1-1-1978

Role of the intact contralateral homologue in the recovery of intracranial self-stimulation behaviour.

Jerrel E. Del Dotto
University of Windsor

39343

National Library of Canada | Bibliothèque nationale du Canada | CANADIAN THESES ON MICROFICHE | THÈSES CANADIENNES SUR MICROFICHE

NAME OF AUTHOR/NOM DE L'AUTEUR Jerel E. Del Dotto

TITLE OF THESIS/TITRE DE LA THÈSE Role of the intact contralateral homologue in the recovery of intracranial self-stimulation behaviour.

UNIVERSITY/UNIVERSITÉ University of Windsor, Windsor, Ontario

DEGREE FOR WHICH THESIS WAS PRESENTED/GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE M.A.

YEAR THIS DEGREE CONFERRED/ANNÉE D'OBTENTION DE CE GRADE Oct. 1978

NAME OF SUPERVISOR/NOM DU DIRECTEUR DE THÈSE Dr. David V. Reynolds

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈQUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

DATED/DATÉ 21 August 1978 SIGNED/SIGNÉ Jerel Eugene Del Dotto

PERMANENT ADDRESS/RÉSIDENCE FIXE

NL-91 (3-74)

NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us a poor photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30. Please read the authorization forms which accompany this thesis.

THIS DISSERTATION
HAS BEEN MICROFILMED
EXACTLY AS RECEIVED

AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de mauvaise qualité.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30. Veuillez prendre connaissance des formules d'autorisation qui accompagnent cette thèse.

LA THÈSE A ÉTÉ
MICROFILMÉE TELLE QUE
NOUS L'AVONS REÇUE

NL-339 (3/77)

ROLE OF THE INTACT CONTRALATERAL HOMOLOGUE IN THE RECOVERY OF INTRACRANIAL SELF-STIMULATION BEHAVIOUR

by

Jerel E. Del Dotto

B.A. (hons), Augsburg College, 1975

A Thesis
Submitted to the Faculty of Graduate Studies
through the Department of Psychology
in Partial Fulfillment of the
Requirements for the Degree
of Master of Arts at the
University of Windsor

Windsor, Ontario, Canada

1978

APPROVED BY:

David V. Reynolds
(Chairman)

ABSTRACT

The possibility that intact structures on one side of the brain are involved in the behavioural recovery of damaged contralateral homologues was studied employing an intracranial self-stimulation (ICSS) technique. If behavioural recovery was dependent upon the integrity of the contralateral homologue, it was predicted that (a) damage to this tissue would impede the recovery process while, (b) electrical stimulation would expedite recovery.

Monopolar electrodes were symmetrically implanted bilaterally in the vicinity of the MFB-LHA of thirty male Wistar rats. Nine additional animals had electrodes implanted asymmetrically. All animals were trained to press a bar to obtain brief electrical shocks to the brain (ICSS). The animals were then lesioned to disrupt ICSS responding. Three days later the animals were divided into four groups and received either: (a) no additional treatment, (b) a second contralateral lesion of the MFB-LHA, (c) contralateral stimulation of the MFB-LHA, or (d) contralateral stimulation outside the MFB-LHA.

Analyses were performed on the total number of brain shocks delivered to the animal, and on the total number of bar press responses by the animal. The analyses revealed that the increase in responding was significant

across the postlesion recovery days, but that the course of recovery was the same for all groups.

The behavioural results did not support the hypotheses but, instead, revealed a paradoxical phenomenon: The damaging of the homologous MFB-LHA on the opposite side of the brain resulted in an immediate and significant enhancement in recovery of self-stimulation behaviour on the day subsequent to the second lesion. Individual planned comparisons of the mean brain shock and bar press responses between C and CL groups on postlesion Day 4 showed a significant increase in responding for the CL animals.

The rapid recovery in CL animals was interpreted as withdrawal of inhibition arising from the contralateral MFB-LHA. Several methodological points were considered to explain the failure of stimulation to expedite the course of recovery. Finally, suggestions for future research were presented and the importance of identifying the mechanisms involved in behavioural recovery was emphasized.

ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. David V. Reynolds whose support and guidance provided a unique learning experience and ensured, on my behalf, a complete understanding of the techniques involved in conducting good research.

I would also like to express my thanks to Dr. B. Rourke, Dr. A. Smith, and Dr. R. Doyle for not only providing their time, but also their critical comments and suggestions.

Finally, a special word of appreciation to Kathy who shared my moments of frustration and elation, and whose enduring faith sustained me in all aspects of my research.

TABLE OF CONTENTS

		Page
ABSTRACT		i
ACKNOWLEDGEMENTS		iii
LIST OF TABLES		vi
LIST OF FIGURES		viii
Chapter		
I	INTRODUCTION	1
	Serial Lesion Phenomenon	5
	Hypotheses	21
II	METHOD	23
	Subjects	23
	Apparatus	23
	Electrodes	24
	Surgery	24
	Stimulus Parameters	25
	Lesion Parameters	26
	Procedure	28
	Training	28
	Testing	29
	Experimental Phase	30
	Retest	31
	Histology	32
	Sacrifice and Sectioning	32
III	RESULTS	34
	Brain Shock Measure	37
	Bar Press Measure	45
	Extent of Recovery	53
	Individual Recovery Curves	53
	Histological Analysis	54
IV	DISCUSSION	64
	Overall Recovery	65
	Contralateral Lesion and Recovery	65
	Contralateral Stimulation and Recovery	71
	Additional Methodological Considerations	73

Page

Summary and Conclusions 74

Appendix

A PRELESION BASELINE BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS 78

B MEAN DAILY BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS ACROSS THE 15 POSTLESION RECOVERY DAYS 83

C MEAN DAILY BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS ACROSS THE 15 POSTLESION RECOVERY DAYS AS A PERCENTAGE OF PRELESION BASELINE LEVELS 90

D MEAN BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS ACROSS THE FIVE 3-DAY POSTLESION RECOVERY BLOCKS 99

E MEAN BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS ACROSS THE FIVE 3-DAY POSTLESION BLOCKS AS A PERCENTAGE OF PRELESION BASELINE LEVELS 104

REFERENCES 109

VITA AUCTORIS 122

LIST OF TABLES

Table		Page
1	Summary of DC Lesion Parameters Required to Disrupt Bar Pressing Behaviour Based on ICSS Current Intensities.	27
2	Experimental Design	33
3	Summary of Mean Percentage Increase of Brain Shock Rate for Control and Experimental Groups Across Five 3-Day Postlesion Recovery Blocks.	38
4	Summary of Analysis of Variance of Brain Shock Rate for Experimental and Control Groups and Five Postlesion Recovery Blocks.	39
5	Neuman-Keuls q_r Values for Differences Between Pairs of Ordered Mean Brain Shock Values for the Postlesion Recovery Blocks Variable.	40
6	Summary of Mean Percentage Increases of Brain Shock Rate for Control and Experimental Groups Across Postlesion Recovery Days 3 and 4.	42
7	Summary of Analysis of Variance of Brain Shock Rate for Control and Experimental Groups on Postlesion Day 3.	43
8	Summary of Planned Comparisons Among Group Brain Shock Means for Postlesion Recovery Day 4.	44
9	Summary of Mean Percentage Increases of Bar Press Responses for Control and Experimental Groups Across Five 3-Day Postlesion Recovery Blocks.	46
10	Summary of Analysis of Variance of Bar Press Responses for Control and Experimental Groups and Five Postlesion Recovery Blocks.	47
11	Neuman-Keuls q_r Values for Differences Between Pairs of Ordered Mean Bar Press Responses for the Postlesion Recovery Blocks Variable.	48

Table		Page
12	Summary of Mean Percentage Increases of Bar Press Responses for Control and Experimental Groups Across Postlesion Recovery Days 3 and 4.	50
13	Summary of Analysis of Variance of Bar Press Responses for Control and Experimental Groups on Postlesion Day 3.	51
14	Summary of Planned Comparisons Among Group Bar Press Means for Postlesion Recovery Day 4.	52

LIST OF FIGURES

Figure		Page
1	Mean Decrease and Subsequent Recovery of Brain Shock Rate Following Lesion thru ICSS Electrode.	35
2	Mean Decrease and Subsequent Recovery of Bar Press Responses Following Lesion thru ICSS Electrode.	36
3	Electrode Placements in C Animals with ICSS Elicited thru Left Electrode.	55
4	Electrode Placements in C Animals with ICSS Elicited thru Right Electrode.	56
5	Electrode Placements in CS Animals with ICSS Elicited thru Left Electrode.	57
6	Electrode Placements in CS Animals with ICSS Elicited thru Right Electrode.	58
7	Electrode Placements in SC Animals with ICSS Elicited thru Left Electrode.	59
8	Electrode Placements in SC Animals with ICSS Elicited thru Right Electrode.	60
9	Location of ICSS Electrodes and Maximal Extent of Contralateral Tissue Damage in CL Animals.	63

CHAPTER I

INTRODUCTION

The fact that a behavioural recovery may occur following damage to the central nervous system (CNS) has intrigued researchers for many years. At times organisms appear capable of ameliorating deficits in behaviour which are normally found to accompany injury to the CNS. Usually the course of recovery involves an initial inability on the part of the organism to perform specific behavioural tasks followed by a gradual return to near normal levels when retested on the same tasks sometime later.

Several models have been proposed to explain behavioural recovery following CNS damage (Luria et. al., 1969; Dawson, 1973; Eidelberg & Stein, 1973; Finger et. al., 1973; Goldberger, 1973; Meyer, 1973). One theory of recovery, Monakow's diaschisis model, posits that deficits seen after injury to the CNS occur not only because of the physical damage to brain tissue but also by a disruption in the activity of undamaged neurons elsewhere in the nervous system (Monakow, 1914, as cited in Luria et. al.,

1969 and Teuber, 1973). Recovery occurred with the elimination of this 'shocklike' effect (Adametz, 1959; Blatt & Lyon, 1968). A second explanation, vicariation theory, asserts that other areas within the brain take over the function of the damaged region (Lashley, 1938; Goldberger, 1973; Meyer, 1973). Pre- and post-injury behaviour is essentially identical, however, in the latter case the behaviour is mediated by an entirely different region. Whether this alternate region is originally involved in the mediation of the behaviour remains unanswered. Recovery in any case results from one area taking over the function normally mediated by another area (Glees & Cole, 1950; Butters et. al., 1973). Resembling the vicariation theory of recovery is that of behavioural (functional) substitution. In this theory a different region is also suspected of taking over the function normally mediated by another area. The recovered behaviour, however, is similar to, but not the same as, the behaviour lost due to injury (Finger et. al., 1973; Goldberger, 1973; Meyer, 1973). Though recovery of the behaviour occurs it may not be identical to the behaviour seen in a normal animal (Glick et. al., 1971; Schultze & Stein, 1975).

A fourth theory, functional reorganization, proposes that two different mechanisms may be involved

in recovery. In the first of these undamaged axons may generate new 'collateral sprouts' which then innervate areas once occupied by the damaged neurons (Finger et. al., 1973; Goldberger, 1973). Sprouting may occur into an adjacent denervated area (Raisman, 1969) or into an denervated area in the contralateral hemisphere (Steward et. al., 1973, 1974). Furthermore, it has been shown that administering certain drugs (e.g. nerve growth factor-NGF) at the time of injury stimulates the sprouting and growth of the regenerating CNS neurons (Bjorklund & Stenevi, 1972; Bjerre et. al., 1975). A second mechanism proposed by the functional reorganization model is denervation supersensitivity. When a lesion disrupts the normal afferent input to an area the area undergoes excitatory changes. Post-synaptic sites where denervated input fibers once terminated show an increased responsiveness (super-sensitivity) to the remaining inputs (Glick, 1973; Goldberger, 1973). Usually the post-synaptic changes involve an increased sensitivity to chemical mediators serving the deprived area. For example, researchers have demonstrated that administering α-methyltyrosine (αMT) following CNS injury facilitates recovery of a passive avoidance habit (Glick & Zimmerberg, 1972) while the same drug given prior to CNS damage may either prevent the impaired performance normally seen in lesioned animals not given the drug (Glick & Zimmerberg, 1972) or facilitate the

post-injury recovery process (Glick et. al., 1972). It is thought that the administration of drugs such as NGF either facilitates behavioural recovery by promoting the development of supersensitivity to certain neurotransmitters (Goldberger, 1973) or by stimulating the growth of regenerating CNS neurons (Bjorklund & Stenevi, 1972; Berger et. al., 1973; Bjerre et. al., 1975).

A final model of recovery is one proposed by Rosner (1970). In this model two different 'devices' are offered to account for behavioural recovery. One device, redundant representation, asserts that many neurons serve similar functions and are actively involved in the mediation of a specific behaviour. While some of these neurons are damaged others are left intact to process information. Recovery amounts to intact residual elements of a partially damaged redundant system resuming the function temporarily disrupted as a result of the damage. A second device, multiple control, suggests that a particular behaviour is mediated by several 'centers' located throughout the nervous system. Each center participates either directly through a common pathway or indirectly by influencing other centers involved in the behaviour. When an injury occurs in one of the centers the remaining intact centers compensate for the damaged tissue by eventually recovering from shock (i.e. re-establishment)

or by taking over the functions normally mediated by another center (i.e. re-organization).

Serial Lesion Phenomenon

One instance where a behavioural recovery appears to occur is in the phenomena of serially damaging a brain structure. That is, certain deficits which normally occur following a simultaneous bilateral lesion of brain tissue can be ameliorated if the same amount of tissue is removed in stages (Dru & Walker, 1972; Finger et. al., 1973; Stein, 1973). The phenomenon, referred to as the 'serial lesion effect', is known to occur with damage to cortical areas involving both learned and unlearned behaviours (Kennard, 1942; Ades & Raab, 1946; Glick & Greenstein, 1972; Stein et. al., 1969; Rosen et. al., 1971) as well as with damage inflicted in subcortical areas involving learned and unlearned behaviours (Adametz, 1959; Blatt & Lyon, 1968; Stein et. al., 1969; Greene et. al., 1972; Stein et. al., 1973; McIntyre & Stein, 1973; Schultze & Stein, 1975). Furthermore, the effect appears to depend upon several factors including the length of time between sequential removal which is called the interoperative interval (IOI) (Kennard, 1942; Isaac, 1964; Patrissi & Stein, 1971), the type of sensory input (specific vs. nonspecific) occurring during the IOI (Meyer et. al., 1958; Thompson, 1960; Petrinovich & Bliss, 1966; Cole et. al., 1967; Petrinovich & Carew, 1969), and the sex and age of

the organism (Kennard, 1942; Stein, 1973; Teitelbaum, 1973).

The serial lesion procedure involves the removal of a bilaterally represented structure in the brain in either successive unilateral operations, with a certain number of days intervening between removals on each side of the brain (i.e. two-stage removal), or by partial bilateral lesions involving both sides of the brain simultaneously. Removal of brain tissue in this manner results in faster recovery or complete sparing of a behaviour normally lost if the entire structure is removed in a single bilateral simultaneous operation (i.e. one-stage removal). For example, Blatt & Lyon (1968) demonstrated that rats that had their mesencephalic tegmentum destroyed in a two-stage operation exhibited less loss of feeding behaviour than animals subjected to a one-stage lesion of the same structure. More recently, Stein et. al. (1973) found that rats who were given a one-stage lesion of the lateral hypothalamic area (LHA) showed a significantly larger decrease in body weight than animals who had their LHA destroyed in two successive operations spaced 30 days apart. Similarly, McIntyre & Stein (1973) demonstrated that the decrease in activity behaviour which normally accompanies bilateral damage to the amygdala was reduced when the amygdala was removed in stages with 28 days between removals on each side of the brain.

When damage is inflicted subcortically and the

organism is tested on acquisition and retention behaviour, seriatim lesioned organisms perform consistently better than simultaneous lesioned animals. For example, Stein et. al., (1969) subjected rats to one- versus two-stage lesions of either the hippocampal area or the amygdala. Animals given the serial lesions had an IOI of 30 days. Both two-stage hippocampal and two-stage amygdala animals showed less impairment on the acquisition of a light-dark discrimination than animals lesioned in one-stage. In fact, the serial lesioned hippocampal rats showed no deficit compared with a sham operated control group while one-stage animals displayed severe impairments. More recently, Schultze & Stein (1975) reported that animals who had their caudate nucleus destroyed in a one-stage operation exhibited severe deficits in the ability to acquire spatial alternation and passive avoidance of shock habits. On the other hand, two-stage lesioned rats performed significantly better than animals ablated in a single operation and, in fact, performed the passive avoidance task better than sham operated controls. Finally, Greene et. al., (1972) found that a two-stage lesion of the fornix in rats resulted in less impairment on retention of a spatial alternation habit than animals lesioned in a single-stage.

At the cortical level, Kennard (1942) demonstrated the effects of serially ablating motor cortex areas 4 & 6

on motor function in monkeys. Using IOIs ranging from 2 to 8 months, Kennard found that animals suffering damage in two-stages displayed less impairment in motor function than those animals who were given a single bilateral ablation. In a related study Ades & Raab (1946) found that if area 4 of the motor cortex was removed in stages separated by 3 to 4 months, the animals displayed only slight impairment of motor function. In rats, Braun (1966) assessed the effects of lesioning the neocortex in one- or two-stages on visual placing behaviour and found that two-stage animals recovered the habit even though the entire neocortex was destroyed. One-stage animals recovered the response only if they were given extensive practice following the operation. A final example of serial lesions involving cortical areas and unlearned behaviours comes from a study by Glick & Greenstein (1973). They found that a two-stage lesion of the frontal cortex in rats had little effect on the animal's body weight compared to a sham operated group of rats. One-stage animals, on the other hand, showed a significant decrease in body weight. Glick & Greenstein concluded that the multi-stage operation facilitated recovery from the normal weight loss seen after single-stage lesions.

Finally, it is in the area of serial damage to cortical structures mediating learned behaviours that recovery has been demonstrated the most. For instance,

Stein et. al. (1969) subjected rats to a one-stage or two-stage lesion of the frontal cortex and assessed their effects on the ability to acquire a delayed spatial alternation habit, a brightness discrimination and its reversal, and a nonspatial simultaneous visual discrimination. An IOI of 30 days was used. On each of the tasks the one-stage group took longer to reach criterion than both two-stage and unoperated control groups. The multi-stage group did not differ from the control group. Employing a variation of the serial lesion procedure, Rosen et. al. (1971) ablated the sulcus principalis in monkeys and then tested the animals for retention on a delayed alternation task and for acquisition of a delayed response task, and on place reversal learning. All of the single-stage animals received a single bilateral operation while those in the multi-stage group received 4 different operations (two on each side of the brain) with 3 weeks separating each operation. The results showed that the multi-stage group made significantly fewer errors than the single-stage group on all three spatial tasks.

The techique of performing serial lesions within the same hemisphere has been reported by other researchers (Barbas & Spear, 1976; Finger et. al., 1971). In the earlier study, Finger and his colleagues (1971) first demonstrated that a two-stage lesion of the somatosensory cortex in rats resulted in less impairment in the ability

to perform a series of tactile discriminations than simultaneous ablation of the same tissue. In the second part of the experiment, small bilateral lesions were placed in the somatosensory cortex destroying approximately 25% of the cortical tissue. After a 35 day IOI the original lesions were enlarged to include the remaining somatosensory cortex. Thus, the serial lesion procedure was performed within the same hemisphere as opposed to a contralateral hemispheric removal. The results showed that the two-stage animals performed better on the tactile discriminations than the single-stage lesion group. In the more recent Barbas & Spear (1976) study, rats were subjected either to serial unilateral lesions of the visual cortex or serial bilateral damage in which each stage of the lesion included a part of the visual cortex of both hemispheres. The animals were tested on the retention of a two-choice brightness discrimination. Both serial groups had an IOI of 10 days. One-stage rats showed a complete loss of the discrimination habit while both serial groups showed retention savings. Similar results have been obtained in an earlier study by Baden et. al. (1965) where a simple light-dark discrimination was relearned by cats after serial bilateral ablations of the lateral, suprasylvian, and ectosylvian gyri involving nearly two-thirds of the entire cortex. More recently, monkeys who had their frontal granular cortex removed in serial bilateral operations exhibited little change in the

ability to execute an escape response compared to severe impairment in a single-stage group (Tanaka, 1974). Also, Treichler (1975) demonstrated that serial bilateral removal of the sulcus principalis in monkeys resulted in less impairment on a delayed response task than tissue ablated in a single bilateral operation.

There have been a few instances where multi-stage removal of tissue has failed to result in amelioration of the behavioural deficit. For example, LeVere (1969) found that rats subjected to one- or two-stage removal of the posterior hypothalamic area exhibited similar impairments in the ability to maintain a waking state while Dawson et. al. (1973) demonstrated that both one-stage and two-stage removal of the hippocampus produced similar effects on measures of arousal. Furthermore, Winans & Powers (1974) reported that male hamsters failed to display the normal patterns of sexual behaviour regardless of whether removal of the olfactory bulbs occurred in one or two-stages.

In the case of subcortical damage and learned behaviours, Reyes et. al. (1973) found that one- or two-stage removal of the ventrobasal thalamus in rats resulted in similar impairments in the acquisition of ridge-smooth tactile discriminations, and Isaacson & Schmaltz (1968) demonstrated deficits on a DRL-20 operant task for both one- and two-stage hippocampal lesioned rats. Finally,

LeVere & Weiss (1973) reported comparable deficits in rats on the retention of a light-dark discrimination task and its reversal following single- or multi-stage damage to the hippocampus.

The data from studies which have failed to demonstrate a 'serial lesion effect' suggests that two-stage recovery may depend upon the site of neural destruction (LeVere, 1969; Dawson et. al., 1973; Reyes et. al., 1973), the task selected to measure recovery (Isaacson & Schmaltz, 1968), and perhaps the species under investigation (Winans & Powers, 1974).

It has been argued that a behaviour which is normally lost as a result of a single bilateral operation can be spared if the same amount of tissue is removed in successive stages. Though the data suggests that a 'serial lesion effect' exists, there is little direct evidence as to why there is greater recovery when lesions are inflicted in two-stages. Some past studies have suggested that behavioural recovery following serial damage may be associated with interhemispheric mechanisms. For example, Finger et. al. (1971), using a variation of the serial lesion procedure, demonstrated that successive bilateral lesions of the somatosensory cortex produced less impairment on a series of tactile discriminations than a single bilateral operation. One group of rats had a large one-stage bilateral operation while a second group had the same amount of tissue damaged in two partial successive

bilateral operations. In the first operation, 20-25% of the somatosensory cortex was removed. After an IOI of 35 days, a second bilateral operation enlarged the original lesions to include the remaining somatosensory cortex. Although the rats who had the enlarged bilateral lesions acquired the tactile discriminations faster than a single-stage group, they were impaired with respect to a third group who received two-stage unilateral operations in which the contralateral homologue remained completely intact during the 35 day IOI. The results of this study suggest that less sparing of behaviour occurs when the contralateral structure is partially damaged between operations than when it remains intact.

In a study involving feeding behaviour, Stein (1973) subjected rats to either bilateral or successive unilateral lesions of the LHA and assessed the affects on body weight regulation. He showed that animals receiving a one-stage bilateral removal of the LHA displayed a severe decrease in body weight. In addition, two-stage animals who had received their first unilateral lesion lost more weight than a sham operated control but less than the one-stage animals. After an IOI of 30 days, the two-stage animals received their second unilateral lesion in the contralateral LHA. The results showed that the second unilateral lesion did not produce any additional weight loss and the two-stage animals maintained their body weight

at a position intermediate to that of one-stage and sham groups. Furthermore, the two-stage animals never required glucose in their water, glucose injections, or the use of special diets to maintain their weight as did the one-stage animals. Since the first lesion had altered body weight regulation in the two-stage animals, Stein had reasoned that a second lesion in the contralateral side 30 days later should affect weight regulation even more. However, since this did not occur Stein suggested that the LHA contralateral to the damaged area changed its 'regulatory' functions after the first unilateral operation. He further suggested that the contralateral homologue may be needed for initiating the recovery process during the time between operations but may not be needed to sustain the regulation once recovery has occurred.

In a series of experiments aimed at investigating possible anatomical substrates mediating recovery, Steward and his colleagues (1973, 1974) studied re-innervation of the dentate gyrus area following damage to the surrounding entorhinal cortex which provides the major synaptic input to the area. Initally, a unilateral lesion was placed in the entorhinal cortex on one side of the brain and degeneration changes in the dentate area were recorded. Within 25 days after the lesion the dentate gyrus was void of any ipsilateral entorhinal fibers. Secondary lesions were then placed in the contralateral entorhinal

cortex at 25, 35, 100, and 200 days after the first lesion. An analysis of degeneration changes following the second lesion revealed that afferent projections from the contralateral entorhinal area which normally terminate ipsilaterally were seen to cross over to the contralateral side to penetrate denervated regions.

Further evidence for the notion that the contralateral structure may initiate the recovery process can be obtained from studies which have investigated the duration of the IOI (Ades & Raab, 1946; Stewart & Ades, 1951; Isaac, 1964; Patrissi & Stein, 1971; Glick & Zimmerberg, 1972). If the suggestion in two-stage recovery is that the contralateral homologue becomes involved in the recovery process some time after the first unilateral lesion then it may be reasonable to expect that performing a second unilateral lesion in the remaining intact contralateral area too soon may completely disrupt recovery.

Ades & Raab (1946) performed successive lesions of the motor cortex in monkeys. They found that when as IOI of 1 - 2 months was used, the animals showed signs of motor impairment. If, however, the time between serial operations was increased to 3 - 4 months, the animals escaped the pyramidal dysfunction. The authors speculated that some bilateral readjustment of 'motor patterning' was occurring. That is, after unilateral cortical damage some compensatory process occurred which involved the role of

the intact side. Similarly, Stewart & Ades (1951) found that in order for a conditioned avoidance response to be spared following a two-stage bilateral lesion of the auditory cortex in monkeys, there had to be at least 7 days between operations. If an IOI of less than 7 days was used, the two-stage animal was as impaired on the habit as a single-stage lesioned animal.

In a more systematic study, Patrissi & Stein (1971) subjected rats to a two-stage lesion of the frontal cortex and tested them on the ability to acquire a spatial alternation problem. The two-stage lesions were separated either by 10, 20, or 30 days. The authors found that the two-stage animals given 20 or 30 days between operations performed the alternation problem as well as a sham control group. On the other hand, animals lesioned with only a 10 day IOI were badly impaired on the task but did perform better than the single-stage lesioned group. Patrissi & Stein argued that recovery after serial lesions appears to be a gradual process requiring a minimum of 10 to 20 days. The results of this study further support the notion that the intact contralateral structure may be involved in initiating the recovery seen after two-stage ablation. In this case a second lesion performed at a certain 'critical' time interrupted the recovery process.

Similar results were found in a study by Glick & Zimmerberg (1972). They subjected mice to a two-stage

lesion of the frontal poles and observed their performance on a passive avoidance task. They found that the deficits seen in the serial animals were a function of the time allowed between operations. Animals that were given two-stage lesions spaced only 7 days apart performed more poorly on a retention test than a serial group which had 21 days between operations. Here again the impaired performance of the shorter IOI group may have resulted because of the second lesion interrupting the recovery initiated by the intact contralateral structure.

Finally, Isaac (1964) trained rats to make an avoidance response to changes in illumination and then subjected them to a two-stage removal of the visual cortex. The animals were either given 10, 12, or 14 days between serial operations. The results showed that as the IOI increased in duration the degree of recovery also increased. Those animals allowed only 10 days between operations performed the worst of all two-stage groups on retention of the habit.

The IOI duration studies suggest that if a second lesion is made in the intact contralateral homologue too soon after the first lesion then less sparing of the behaviour occurs. This may explain why some investigators have failed to find a savings following two-stage damage (Isaacson & Schmaltz, 1968; LeVere, 1969; LeVere & Weiss, 1973), and is consistent with the view that the intact

contralateral structure may be involved in two-stage behavioural recovery.

If the recovery process can be retarded by destroying tissue on the opposite side of the brain, perhaps it is reasonable to suggest that stimulating this tissue may expedite recovery. It is known that stimulation can produce excitatory changes in the normal neural activity (Akert & Walker, 1966; Amassian & Patton, 1966). This may be accomplished by injecting various drugs into the neural area which alter the normal chemical balance or by stimulating through implanted electrodes with brief electric shocks (Grossman, 1967). While there are numerous reports of chemically stimulating to enhance recovery (Ward & Kennard, 1942; Bjorklund & Stenevi, 1972; Glick et. al., 1972; Balagura et. al., 1973; Berger et. al., 1973; Bjerre et. al., 1975), relatively little has been reported on the effects of electrically stimulating to facilitate the process.

In a study involving feeding behaviour, Thode & Carlisle (1968) assessed the effects of LHA stimulation on amphetamine-induced anorexia. Rats were first implanted with bilateral electrodes in the LHA and were stimulated until feeding behaviour was elicited. The animal's were then injected intraperitoneally with d-amphetamine, a drug known to produce an anorexic effect by decreasing the excitability of the LHA, 30 minutes before feeding. At

the time of feeding one group was allowed to eat ad libitum with no stimulation and a second group was given brief electric shocks to the LHA. The results indicated that administering amphetamine alone produced a significant decrease in food intake while stimulation alone produced an opposite increase. More importantly, those animals given electrical stimulation and the drug showed a level of food intake comparable to the stimulation only group. The authors concluded that electrical stimulation of LHA sites that are found to elicit feeding can eliminate a normal anorexic effect produced by injecting the animal with d-amphetamine.

More recently, Harrell et. al. (1973) demonstrated that recovery of feeding behaviour could be enhanced by electrically stimulating the lesioned area. Mechanical lesions were produced bilaterally in the LHA of rats by inserting chronic macro-electrodes. The mechanical lesions produced 6 days of aphagia in the animals. If, however, the animals were electrically stimulated through the same electrodes for 1 hour daily the animals recovered their feeding behaviour within 2 - 3 days after the initial operation. Harrell and his colleagues concluded that the length of the recovery period for feeding depended upon whether or not the animal was given electrical stimulation of the damaged area. They suggested that the faster recovery seen in stimulated animals was most likely due to

altering the norepinephrine levels in the LHA. Finally, Valenstein & Campbell (1966) discovered that intracranial self-stimulation in the septal area facilitated the recovery of eating and drinking behaviour disrupted as a result of lesions placed in the vicinity of the medial forebrain bundle-lateral hypothalamus. In this particular study stimulation outside the damaged region enhanced the recovery process.

The studies mentioned up to this point imply that the integrity of the contralateral homologue may be required during the IOI for recovery to occur. Others have suggested that because of the high degree of bilateral symmetry existing in the brain of certain organisms (i.e. the rat) (Zornetzer, 1973), it may be reasonable to expect that one homologous structure would participate in the recovery of its contralateral counterpart. Perhaps, as Stein (1973) suggests, to 'serve as a template for establishing alternate neural patterns in other areas anatomically related to the damaged structure' (p. 396). The present study was undertaken to provide specific data relevant to the notion that intact structures on one side of the brain become involved in the recovery of damaged contralateral homologues during the interoperative interval of a two-stage lesion. The problem was studied in a subcortical system (i.e. medial forebrain bundle-lateral

hypothalamic area (MFB-LHA)) employing a learned operant response (i.e. bar pressing for intracranial self-stimulation (ICSS)). The main reason for selecting ICSS to investigate behavioural recovery is the fact that it is both easily and reliably obtainable. That is, numerous researchers have reported that an organism will repeatedly press a bar to obtain brief electric shocks to the brain (Olds & Milner, 1954; Rolls, 1975). The shocks act as a reinforcement for the bar pressing behaviour. Furthermore, researchers have found that the phenomena of ICSS can be obtained from many areas throughout the brain. One of the areas where ICSS is known to produce a strong reinforcing effect is in the vicinity of the MFB-LHA (Olds et. al., 1960; Rolls, 1975). Animals stimulated in this region have been shown to bar press anywhere from 300-1,000 times in a mere 10 minute test session (Olds & Olds, 1969; Huang & Routtenberg, 1971). Hence, the selection of bar pressing for ICSS offers a model for studying behavioural recovery in the CNS.

Hypotheses

The following hypotheses have been formulated in regards to recovery of bar pressing behaviour for ICSS:

(1) If the intactness of the contralateral homologue is necessary for recovery to occur following damage to one side of the brain, then it might be expected that further damaging the contralateral homologue soon

after the initial ablation should result in a disruption in recovery. This would amount to an absence of recovery if the ablation in the opposite hemisphere was performed before any recovery was initiated (Stewart & Ades, 1951; LeVere, 1969; LeVere & Weiss, 1973). Or, if the second lesion was performed some time after the contralateral structure initiated the recovery process then recovery may be expected to be retarded but not eliminated (Isaac, 1964; Finger et. al., 1971; Patrissi & Stein, 1971; Glick & Zimmerberg, 1972). Finally, damage to the contralateral structure could be postponed for a sufficient period of time so that neither retardation nor elimination of the behaviour results (Patrissi & Stein, 1971; Stein, 1973).

(2) Secondly, if the intact contralateral homologue is involved in initiating, and possibly co-ordinating the recovery process, then leaving the structure intact (i.e. unilateral removal only) should permit the animal to eventually recover but at a faster rate than would be seen if the contralateral structure was damaged.

(3) Finally, assuming that a structure homologous to one damaged on the opposite side of the brain is involved in recovery, then electrically stimulating this intact structure may serve to facilitate the course of recovery. (Thode & Carlisle, 1968; Harrell et. al., 1973).

CHAPTER II

METHOD

Subjects

The subjects were thirty-nine male albino rats of the Wistar strain, weighing between 400 and 500 grams at the time of surgery. Each animal was housed individually in a wire mesh cage (7" x 10" x 7") with room temperature constant at 72 degrees Fahrenheit. Food and water was available ad libitum throughout the entire experiment and the subjects were maintained on a 12:12 hour light/dark cycle.

Apparatus

The apparatus consisted of an operant test chamber (Lehigh Valley, Model #1417) connected to an electrical brain stimulation circuit. The circuit consisted of a pulse generator (Berl-Model 210, constant current source) which delivered brain shocks when a lever was pressed, and a series of solid state programming modules (BRS Digi-Bits) which controlled the timing sequence of the shocks. An oscilloscope (Tektronix Inc., Type D61A) monitored the output of the pulse generator.

The animals' bar presses and the number of brain shocks delivered were registered separately on a cumulative digital counter.

Electrodes

The monopolar electrodes were constructed from stainless steel insect pins (Clay Adams, Size E-80) with a short straight portion of a paper clip soldered to the pin. Each electrode was insulated up to a point slightly above the soldering junction with FORMVAR. Electrodes were coated at least twice, and baked in an oven (Bockel, Model #1078)at 350 degrees Fahrenheit for at least 24 hours after each coat. Approximately 0.5 mm of the electrode tip was exposed by scraping the tip with a scapel. The electrodes were then tested for leaks in a saline solution by applying a 40 volt stimulus to the electrodes from an AC power source.

Surgery

Surgery was carried out under sodium pentobarbital (NEMBUTAL) anesthesia administered intraperitoneally. The animal was weighed and 0.5 cc of NEMBUTAL, diluted in a solution of 5 parts water, was injected per 100 grams of body weight. Thirty animals had electrodes symmetrically planted bilaterally in the vicinity of the medial forebrain bundle-lateral hypothalamic region (MFB-LHA) using stereotaxic coordinates of 5.0 mm anterior to the interaural line, 1.5 mm lateral to the midline, and 3.0 mm below the

horizontal reference plane as adapted from the de Groot (1961) atlas for the rat. The remaining nine animals underwent asymmetrical electrode implantation. This was accomplished by raising the electrode 2 mm on one side of the brain with anterior - posterior and midline coordinates remaining the same. The electrodes were implanted using a Trent H. Wells Jr. stereotaxic instrument (Mechanical Developments Co.) following a procedure outlined in Skinner (1971). The electrodes plus a 'ground' made of stainless steel wire were anchored to the skull of the animal using KADON dental cement.

Stimulus Parameters

The bar pressing stimulation consisted of a 0.5 sec train of negative going rectangular wave pulses. Each pulse had a duration of 0.2 milliseconds. The frequency of the pulse pairs in the train was 100 per second. The intensity of the constant current stimulation began at a base of 100 ua and was increased in 50 ua steps every 5 minutes until bar pressing was elicited. The stimulus parameters used in those animals receiving contralateral brain stimulation consisted of a similar train duration with a pulse duration increased to 1.0 msec. Contralateral brain stimulation was programmed to deliver one pulse every 2 seconds so that the animal received approximately 450 pulses in a 15 minute period. Current intensity in these animals was maintained at a constant 10 ua.

Lesion Parameters

The lesions were made through the same chronically implanted electrodes that were used for testing brain stimulation effects. Sommers and Teitelbaum (1974) have suggested that by stimulating through the same electrode that produced the damage it is possible to observe more directly the behavioural evidence of ablation. The electrolytic lesions performed to disrupt bar pressing behaviour were created by using 0.1 - 0.3 ma direct anodal current passed for a duration of 15 seconds. A range of lesion values was required to compensate for differences in electrode placement. That is, animals were lesioned based on the current intensity used to elicit ICSS behaviour. Table 1 presents DC lesion parameters derived from pilot work which correspond to ICSS current values.

A DC lesion maker was constructed consisting of a DC power supply (Harrison, Model #6204B), a separate meter (Bach-Simpson LTD, Model #269) used to monitor the DC current intensity, and a timer (Hunter Mfg. Co., Model 111-C). Lesions produced to damage contralateral MFB-LHA tissue were created by applying a 2 ma direct anodal current for a duration of 10 seconds. All lesions were performed while the animal was anesthetized with NEMBUTAL (50 mg/kg).

TABLE 1

Summary of DC Lesion Parameters Required to Disrupt Bar Pressing Behaviour Based on ICSS Current Intensities

ICSS Current Intensity*	DC Lesion Parameters		
	Intensity	Duration	Coulombs (I X D)
100-150 ua	0.1 ma	15 sec.	1.5
150-200 ua	0.2 ma	15 sec.	3.0
>200 ua	0.3 ma	15 sec.	4.5

* Based on at least 300 brain shocks and bar presses in a 10 minute test session.

Procedure

Training

Following a two day postoperative recovery period each animal was placed in the test chamber for a 10 minute exploratory session. The exploratory session was followed the next day by a training session where each animal was shaped to press a bar for brain stimulation reward. Using the technique of successive approximations, the animal was manually stimulated each time it performed a behaviour which was progressively more like the desired bar pressing response. The animal was stimulated during the shaping phase using a series of 5 minute intervals where the current ascended 50 ua each interval. Current levels began at 100 ua and were increased until the animal displayed either self-stimulation behaviour or an overt competing motor response such that it interfered with the animal's ability to bar press. Animals that bar pressed at least 100 times in a 5 minute pretest session were classified as 'self-stimulators'. The lowest current which elicited bar pressing was determined by decreasing the current to a level 50% below the intensity which initially elicited the 100 bar presses/5 minute session criterion and then raising the current 50% of the difference in each subsequent session. For example, if 150 ua was found to elicit 100 bar presses in a 5 minute session then the current was decreased to 75 ua (i.e. 50% level) in the next session

and raised to 110 ua (75% level), 130 ua (87.5% level), 150 ua (100% level), etc., until at least 100-bar presses/5 minutes resulted. Bar pressing behaviour was elicited through the left electrode in half of the animals and through the right electrode in the remaining half. Electrical self-stimulation was administered using a continuous schedule of reinforcement.

Testing

The training period was followed by a testing period where each animal was given two 12 minute test sessions per day until bar pressing stabilized. The first 2 minutes of each session was a 'warm-up' period followed by a 10 minute test session. Animals were tested on successive days until they reached a stability criterion where their brain shock values and bar pressing scores did not deviate ± 20% from the mean of any six consecutive sessions. Once an animal had reached this criterion then bar pressing was considered stable. Bar pressing was stabilized through the left electrode in half of the animals and through the right electrode in the remaining half. The mean of the six consecutive criterion sessions for brain shocks and the mean of the six consecutive criterion sessions for bar presses constituted baseline values for each animal (B_1). Following stability testing each animal was lesioned through the same electrode that elicited self-stimulation using a range of 0.1 - 0.3 ma

of direct anodal current passed for a duration of 15 seconds. These lesion parameters served to disrupt bar pressing behaviour without totally eliminating it. After a 1 day recovery period the animals were retested (R_1) for the next 3 days (i.e. 6 sessions) to determine the effect of the lesion on bar pressing behaviour. If the initial lesion did not produce a noticeable effect (i.e. decreased bar pressing without completely abolishing the behaviour) within the 3 day postlesion period, the animals were relesioned at a DC lesion value .10 ma higher than the previous level. Only those animals whose bar pressing responses were successfully reduced but not eliminated were used in the experiment. The postlesion current intensity was the same as was used before the lesion.

Experimental Phase

On the third postlesion day the self-stimulating animals were divided into four groups matched on the basis of percentage of postlesion decrease in brain shock values from the prelesion baseline. The four groups were:

(1) a contralateral homologue stimulation condition (CS), n = 11

(2) a contralateral lesion condition (CL), n = 9

(3) an intact contralateral control condition (C), n = 10

(4) a stimulation control condition (SC), n = 9.

Animals in the CS group received stimulation in the intact contralateral MFB-LHA for two 15 minute sessions daily for the next 12 days. The animals received a combined total of approximately 900 pulses (1.0 msec in duration) in the two sessions with current intensity maintained at a constant 10 ua. The CL animals underwent a second lesion on Day 3 which damaged the remaining contralateral MFB-LHA. The animals were lesioned by using a 2 ma direct anodal current applied for 10 seconds. The cathode was connected to the animal's ear. Animals in control group C retained an intact contralateral MFB-LHA during the next 12 days following the first lesion. These animals were allowed to recover from the first unilateral lesion without being given additional stimulation or a second lesion in the MFB-LHA on the opposite side of the brain. Finally, stimulation control animals (SC) received two 15 minute sessions of stimulation daily in an area adjacent to the MFB-LHA using the same stimulus parameters as was used in the CS group.

Retest

All animals were retested (R_2) for self-stimulation for the next 12 days after the R_1 retest period. The R_2 period consisted of two 12 minute test sessions daily using the same stimulus parameters as pretesting and maintained the same level of current intensity. Self-stimulation values during this retesting period were then

divided into blocks of 3 days each (i.e. 6 sessions) and comparisons in recovery rates were made.

The complete experimental design is depicted in Table 2.

Histology

Sacrifice and Sectioning

Following the second retesting period all animals were sacrificed with an overdose of sodium pentobarbital (NEMBUTAL) and the decapitated heads were placed in a 10% formalin solution for 24 hours. The brains were then extracted from the skull, the electrodes were removed, and the brain was allowed to fixate in the 10% formalin solution for an additional 7 days. The fixated brain was then removed from the formalin, blocked, and 75 micron thick coronal sections were cut using a freezing microtome (American Optical Corp., Model #880). Every third section starting from a point where the electrode tracks first became visible was preserved in 10% ethanol. Each section was then mounted on a slide and placed in a microprojector (Bausch and Lomb Inc.). Hand drawings of the electrode tracks were constructed for gross verification of electrode placement and extent of tissue damage. The sections were then stored in a 10% ethyl alcohol solution so future photographic prints could be made.

TABLE 2
Experimental Design

Surgical Procedure	Training	Lesion	Retest (R_1) (Day 1-3)	Experimental phases (Day 3-15)		Retest (R_2) (Day 4-15)
Symmetrical Implantation Group	Shaping: ICSS threshold; ICSS stabilized; Prelesion baseline. (1/2 left; 1/2 right)	MFB-LHA lesioned unilaterally at 0.1-0.3 ma DC for 15 seconds.	ICSS decrease tested.	CL:	Second lesion to contralateral MFB-LHA at 2 ma DC for 10 seconds.	ICSS retested.
				C:	Intact contralateral MFB-LHA (no stimulation or second lesion).	ICSS retested.
				CS:	Stimulation of contralateral MFB-LHA at 10 ua/1 hour daily.	ICSS retested.
Asymmetrical Implantation Group	Shaping; ICSS threshold; ICSS stabilized; Prelesion baseline. (1/2 left; 1/2 right)	MFB-LHA lesioned unilaterally at 0.1-0.3 ma DC for 15 seconds.	ICSS decrease tested	SC:	Stimulation of area adjacent to MFB-LHA for 1 hr. daily at 10 ua.	ICSS retested.

CHAPTER III

RESULTS

Figures 1 and 2 show the mean brain shock rates, and bar press responses, respectively, of the control and experimental groups for four days prior to the initial lesion and for the 15 postlesion recovery days. To reiterate, the following abbreviations were used for each group:

1) C = intact control
2) CL = contralateral lesion
3) CS = contralateral stimulation; and
4) SC = stimulation control.

The brain shock rates and bar press responses of each group are represented as a percentage of the prelesion baseline levels. The baseline level is designated as 1.00. The conversion of absolute brain shock and bar press values to percentages was necessary so that direct comparisons could be made between animals that differed greatly in their absolute brain shock and bar press values. Brain shock and bar press measures were subjected to the same statistical analyses and the results of the analyses are presented separately for each dependent measure.

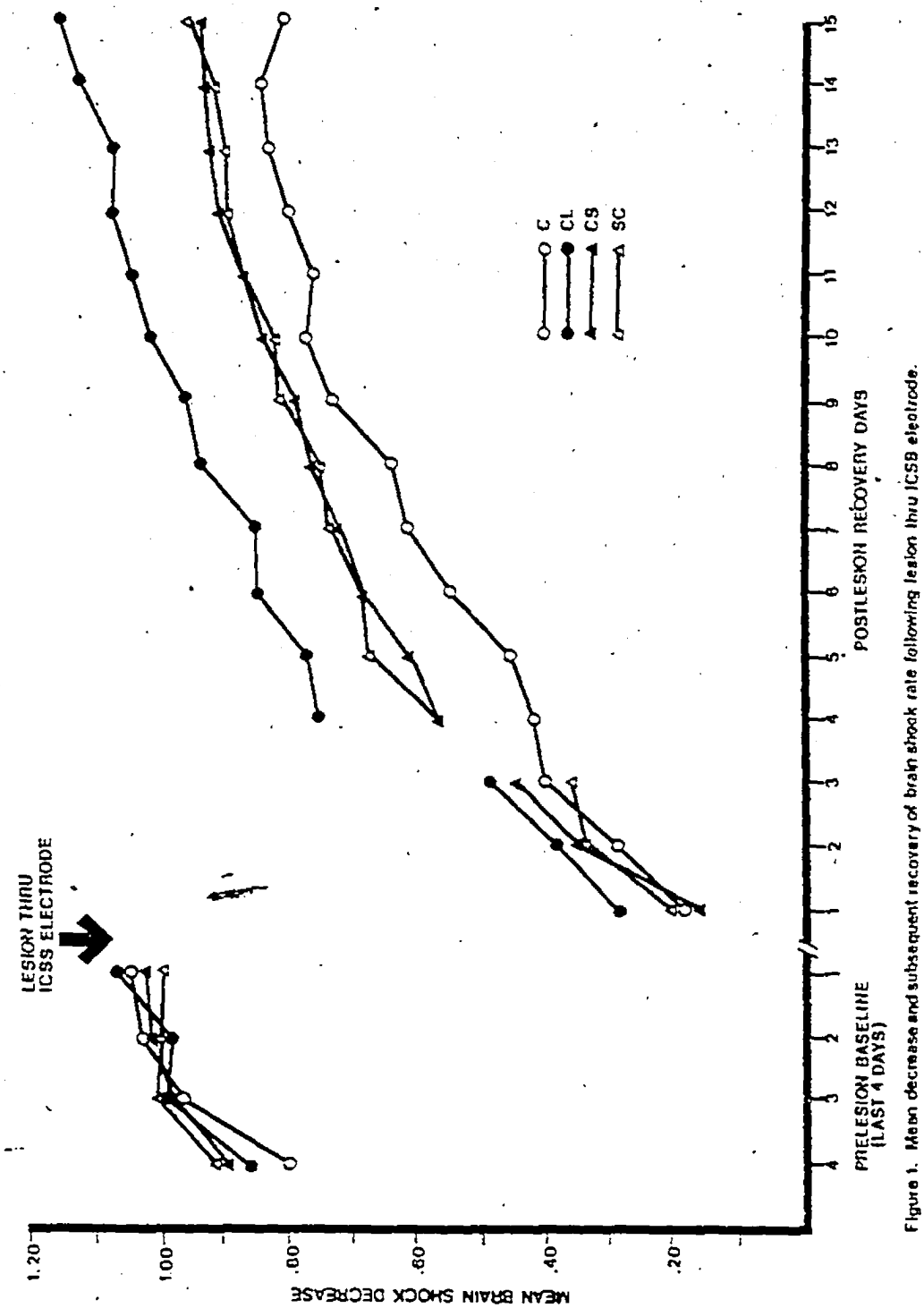

Figure 1. Mean decrease and subsequent recovery of brain shock rate following lesion thru ICSS electrode.

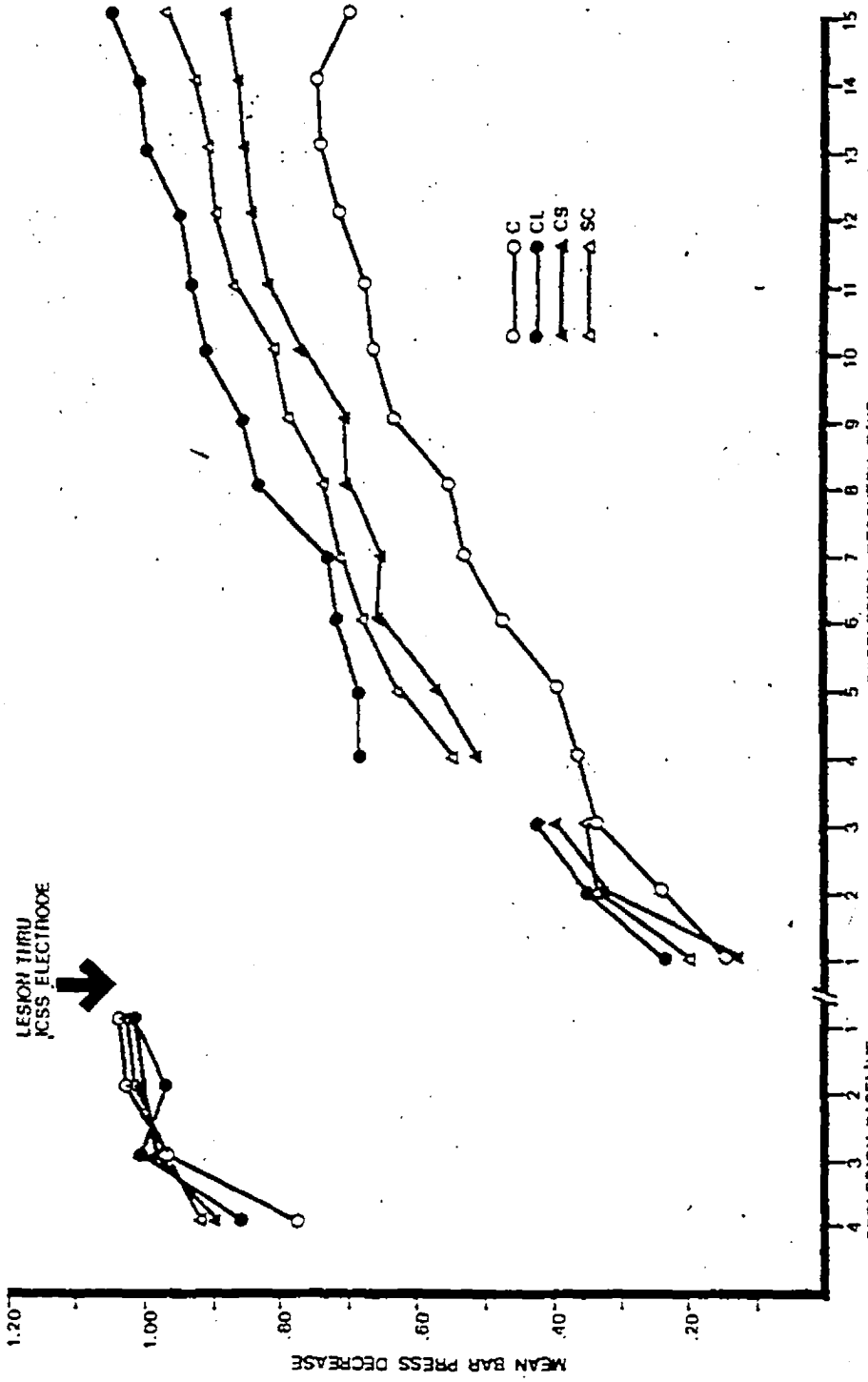

Figure 2. Mean decrease and subsequent recovery of bar press responses following lesion thru ICSS electrode.

Brain Shock Measure

The initial lesion to disrupt ICSS behaviour, indicated by the arrow on Figure 1, caused a marked decrease in the response rates for control and experimental groups. Following the initial lesion, a similar pattern of recovery is seen between groups across the 15 postlesion recovery days. Table 3 shows the mean percentage increases of brain shock rates for control and experimental groups across the 15 postlesion recovery days combined into five 3-day blocks. Table 4 shows a repeated measures unweighted means; analysis of variance using the data presented in Table 3 (4 x 5 design) (Winer, 1971).

The analysis revealed a significant effect due to postlesion recovery blocks only. Tests on the differences between all pairs of means (Neuman - Keuls) revealed that all recovery blocks differed significantly from one another with the exception of the Block 4 to Block 5 comparison (Table 5). The secondary analysis indicated that a significant increase in brain shock rate occurred across the postlesion recovery blocks with recovery approaching an asymptote by Block 5. A check on the hypothesis of homogeneity (Hartley's test; Winer, 1971) showed that the brain shock data was homogeneous (For the Subjects w. groups variation: $F_{max} = 2.82$, $k = 4$, $df = 10$, $p > .01$; For the B X Subjects w. groups variation: $F_{max} = 2.64$, $k = 4$, $df = 40$, $p > .01$).

As can be seen in Figure 1, the most acute change

TABLE 3

Summary of Mean Percentage Increases of Brain Shock Rate for Control and Experimental Groups Across Five 3-Day Postlesion Recovery Blocks

Group	Postlesion Recovery Block 1	2	3	4	5
C	.29	.48	.66	.77	.82
CL	.39	.79	.91	1.04	1.12
CS	.32	.63	.77	.88	.93
SC	.31	.65	.77	.87	.94

TABLE 4

Summary of Analysis of Variance of Brain Shock Rate for Experimental and Control Groups and Five Postlesion Recovery Blocks

Source	SS	df	MS	F
Between Subjects	11.64	38		
Group	1.56	3	.52	1.79
Subjects w. Groups	10.08	35	.29	
Within Subjects	11.40	156		
Blocks	9.67	4	2.42	242.00*
Groups X Blocks	.10	12	.01	1.00
B X Subjects w. Groups	1.63	140	.01	
Total	23.04	194		

* $p < .001$

TABLE 5

Neuman-Keuls q_r Values for Differences Between Pairs of Ordered Mean Brain Shock Values for the Postlesion Recovery Blocks Variable

	Postlesion Recovery Blocks				
	1 (.33)	2 (.63)	3 (.78)	4 (.89)	5 (.95)
1	—	.30*	.45*	.56*	.62*
2	—	—	.15*	.26*	.32*
3	—	—	—	.11*	.17*
4	—	—	—	—	.06

* $p < .01$

in recovery occurred between postlesion Days 3 and 4. Here CL animals, in particular, displayed a precipitous increase in brain shock rate. Table 6 shows the mean percentage increases of brain shock rate for control and experimental groups across postlesion recovery Days 3 and 4. The brain shock means listed on postlesion Day 3 represent the matching of the four groups. Table 7 shows a one-way analysis of variance of brain shock rate for control and experimental groups on postlesion Day 3. The overall analysis indicated that the groups did not differ significantly on the brain shock measure. A test on the hypothesis of homogeneity (Hartley test) revealed that the assumption was not violated for the brain shock data (F_{max} = 7.00, k = 4, df = 10, $p > .01$).

Individual planned comparisons (Hays, 1963; Keppel, 1973) among group brain shock means on postlesion Day 4 are shown in Table 8. As seen in this table, a comparison between C and CL groups showed a significant difference between their group brain shock means. Individual comparisons between C and CS group means indicated no significant difference in brain shock rates. It appeared that there was a significant difference in brain shock recovery on postlesion Day 4 between those animals whose contralateral MFB-LHA was damaged when compared to unlesioned control animals.

TABLE 6

Summary of Mean Percentage Increases of Brain Shock Rate for Control and Experimental Groups Across Postlesion Recovery Days 3 and 4

Group	Postlesion Recovery Day 3	4
C	.40	.42
CL	.49	.75
CS	.46	.58
SC	.37	.58

TABLE 7

Summary of Analysis of Variance of Brain Shock Rate for Control and Experimental Groups on Postlesion Day 3

Source	SS	df	MS	F
Groups	.07	3	.02	.40
Error	1.58	35	.05	
Total	1.65	38		

TABLE 8

Summary of Planned Comparisons Among Group Brain Shock Means for Postlesion Recovery Day 4

Source	SS	df	MS	F
Between Groups	10.35	3		
Comparisons				
C vs CL	.53	1	.53	6.64*
C vs CS	.12	1	.12	1.56
Remainder	9.70	1	9.70	
Error	2.68	35	.08	
Total	13.03	38		

* $p < .05$

Bar Press Measure

In addition to the brain shock measure the total number of bar press responses were recorded for each animal. The effects of ICSS lesions on bar press responses, and the subsequent recovery of ICSS behaviour across the 15 postlesion recovery days are represented in Figure 2. The overall pattern of bar press recovery depicted in Figure 2 resembled that seen for the brain shock data in Figure 1. For statistical analysis, the 15 postlesion recovery days were again combined into 3-day blocks. The five means for each control and experimental group are represented in Table 9. The bar press means shown in this table were subjected to a repeated measures unweighted means, analysis of variance (4 x 5 design) (Table 10). The main analysis of variance revealed that recovery differed significantly across the postlesion blocks. This main day effect did not, however, interact with groups, nor was there a significant main group effect. Table 11 shows a Neuman - Keuls analysis on the differences between all pairs of means. As can be seen from the analysis, all block means differed significantly from one another with the exception of the Block 4 to Block 5 comparison. As was the case with brain shock recovery, a significant increase in bar press responses occurred across the postlesion blocks with recovery approaching an asymptote by Block 5. A check on the homogeneity of the bar press data revealed

TABLE 9

Summary of Mean Percentage Increases of Bar Press Responses for Control and Experimental Groups Across Five 3-Day Postlesion Recovery Blocks

Group	Postlesion Recovery Block 1	2	3	4	5
C	.24	.42	.58	.69	.73
CL	.33	.68	.80	.92	1.02
CS	.28	.57	.69	.80	.86
SC	.29	.62	.75	.86	.93

TABLE 10

Summary of Analysis of Variance of Bar Press Responses for Control and Experimental Groups and Five Postlesion Recovery Blocks

Source	SS	df	MS	F
Between Subjects	11.41	38		
Group	1.27	3	.42	1.45
Subjects w. Groups	10.14	35	.29	
Within Subjects	10.99	156		
Blocks	8.78	4	2.20	110.00*
Groups X Blocks	.10	12	.01	.50
B X Subjects w. Groups	2.11	140	.02	
Total	22.40	194		

* $p < .001$

TABLE 11

Neuman-Keuls q_r Values for Differences Between Pairs of Ordered Mean Bar Press Responses for the Postlesion Recovery Blocks Variable

	Postlesion Recovery Blocks				
	1 (.29)	2 (.57)	3 (.71)	4 (.82)	5 (.89)
1	—	.30*	.45*	.56*	.62*
2	—	—	.15*	.26*	.32*
3	—	—	—	.11*	.17*
4	—	—	—	—	.06

* $p < .01$

that the data was homogeneous with respect to Subjects within groups variation, but not for B X Subjects within groups variation (For Subject but n groups variation: F_{max}= 5.14, k=4, df=10, p>.01; For B X Subjects w. groups variation: F_{max}=3.46, k=4, df=40, p<.01). However, since analysis of variance is robust with respect to minor violations of homogeneity assumptions (Box, 1954), the original bar press data were not transformed.

As was seen in the case of the brain shock data, Figure 2 showed that the most abrupt change in bar press recovery occurred between postlesion Days 3 and 4. Table 12 shows the mean percentage increases in bar press recovery for all groups across these two days. Although animals were not matched on the basis of bar press responses, a one-way analysis of variance of bar press responses for control and experimental groups on postlesion Day 3 indicated no significant differences between the groups (Table 13). A check on the assumption of homogeneity indicated that it was not contradicted for the bar press data (F_{max}=1.50, k=4, df=10, p>.05).

Individual planned comparisons among group means were conducted using the bar press data on postlesion Day 4 (Table 14). The analysis revealed that C and CL groups differed significantly from one another in bar press recovery. Comparisons between C and CS groups however, resulted in no significant differences. Consonant with the brain

TABLE 12

Summary of Mean Percentage Increases of Bar Press Responses for Control and Experimental Groups Across Postlesion Recovery Days 3 and 4

Group	Postlesion Recovery Day 3	4
C	.34	.37
CL	.42	.68
CS	.39	.51
SC	.35	.55

TABLE 13

Summary of Analysis of Variance of Bar Press Responses for Control and Experimental Groups on Postlesion Day 3

Source	SS	df	MS	F
Groups	.05	3	.02	.40
Error	1.78	35	.05	
Total	1.83	38		

TABLE 14

Summary of Planned Comparisons Among Group Bar Press Means for Postlesion Recovery Day 4

Source	SS	df	MS	F
Between Groups	8.49	3		
Comparisons				
C vs CL	.47	1	.47	6.71*
C vs CS	.09	1	.09	1.37
Remainder	7.93	1	7.93	
Error	2.46	35	.07	
Total	10.95	38		

* $p < .05$

shock data, there was a difference in bar press recovery on postlesion Day 4 between contralateral lesioned (CL) animals and intact controls (C).

Extent of Recovery

The extent of brain shock and bar press recovery is seen on postlesion recovery Day 15 on Figures 1 and 2, respectively. Inspection of these figures indicated that mean brain shock and bar press responses in C, CS, and SC groups failed to completely recover to prelesion baseline levels at the time the experiment was terminated. CL animals, on the other hand, showed a final recovery level which exceeded the prelesion baseline level. Differences between the baseline and postlesion Day 15 brain shock and bar press responses for each group were analyzed by means of correlated t-tests. The analyses indicated that prelesion and postlesion scores were significantly different in C animals for both the brain shock and bar press data (For brain shock data: $t=-2.29$, $df=9$, $p<.05$; For bar press data: $t=-3.16$, $df=9$, $p<.05$). CL, CS and SC animals, on the other hand, did not demonstrate a significant difference between prelesion and postlesion brain shock and bar press responses.

Individual Recovery Curves

Recovery curves for all animals were inspected to see if individual recovery curves corresponded to the overall group mean curves depicted in Figures 1 and 2. All C

animals displayed recovery curves which did not vary greatly from the mean recovery curve. Animals in the CS and SC groups however, showed more individual variation. The main difference between recovery curves of animals in these groups involved the degree of recovery between postlesion Days 3 and 4. That is, about half of the animals within each of these groups demonstrated a distinct increase in recovery. Recovery curves in the remaining animals showed a more gradual increase in brain shock and bar press responses. Finally, individual CL animals showed recovery patterns which were consonant with the group mean recovery curve. All animals in this group, with the exception of one, exhibited a rather precipitous increase in recovery between postlesion Days 3 and 4 followed by a gradual increase in responding over the remaining 11 postlesion days.

Histological Analysis

In Figures 3-8, locations of electrode tips in C, CS, and SC animals are marked on tracings of coronal sections from deGroot's (1959) atlas of the rat brain. On one side of each figure, individual ICSS electrode placements are represented by different symbols. The other half of each figure indicates the location of an animal's corresponding non-ICSS electrode. Finally, the number on the far right of each section represents the anterior-posterior coordinate according to the deGroot atlas.

Figures 3 and 4 are electrode placements in C an-

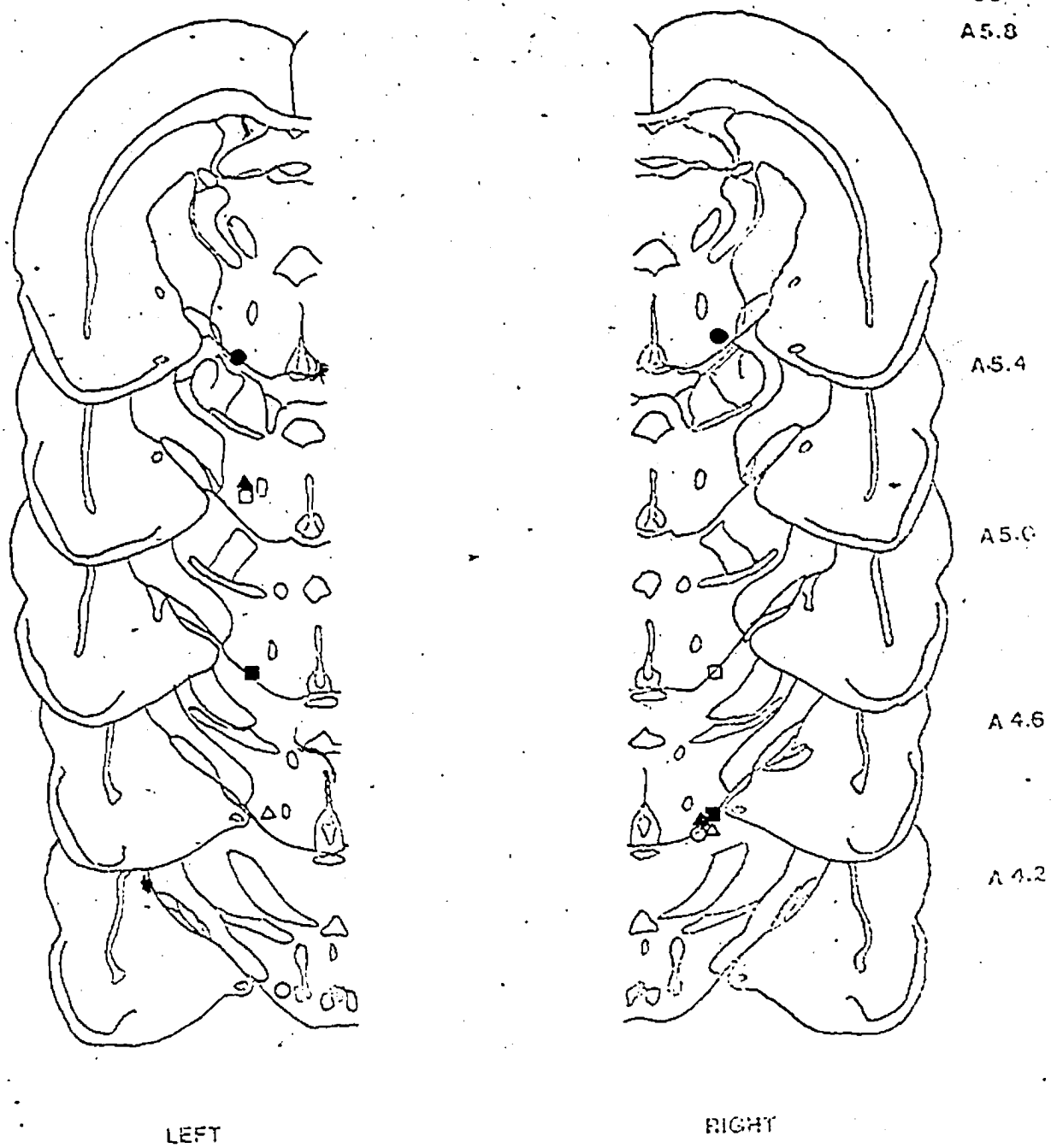

Figure 3. Electrode placements in C animals with ICSS elicited thru left electrode.

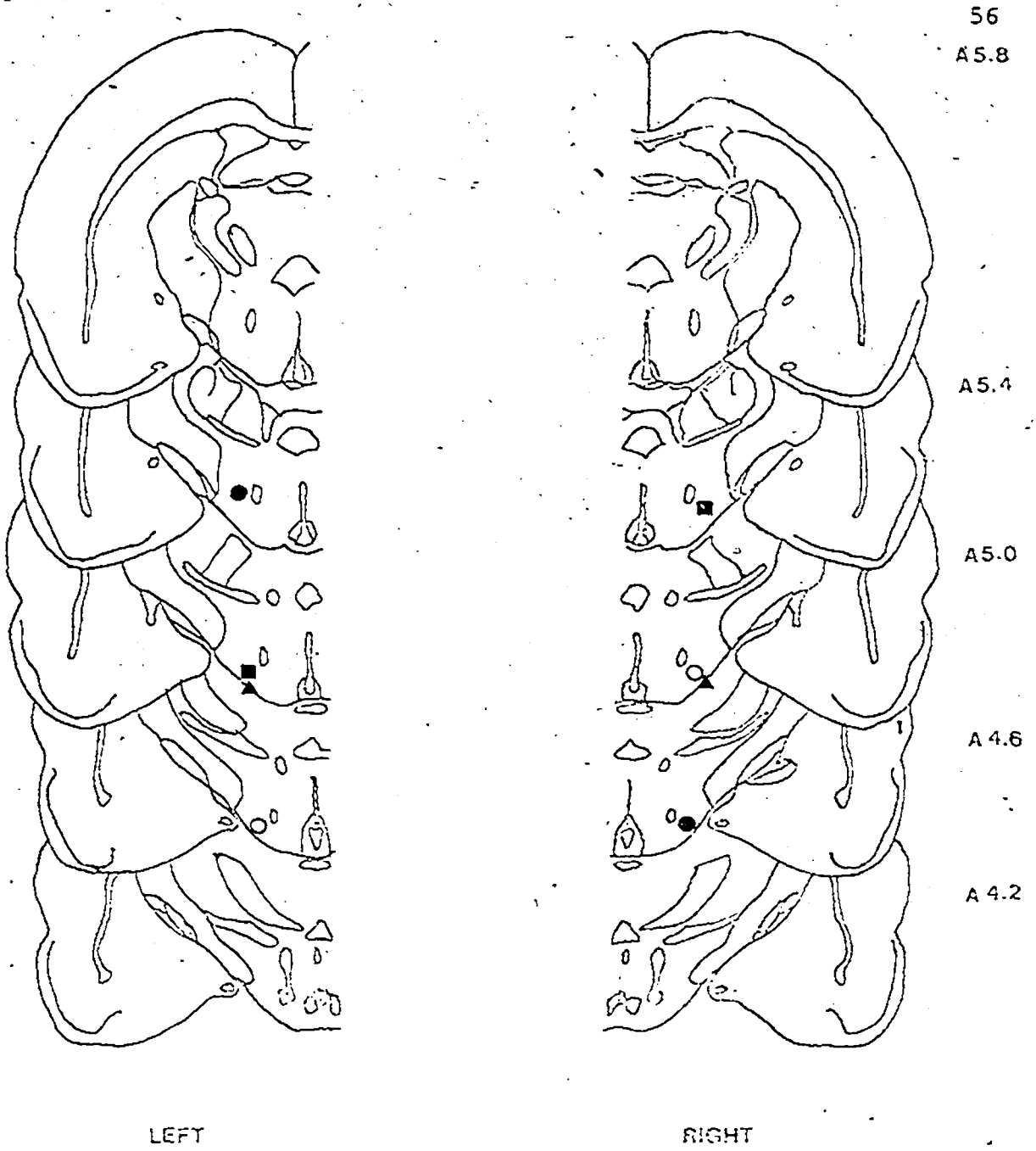

Figure 4. Electrode placements in C animals with ICSS elicited thru right electrode.

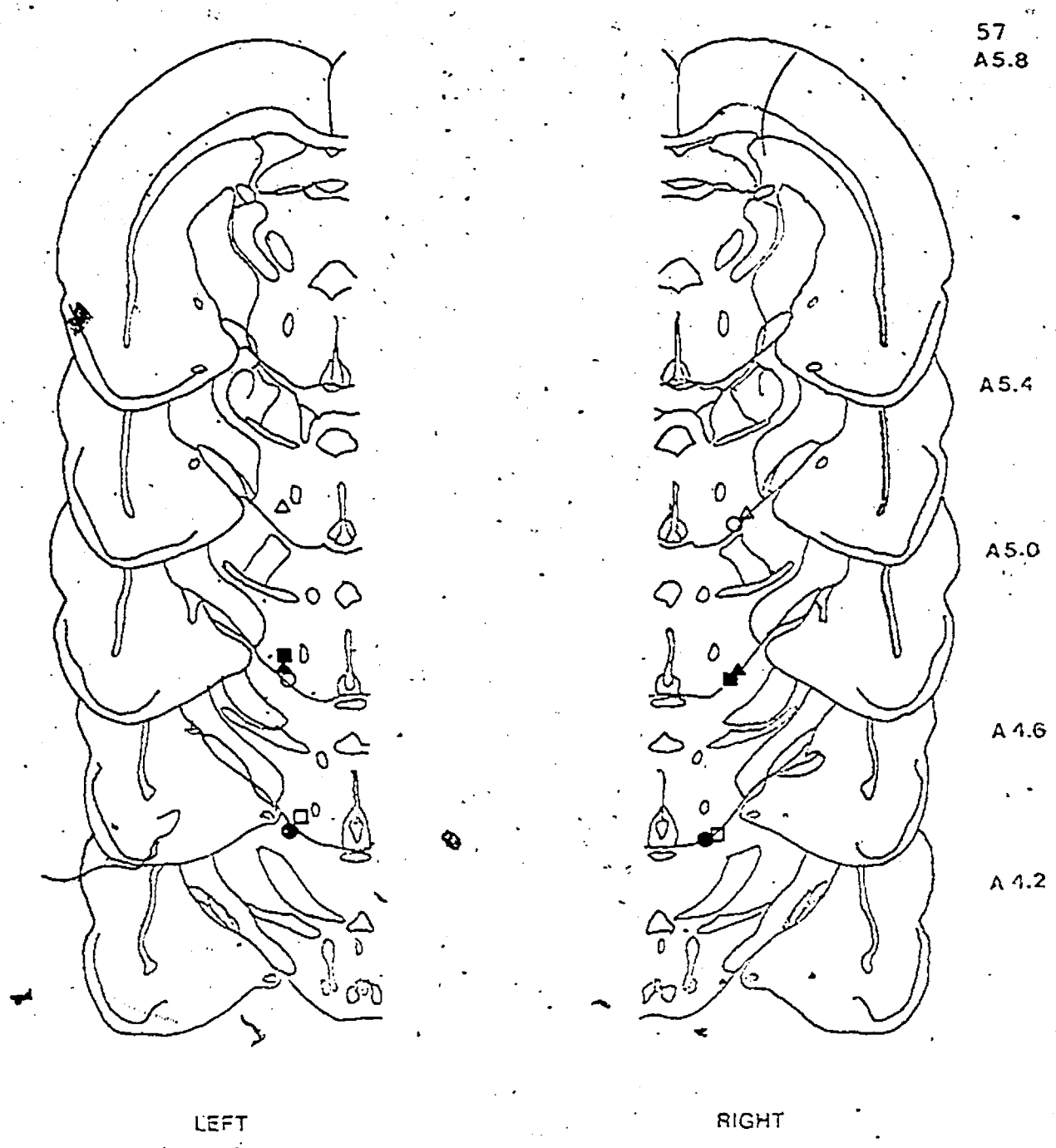

Figure 5. Electrode placements in CS animals with ICSS elicited thru left electrode.

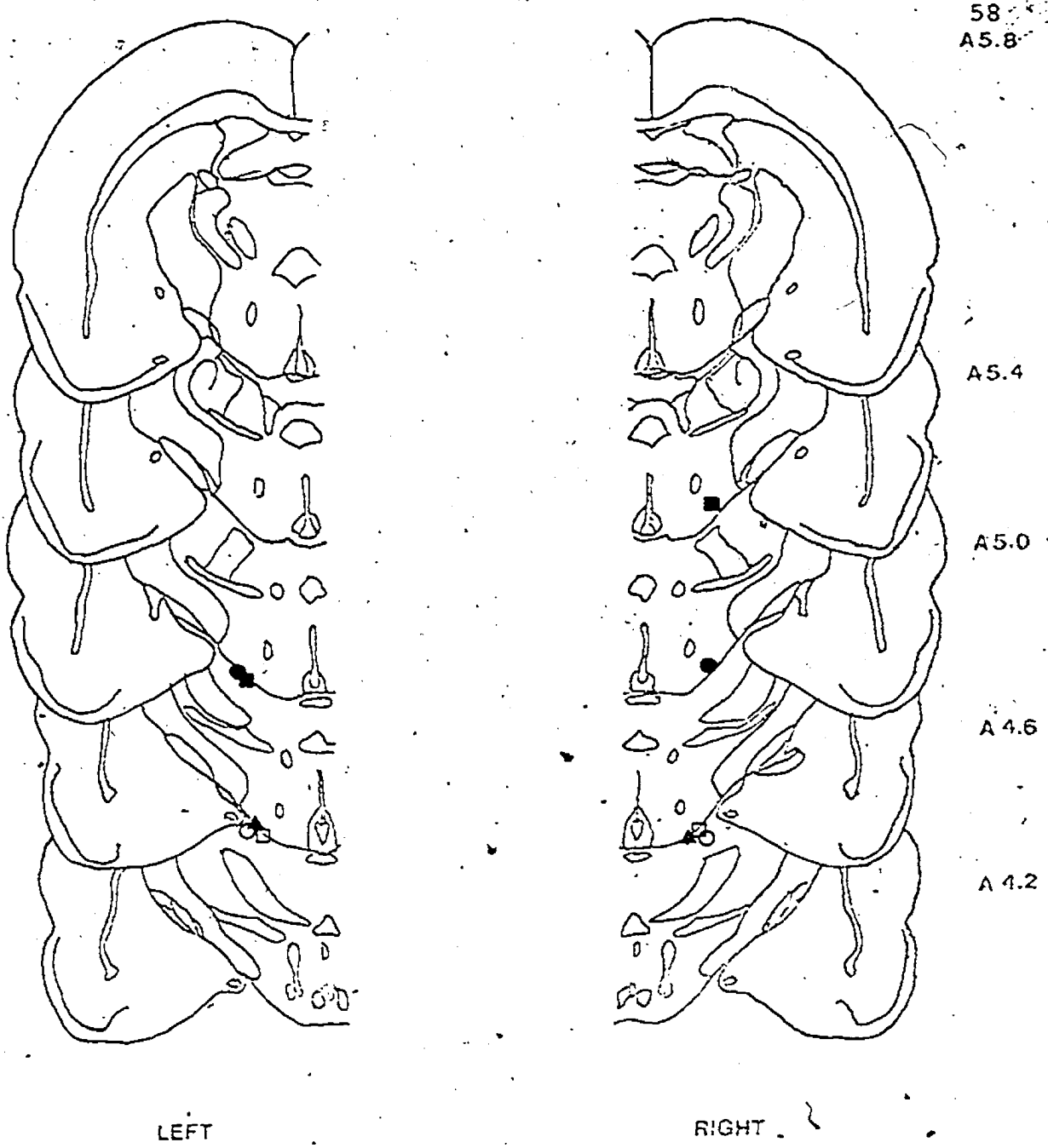

Figure 6. Electrode placements in CS animals with ICSS elicited thru right electrode.

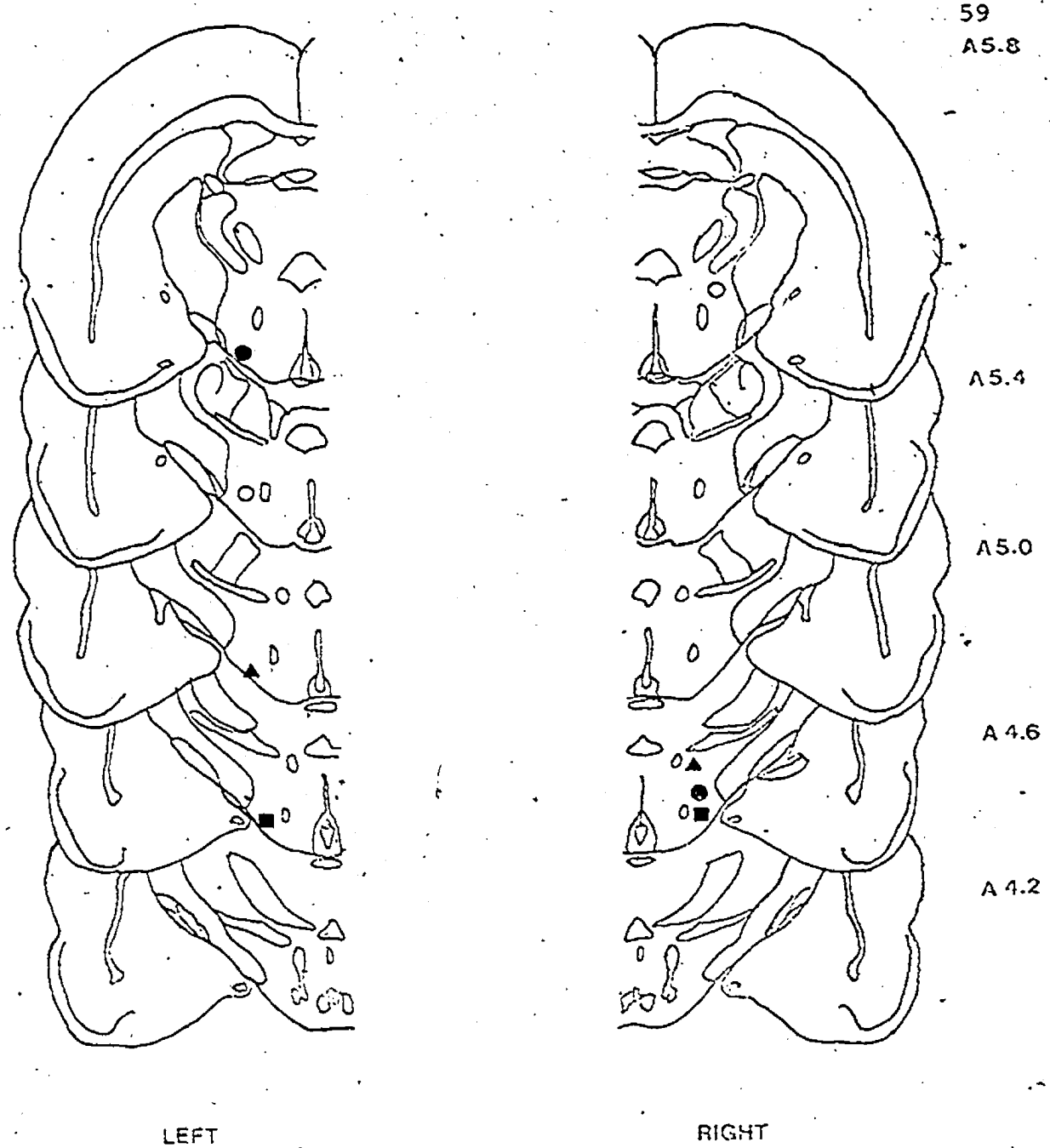

Figure 7. Electrode placements in SC animals with ICSS elicited thru left electrode.

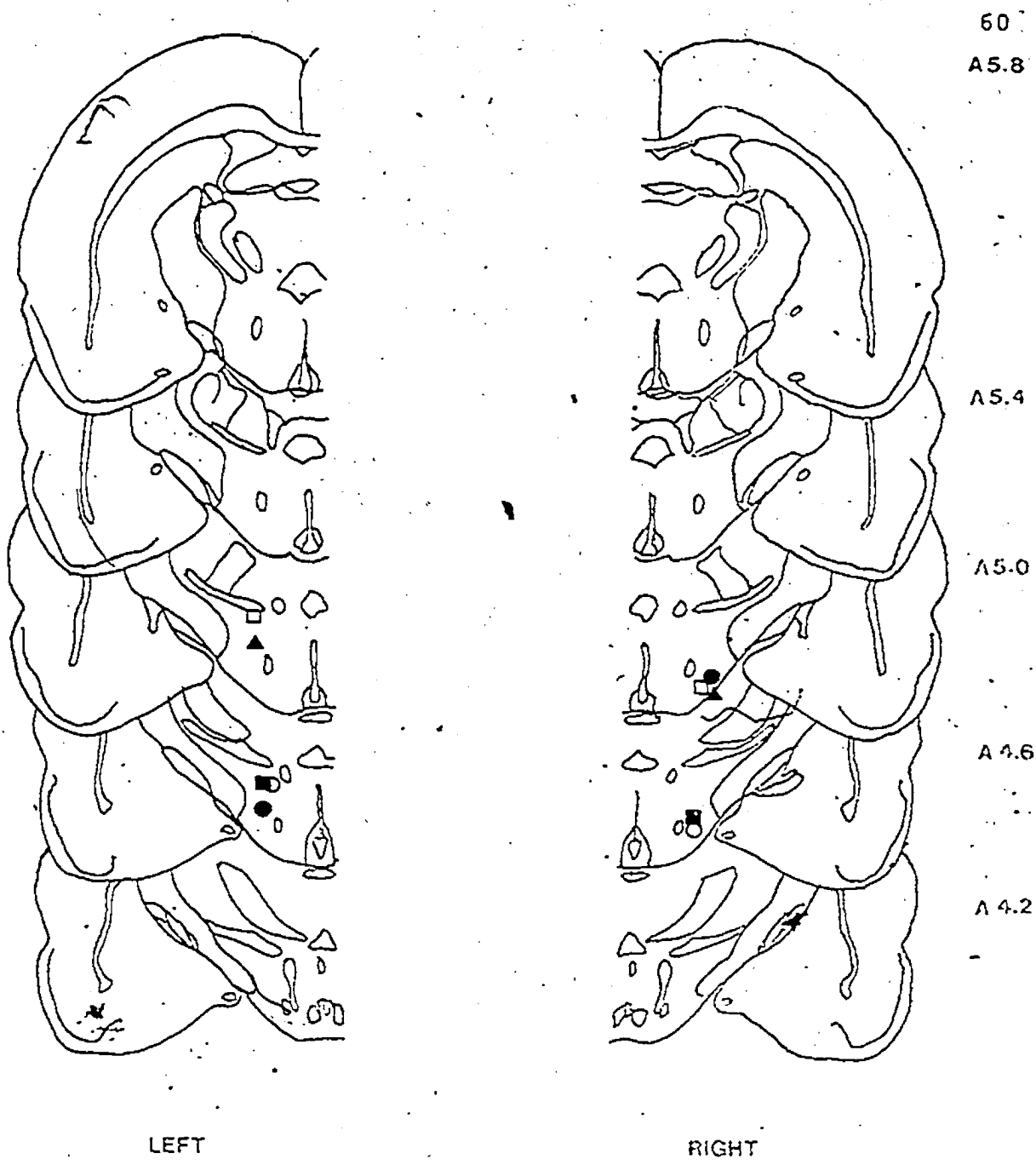

Figure 8. Electrode placements in SC animals with ICSS elicited thru right electrode.

imals. As can be seen from these two figures, ICSS electrodes were implanted in or around the MFB-LHA in all of the animals. Placements of electrode tips ranged from A5.8 to A4.2, and were located within the MFB-LHA. Most of the electrode placements, however, were centered in the extreme ventral MFB-LHA. Placements of non-ICSS electrodes ranged from A5.8 to A4.6, and were also found to be largely implanted in the ventral MFB-LHA.

Figures 5 and 6 show the electrode placements in CS animals. Electrodes eliciting ICSS penetrated the extreme ventral part of MFB-LHA. The electrodes were located from 4.6 to 5.4mm anterior to the interaural line. Non-ICSS electrode tips were implanted from A5.4 to A4.6 and also were concentrated in the extreme ventral MFB-LHA.

Though it appeared that many of the electrodes in the C and CS groups had been implanted deep enough to completely bisect the MFB-LHA, the electrodes were found to elicit ICSS behaviour when tested. If an electrode on either side of the brain was found not to result in ICSS behaviour, the animal was discarded from the study. Thus, the occurrence of ICSS behaviour was used as a functional index of appropriate electrode placement.

Figures 7 and 8 indicate the electrode placements in SC animals. In these animals it was intended that one electrode be implanted within the MFB-LHA on one side of

the brain, and the contralateral electrode implanted in an area outside the MFB-LHA. As shown in Figures 7 and 8, ICSS electrodes were implanted within the ventral boundary of the MFB-LHA. Contralateral non-ICSS electrodes, on the other hand, were found to be located in areas consistently dorsal to ICSS placements. Six of the non-ICSS electrodes were implanted in the zona incerta, while the remaining three electrodes were located in the dorsal part of the MFB-LHA. All non-ICSS electrode placements were tested for ICSS behaviour and an animal was discarded if ICSS could be demonstrated in an intended non-ICSS electrode.

The location of the ICSS electrode tip, and the maximal extent of contralateral tissue damage for each CL animal is represented in Figure 9. Six of the CL animals had ICSS behaviour elicited through the left electrode while three of the animals had ICSS elicited through the right electrode. In all cases, ICSS electrodes were implanted in the ventral boundary of the MFB-LHA extending from an anterior-posterior range of A5.8 to A4.6. The shaded areas in the figure indicate the maximal extent of contralateral tissue damage in each animal. All the lesions included damage to a portion of the MFB-LHA. The extent of damage in the largest lesion included the MFB-LHA, zona incerta, fornix, ventromedial hypothalamus, dorsomedial hypothalamus, and portions of the ventral premamillary and lateral mamillary nuclei.

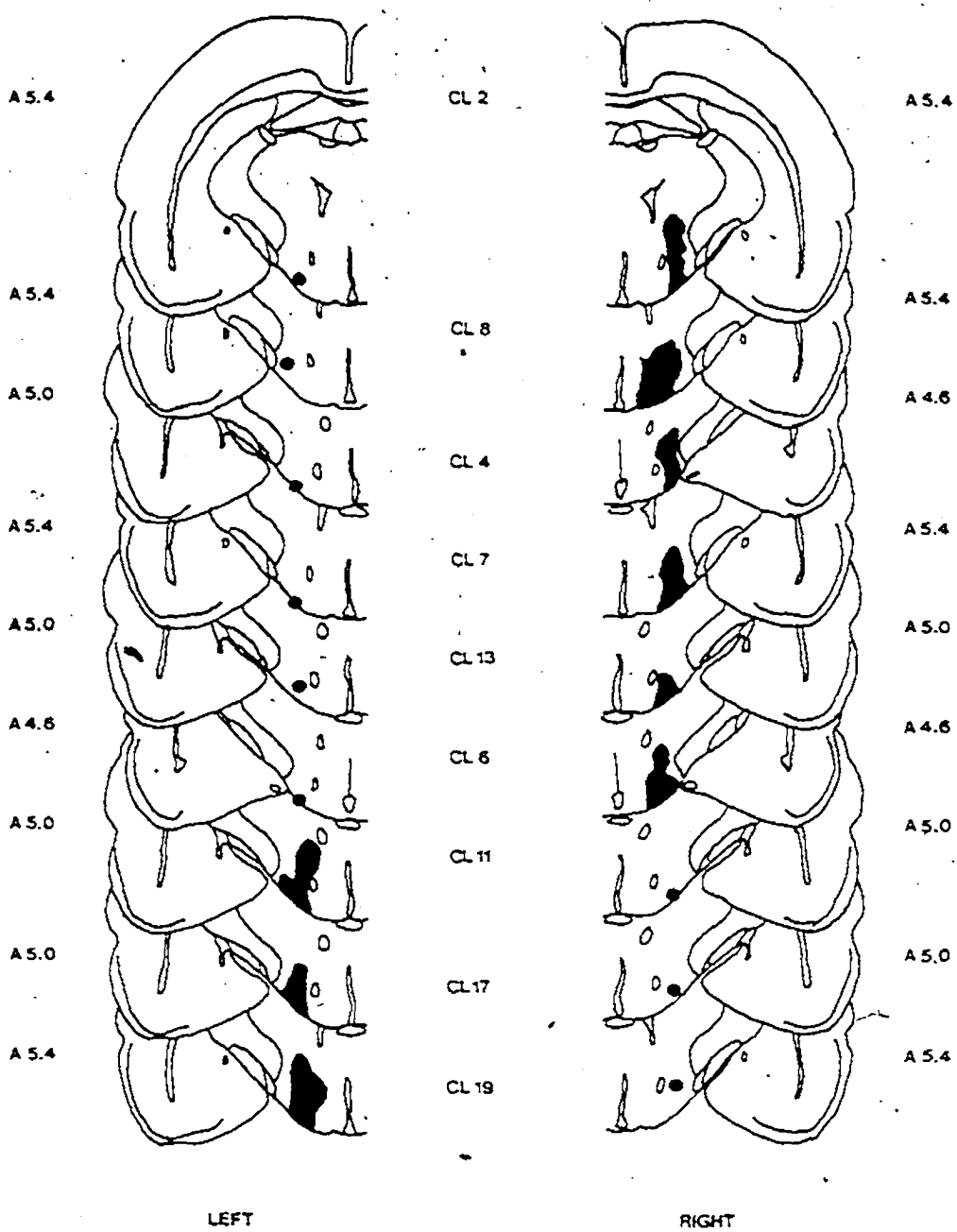

Figure 9. Location of ICSS electrodes and maximal extent of contralateral tissue damage in CL animals.

CHAPTER IV

DISCUSSION

The primary purpose of the present experiment was to determine if intact structures on one side of the brain become involved in the recovery of damaged contralateral homologues during the interoperative interval of a two-stage lesion. It was thought that if behavioural recovery was dependent upon the integrity of homologous tissue contralateral to a brain damaged area, then: a) subsequent damage to this tissue may impede the recovery process while, b) subsequent electrical stimulation of the tissue may expedite recovery.

In the present study, rats were trained to press a bar to receive brief electrical shocks to the brain (ICSS). The animals were then lesioned to disrupt ICSS behaviour and the subsequent postlesion recovery patterns were observed. The two dependent measures were: a) the total number of brain shocks delivered to the animal, and b) the total number of bar press responses by the animal. The results indicated that the course of ICSS recovery was similar for brain shock and bar press measures (Figures 1 and 2). Since brain shock and bar press recovery demonstrated a high degree of similarity, the discussion of ICSS recovery is confined to the brain shock data.

Overall Recovery

Following the initial unilateral lesion of the MFB-LHA, animals recovered self-stimulation behaviour regardless of whether or not the MFB-LHA on the opposite side of the brain was damaged (CL), intact (C), or intact and subjected to daily sessions of electrical stimulation (CS) (Figure 1). Furthermore, animals who underwent daily sessions of electrical stimulation of an area adjacent to the contralateral MFB-LHA (SC) manifested a brain shock recovery pattern remarkably similar to the course of recovery seen in CS animals. An analysis of the brain shock recovery rate for experimental and control groups across the entire 15 day postlesion recovery period revealed a significant increase in brain shock rate, but the course of recovery was the same for all groups (Table 4). That is, subsequent contralateral lesioning or stimulating did not produce a significant difference in the overall recovery pattern among the groups. These results failed to support the hypotheses that damage to homologous tissue on the opposite side of the brain would impede, and contralateral stimulation of this area enhance, the course of ICSS recovery.

Contralateral Lesion and Recovery

Although the behavioural results did not support the hypotheses, they did reveal a paradoxical phenomenon: Damage to the homologous MFB-LHA on the opposite side of the brain resulted in a significant immediate enhancement in re-

covery of self-stimulation behaviour (Table 7). On postlesion Day 4, contralateral lesion animals showed a precipitous increase in brain shock responses. Individual planned comparisons of the mean brain shock rates between control and contralateral lesion groups revealed a significant increase in responding for the contralateral lesion animals. At the same time, the analyses indicated no significant difference in recovery between control and contralateral stimulation animals (Table 8). The importance of this immediate heightening in recovery on postlesion Day 4 is accented by the return to a more gradual increase in responding over the remaining 11 postlesion days.

A word of caution is necessary before attempting to explain the paradoxical recovery seen in the CL group. Since it was not expected that contralateral damage would produce enhancement in the course of recovery, an important control group was left out. That is, it is not known whether the improvement seen in CL animals was due to lesioning of the homologous structure per se, or the consequence of inflicting additional damage anywhere in the brain. An additional group of animals whose contralateral MFB-LHA remained intact and who received damage to an area outside the MFB-LHA area would help to answer this particular question.

Despite the limitations imposed by the lack of a proper control group, a few suggestions can be offered to explain the immediate recovery seen in the CL animals. To

begin with, largely because of the rapidity of brain shock recovery, it seems unlikely that mechanisms such as vicarious functioning, behavioural substitution, or neuronal sprouting (Finger et. al., 1973; Goldberger, 1973; Meyer, 1973) were responsible for such immediate recovery. The assumption, of course, is that these mechanisms require a much longer time period to become functionally operative (Butters et. al., 1973; Steward et. al., 1973, 1974; Schultze and Stein, 1975) and, thus cannot plausibly explain rapid changes in behavioural recovery.

One possible explanation is that the initial ICSS lesion initiated reactions in the denervated area which served to facilitate the effect of the subsequent contralateral lesion, and thus, promoted a more rapid behavioural recovery (Scheff et. al., 1977). Scheff and his colleagues demonstrated that a partial lesion of the entorhinal cortex on one side accelerated the course of 'axonal sprouting' produced by a subsequent lesion four days later of the entorhinal area of the opposite side. In effect, the authors suggested that the initial lesion acted as a 'conditioning' stimulus. That is, the lesion activated the cellular events necessary for fiber growth and thus conditioned the system so that axonal growth began within two days. Animals who had the entire entorhinal cortex removed at one time, on the other hand, required at least six days before sprouting began. The authors suggested that the cellular changes were biochem-

ical in nature and included changes in the metabolism of the reactive afferents and postsynaptic (deafferented) cells. The explanation is closely associated with a denervation supersensitivity model of recovery. This model proposes that a damaged area undergoes postsynaptic excitatory changes which usually involve an increased sensitivity to chemical mediators serving the deprived area (Glick and Zimmerberg, 1972; Glick et. al., 1972; Glick and Greenstein, 1972).

An alternative possibility is that the rapid recovery of behavioural responding may have resulted from the withdrawal of inhibition. For example, Bard (1938) demonstrated that subsequent lesions in the opposite hemisphere immediately ameliorated the deficits in contact placing and hopping behaviour produced by an initial unilateral lesion to the motor cortex area. Along this same line, Semmes and Chow (1955) found that many of the contralateral defects which accompany unilateral ablation of the precentral gyrus could be rapidly ameliorated following massive lesioning of areas surrounding the precentral gyrus in the opposite hemisphere. At the subcortical level, Goldberger (1969) found that a loss of contact placing behaviour, as a result of a unilateral pyramidal lesion, could be reinstated when a subsequent lesion was made in the ventrolateral funiculus of the spinal cord on the opposite side. Though these studies represent relationships that may exist between heterotopic regions of the hemispheres, the results do suggest that rapid

recovery may occur as a function of the elimination of an otherwise intact inhibitory mechanism.

As further support for the suggestion that immediate behavioural recovery may reflect a withdrawal of inhibitory influences, Sprague (1966) conducted a study involving the visual system in cats. First, he demonstrated that unilateral removal of the entire occipito-temporal cortex resulted in the usual contralateral hemianopia. Subsequent removal of the superior colliculus contralateral to the cortical lesion restored vision to the previously hemianopic field. Sprague argued that the superior colliculus ipsilateral to the cortical lesion was functionally depressed because of an inhibition resulting from imbalance of visual centers after the cortical lesion. Since the subsequent ablation of the contralateral colliculus returned vision to the hemianopic field, Sprague suggested that visual restitution was due to recovery of function of the ipsilateral colliculus, and that recovery was the result of removal of inhibition arising from the superior colliculus of the opposite side. Finally, Bogen and Campbell (1962) demonstrated that the inhibitory hypothesis is not restricted to interhemispheric mechanisms. In their study, they discovered that placing behaviour lost as a result of 'hemicerebrectomy' of one side of the brain could be restored following a second frontal lesion placed within the same hemisphere. Bogen and Campbell suggested that recovery was the result

of a removal of ipsilateral, corticifugal inhibition.

More recently, LeVere (1975) reviewed the inhibitory-facilitory hypothesis suggested by Sprague (1966). LeVere suggested that Sprague's findings represented a 'systems' view of brain function. That is, many behavioural functions can be shown to be mediated at cortical and subcortical levels by brain areas organized into systems. Any damage inflicted to the brain causes dysfunction through an imbalance in the inhibitory-facilitory relations throughout the system (LeVere, 1975, p. 355). Thus, in the case of Sprague (1966), the visual cortex sends facilitating impulses to the ipsilateral colliculus. The colliculi on both sides, in turn, inhibit each other. Unilateral lesioning of the cortical centers disturbs the balance between the visual cortex and the colliculus. Subsequent damage to the contralateral colliculus restores the normal balance between inhibition and facilitation (Rosner, 1970).

With regard to the present behavioural results, it may be that a balance exists between homologous brain areas, particularly if they redundantly mediate similar behaviours. It is likely that damage to the MFB-LHA on one side of the brain resulted in a removal of inhibition to the opposite homologous area, and thus, produced a rapid increase in ICSS responding. The fact that CL animals eventually recovered to a level beyond the original baseline (Figure 1) is consistent with this idea.

Contralateral Stimulation and Recovery

The results have shown that subsequent electrical stimulation of homologous tissue contralateral to an area of CNS damage did not facilitate the course of behavioural recovery (Figure 1). One of the major problems in the present study however, involved the selecting of appropriate stimulus parameters in those animals receiving contralateral brain stimulation. While it was intended that the stimulation be of sufficient duration to cause a change in the normal brain activity, permanent tissue damage was to be averted. Furthermore, it was intended that the intensity of the current be maintained at a minimal level to avoid the occurrence of overt behavioural responses. A range of stimulus durations and intensities have been shown to have an effect on behavioural recovery following brain damage. For example, Thode and Carlisle (1964) found that animals stimulated in the lateral hypothalamic area for 30 minutes daily recovered from an anorexic effect produced by administration of amphetamine. While the authors failed to mention the train and pulse durations used, they did report that a current intensity of 75 ua was sufficient to reinstate feeding behaviour. More recently, Harrell et. al. (1974) demonstrated that the feeding recovery period following lateral hypothalamic damage could be reduced from 6 days to 2 days if the damaged area was stimulated with a train of pulses 1.0 msec in duration for 1 hour daily. The intensity of the stimulation was held constant

at 8 ua.

Finally, Heath (1977) has demonstrated some success in the treatment of certain intractable psychiatric illnesses by stimulating specific cerebellar sites over a much longer time span. Through means of a chronically implanted receiver activated by an external power source, a pulse .25 msec in duration was administered to the cerebellum for 3-6 months depending on the disorder under treatment. The intensity of the current was varied from 3-6 volts.

In the present experiment, CS and SC animals were stimulated with a .5 sec train of pulses 1.0 msec in duration. The shocks were administered for two 15 minute sessions daily and were programmed to deliver one pulse every 2 seconds. Thus, each animal received approximately 900 shocks daily over 12 postlesion recovery days. The current intensity was held constant at 10 ua. My point is simply that the similarity in the course of recovery between stimulated and unstimulated animals may reflect the use of inappropriate stimulus parameters (i.e. train and pulse durations, current intensity), or an insufficient application period (Harrell et. al., 1974; Heath, 1977).

A second point can be made on the effects of stimulation. It was thought that the direct effect of stimulating would be to alter the state of neural organization within the vicinity of the stimulating electrode. This modifica-

tion in function may, in turn, have an indirect effect on interconnected neural activity remote from the site of stimulation (Doty, 1969). However, changes in the ongoing neural activity at local and distant sites may be either inhibitory or excitatory in nature (Ervin and Kenney, 1971). That is, electrical shocks may serve to activate or inactivate existing neural function. Thus, in the case of CS and SC animals, electrical stimulation may have produced a complex network of both excitatory and inhibitory influences acting on local and distant neurons which, when summated, had a net effect of neither excitation nor inhibition. The similarity in recovery between the stimulated and control groups would tend to support this interpretation (Figure 1).

Additional Methodological Considerations

An incidental purpose of the present experiment was to provide data pertaining to the feasibility of selecting ICSS as a model for studying behavioural recovery after CNS damage (Phillips, 1976). It was thought that changes in ICSS responding would be clearly observable, and therefore, interpretations of behavioural impairment and recovery less ambiguous. While this appeared to be the case in the present experiment, a methodological technique used in the study may have confounded the results. That is, it was exceedingly difficult to produce a lesion which disrupted ICSS behaviour and yet did not result either in complete recovery or cessation of responding. While those ani-

mals who completely lost self-stimulation behaviour were discarded from the study, animals who recovered the next day had to be relesioned. Thus, many animals were lesioned more than once to disrupt ICSS behaviour. What effect this may have had on the course of ICSS recovery is unanswered. Either a new technique should be used to produce the initial brain damage, or a subsequent experiment performed to assess the effects of using multiple ablations.

Secondly, this study was not designed to compare the effects of early and later brain damage, nor was it intended to compare to what extent behavioural recovery is a function of the sex of the organism. However, it would seem plausible to investigate both of these variables considering the extent of recovery seen in young versus older animals (Stein, 1973; Goldman, 1975), and males versus females (Teitelbaum, 1973).

Summary and Conclusions

In summary, it has been shown that (a) subsequent electrical stimulation of homologous tissue contralateral to an area of CNS damage does not facilitate the course of behavioural recovery, and (b) subsequent damage to this same tissue resulted in an immediate paradoxical increase in behavioural responding. It was suggested that this rapid increase in responding may be explained in terms of a release of inhibitory influences arising from the MFB-LHA on the opposite side of the brain. While these results pro-

vide some information on the involvement of contralateral homologues in recovery, there are a number of questions yet to be answered.

First, there is the question of whether there is a 'critical' period between initial damage and subsequent contralateral intervention. That is, the initiation of the recovery process by the contralateral homologue may have taken place immediately following the initial ablation, and therefore, subsequent damage and stimulation a short time later may have had a different effect on recovery than if it were produced immediately following the initial brain damage. Along this line, Stein (1973) has suggested that homologous tissue on the opposite side of the brain may provide the impetus by which recovery begins but then is no longer needed once recovery is set in motion. In the present experiment, contralateral damage and stimulation were not produced until three days after the initial lesion, thus already allowing for what may have been sufficient time for initiation of recovery. This possibility is likely, considering the importance of the length of the interoperative interval in two-stage recovery (Stewart and Ades, 1946; Patrissi and Stein, 1971; Glick and Zimmerberg, 1972). A more definitive answer to this question must await the outcome of a subsequent experiment where the 'critical' postlesion period is systematically varied.

Second, one of the major problems in the present

study involved the selecting of stimulus parameters which were best suited for the experimental requirements. Except for the likelihood that certain stimulus parameters can result in tissue damage (Lilly, 1966), the selecting of appropriate stimulation parameters for the purpose of expediting recovery was not clear cut in the present study. It may not have been the stimulation per se therefore, that failed to facilitate recovery in the CS group but, instead, the result of stimulating with inappropriate stimulus parameters. Clearly the next step would be to systematically investigate the effects of various parameters on the course of recovery following brain damage.

Finally, the paradoxical finding that subsequent contralateral damage enhanced the course of ICSS recovery is of special interest. While this finding resulted from damage to the homologous brain region on the opposite side, it does not imply that the damage must necessarily be confined to this area to facilitate recovery. To answer this question, it is necessary to demonstrate that subsequent lesions placed in a heterotopic brain region result in less behavioural recovery than the same sized lesion located in a homologous area.

The rapid recovery seen in the CL animals brings up an interesting point. That is, brain damaged subjects may not necessarily be made worse by additional damage. The question as to whether a subsequent lesion improves one con-

dition and creates another, however, remains unanswered. This, of course, would depend upon the brain area involved as well as the behaviour mediated by the area. It would seem worthshile, therefore, to investigate whether subsequent lesioning in other brain areas may ameliorate the behavioural deficits caused by an earlier lesion while at the same time keeping deficits produced by the second lesion to a minimum.

To demonstrate that an homologous region on the opposite side of the brain is involved in recovery following CNS damage is of both theoretical and clinical importance. That is, the demonstration that intervention can have an effect on the behavioural responses elicited by an area on the opposite side may provide insight into basic brain-behaviour relationships. Furthermore, this kind of research may provide basic knowledge of relevance to the treatment of brain-damaged subjects. If the mechanism responsible for behavioural recovery can be more clearly defined, than perhaps the course of recovery may be hastened either by means of surgical intervention, or with the aid of appropriate pharmacological agents.

APPENDICES

APPENDIX A

PRELESION BASELINE BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS

Control Animals

Subject	Brain Shocks	Bar Presses
C1	592	696
C10	628	902
C4	488	559
C5	642	1079
C2	756	956
C6	733	1090
C7	462	615
C13	598	816
C16	737	936
C20	508	763

Contralateral Lesion Animals

Subject	Brain Shocks	Bar Presses
CL2	600	657
CL8	492	649
CL4	762	908
CL7	641	1079
CL13	784	984
CL6	624	759
CL11	566	1073
CL17	513	636
CL19	469	610

Contralateral Stimulation Animals

Subject	Brain Shocks	Bar Presses
CS3	613	629
CS4	579	694
CS1	707	901
CS9	687	929
CS6	563	577
CS11	692	1421
CS10	379	388
CS15	502	625
CS14	573	709
CS12	621	806
CS17	580	732

Stimulation Control Animals

Subject	Brain Shocks	Bar Presses
SC1	347	379
SC5	597	639
SC8	518	581
SC9	541	621
SC4	632	648
SC10	641	802
SC12	679	961
SC13	458	522
SC17	331	349

APPENDIX B

MEAN DAILY BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS ACROSS THE 15 POSTLESION RECOVERY DAYS

Control Animals

Subject		Postlesion Recovery Days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C1	BS	60	5	80	132	138	152	222	222	247	298	227	279	342	310	307
	BP	62	5	83	134	144	158	253	248	277	332	248	301	389	366	344
C10	BS	67	211	164	153	256	346	355	399	457	427	370	449	395	570	463
	BP	80	240	197	189	315	435	419	499	552	549	445	586	541	815	608
C4	BS	81	156	293	324	342	360	408	416	516	517	497	508	529	513	524
	BP	84	159	312	347	368	380	449	448	592	579	562	567	573	595	587
C5	BS	31	57	59	67	103	91	129	155	190	225	321	387	388	273	136
	BP	46	82	83	87	144	133	184	239	271	363	544	641	651	374	180
C2	BS	188	265	399	307	219	540	536	372	536	578	577	636	657	643	676
	BP	191	267	415	323	225	574	551	398	549	589	589	659	664	650	694
C6	BS	13	10	45	71	59	107	163	228	214	302	311	284	416	492	502
	BP	13	11	49	75	56	117	186	249	225	333	332	296	447	535	533
C7	BS	307	342	252	281	294	325	409	432	477	469	469	488	454	457	476
	BP	327	410	277	309	331	359	467	488	560	539	550	559	511	520	556
C13	BS	13	104	410	456	486	508	531	552	571	602	627	653	645	598	607
	BP	13	123	497	564	591	622	636	667	711	703	786	838	839	780	754

Control Animals (cont.)

Subject		Postlesion Recovery Days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C16	BS	260	406	499	548	533	611	658	649	663	673	702	609	741	762	769
	BP	283	425	551	592	571	667	711	676	705	729	779	660	867	863	856
C20	BS	51	183	175	196	263	292	323	397	433	440	460	500	446	459	421
	BP	74	211	193	270	354	387	421	534	597	603	633	687	602	599	515

Contralateral Lesion Animals

Subject		Postlesion Recovery Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CL2	BS	171	315	445	555	534	622	532	639	692	738	740	744	752	806	813
	BP	180	378	460	577	569	658	565	682	746	807	771	788	838	895	879
CL8	BS	249	291	295	530	558	538	576	567	615	618	655	675	648	729	745
	BP	252	298	330	620	592	551	616	609	651	653	690	718	671	778	805
CL4	BS	21	29	94	298	456	500	612	638	691	693	726	753	769	767	790
	BP	23	29	96	315	471	536	677	763	848	813	869	918	966	939	984
CL7	BS	41	40	247	433	508	475	520	655	635	780	806	808	775	827	826
	BP	47	41	283	492	584	565	625	815	763	1041	1078	1042	1021	1116	1126
CL13	BS	167	333	214	530	497	496	548	536	567	607	619	634	652	661	667
	BP	175	354	224	584	545	518	601	590	606	650	654	705	699	715	727
CL6	BS	165	271	391	610	528	638	617	670	607	676	661	684	664	664	617
	BP	180	312	479	860	622	746	725	828	654	778	734	742	748	750	677
CL11	BS	252	316	379	477	451	563	542	515	547	510	565	533	605	591	638
	BP	343	459	494	747	622	800	731	714	827	829	893	811	1163	940	1057
CL17	BS	5	50	82	171	205	279	202	343	338	340	378	390	426	426	438
	BP	5	70	95	212	252	359	279	474	485	470	512	515	561	542	573
CL19	BS	370	380	382	396	382	415	435	472	463	495	489	523	513	557	639
	BP	390	425	420	418	391	427	450	498	507	528	536	580	571	627	751

Contralateral Stimulation Animals

Subject		Postlesion Recovery Days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CS3	BS	62	352	328	131	308	463	425	554	580	629	662	654	663	646	638
	BP	63	354	328	131	309	465	426	555	581	632	662	655	664	648	642
CS4	BS	57	258	450	555	538	604	616	643	671	657	665	688	701	699	713
	BP	58	268	480	618	572	645	673	713	745	766	777	840	853	841	847
CS1	BS	420	531	532	557	594	580	465	448	489	515	566	584	619	612	637
	BP	427	545	541	573	502	490	470	453	504	527	592	615	685	672	718
CS9	BS	80	103	191	165	151	186	480	387	567	562	647	669	636	629	636
	BP	82	161	199	188	180	212	555	430	665	648	799	763	724	752	782
CS6	BS	9	69	148	319	384	416	434	505	462	482	520	489	550	518	543
	BP	10	72	152	334	409	437	468	528	478	498	536	501	568	527	558
CS11	BS	161	393	377	579	580	566	604	624	613	639	653	666	639	701	659
	BP	173	423	402	721	708	734	780	818	735	792	1000	1014	982	1089	1026
CS10	BS	90	228	271	370	430	398	383	398	388	420	436	430	436	453	457
	BP	96	237	287	388	476	441	416	420	401	448	458	444	442	462	484
CS15	BS	24	24	49	146	114	226	191	286	268	345	316	358	366	376	408
	BP	30	29	56	174	139	266	240	329	301	427	367	404	393	412	459

Contralateral Stimulation Animals (cont.)

Subject		Postlesion Recovery Days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CS14	BS	142	303	436	444	541	568	511	544	555	547	556	616	564	641	615
	BP	168	334	506	482	667	754	555	608	602	634	603	691	628	704	707
CS12	BS	0	50	157	196	223	257	322	309	323	358	356	477	483	447	471
	BP	0	54	162	213	252	288	354	343	353	390	400	549	575	517	572
CS17	BS	6	62	116	227	191	309	277	271	267	303	302	302	324	320	332
	BP	6	72	122	237	198	331	283	278	276	317	310	308	332	334	338

Stimulation Control Animals

Subject		Postlesion Recovery Days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SC1	BS	26	11	37	216	187	185	152	196	182	172	175	204	227	205	216
	BP	27	13	38	235	191	192	171	204	185	175	177	207	231	209	226
SC5	BS	233	327	297	364	377	412	476	509	599	573	602	617	630	609	642
	BP	233	333	299	365	377	416	477	511	601	575	604	619	681	613	651
SC8	BS	189	303	360	453	466	485	477	536	524	523	531	522	530	546	561
	BP	191	308	367	466	488	494	507	577	563	569	572	559	569	605	617
SC9	BS	116	140	188	291	337	307	316	292	339	344	362	385	362	367	400
	BP	140	173	222	367	411	370	394	349	397	386	425	469	438	457	466
SC4	BS	34	114	136	175	298	284	359	343	374	445	408	446	442	444	382
	BP	38	116	138	185	322	299	391	360	395	475	425	465	463	465	398
SC10	BS	82	232	241	372	387	376	390	401	453	456	461	440	514	508	516
	BP	87	238	246	390	388	389	395	416	475	476	493	461	555	580	558
SC12	BS	18	18	12	14	24	67	118	118	145	191	264	329	400	440	424
	BP	21	19	14	16	27	82	142	129	162	213	297	370	476	529	514
SC13	BS	271	273	263	339	422	450	479	484	493	494	552	539	549	581	613
	BP	294	288	280	373	449	498	528	538	562	562	668	643	635	696	756
SC17	BS	24	190	173	314	420	469	503	490	525	502	581	581	511	536	631
	BP	24	194	176	316	437	511	538	522	575	610	661	667	574	612	709

APPENDIX C.

MEAN DAILY BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS ACROSS THE 15 POSTLESION RECOVERY DAYS AS A PERCENTAGE OF PRELESION BASELINE LEVELS

Control Animals

Subject		Postlesion Recovery Days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C1	BS	.10	.01	.14	.22	.23	.26	.38	.38	.42	.51	.38	.47	.58	.52	.52
	BP	.09	.01	.12	.19	.21	.23	.36	.36	.40	.48	.36	.43	.56	.53	.49
C10	BS	.11	.34	.26	.24	.41	.55	.57	.64	.73	.78	.59	.72	.63	.91	.74
	BP	.09	.27	.22	.21	.35	.48	.46	.55	.61	.61	.49	.65	.60	.90	.67
C4	BS	.17	.32	.60	.66	.70	.74	.84	.85	1.06	1.06	1.02	1.04	1.08	1.05	1.07
	BP	.15	.28	.56	.62	.66	.68	.80	.80	1.06	1.04	1.01	1.01	1.03	1.06	1.05
C5	BS	.05	.09	.09	.10	.16	.14	.20	.24	.30	.35	.50	.60	.60	.43	.21
	BP	.04	.08	.08	.08	.13	.12	.17	.22	.25	.34	.50	.59	.60	.35	.17
C2	BS	.25	.35	.53	.41	.29	.71	.71	.50	.71	.77	.76	.84	.87	.85	.89
	BP	.20	.28	.43	.34	.24	.60	.58	.42	.57	.62	.62	.69	.70	.68	.73
C6	BS	.02	.01	.06	.10	.08	.15	.22	.31	.29	.41	.42	.39	.57	.67	.69
	BP	.01	.01	.05	.07	.05	.11	.17	.23	.21	.31	.31	.27	.41	.49	.49
C7	BS	.67	.74	.55	.61	.64	.70	.89	.94	1.03	1.02	1.02	1.06	.98	.99	1.03
	BP	.53	.67	.45	.50	.54	.58	.76	.79	.91	.88	.89	.91	.83	.85	.90
C13	BS	.02	.17	.69	.76	.81	.85	.89	.92	.96	1.01	1.05	1.09	1.08	1.00	1.02
	BP	.02	.15	.61	.69	.72	.76	.78	.82	.87	.86	.96	1.03	1.03	.96	.92

Control Animals (cont.)

Subject		Postlesion Recovery Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C16	BS	.35	.55	.68	.74	.72	.83	.89	.88	.90	.91	.95	.83	1.01	1.03	1.04
	BP	.30	.45	.59	.63	.61	.71	.76	.72	.75	.78	.83	.71	.93	.92	.92
C20	BS	.10	.36	.35	.39	.52	.58	.64	.78	.85	.87	.91	.98	.88	.90	.83
	BP	.10	.28	.25	.35	.46	.51	.55	.70	.78	.79	.83	.90	.79	.79	.68
GROUP	BS	.18	.29	.40	.42	.46	.55	.62	.64	.73	.77	.76	.80	.83	.84	.80
	BP	.15	.25	.34	.37	.40	.48	.54	.56	.64	.67	.68	.72	.75	.75	.70

Contralateral Lesion Animals

Subject		Postlesion Recovery Days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CL2	BS	.29	.53	.74	.93	.89	1.04	.89	1.07	1.15	1.23	1.23	1.24	1.25	1.34	1.36
	BP	.27	.58	.70	.88	.87	1.00	.86	1.04	1.14	1.23	1.17	1.20	1.28	1.36	1.34
CL8	BS	.51	.59	.60	1.08	1.13	1.09	1.17	1.15	1.25	1.26	1.33	1.37	1.32	1.48	1.51
	BP	.39	.46	.51	.96	.91	.85	.95	.94	1.00	1.01	1.06	1.11	1.03	1.20	1.24
CL4	BS	.03	.04	.12	.39	.60	.66	.80	.84	.91	.91	.95	.99	1.01	1.01	1.04
	BP	.03	.03	.11	.35	.52	.59	.75	.84	.93	.90	.96	1.01	1.06	1.03	1.08
CL7	BS	.06	.06	.39	.68	.79	.74	.81	1.02	.99	1.22	1.26	1.26	1.21	1.29	1.29
	BP	.04	.04	.26	.46	.54	.52	.58	.76	.71	.97	1.00	.97	.95	1.03	1.04
CL13	BS	.21	.43	.27	.68	.63	.63	.70	.68	.72	.77	.79	.81	.83	.84	.85
	BP	.18	.36	.23	.59	.55	.53	.61	.60	.62	.66	.67	.72	.71	.73	.74
CL6	BS	.26	.43	.63	.98	.85	1.02	.99	1.07	.97	1.08	1.06	1.10	1.06	1.06	.99
	BP	.24	.41	.63	1.13	.82	.98	.96	1.09	.86	1.03	.97	.98	1.00	1.00	.89
CL11	BS	.45	.56	.67	.84	.80	1.00	.96	.91	.97	.90	.98	.94	1.07	1.04	1.13
	BP	.32	.43	.46	.70	.58	.75	.68	.67	.77	.77	.83	.76	1.08	.88	.99

Contralateral Lesion Animals (cont.)

Subject		Postlesion Recovery Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CL17	BS	.01	.10	.16	.33	.40	.54	.39	.67	.66	.66	.74	.76	.83	.83	.85
	BP	.01	.11	.15	.33	.40	.57	.44	.75	.76	.74	.81	.81	.88	.85	.90
CL19	BS	.79	.81	.82	.84	.82	.89	.93	1.01	.99	1.06	1.04	1.12	1.09	1.19	1.36
	BP	.64	.70	.69	.69	.64	.70	.74	.82	.83	.87	.88	.95	.94	1.03	1.23
GROUP	BS	.29	.39	.49	.75	.77	.85	.85	.94	.96	1.01	1.04	1.07	1.07	1.12	1.15
	BP	.24	.35	.42	.68	.68	.72	.73	.83	.85	.91	.93	.95	.99	1.01	1.05

Contralateral Stimulation Animals

Subject		Postlesion Recovery Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CS3	BS	.10	.57	.37	.21	.50	.76	.69	.90	.95	1.03	1.08	1.07	1.08	1.05	1.04
	BP	.10	.56	.36	.21	.49	.74	.68	.88	.92	1.01	1.05	1.04	1.06	1.03	1.02
CS4	BS	.10	.45	.78	.96	.93	1.04	1.06	1.11	1.16	1.14	1.15	1.19	1.21	1.21	1.23
	BP	.08	.39	.69	.89	.82	.93	.97	1.03	1.07	1.10	1.12	1.21	1.23	1.21	1.22
CS1	BS	.59	.75	.75	.79	.70	.68	.66	.63	.69	.73	.80	.83	.88	.87	.90
	BP	.47	.61	.60	.64	.56	.54	.52	.50	.56	.59	.66	.68	.76	.75	.80
CS9	BS	.12	.15	.28	.24	.22	.27	.70	.56	.83	.82	.94	.97	.93	.92	.93
	BP	.09	.17	.21	.20	.19	.23	.60	.46	.72	.70	.86	.82	.78	.81	.84
CS6	BS	.02	.12	.26	.57	.68	.74	.77	.90	.82	.86	.92	.87	.98	.92	.97
	BP	.02	.13	.26	.58	.71	.76	.81	.92	.83	.86	.93	.87	.98	.91	.97
CS11	BS	.23	.57	.55	.84	.84	.82	.87	.90	.89	.92	.94	.96	.92	1.01	.95
	BP	.12	.30	.28	.51	.50	.52	.55	.58	.52	.56	.70	.71	.69	.77	.72
CS10	BS	.24	.60	.72	.98	1.14	1.05	1.01	1.05	1.02	1.11	1.15	1.14	1.15	1.20	1.21
	BP	.25	.61	.74	1.00	1.23	1.14	1.07	1.08	1.03	1.16	1.18	1.14	1.14	1.19	1.25
CS15	BS	.05	.05	.10	.29	.23	.45	.38	.57	.53	.69	.63	.71	.73	.75	.81
	BP	.05	.05	.09	.28	.22	.43	.38	.53	.48	.68	.59	.65	.63	.66	.73

Contralateral Stimulation Animals (cont.)

Subject		Postlesion Recovery Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CS14	BS	.25	.53	.76	.78	.94	.99	.89	.95	.97	.96	.97	1.08	.98	1.12	1.07
	BP	.24	.47	.71	.68	.94	1.06	.78	.86	.85	.89	.85	.98	.89	.99	1.00
CS12	BS	.00	.08	.25	.32	.36	.41	.52	.50	.52	.58	.57	.77	.78	.72	.76
	BP	.00	.07	.20	.26	.31	.36	.44	.43	.44	.48	.50	.68	.71	.64	.71
CS17	BS	.01	.11	.20	.39	.33	.53	.48	.47	.46	.52	.52	.52	.56	.55	.57
	BP	.01	.10	.17	.31	.27	.45	.39	.38	.38	.43	.42	.42	.45	.46	.46
GROUP	BS	.16	.36	.46	.58	.63	.70	.73	.78	.80	.85	.88	.92	.93	.94	.95
	BP	.13	.32	.39	.51	.57	.65	.65	.70	.71	.77	.81	.84	.85	.86	.88

Stimulation Control Animals

Subject		Postlesion Recovery Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SC1	BS	.08	.03	.11	.62	.54	.53	.44	.57	.53	.50	.50	.59	.65	.59	.62
	BP	.07	.03	.10	.62	.50	.52	.45	.54	.49	.46	.47	.55	.61	.55	.60
SC5	BS	.39	.55	.50	.61	.63	.69	.80	.85	1.00	.96	1.01	1.03	1.06	1.02	1.08
	BP	.37	.52	.47	.57	.59	.65	.75	.80	.94	.90	.95	.97	1.07	.96	1.02
SC8	BS	.37	.59	.70	.88	.90	.94	.92	1.04	1.01	1.01	1.03	1.01	1.02	1.05	1.08
	BP	.33	.53	.63	.80	.84	.85	.87	.99	.97	.98	.99	.96	.98	1.04	1.06
SC9	BS	.21	.26	.35	.54	.62	.57	.58	.54	.63	.64	.67	.71	.67	.68	.74
	BP	.23	.28	.36	.59	.66	.60	.64	.56	.64	.62	.68	.76	.71	.74	.75
SC4	BS	.05	.18	.22	.28	.47	.45	.57	.54	.59	.70	.65	.71	.70	.70	.60
	BP	.06	.18	.21	.29	.50	.46	.60	.56	.61	.73	.66	.72	.72	.72	.61
SC10	BS	.13	.36	.38	.58	.60	.59	.61	.63	.71	.71	.72	.69	.80	.79	.81
	BP	.11	.30	.31	.46	.48	.49	.49	.52	.59	.59	.62	.58	.69	.72	.70
SC12	BS	.03	.03	.02	.02	.04	.10	.17	.17	.21	.28	.39	.49	.59	.65	.62
	BP	.02	.02	.02	.02	.03	.09	.15	.13	.17	.22	.31	.39	.50	.55	.54
SC13	BS	.59	.60	.57	.74	.92	.98	1.05	1.06	1.08	1.08	1.21	1.18	1.20	1.27	1.34
	BP	.56	.55	.54	.72	.86	.95	1.01	1.03	1.08	1.08	1.28	1.23	1.22	1.33	1.45

Stimulation Control Animals (cont.)

Subject		Postlesion Recovery Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SC17	BS	.07	.57	.52	.95	1.27	1.42	1.52	1.48	1.59	1.52	1.76	1.76	1.54	1.62	1.91
	BP	.07	.56	.50	.91	1.25	1.46	1.54	1.50	1.65	1.75	1.89	1.91	1.65	1.75	2.03
GROUP	BS	.21	.35	.37	.58	.67	.70	.74	.76	.82	.82	.88	.91	.91	.93	.98
	BP	.20	.33	.35	.55	.63	.67	.72	.74	.79	.81	.87	.90	.91	.93	.97

APPENDIX D

MEAN BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS ACROSS THE FIVE 3-DAY POSTLESION RECOVERY BLOCKS

Control Animals

Subject		Postlesion Recovery Blocks 1	2	3	4	5
C1	BS	48	140	230	268	319
	BP	49	145	259	293	366
C10	BS	147	251	403	415	476
	BP	172	313	490	526	654
C4	BS	176	342	446	507	521
	BP	184	364	496	569	585
C5	BS	48	87	158	310	265
	BP	70	121	231	515	401
C2	BS	283	355	481	597	658
	BP	290	374	499	612	669
C6	BS	22	78	201	299	469
	BP	25	84	220	320	505
C7	BS	300	300	439	475	462
	BP	336	333	505	549	529
C13	BS	175	483	551	627	617
	BP	211	592	671	776	791
C16	BS	388	564	657	661	757
	BP	420	608	697	723	862
C20	BS	136	250	385	467	442
	BP	159	337	518	641	572

Contralateral Lesion Animals

Subject		Postlesion Recovery Blocks 1	2	3	4	5
CL2	BS	327	570	621	741	790
	BP	339	601	664	789	871
CL8	BS	278	542	586	649	707
	BP	293	588	625	686	751
CL4	BS	48	418	647	724	775
	BP	49	440	762	866	979
CL7	BS	110	478	603	798	809
	BP	123	547	734	1054	1088
CL6	BS	275	592	631	673	648
	BP	323	742	735	751	725
CL13	BS	238	491	550	620	659
	BP	251	549	599	669	713
CL11	BS	315	497	535	532	611
	BP	432	723	758	845	1053
CL17	BS	45	218	294	369	430
	BP	56	274	412	496	559
CL19	BS	377	397	456	502	569
	BP	411	412	485	548	649

Contralateral Stimulation Animals

Subject		Postlesion Recovery Blocks 1	2	3	4	5
CS3	BS	214	301	519	648	649
	BP	215	302	520	650	651
CS4	BS	255	565	643	669	704
	BP	268	611	710	794	847
CS1	BS	494	510	467	555	624
	BP	505	521	475	578	691
CS9	BS	141	167	478	626	633
	BP	147	188	550	737	752
CS6	BS	75	373	465	497	537
	BP	78	393	491	511	551
CS11	BS	311	575	613	653	666
	BP	332	721	778	935	1032
CS10	BS	196	399	390	428	449
	BP	206	435	412	449	462
CS15	BS	32	162	248	340	383
	BP	38	193	290	399	421
CS14	BS	293	517	542	573	607
	BP	336	633	588	643	680
CS12	BS	59	225	318	397	467
	BP	72	251	349	446	555
CS17	BS	61	242	272	302	325
	BP	66	255	279	311	335

Stimulation Control Animals

Subject		Postlesion Recovery Blocks 1	2	3	4	5
SC1	BS	24	196	177	184	215
	BP	26	206	186	186	222
SC5	BS	285	384	528	597	627
	BP	288	386	529	599	648
SC8	BS	284	468	512	525	545
	BP	288	482	549	567	597
SC9	BS	148	311	315	363	376
	BP	178	383	380	426	453
SC4	BS	94	252	358	433	423
	BP	97	268	382	455	442
SC10	BS	185	378	415	452	512
	BP	190	389	429	477	564
SC12	BS	16	35	127	261	421
	BP	18	41	144	293	506
SC13	BS	269	403	485	528	581
	BP	287	440	543	624	696
SC17	BS	129	401	506	556	559
	BP	131	421	545	646	631

APPENDIX E

MEAN BRAIN SHOCKS AND BAR PRESSES FOR CONTROL AND EXPERIMENTAL ANIMALS ACROSS THE FIVE 3-DAY POSTLESION BLOCKS AS A PERCENTAGE OF PRELESION BASELINE LEVELS

Control Animals

Subject		Postlesion Recovery Blocks 1	2	3	4	5
C1	BS	.08	.24	.39	.45	.54
	BP	.07	.21	.37	.42	.53
C10	BS	.23	.40	.64	.66	.76
	BP	.19	.35	.54	.58	.73
C4	BS	.36	.70	.91	1.04	1.07
	BP	.33	.65	.89	1.02	1.05
C5	BS	.07	.14	.25	.48	.41
	BP	.06	.11	.21	.48	.37
C2	BS	.37	.47	.64	.79	.87
	BP	.30	.39	.52	.64	.70
C6	BS	.03	.11	.27	.41	.64
	BP	.02	.08	.20	.29	.46
C7	BS	.64	.64	.95	1.03	1.00
	BP	.54	.54	.82	.89	.86
C13	BS	.29	.81	.92	1.05	1.03
	BP	.25	.73	.83	.95	.97
C16	BS	.52	.77	.89	.90	1.03
	BP	.44	.65	.75	.77	.92
C20	BS	.27	.49	.76	.92	.87
	BP	.21	.44	.68	.84	.75
GROUP	BS	.29	.48	.66	.77	.82
	BP	.24	.42	.58	.69	.73

Contralateral Lesion Animals

Subject		Postlesion Recovery Blocks 1	2	3	4	5
CL2	BS	.54	.95	1.04	1.24	1.32
	BP	.51	.91	1.01	1.20	1.33
CL8	BS	.57	1.10	1.19	1.32	1.44
	BP	.45	.91	.96	1.06	1.16
CL4	BS	.06	.55	.85	.95	1.02
	BP	.05	.48	.84	.95	1.08
CL7	BS	.17	.75	.94	1.25	1.26
	BP	.11	.50	.68	.97	1.01
CL6	BS	.44	.95	1.01	1.08	1.04
	BP	.42	.97	.96	.98	.96
CL13	BS	.30	.63	.70	.79	.84
	BP	.26	.56	.60	.68	.72
CL11	BS	.55	.88	.95	.94	1.08
	BP	.40	.67	.71	.79	.98
CL17	BS	.09	.43	.57	.72	.84
	BP	.09	.43	.65	.78	.89
CL19	BS	.80	.85	.97	1.07	1.21
	BP	.67	.68	.80	.90	1.06
GROUP	BS	.39	.79	.91	1.04	1.12
	BP	.33	.68	.80	.92	1.02

Contralateral Stimulation Animals

Subject		Postlesion Recovery Blocks 1	2	3	4	5
CS3	BS	.35	.49	.85	1.06	1.06
	BP	.34	.48	.83	1.03	1.03
CS4	BS	.44	.98	1.11	1.15	1.22
	BP	.38	.88	1.04	1.14	1.22
CS1	BS	.69	.72	.66	.79	.88
	BP	.56	.58	.53	.64	.77
CS9	BS	.21	.24	.70	.91	.92
	BP	.16	.20	.59	.79	.81
CS6	BS	.13	.66	.83	.88	.95
	BP	.13	.68	.85	.89	.95
CS11	BS	.45	.83	.89	.94	.96
	BP	.23	.51	.55	.66	.73
CS10	BS	.52	1.05	1.03	1.13	1.19
	BP	.53	1.12	1.06	1.16	1.19
CS15	BS	.06	.32	.49	.68	.76
	BP	.06	.31	.46	.64	.67
CS14	BS	.51	.90	.95	1.00	1.06
	BP	.47	.89	.83	.91	.96
CS12	BS	.09	.36	.51	.64	.75
	BP	.09	.31	.43	.55	.69
CS17	BS	.11	.42	.47	.52	.56
	BP	.09	.35	.38	.43	.46
GROUP	BS	.32	.63	.77	.88	.93
	BP	.28	.57	.69	.80	.86

Stimulation Control Animals

Subject		Postlesion Recovery Blocks 1	2	3	4	5
SC1	BS	.07	.57	.51	.53	.62
	BP	.07	.54	.49	.49	.59
SC5	BS	.48	.64	.88	1.00	1.05
	BP	.45	.60	.83	.94	1.01
SC8	BS	.55	.90	.99	1.01	1.05
	BP	.50	.83	.95	.98	1.03
SC9	BS	.27	.58	.58	.67	.70
	BP	.29	.62	.61	.69	.73
SC4	BS	.15	.40	.57	.69	.67
	BP	.15	.41	.59	.70	.68
SC10	BS	.29	.59	.65	.71	.80
	BP	.24	.49	.54	.60	.70
SC12	BS	.02	.05	.19	.38	.62
	BP	.02	.04	.15	.31	.53
SC13	BS	.60	.88	1.06	1.15	1.27
	BP	.55	.84	1.04	1.20	1.33
SC17	BS	.39	1.21	1.53	1.68	1.69
	BP	.38	1.21	1.56	1.85	1.81
GROUP	BS	.31	.65	.77	.87	.94
	BP	.29	.62	.75	.86	.93

REFERENCES

Adametz, J. H. Rate of recovery of functioning in cats with rostral reticular lesions. Journal of Neurosurgery, 1959, 16, 85-97.

Ades, H. W. & Raab, D. H. Recovery of motor function after two-stage extirpation of area 4 in monkeys. Journal of Neurophysiology, 1946, 9, 55-60.

Akert, K. & Walker, W. I. Problems and methods of anatomical localization. In D. E. Sheer (Ed.), Electrical stimulation of the brain. Texas: University of Texas Press, 1966.

Amassian, V. E. & Patton, H. D. Microelectrode analysis of stimulation effects on a complex synaptic network. In D. E. Sheer (Ed.), Electrical stimulation of the brain. Texas: University of Texas Press, 1966.

Baden, J. P., Urbaitis, J. C., & Meikle, T. H. Effects of serial bilateral neocortical ablations on a visual discrimination by cats. Experimental Neurology, 1965, 13, 233-251.

Balagura, S., Harrell, L., & Ralph, T. Glucodynamic hormones modify the recovery period after lateral hypothalamic lesions. Science, 1973, 182, 59-60.

Barbas, H. & Spear, P. Effects of serial unilateral and serial bilateral visual cortex lesions on brightness discrimination relearning in rats. Journal of Comparative and Physiological Psychology, 1976, 90(3), 279-292.

Bard, P. Studies on the cortical representation of somatic sensibility. Harvey Lectures, 1938, 33, 143-169.

Berger, B. D., Wise, C. D., & Stein, L. Nerve growth factor: enhanced recovery of feeding after hypothalamic damage. Science, 1973, 180, 506-508.

Bjerre, B., Bjorklund, A., & Stenevi, U. Stimulation of growth of new axonal sprouts from lesioned monoamine neurones in adult rat brain by nerve growth factor. Brain Research, 1975, 60, 161-176.

Bjorklund, A. & Stenevi, U. Nerve growth factor: stimulation of regenerative growth of central noradrenergic neurons. Science, 1972, 175, 1251-1253.

Blatt, B. & Lyon, M. The relationship of forebrain and midbrain structures involved in feeding behavior. Acta. Neurologica Scandinavica, 1968, 44, 576-595.

Bogen, J. E. & Campbell, B. Recovery of foreleg placing after ipsilateral frontal lobectomy in the hemicerebrectomized cat. Science, 1962, 135, 309-310.

Box, G. E. P. Some theorems on quadratic forms applied in the study of analysis of variance problems. The Annals of Mathematical Statistics, 1954, 25, 290-302, 484-498.

Butters, N., Rosen, J., & Stein, D. Recovery of behavioral functions after sequential ablation of the frontal lobes of monkeys. In D. G. Stein, J. J. Rosen, & N. Butters (Eds.), Plasticity and recovery of function in the central nervous system. New York: Academic Press Inc., 1973.

Braun, J. J. The neocortex and visual placing in rats. Brain Research, 1966, 1, 381-394.

Cole, D. D., Sullins, W. R., & Isaac, W. Pharmacological modification of the effects of spaced occipital ablations. Psychopharmacologica, 1967, 11, 311-316.

Dawson, R. G. Recovery of function: implications for theories of brain functions. Behavioral Biology, 1973, 8, 439-460.

Dawson, R. G., Conrad, L., & Lynch, G. Single and two-stage hippocampal lesions: a similar syndrome. Experimental Neurology, 1973, 40, 263-277.

DeGroot, J. The rat forebrain in stereotaxic coordinates. Verhandelingen der koninklijke Nederlandse Akademie van Wetenschappen, Afd., Natuurkunder. N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam, 1959.

Doty, R. W. Electrical stimulation of the brain in behavioral context. Annual Review of Psychology, 1969, 20, 289-320.

Dru, D. & Walker, J. B. Central nervous system recovery of function: serial lesion effects. In A. H. Riesen & R. F. Thompson (Eds.), Advances in psychobiology. New York: John Wiley & Sons, 1976.

Eidelberg, E. & Stein, D. G. Functional recovery after lesions of the nervous system. Neurosciences Research Progress Bulletin, 1973, 12, 275-277.

Ervin, F. & Kenney, G. J. Electrical stimulation of the brain. In R. D. Myers (Ed.), Methods in psychobiology. New York: Academic Press, 1971.

Finger, S., Marshak, R. A., Cohen, M., Scheff, S., Trace, R. & Niemand, D. Effects of successive and simultaneous lesions of somatosensory cortex on tactile discrimination in the rat. Journal of Comparative and Physiological Psychology, 1971, 77, 221-227.

Finger, S., Walbran, B., & Stein, D. G. Brain damage and behavioral recovery: serial lesion phenomena. Brain Research, 1973, 63, 1-18.

Glees, P., & Cole, J. Recovery of skilled motor functions after small repeated lesions of motor cortex in macaque. Journal of Neurophysiology, 1950, 13, 137-148.

Glick, S. D. Changes in drug sensitivity and mechanisms of functional recovery following brain damage. In D. G. Stein, J. J. Rosen, and N. Butters (Eds.), Plasticity and recovery of function in the central nervous system. New York: Academic Press Inc., 1973.

Glick, S. D. & Greenstein, S. Facilitation of recovery after lateral hypothalamic damage by prior ablation of frontal cortex. Nature New Biology, 1972, 239, 187-188.

Glick, S. D., Greenstein, S., & Zimmerberg, B. Facilitation of recovery by ∝-methyl-p-tyrosine after lateral hypothalamic damage. Science, 1972, 177, 534-535.

Glick, S. D. & Greenstein, S. Recovery of weight regulation following ablation of frontal cortex in rats. Physiology and Behavior, 1973, 10, 491-496.

Glick, S. D., Nakamura, R. K. & Jarvik, M. E. Recovery of function following frontal brain damage in mice: changes in sensitivity to amphetamine. Journal of Comparative and Physiological Psychology, 1971, 76, 454-459.

Glick, S. D. & Zimmerberg, B. Comparative recovery following simultaneous and successive-stage frontal brain damage in mice. Journal of Comparative and Physiological Psychology, 1972, 79, 481-487.

Goldberger, M. E. Recovery of movement after central nervous system lesions in monkeys. In D. G. Stein, J. J. Rosen, & N. Butters (Eds.), Plasticity and recovery of function in the central nervous system. New York: Academic Press Inc., 1973.

Goldberger, M. E. The extrapyramidal systems of the spinal cord: II. results of combined pyramidal and extrapyramidal lesions in the macaque. Journal of Comparative Neurology, 1969, 135, 1.

Goldman, P. S. An alternative to developmental plasticity: heterology of CNS structures in infants and adults. In D. G. Stein, J. J. Rosen, and N. Butters (Eds.), Plasticity and recovery of function in the central nervous system. New York: Academic Press Inc. 1974.

Greene, E., Stauff, C., & Walters, J. Recovery of function with two-stage lesions of the fornix. Experimental Neurology, 1972, 37, 14-22.

Grossman, S. P. A textbook of physiological psychology. New York: John Wiley & Sons Inc., 1967.

Harrell, L. E., Raubeson, R., & Balagura, S. Acceleration of functional recovery following lateral hypothalamic damage by means of electrical stimulation in the lesioned areas. Physiology and Behavior, 1974, 12, 897-899.

Hays, W. L. Statistics. New York: Holt, Rinehart and Winston, 1963.

Heath, R. G. Modulation of emotion with a brain pacemaker. The Journal of Nervous and Mental Disease, 1977, 165, 300-317.

Huang, Y. H. & Routtenberg, A. Lateral hypothalamic self-stimulation pathways in rattus norvegicus. Physiology and Behavior, 1971, 7, 419-432.

Isaac, W. Role of stimulation and time in the effects of spaced occipital ablations. Psychological Reports, 1964, 14, 151-154.

Isaacson, R. L. & Schmaltz, L. W. Failure to find savings from spaced two-stage destruction of hippocampus. Communications in Behavioral Biology, Part A, 1968, 1, 353-359.

Kennard, M. A. Cortical reorganization of motor function. Archives of Neurology and Psychiatry, 1942, 48, 227-240.

Keppel, G. Design and analysis: a researcher's handbook. New Jersey: Prentice-Hall Inc., 1973.

Lashley, K. S. Factors limiting recovery after central nervous lesions. Journal of Nervous and Mental Disease, 1938, 88, 733-755.

LeVere, T. E. Neural stability, sparing and behavioral recovery following brain damage. Psychological Review, 1975, 82, 344-358.

LeVere, T. E. Recovery of function after brainstem lesions in the rat. Journal of Comparative and Physiological Psychology, 1969, 69, 339-344.

LeVere, T. E. & Weiss, J. Failure of seriatim dorsal hippocampal lesions to spare spatial reversal behavior in rats. Journal of Comparative and Physiological Psychology, 1973, 82, 205-210.

Lilly, J. C. Injury and excitation by electric currents. In D. E. Sheer (Ed.), Electrical stimulation of the brain. Texas: University of Texas Press, 1966.

Luria, A. R., Naydin, V. L., Tsvetkova, L. S. & Vinarskaya, E. N. Restoration of higher cortical function following local brain damage. In R. J. Vinken & G. W. Bruyn (Eds.), Handbook of Clinical Neurology, 1969, 3, 368-433.

McIntyre, M. & Stein, D. G. Differential effects of one- versus two-stage amygdaloid lesions on activity, exploratory, and avoidance behavor in the albino rat. Behavioral Biology, 1973, 9, 451-465.

Meyer, P. M. Recovery from neocortical damage. In G. M. French (Ed.), Cortical functioning in behavior, 1973.

Meyer, D. R., Isaac, W., & Maher, B. The role of stimulation in spontaneous reorganization of visual habits. Journal of Comparative and Physiological Psychology, 1958, 51, 546-548.

Olds, J. & Milner, P. Positive reinforcement by electrical stimulation of septal area and other regions of rat brain. Journal of Comparative and Physiological Psychology, 1954, 47, 419-427.

Olds, M. E. & Olds, J. Effects of lesions in medial forebrain bundle on self-stimulation behavior. American Journal of Physiology, 1969, 217, 1253-1264.

Olds, J., Travis, R. P. & Schwing, R. C. Topographic organization of hypothalamic self-stimulation functions. Journal of Comparative and Physiological Psychology, 1960, 53, 23-32.

Petrinovich, L. & Bliss, D. Retention of a learned brightness discrimination following ablations of the occipital cortex in the rat. Journal of Comparative and Physiological Psychology, 1966, 61, 136-138.

Petrinovich, L. & Carew, T. J. Interaction of neocortical lesion size and interoperative experience in retention of a learned brightness discrimination. Journal of Comparative and Physiological Psychology, 1969, 68, 451-454.

Phillips, M. I. Self-stimulation as a model of recovery of function in the brain. In A. Wauquier and E. T. Rolls (Eds.), Brain-stimulation reward. Amsterdam: North Holland Publishing Co., 1976.

Patrissi, G. A. & Stein, D. G. Time factors in recovery of function following frontal lobe lesions in the rat. Paper presented at First Annual meeting of Society for Neuroscience, Washington, D. C. October. Cited in Stein, D. G. Some variables influencing recovery of function after central nervous system lesions in the rat. In D. G. Stein, J. J. Rosen, & N. Butters (Eds.), Plasticity and recovery of function in the central nervous system. New York: Academic Press Inc., 1973.

Raisman, G. Neuronal plasticity in the septal nuclei of the adult rat. Brain Research, 1969, 14, 25-48.

Reyes, R., Finger, S., & Frye, J. Serial thalamic lesions and tactile discrimination in the rat. Behavioral Biology, 1973, 8, 807-813.

Rolls, E. T. The brain and reward. Oxford: Permagon Press, 1975.

Rosner, B. S. Brain functions. Annual Review of Psychology, 1970, 21, 555-594.

Rosen, J., Stein, D. G. & Butters, N. Recovery of function after serial ablation of prefrontal cortex in the rhesus monkey. Science, 1971, 173, 353-355.

Scheff, S., Benardo, L. & Cotman, C. Progressive brain damage accelerates axon sprouting in the adult rat. Science, 1977, 197, 795-797.

Schultze, M. J. & Stein, D. G. Recovery of function in the albino rat following either simultaneous or seriatim lesions of the caudate nucleus. Experimental Neurology, 1975, 46, 291-301.

Semmes, J. & Chow, K. L. Motor effects of lesions of precentral gyrus and of lesions sparing this area in monkey. Archives of Neurology and Psychiatry, 1955, 73, 546-556.

Skinner, J. E. Neuroscience: a laboratory manual. Philidelphia: W. B. Saunders Co., 1971.

Sommers, P. V. & Teitelbaum, P. Spread of damage produced by electrolytic lesions in the hypothalamus. Journal of Comparative and Physiological Psychology, 1974, 86, 288-299.

Sprague, J. M. Interaction of cortex and superior colliculus in mediation of visually guided behavior in the cat. Science, 1966, 153, 1544-1547.

Stein, D. G. Sequential versus single lesions and some other variables contributing to recovery of function in the rat. Neuroscience Research Progress Bulletin, 1973, 12, 260-269.

Stein, D. G. Some variables influencing recovery of function after central nervous system lesions in the rat. In D. G. Stein, J. J. Rosen, & N. Butters (Eds.), Plasticity and recovery of function in the central nervous system. New York: Academic Press Inc., 1973.

Stein, D. G., Rosen, J. J., Graziade, J., Mishkin, D., & Brink, J. J. Central nervous system: recovery of function. Science, 1969, 166, 528-529.

Stein, D. G. The effects of simultaneous or successive lesions of the lateral hypothalamic area on body weight regulation. Cited in Stein, D. G. Some variables influencing recovery of function after central nervous system lesions in the rat. In D. G. Stein, J. J. Rosen, & N. Butters (Eds.), Plasticity and recovery of function in the central nervous system. New York: Academic Press Inc., 1973.

Stewart, J. W. & Ades, H. W. The time factor in reintegration of a learned habit lost after temporal lobe lesions in the monkey. Journal of Comparative and Physiological Psychology, 1951, 44, 479-486.

Steward, O., Cotman, C. W., & Lynch, G. S. Reestablishment of electrophysiologically functional entorhinal cortical input to the dentate gyrus deafferented by ipsilateral entorhinal lesions: innervation by the contralateral entorhinal cortex. Experimental Brain Research, 1973, 18, 396-414.

Steward, O., Cotman, C. W., & Lynch, G. S. Growth of a new fiber projection in the brain of adult rats: re-innervation of the dentate gyrus by the contralateral entorhinal cortex following ipsilateral entorhinal lesions. Experimental Brain Research, 1974, 20, 45-66.

Tanaka, D. Sparing of an escape response following serial prefrontal decortication in the monkey. Brain Research, 1974, 65, 195-201.

Teitelbaum, B. Sequential versus single lesions and some other variables contributing to recovery of function in the rat. In Functional recovery following damage to the nervous system. Neurosciences Research Progress Bulletin, 1973, 12, 260-269.

Teuber, H. L. Recovery of function after lesions of the central nervous system: history and prospects. Neurosciences Research Progress Bulletin, 1973, 12, 197-209.

Thode, W. E. & Carlisle, H. J. Effect of lateral hypothalamic stimulation on amphetamine induced anorexia. Journal of Comparative and Physiological Psychology, 1968, 66, 547-548.

Thompson, R. Retention of a brightness discrimination following neocortical damage in the rat. Journal of Comparative and Physiological Psychology, 1960, 53, 212-215.

Treichler, F. R. Two-stage frontal lesion influences upon severity of delayed-response deficit. Behavioral Biology, 1975, 13, 35-47.

Valenstein, E. S. & Campbell, J. F. Medial forebrain bundle-lateral hypothalamic area and reinforcing brain stimulation. American Journal of Physiology, 1966, 210, 270-274.

Winans, S. S. & Powers, J. B. Neonatal and two-stage olfactory bulbectomy: effects on male hamster sexual behavior. Behavioral Biology, 1974, 10, 461-471.

Ward, A. A. & Kennard, M. A. Effect of cholinergic drugs on recovery of function following lesions of the central nervous system in monkeys. Yale Journal of Biology and Medicine, 1942, 15, 189-228.

Winer, B. J. Statistical principles in experimental design. New York: McGraw-Hill, 1971.

Zornetzer, S. F., Chronister, R. B., & Ross, B. The hippocampus and retrograde amnesia: localization of some positive and negative memory disruptive sites. Behavioral Biology, 1973, 8, 507-518.

VITA AUCTORIS

Jerel Eugene Del Dotto

1950 - Born in Minneapolis, Minnesota, U.S.A..

1968 - Graduated from Edina High School, Edina, Minnesota.

1975 - Granted degree of Bachelor of Arts (Magna Cum Laude) with Honours in Psychology from Augsburg College, Minneapolis, Minnesota.

1975 - Registered as a full-time graduate student in Psychology at the University of Windsor, Windsor, Ontario, Canada.