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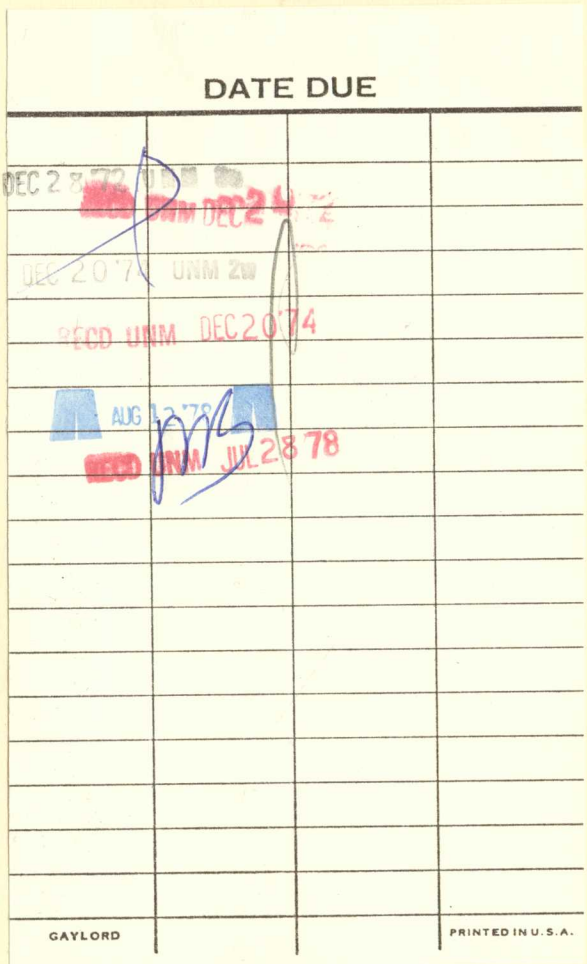
# Transfers in Handedness as a Function of Lesion Size in Animals with Varying Degrees of Forced Practice

James V. Devine

TRANSFERS IN HANDEDNESS - DEVINE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# TRANSFERS IN HANDEDNESS AS A FUNCTION OF LESION SIZE IN ANIMALS WITH VARYING DEGREES OF FORCED PRACTICE

By

James V. Devine

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

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This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Stuart A. Northrop
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Date

# TRANSFERS IN HANDEDNESS AS A FUNCTION OF LESION SIZE IN ANIMALS WITH VARYING DEGREES OF FORCED PRACTICE

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# INTRODUCTION

Since 1934, a series of studies (1-10) have been performed at the University of New Mexico in an attempt to determine the anatomical locus of handedness in the rat. This series has been labeled the "Peterson handedness studies" (10). Throughout the Peterson handedness studies, attempts have been made to locate the precise anatomical area that controls handedness in order to submit this area to histological investigation. Ultimately, these studies seek a means of determining the neural equivalent of practice.

The latest study in this series is an unpublished doctoral dissertation by L. W. Rook (10). Rook's findings indicate that a critical handedness area "located in or near layer 6. . . approximately 4.8mm. caudal from the frontal pole and 2.7mm. lateral from the midsagittal plane must be destroyed to produce a change in handedness" (10, p. 57). Rook used a stereotaxic instrument and measured from bregma 2.7mm. lateral, 1.6mm. rostral, and 2.1mm. minus .4mm.[1] ventral (approximately layer 6) to make his lesions by electrocoagulation. These measures from bregma best approximate the critical area.

---

[1]The electrode is allowed to drop 2.1mm. from the point of contact with the cortex and then lifted .4mm., so that the point of the electrode is actually 1.7mm. deep. This is done to insure a proper depth and to guard against the tissue depressing at the point of the electrode instead of allowing the electrode to penetrate the tissue.

Rook systematically placed his lesions in an area 4mm. in the rostral-caudal dimension and 2mm. in the medial-lateral dimension. Ten of the 73 animals operated on in the early stages of his experiment had lesions of approximately 1mm.$^3$ and only two of these animals showed any effect. Therefore, for the majority of the animals in his study, he used lesions in the range 3.5mm.$^3$ to 4.5mm.$^3$ as he thought "that the lower limit of volume had been approached" (10, p. 23).

In order to submit the handedness area to histological investigation, the volume to be examined must be relatively small. It has been estimated that there are approximately $5 \times 10^4$ cells per mm.$^3$ within layer 6 alone (10). Therefore, a destruction as large as 3.5mm.$^3$ would prove almost impossible to investigate by available histological methods.

The present study was an attempt to produce transfers in handedness with lesions smaller than 3.5mm.$^3$ using Rook's measurements from bregma to determine the critical area.

Peterson (4), using forced-practice techniques, has found that "practice exerts its influence early, since small amounts [of practice] seem to have a relatively stronger influence and additional amounts [of practice] add only smaller increments." Thus, to facilitate transfers, practice was given in the early stages of handedness training with the non-preferred hand.

## METHOD

The method was essentially that used by Rook with the exception of the inclusion of forced-practice training.

Apparatus: The testing and training apparatus was a 12 x 12 x 12 inches cage which contained a short wire-enclosed runway 2 inches wide, 4 inches high, and 5 inches long, mounted perpendicularly to one side of the cage. An opening at the runway intersection and the side of the cage accommodated the reaching dish.

Three reaching dishes were used:

(1) A ceramic replica of the glass reaching dishes used in all previous studies of this series. This dish will be referred to as the "unbiased" dish, and was used both in the training and testing stages of the experiment.

(2) A ceramic replica of the glass reaching dishes used in this series but with the added attachment of a metal strip cemented to the front of the dish. The metal strip was 2 inches high and ran along one-half of the front of the dish. The strip prevented reaches with the preferred hand. This dish and its mirror image will be referred to as the biased-right or biased-left dish, since the rat could only reach with his non-preferred hand when this biasing was introduced.

Electrodes of approximately 150 microns diameter, made of silver, and insulated with a layer of glass, were used to produce lesions. A low impedance radio frequency current was provided by a surgical Hyfrecator. The Hyfrecator was used to control the amount of cortical destruction at the tip of the electrode.

A Johnson-Krieg stereotaxic instrument immobilized the experimental animals during the operation. The stereotaxic instrument was the same one used by Rook. The instrument had positioning scales which allowed the tip of the electrode to be placed with an accuracy of approximately .2mm. in any of three planes.

Procedure: Five albino rats were selected at random each week of the experiment from the general colony. The S's were placed in isolated cages for 72 hours with a ten gram-per-day diet of Purina Chow. These 5 rats were selected for inclusion in the experiment if they gave 9 out of 10 single-handed reaches with the unbiased dish on their first day of training. Any animals not reaching this criterion were discarded.

Forced-practice: After the 10 initial unbiased reaches to determine the S's hand preference, each S was given one forced reach and one unbiased reach in an alternating sequence (1 to 1) until each S had a total of 20 forced reaches and 20 unbiased reaches. All forced reaches were with the non-preferred hand.

Pre-operation testing: The experimental rats were then given 250 unbiased reaches--50 each day for 4 days and 50 immediately before

operation. The 50 reaches for day 4, plus the 50 reaches from day 5, were computed as the rats pre-operation handedness score. Scores were computed as percent preferred hand reaches.

Operation: All lesions were placed from bregma--approximately 2.7mm. lateral, 1.6mm. rostral, and 2.1mm. ventral. All operations were performed on the hemisphere contralateral to the preferred hand.

Post-operation testing: The S's were placed in recovery cages immediately following the operation. They were tested for 2 days following the operation (50 reaches per day) to determine the post-operational handedness score. Scores were computed as percent preferred hand reaches. The animals were tested not sooner than 12 hours after the operation, and not later than 24 hours after the operation.

After testing: Immediately following the 100 post-operational reaches, the S's were destroyed and the brains removed and left in formol for 1 week. The following week the brains were sectioned in parasagittal plane at 100 microns by the freezing method. All sections containing any part of the lesion were saved and mounted on slides. All sections were counted from the first slice to the lesion, in order to determine the lesion distance from the midline. Sections were stained in thionin. Table 1 is a summary of the exact order of the treatments for all animals in this study.

Microscopic examination of the mounted sections was performed to reconstruct and measure the size of the lesion. Lesion volume, dis-

TABLE 1

ORDER OF TREATMENTS FOR ALL ANIMALS

| Day | Treatment |
|---|---|
| 1 | Forced-practice |
| 2 | Pre-operation test |
| 3 | Pre-operation test |
| 4 | Pre-operation test |
| 5 | Pre-operation test |
| 6 | Pre-operation test and operation |
| 7 | Post-operation test |
| 8 | Post-operation test and sacrifice (Place brain in formol for 1 week) |
| 15 | Section brain |
| 16 | Stain sections |

tance from the midline to the center of the destruction, distance from the frontal pole to the center of destruction, and distance from the head of the caudate nucleus to the center of the destruction were measured. Involvement of layers 4, 5 and 6 was noted, and also any penetration into white matter.

## RESULTS

General: Fifty-two animals were selected for the experiment. Nine animals had to be discarded for the reasons listed in Appendix A. Therefore, 43 rats were included in the final analysis. Of the 43 used in the final analysis, 11 animals showed effects due to the operation which were greater than a 50% change in handedness score. Five animals showed effects of less than 50% but greater than 10%. Five animals showed qualitative affects, such as poor coordination after the operation, but did not show a change in handedness score. These latter 5 cases are described below, along with other atypical cases.

Rook's area: The results that relate directly to Rook's hypothesized area are shown in Figures 1-4.

Figure 1 shows the boundaries of all affected cases in relation to Rook's area. Ten of the cases, or 62.5% of the affected cases, overlapped[2] Rook's area. Six cases, or 37.5% of the affected cases, did not overlap Rook's area. All lesions involve parts of layer 6.

Figure 2 is an overlay of affected cases involving small lesions (.58mm.$^3$ to 1.72mm.$^3$) in relation to Rook's area. There are a total of nine cases shown in this overlay. Five of the cases, or 55.56% of the

[2]An overlapping case is here defined as a case with a destruction that involves any part of Rook's area.

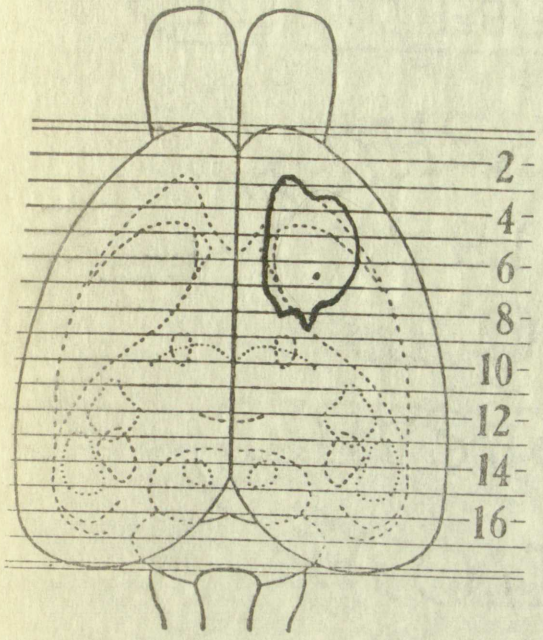



FIGURE 1. Total extentof destructions in affected cases (16). The dot is Rook's area.

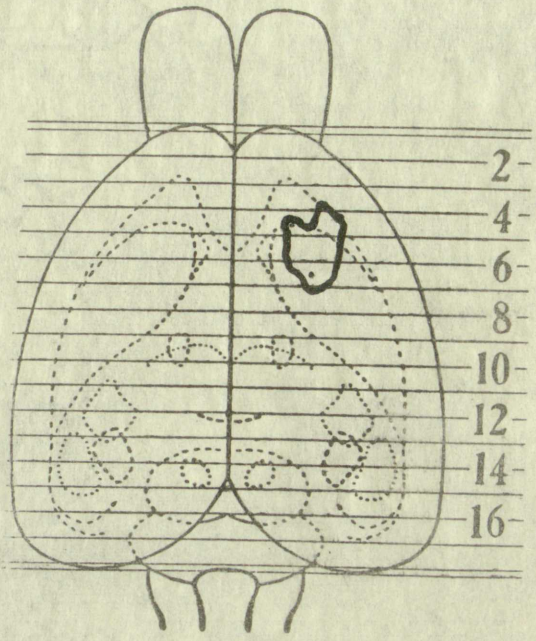



FIGURE 2. Total extent of destructions in affected cases (9) with lesions less than 2mm.$^3$. The dot is Rook's area.

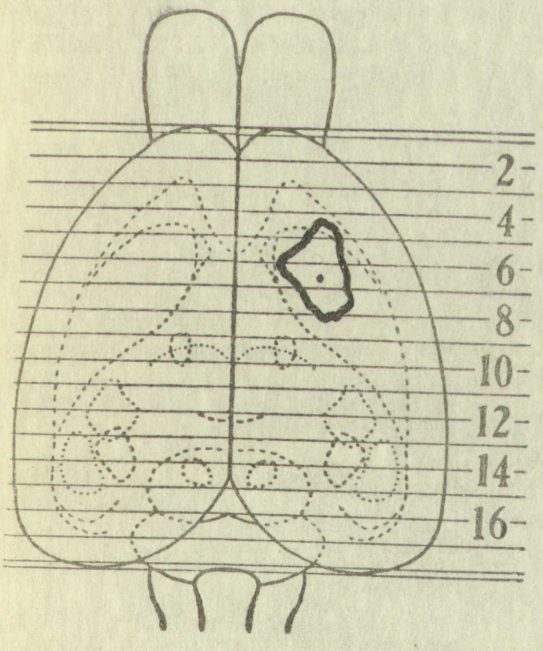



FIGURE 3. Total extent of destructions in negative cases (14) that overlapped Rook's area. The dot is Rook's area.

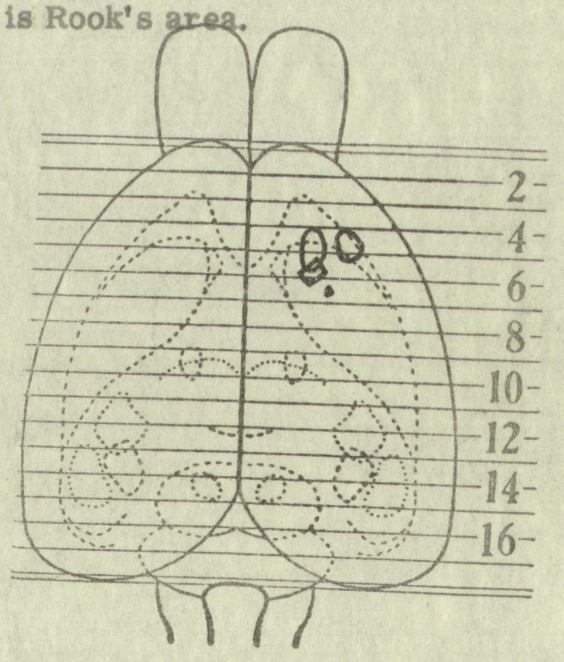



FIGURE 4. Three extreme affected cases in relation to Rook's area. The dot is Rook's area.

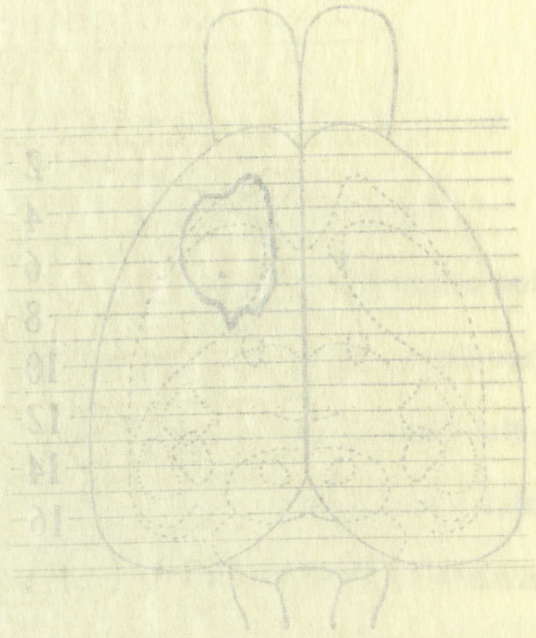


FIGURE 1. Total extent of destructions in affected canes (16). The dot is Rook's area.

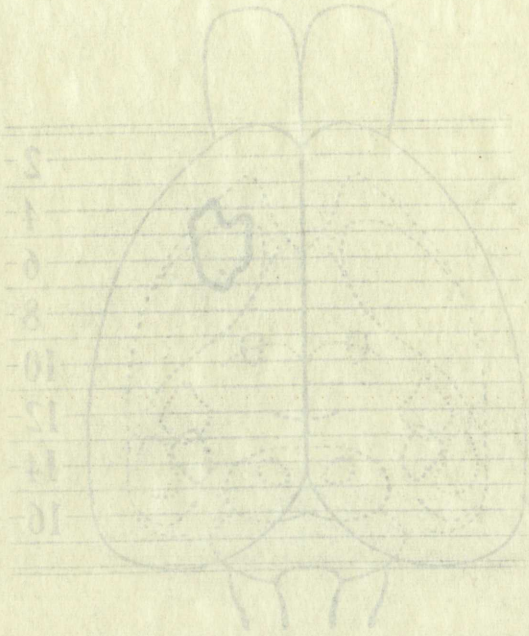


FIGURE 2. Total extent of destructions in affected canes (3) with lashing less than 2mm. The dot is Rook's area.

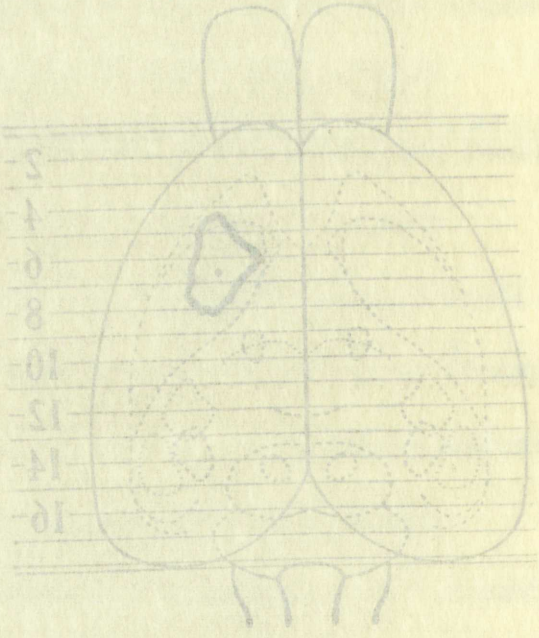


FIGURE 3. Total extent of destructions in negative canes (14) than overlapped Rook's area. The dot is Rook's area.

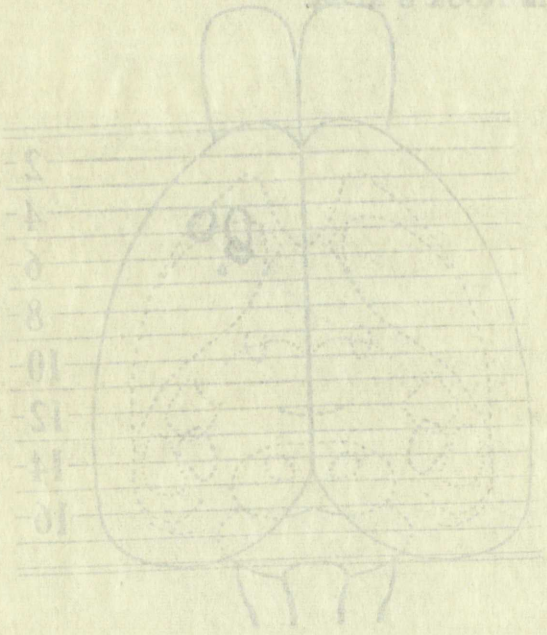


FIGURE 4. Three extents of affected canes in relation to Rook's area. The dot is Rook's area.

small affected cases overlap Rook's area. Four, or 44.44% of the small affected cases, do not overlap Rook's area. All lesions involve parts of layer 6.

Figure 3 is an overlay of the 14 negative cases (cases that were not affected) that overlapped Rook's area. There were a total of 27 negative cases. Only one case out of all the negatives did not involve parts of layer 6, and that case (number 15) did not overlap Rook's area. Rook's hypothesis of a critical area highly localized in this spot cannot explain these negative cases.

Figure 4 is an overlay of three extreme positive cases, i.e., extreme in terms of distance from Rook's area. The three cases (nos. 18, 25 and 38) showed marked effects. The effects and related measures are summarized in Table 1.

TABLE 1

THREE EXTREME CASES

| | | Lesion | Distance From* | | |
|---|---|---|---|---|---|
| No. | Effect | Size | Frontal Pole | Midline | Caudate Nucleus |
| 18 | 52L-96R | .58mm.$^3$ | 4.2mm. | 2.4mm. | -.84mm.** |
| 25 | 65L-100R | .72mm.$^3$ | 3.9mm. | 2.1mm. | -.32mm. |
| 38 | 72L-100R | .80mm.$^3$ | 3.2mm. | 3.2mm. | +.21mm. |

*All measures are to the center of the lesion.

**A minus sign designates a center posterior to the most anterior protrusion of the head of the caudate nucleus, while a plus sign designates a center anterior to the head of the caudate nucleus.

All 43 cases are listed in Appendix B in the same format as Table 1. The cases in Appendix B are divided into two groups: Group I, small destructions, and Group II, large destructions. Rook's hypothesized area cannot account for the three cases shown in Figure 4. Number 18 in Figure 4 can account for number 25 and vice versa, but cannot account for number 38 in terms of a highly localized area.

New area: Figure 5 shows the overlay of extreme cases with an overlapping case (number 43) which can account for all three destructions. Number 43 involves a volume of 1.09mm.$^3$. The center of the lesion lies 3.8mm. caudal to the frontal poles, 3.0mm. from the midline, and -.42mm. from the head of the caudate nucleus. Number 43 showed a 100% transfer from complete left handedness to complete right handedness. Fifteen of the affected cases overlap with number 43 in some manner. However, the degree of overlap is slight in the majority of these cases. The only affected case that cannot be explained in any manner by number 43 is number 8. Number 8 was only slightly affected. He gave a change of only 10% from 100 left to 90 left. However, 21 of the 27 negative cases also show overlap with number 43. Thus, a hypothesis that would establish number 43 as the critical area in handedness would not be able to explain the 21 negative cases, and therefore would not be a tenable hypothesis.

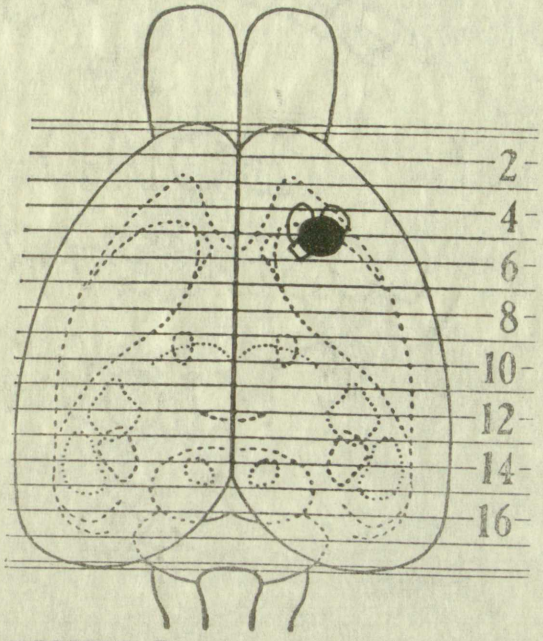
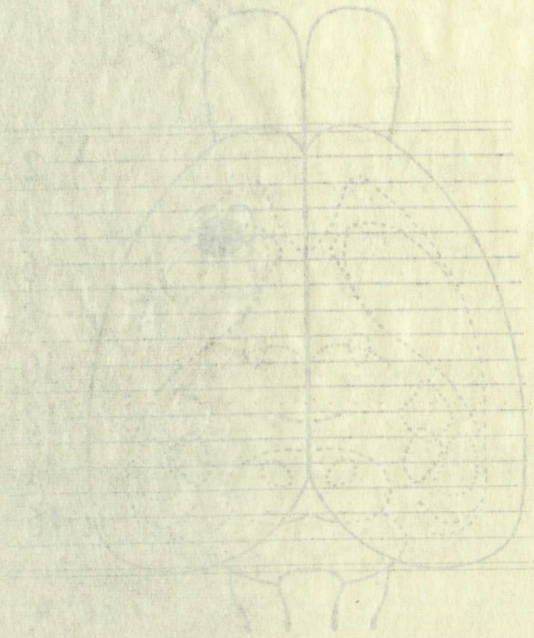



FIGURE 5. Three extreme affected cases with overlapping case.

Atypical destructions: Two of the 16 affected cases (numbers 22 and 34) are atypical in terms of the placement of the lesions. Both of these cases involved destructions which penetrated through the corpus callosaum and into the dorsal convexity of the caudate nucleus. Number 34 involved a volume of 1.3mm.$^3$ and caused a 100% transfer. Number 22 involved a total volume of 9.43mm.$^3$ and produced a transfer from 83% right to 81% left. Both of these cases were dropped from the final analysis because the involvement of the corpus striatum could include fibers of the pyramidal tract.

Atypical behaviors: Case number 7, which involved a lesion of 2.24mm.$^3$ and an affect of 51% from 99 right to 52 left, is atypical in terms of its behavior in the post-operation testing situation. On the



first day of testing, the animal showed a complete transfer giving 50 reaches with the non-preferred hand. On the second day of testing, the animal switched back to the preferred hand, giving 48 preferred to 2 non-preferred reaches. The animal was able to grasp the food with his preferred hand, but was not able to bring it to his mouth. On the second day, he grasped the food with his preferred hand, brought it close to the mouth, dropped the food from the preferred hand into the non-preferred hand, which he held under his chin, then took the food to his mouth with the non-preferred hand. All the reaches performed in this manner were called preferred hand reaches. Number 12 repeated this performance, but only 18 times in the 100 trials. All 18 were called preferred. The other 82 reaches were given solely with the non-preferred hand. Number 31 also showed this phenomena and demonstrated the above behavior for 100 reaches. The last case is listed as a negative case, although there was definitely an affect. The apparent finding here was that the ability to bring the food to the mouth had been destroyed. None of these animals demonstrated the ability to bring the food to the mouth with the preferred hand after the operation. A breakdown of the handedness situation, in terms of stimuli and responses, can be approximated as follows:

| Stimuli | Responses |
|---|---|
| 1. Visual dish | 1. Approach the dish |
| 2. Visual food | 2. Reach into food |
| 3. Tactual food | 3. Grasp food |

| Stimuli | Responses |
|---|---|
| 4. Food-in-hand | 4. Pull hand back, palm face down |
| 5. Proprioceptive | 5. Turn palm face up ($90^{o}$) |
| 6. Proprioceptive-tactile | 6. Push food into mouth |
| 7. Food-in-mouth | 7. Chewing food |

The responses most influenced in the above three cases were responses number 5 and 6. Rat number 35 corroborated the atypical behavior of these three cases, in that this case could not perform response number 5, but continued to reach with the preferred hand and succeeded by dropping his hand to the floor and moving his head down to eat out of the hand. Number 35 was listed as a negative case, even though this affect was noted.

Five other negative cases showed varying degrees of affects. These other five animals showed affects in their abilities to perform response number 2 above (reach into food). Their efforts would often lead to thrusts into the wiring around the dish, to thrusts to the far extremes of the dish, and to grasping motions while the hand was well above the food in the dish.

Of the 16 positive cases, 13 showed affects in reaching for the food; two showed affects in turning palm face up (number 5 in the responses); and one animal, number 38, did not even try his preferred hand in the post-operational testing situation. Therefore, the two most frequent responses influenced were number 2 and number 5 when the rat showed an affect.

## DISCUSSION

The main purpose of the study was to submit Rook's area to a precise analysis, using smaller destructions than he was able to employ and still get transfers. This was done by "building in," through forced practice, a certain degree of ability to reach with the non-preferred limb.

Rook has stated that this area ". . . in or near layer 6. . . approximately 4.8mm. caudal from the frontal poles and 2.7mm. lateral from the midsagittal plane must be destroyed to produce change in handedness" (10, p. 57). Rook's area does not in any way overlap with cases 25, 38 and 18. All three of these cases showed marked effects (see Table 1). Furthermore, 14 cases overlapped Rook's area, but showed no effects. Rook stated that ". . . destruction [of the common area] does not necessarily assure an effect" (10, p. 41). Therefore, Rook's hypothesis would be that a critical area must always be involved to cause a transfer, but that destructions of this area will not always cause transfers. The negative cases that overlapped Rook's area would support the second part of his hypothesis, but the three positive cases which did not involve his area would not support the first and most significant part of his hypothesis.

On the basis of the results of this study, an area was hypothesized which would account for the three cases which Rook's area could not explain. This new area involved a volume of 1.09mm.$^3$ and overlaps all affected cases except number 8. Number 8 showed only a slight affect (10% change), and therefore it would not unequivocally disprove this new area. However, 21 negative cases overlapped this new area. This experimenter sees little value in hypothesizing a critical area of specific coordinates which cannot explain negative cases, even though the area may explain the majority of positive cases.

Rook, on the basis of his results, has hypothesized that a highly critical mass of approximately .012mm.$^3$ volume exists within a larger less critical mass, and that it is this highly critical mass that must be destroyed to cause a transfer. Using this hypothesis of a highly critical, but very small mass, this experimenter would hypothesize on the basis of this study that a very small mass is critical, but that this mass shows individual variability in moving about from animal to animal. This highly critical mass could be anywhere from .21mm. anterior to the head of the caudate nucleus, to 1.4mm. posterior to the head of the caudate nucleus. In terms of measures from the midline, the area could lie anywhere from 1.4mm. to 3.2mm. lateral. Figure 6 shows the hypothesized area in which this critical mass could exist. Figure 6 was constructed by taking the

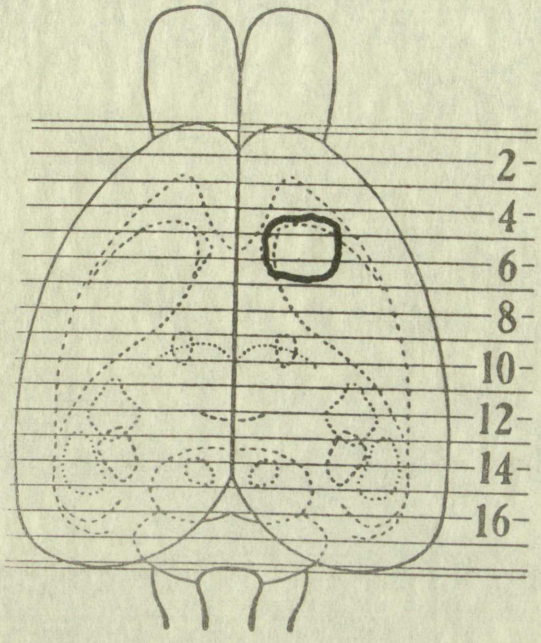
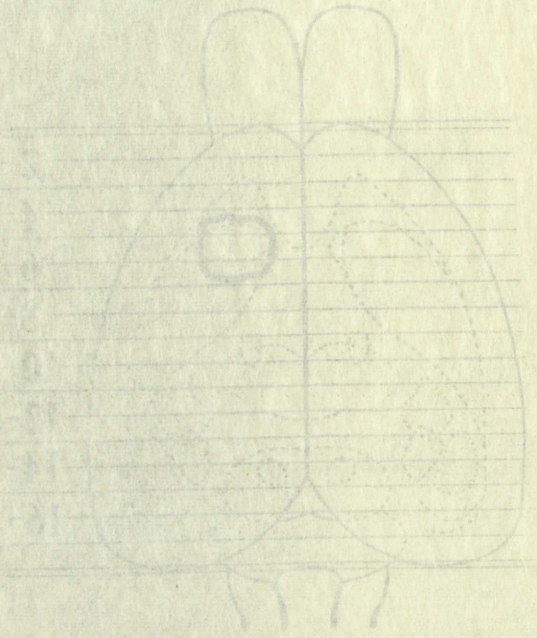



FIGURE 6. Hypothesized area of 2.9mm.$^2$ within which the smaller handedness area may vary.

most extreme measures of 21 cases that showed either a quantative effect or a qualitative affect. See Appendix C for the cases involved. The extent of this hypothesized area is 2.9mm.$^2$ but destructions as small as 0.6mm.$^3$ within this region can produce transfers.

An hypothesis of layer 6 being the layer in which the critical area exists has not been refuted by this study. However, all positive effects also involved layer 5. Number 38, which showed a marked effect, demonstrated very little layer 6 involvement. The lower boundaries of the lesion just touched the upper limit of layer 6. This case would certainly not refute the idea of layer 6 as the critical layer,



but does suggest that layer 5 may be the critical layer. A destruction that would not involve layer 5, but only layer 6, would be very difficult to obtain without involving white fibers. Therefore, until destructions which can be confined to only one layer are performed with positive effects, the hypothesis most consistent with results would be that layers 5 and 6 are both critical.

Two specific responses were observed to have been interfered with due to the operation. Both of these responses [number 2 (reach into food) and number 5 (turn palm face up $90^{o}$)] were observed to have been interfered with in 21 of the 41[2] cases. Seven of the 21 cases did not show an effect in handedness score, i. e., they all used the preferred hand, but did show affects in terms of their ability to obtain food. This finding would support Rook's interpretation of his final multiple regression equation. He concluded that the very small and highly critical region involved in handedness changes was ". . . surrounded by a slightly larger region of lesser significance" (10, p. 61). This interpretation would explain cases that do not show complete transfers, and also cases that only show qualitative affects. These cases would lie somewhere in the larger region of lesser significance.

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[2]Numbers 22 and 34 have been removed from the analysis due to extensive sub-cortical involvement.

## CONCLUSIONS

The findings from this study may be summarized as follows:

1. Rook's hypothesis of a highly localized area with specific coordinates was not supported.

2. The next best approximation to a critical area with specific coordinates was also found to be untenable.

3. The study supports Rook's conclusion that layer 6 is a critical area, but does not disprove the value of layer 5 as a critical layer.

4. The study also supports Rook's hypothesis that there exists a less critical region which surrounds the highly critical mass of cells significant in handedness.

5. An area of 2.9mm.$^2$ was hypothesized as a mass within which a smaller critical mass may vary from animal to animal.

Thus, the main conclusions of the study are that there exists a very small and highly critical mass of cells with a surrounding, less critical mass of cells, which vary within an area of 2.9mm.$^2$ from animal to animal. This critical mass of cells is believed to contain the main mechanism in the control of handedness.

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## APPENDIX A

## DISCARDS

| Number | Reason |
|---|---|
| 1. . . . . | Too ambidextrous (5R - 5L). |
| 2. . . . . | Too ambidextrous (4R - 6L). |
| 3. . . . . | Solved problem by reaching over the top of the biased dish with preferred hand. |
| 4. . . . . | Tested 0R - 10L, but only 2 forced and 2 free reaches could be obtained in 3 days. |
| 5. . . . . | Destroyed during operation. |
| 6. . . . . | Too ambidextrous (7R - 3L). |
| 7. . . . . | Destroyed during staining. |
| 8. . . . . | Too ambidextrous (6R - 4L). |
| 9. . . . . | Destroyed during sectioning. |

## APPENDIX B

### GROUP I -- SMALL DESTRUCTIONS

(Less than 2mm.$^3$)

| No. | Effect | Size | F. P. | Midline | C. N. |
|---|---|---|---|---|---|
| 2 | 75L-86L | 1.14mm.$^3$ | 3.4mm. | 2.8mm. | -.21mm. |
| 3 | 100R-100R | 1.80 | 3.9 | 2.4 | -.32 |
| 5 | 100L-98R | 1.69 | 4.6 | 2.4 | -1.30 |
| 6 | 81L-82L | .82 | 5.0 | 2.8 | -1.50 |
| 9 | 94R-100L | 1.33 | 4.2 | 2.7 | -.63 |
| 11 | 50L-78L | .62 | 4.6 | 2.2 | -1.30 |
| 12 | 76R-82L | 1.72 | 4.2 | 2.6 | -.84 |
| 14 | 100R-100R | 1.49 | 3.8 | 1.9 | +.11 |
| 15 | 100L-100L | .54 | 3.9 | 2.1 | -.21 |
| 17 | 82L-63R | .68 | 4.0 | 2.7 | -.84 |
| 18 | 52L-96R | .58 | 4.2 | 2.4 | -.84 |
| 19 | 100R-100R | 1.61 | 5.2 | 2.5 | -1.60 |
| 20 | 100L-100L | 1.35 | 5.0 | 2.7 | -1.50 |
| 21 | 67L-59R | .60 | 4.7 | 2.9 | -1.40 |
| 23 | 100R-100R | 1.24 | 2.2 | 2.2 | -.84 |
| 24 | 100R-97R | .63 | 4.0 | 2.9 | -.67 |
| 25 | 65L-100R | .72 | 3.9 | 2.1 | -.32 |

| No. | Effect | Size | F. P. | Midline | C. N. |
|---|---|---|---|---|---|
| 26 | 98R-100R | 1.20mm.$^3$ | 4.6mm. | 3.8mm. | -.74mm. |
| 28 | 100L-100L | .95 | 4.4 | 2.3 | -.74 |
| 29 | 98L-97L | 1.19 | 3.5 | 2.7 | 0 |
| 30 | 96L-93L | .47 | 4.6 | 2.7 | -1.20 |
| 31 | 100R-100R | 1.48 | 5.6 | 3.0 | -2.0 |
| 33 | 100L-100L | 1.20 | 4.1 | 2.5 | -.74 |
| 34 | 100L-100R | 1.30 | 3.8 | 2.6 | -.74 |
| 35 | 99R-97R | 1.32 | 3.9 | 2.7 | -.74 |
| 36 | 98R-97R | 1.30 | 3.5 | 2.5 | -.21 |
| 37 | 100L-99L | 1.36 | 4.5 | 3.0 | -1.40 |
| 38 | 72L-100R | .80 | 3.2 | 3.2 | +.21 |
| 39 | 99R-99R | .71 | 3.3 | 3.0 | +.11 |
| 40 | 100R-100R | 1.46 | 4.2 | 2.6 | -.63 |
| 43 | 100L-100R | 1.09 | 3.8 | 3.0 | -.42 |
| 45 | 97R-95R | 1.01 | 4.2 | 3.1 | -.84 |
| 46 | 100L-82L | 1.26 | 4.8 | 2.8 | -.84 |

| No. | Effect | Size | F.P. | Midline | C.N. |
|---|---|---|---|---|---|
| 26 | 98R-100R | 1.20mm. | 4.8mm. | 3.4mm. | -.74m. |
| 28 | 100L-100L | .95 | 4.4 | 2.8 | -.74 |
| 29 | 98L-97L | 1.19 | 3.8 | 2.7 | 0 |
| 30 | 96L-95L | .47 | 4.0 | 2.7 | -1.20 |
| 31 | 100R-100R | 1.43 | 5.4 | 3.0 | -2.0 |
| 33 | 100L-100L | 1.20 | 4.1 | 2.5 | -.74 |
| 34 | 100L-100R | 1.30 | 3.8 | 2.8 | -.74 |
| 35 | 98R-97R | 1.32 | 3.9 | 2.7 | -.74 |
| 36 | 98R-97R | 1.30 | 3.8 | 2.6 | -.21 |
| 37 | 100L-99L | 1.36 | 4.8 | 3.0 | -1.40 |
| 38 | 72L-100R | .80 | 3.2 | 3.2 | +.21 |
| 39 | 89R-88R | .71 | 3.3 | 3.0 | +.11 |
| 40 | 100R-100R | 1.46 | 4.2 | 2.8 | -.85 |
| 42 | 100L-100R | 1.09 | 3.8 | 3.0 | -.42 |
| 45 | 97R-95R | 1.01 | 4.2 | 3.1 | -.84 |
| 46 | 100L-82L | 1.26 | 4.8 | 2.8 | -.84 |

## APPENDIX B

## GROUP II -- LARGE DESTRUCTIONS

(Greater than 2mm.$^3$)

| No. | Effect | Size | F. P. | Midline | C. N. |
|---|---|---|---|---|---|
| 1 | 100R-99R | 2.88mm.$^3$ | 4.4mm. | 2.9mm. | -1.20mm |
| 7 | 99R-52L | 2.24 | 4.4 | 2.2 | -1.30 |
| 8 | 100L-90L | 2.16 | 4.8 | 1.4 | -1.30 |
| 10 | 95R-98R | 2.22 | 5.3 | 1.8 | -1.70 |
| 16 | 98R-84L | 3.05 | 4.0 | 1.6 | -.11 |
| 22 | 83R-81L | 9.43 | 4.8 | 2.1 | -.84 |
| 27 | 91L-87L | 3.63 | 3.8 | 2.1 | -.11 |
| 32 | 100L-68R | 2.95 | 4.2 | 2.4 | -1.05 |
| 41 | 100L-100R | 6.23 | 4.0 | 2.7 | -.84 |
| 44 | 89R-81L | 4.19 | 4.4 | 2.4 | -1.30 |

## APPENDIX C

(21 cases shown in Figure 7)

| No. | Response Effected | Showed in Score | Midline | Caudate Nucleus |
|---|---|---|---|---|
| 7 | 5 | Yes | 2.2mm. | -1.30mm. |
| 8 | 2 | Yes | 1.4 | -1.30 |
| 12 | 5 | Yes | 2.6 | -.84 |
| 16 | 2 | Yes | 1.6 | -.11 |
| 17 | 2 | Yes | 2.7 | -.84 |
| 18 | 2 | Yes | 2.4 | -.84 |
| 21 | 2 | Yes | 2.9 | -1.40 |
| 25 | 2 | Yes | 2.1 | -.32 |
| 32 | 2 | Yes | 2.4 | -1.05 |
| 38 | 2 | Yes | 3.2 | +.21 |
| 41 | 2 | Yes | 2.7 | -.84 |
| 43 | 2 | Yes | 3.0 | -.42 |
| 44 | 2 | Yes | 2.4 | -1.30 |
| 46 | 2 | Yes | 2.8 | -.84 |
| 22 | 2 | No | 2.1 | -.84 |
| 27 | 2 | No | 2.1 | -.11 |
| 30 | 2 | No | 2.7 | -1.20 |
| 36 | 2 | No | 2.5 | -.21 |
| 45 | 2 | No | 3.1 | -.84 |
| 31 | 5 | No | 3.0 | -2.00 |
| 35 | 5 | No | 2.7 | -.74 |

# IMPORTANT!

Special care should be taken to prevent loss or damage of this volume. If lost or damaged, it must be paid for at the current rate of typing.