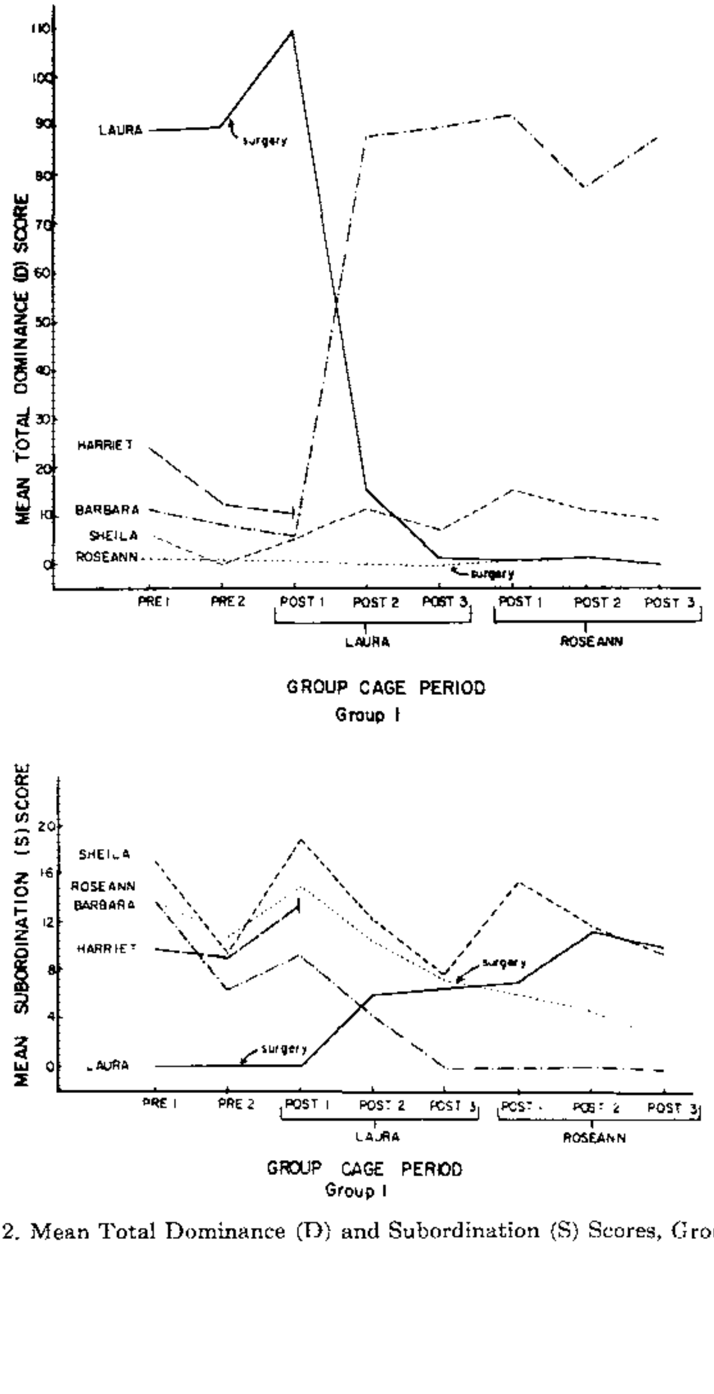

FIG. 2. Mean Total Dominance (D) and Subordination (S) Scores, Group 1

hierarchy remained unchanged during the life of the group and there were no significant changes in any of Bobby's scores in the immediate postoperative comparison. In the delayed postoperative comparison, Bobby showed a small but significant increase in his O Score, which was also reflected in his D Score (Table 2; also Fig. 4).

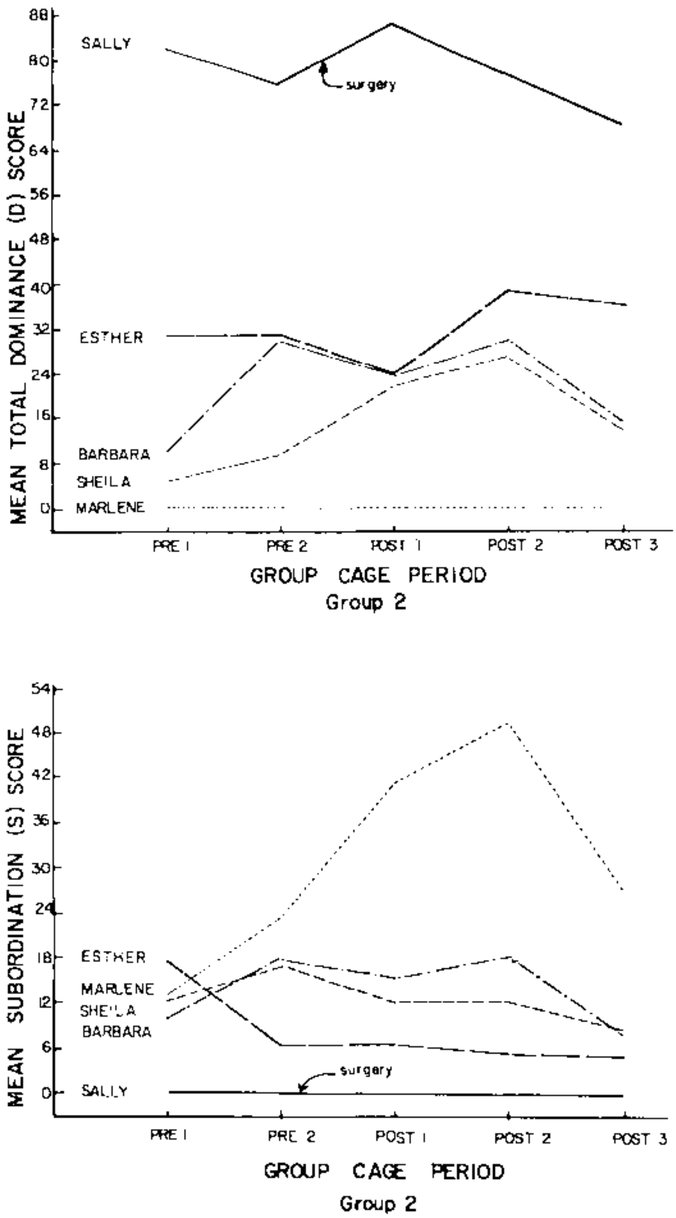

FIG. 3. Mean Total Dominance (D) and Subordination (S) Scores, Group 2.

Group 4. Figure 5 presents the mean D and S Scores of the animals in Group 4 over the five group-cage periods. Preoperatively the dominance hierarchy was as follows: 1, Dot; 2, Jean; 3, Molly; 4, Barbara; 5, Marlene. The hierarchy remained unchanged for as long as Group 4 was studied and there were no significant changes in Dot's scores in either the immediate or the delayed postoperative comparisons.

Individual-cage behavior. Table 3 summarizes the data of the individual-

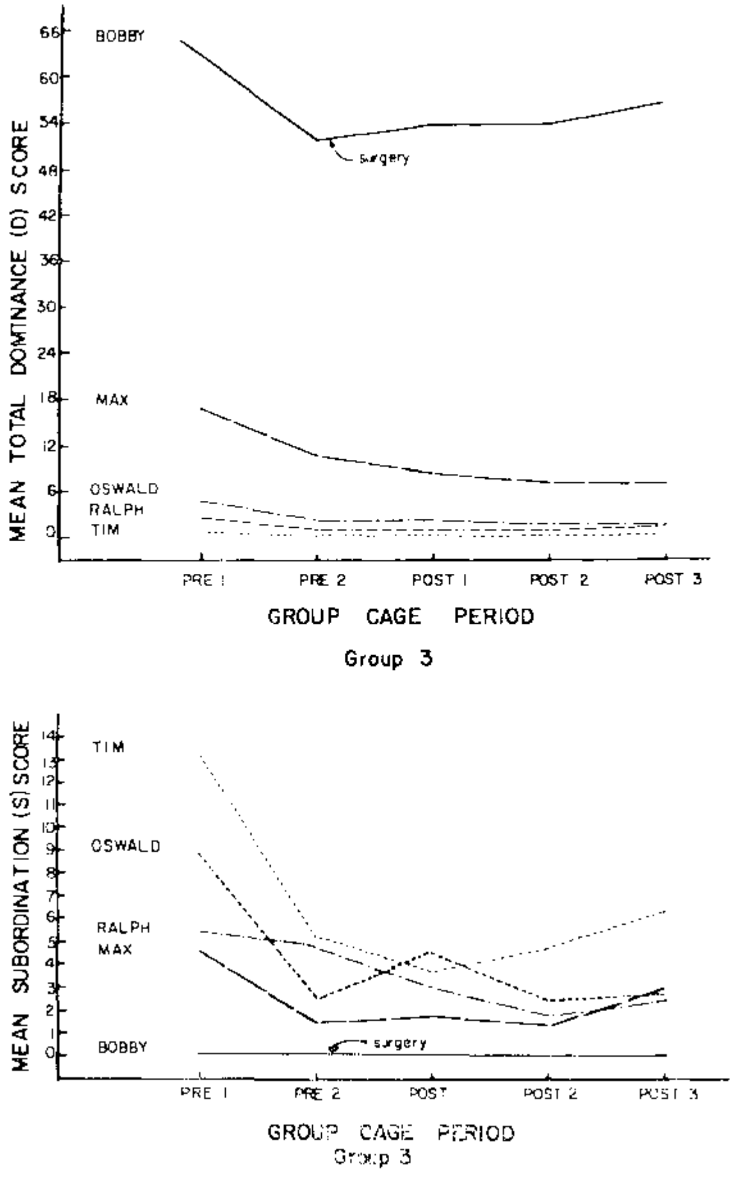

FIG. 4. Mean Total Dominance (D) and Subordination (S) Scores, Group 3.

cage observations. For the scores of each operated animal that was number one in the hierarchy the scores of the number two animal in that group were used as control data. For the scores of Roseann, who was the bottom animal in the hierarchy of Group 1, the scores of Marlene, the bottom animal in the hierarchy of Group 2 were used as control data.

The immediate effects of the lesion were evaluated by determining the

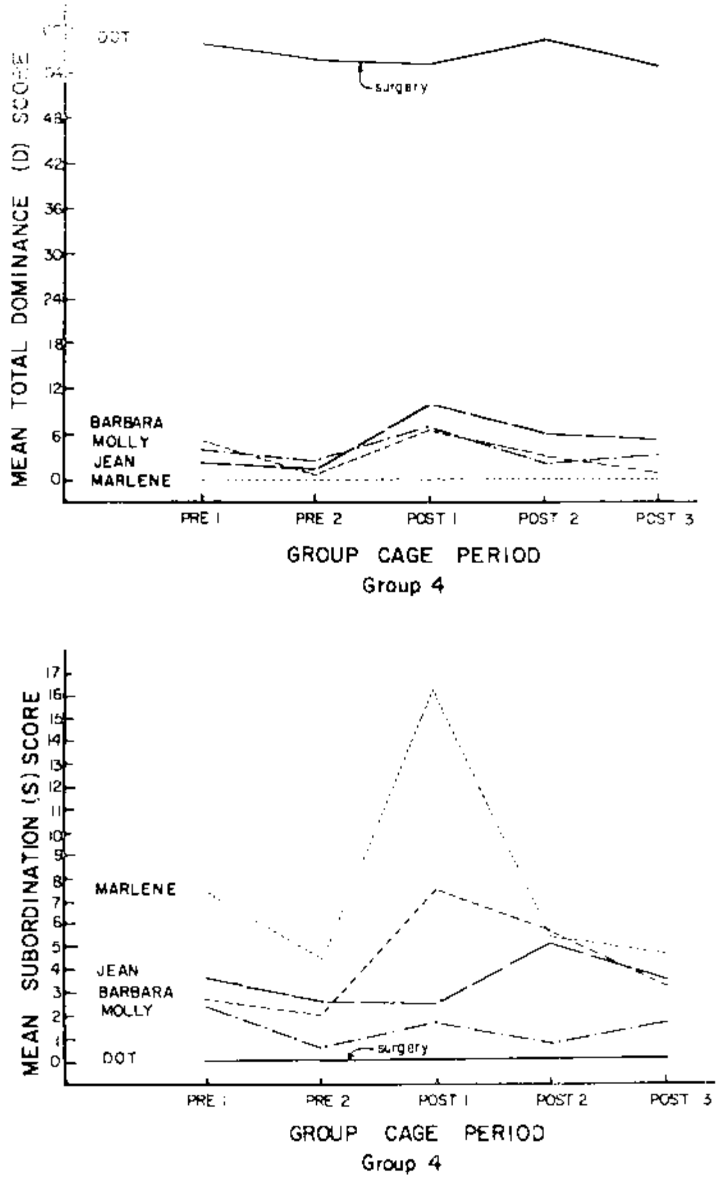

FIG. 5. Mean Total Dominance (D) and Subordination (S) Scores, Group 4.

difference between the first postoperative score and the second preoperative score for each operated animal and comparing these differences with those obtained for the matched controls. This comparison (restricted to pairs 1, 2, 3 and 5 for whom the data were available) revealed a difference significant at $p < 0.05$ (t test for matched groups), indicating that the operated animals showed an increase in their aggressiveness (or fearlessness) score postoperatively, as compared with their controls. The delayed effects of the lesion were evaluated similarly, using this time the second preoperative scores and the third postoperative scores. This comparison (restricted to pairs 2, 3, 4, and 5) was not significant ($p < 0.70$), indicating that there was no increase in the operated animals' scores in the third postoperative period, as compared with

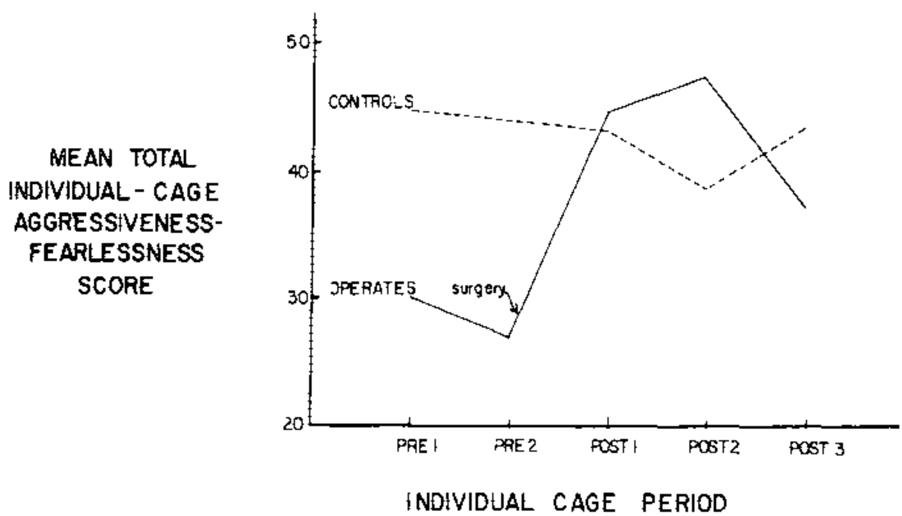

FIG. 6. Individual-cage aggressiveness-fearlessness scores for operated and control pairs 2, 3 and 5.

the controls. These relationships are clearly evident in Fig. 6, which graphs the data from the three pairs (2, 3, and 5) for which all period measures were obtained.

Although the group effect was significant in the immediate postoperative comparison, it should be noted that individually considered, one of the operated animals, Roseann, showed no increase in the immediate postoperative test; although the first postoperative test data are not available for Bobby, he showed a decrease in the second and third postoperative test. Thus, only three of the five operated animals, Laura, Dot and Sally, apparently show any increase in individual-cage aggressiveness (fearlessness) and the significant immediate postoperative effect is due to the change in their scores.

Discussion

In discussing the results of this study, and in relating them to previous studies of cingulectomy, the effects of the lesion on individual-cage behavior (the response of the animal to the human observer) will be considered separately from the effects of cingulectomy on group-cage behavior (the response of the animal to other monkeys of the group).

With respect to individual-cage behavior, the operated animals were significantly more aggressive (or less fearful) in the immediate postoperative comparison. At a later postoperative comparison, this difference had disappeared. Even in the immediate postoperative period, however, there was apparently no change in the scores of two of the operated animals, Roseann and Bobby. The lesions in Roseann and Bobby do not appear to be systematically different from those of the other operated animals; Roseann had the largest overall lesion, and Bobby had the second smallest. It may be concluded that surgery had the effect of making three of the five operated animals temporarily more aggressive (less fearful) in relation to man, and that compared with the controls, the group effect was significant. This finding agrees with that of Smith, which he summarized as follows: "The animals appear less frightened when approached and, instead of running away and crouching in the far corner of the cage, will now take food from one's hand. However, they will not permit themselves to be handled" (8, p. 43).

The group-cage results of this study do not confirm those of previous workers, excepting Pribram and Fulton. In none of the several measures of group-cage behavior used in this study was there any significant group effect of the surgery. Therefore, individual changes must be regarded with caution. With the exception of Laura, none of the operated animals showed any significant changes in the measures of dominance behavior in the immediate postoperative comparison; the few changes which occurred in the delayed postoperative comparison show little consistency. These changes might equally well be interpreted as chance fluctuations in dominance and subordination scores. Such fluctuations are not uncommon in monkey groups (4). Attributing these changes to chance seems particularly appropriate since, with the exception of Laura, there was no change in the hierarchical rank of any operated animal. Interpretation of the marked changes in Laura, including her fall in hierarchy, is equivocal. With respect to the lesion, Laura does not differ markedly from Dot, who showed no significant change in measures of social behavior at any time postoperatively. Roseann had a larger lesion than Laura and she showed only one significant postoperative score change, which by the previous analysis does not appear to be due to the lesion.

The death of Harriet, the number two animal in the hierarchy of Laura's group, changed the group composition and alone may have been responsible for the fall. However, even in Laura's fall to the number three position in the group of four animals, she behaved in an entirely appropriate fashion. She was dominated by the animals above her in the hierarchy and dominated the animal below her in the hierarchy. Neither Laura nor any of the other operated animals ever exhibited behavior which could be described as lacking in "social conscience" or as "socially indifferent."

What can account for the lack of agreement in the several reports of the effects of cingulectomy on social behavior? Several factors seem reasonable to consider. The continual restless pacing reported by Glees *et al.* may give the impression of loss of social conscience. Thus, in the absence of rigorous measurement of dominance, an animal restlessly pacing may appear to be socially indifferent or more dominant as he walks into his cage mates. Ward, however, reports hyperactivity in only one of his four operated animals, all of which presumably showed the same kind of socially indifferent behavior, and Pribram and Fulton report no change in the activity of their operated animals as measured in several ways. Moreover, Smith stated that his animals show a temporary decrease in activity. Therefore, the reported behavioral changes cannot all be interpreted in terms of increased activity.

A further possibility relates to the adequacy of the behavioral observation technique used in previous studies. Those who have reported changed social responsiveness may not have observed their animals systematically enough, or may not have had an adequate sample of the preoperative behavior of the group with which to compare postoperative behavior, or may not have have made the important distinction between changes in response to man and changes in response to other animals. Consequently they may have generalized from one situation to another without adequate information.

Finally, differences between lesions must be considered. The only other published anatomy is that of Glees and coworkers, and Pribram and Fulton. Although the lesions in the present study are not exactly comparable to those of Glees *et al.* (in that the present lesions are larger and extend more caudally), the lesions in the animals in the Pribram and Fulton study that were observed in a social situation (cingulates 7, 8, and 9) appear to be comparable to those of Glees. In both instances, the lesions were largely confined to area 24. Pribram and Fulton report no effect on social behavior; Glees *et al.* report marked changes, including increased dominance in two of the five animals on whom dominance tests were performed. The differences cannot, therefore, be attributed to differences in the lesions.

Clearly, none of the animals in this study showed any behavior which could be classified as socially indifferent. Therefore the only conclusion possible on the basis of the evidence presented here is that cingulectomy may have the effect of making monkeys temporarily more aggressive or less fearful in relation to man but that it is generally without effect on social behavior as measured by the several indices of dominance and subordination employed in this study. From the available evidence from lesions in the amygdala and cingulate gyrus it would appear that the limbic system as described by Papez may be equipotential with respect to emotional behavior as measured by change in reactivity to man (since lesion in both areas may alter this behavior) but that it is not equipotential with respect to the emotional behavior as measured by inter-animal social interaction. Some behavioral confirmation is thereby provided for the findings of Pribram and MacLean (6) that the cingulate gyrus and the amygdala are parts of functionally distinct systems. Moreover, it is clear that the unqualified conclusion, on the basis of experiments in monkeys, that the cingulate gyrus is intimately concerned with personality and emotion is unacceptable.

Summary

1. Bilateral cingular gyrus ablations were performed in five young *Macaca mulatta* monkeys, after systematic observations of their behavior in response to man (individual-cage situation) and to other animals in a social colony (group-cage situation).

2. Three of the five operated animals showed more aggressiveness (or fearlessness) in response to man immediately after operation and the group effect was significant. This change proved to be temporary, for the operated animals did not differ significantly from their preoperative status in a postoperative comparison approximately two months later.

3. Only one of the operated animals showed any marked changes in the group-cage situation, and the interpretation of these changes is equivocal.

4. The differences among the effects in the several animals do not appear to be related to differences in the locus or extent of the lesions.

5. These findings were discussed in relation to previous studies: the effect on individual-cage behavior appears to be a fairly consistent and repeatable effect of cingulectomy; the effects previously reported on group-cage behavior may be a function of the inadequacy of the observational technique used in these studies.

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