UNIVERSITY OF MANITOBA

The Effects of
Caudate Nucleus and Dentate-Interposed Nuclei Lesions
On
Temporal and Delay Conditioning
In
Rats

By
Ying Cheng

A Thesis
Submitted To The Faculty of Graduate Studies
In Partial Fulfillment of The Requirements for The Degree
of Doctor of Philosophy

Department of Psychology

Winnipeg, Manitoba

February 1979

THE EFFECTS OF
CAUDATE NUCLEUS AND DENTATO-INTERPOSED NUCLEI LESIONS
ON
TEMPORAL AND DELAY CONDITIONING
IN RATS

BY

YING CHENG

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

To Dr. Terrence P. Hogan, whose dedication to education helped shape the course of my pursuit for knowledge.

To my family, whose persistent support and sacrificial love through the years made possible the completion of this work.

ACKNOWLEDGEMENT

The author wishes to express her deep appreciation to members on the committee: to Dr. T.P. Hogan, who so willingly took up the chair manship during the most difficult phase of her endeavour and made it possible for her to finish the task ; to Dr. K.R. Hughes, who, amidst his heavy and demanding responsibilities as the Provost of the University, gave all his moral and actual support to the completion of the task; and to Dr. R.W. Tait, who spent many dreary hours plowing through the manuscript and whose perfectionistic approach to scientific research helped to sharpen up many critical concepts.

Her gratitude goes to Dr. M. F. Halasz, the External Examiner and a genius in his own right. It was through him that she learned all the basics and the essentials in experimental research, eg. how to handle a rat, how to design and construct electronic equipments, how to study behaviour within the context of control theory model, etc..

Her deepest gratitude goes to Miss Yuen Cheng, a computor genius, a wizard with mathematics and a confirmed altruist. Her hard labour and many a sleepless night resulted in the production of figures, graphs and pages of the manuscript via the TSO and Text 360 of the computor.

Her thanks also goes to Mrs. B. Lough who helped in so many ways big and small through the years; to Dr.

J. MacIntyre, Dr. V. Havlichuk, Dr. J. Pear, Dr. C. Boast, Mr. W. Mostoway and Mrs. D. Orhial who contributed in various ways during the course of the research.

Last but not least, her thanks goes to Dr. R. de von Flindt whose insistance on the personal worth of a researcher added a dimension of value to the otherwise indifferent world of science.

TABLE OF CONTENTS

ABSTRACT

Using the concept in control theory, conditioned behaviour in general and the delayed conditioned approach behaviour in particular are viewed as optimally controlled processes. As such learned habits are subject to quantitative analysis as continuous processes in the time domain. The characteristics of a behavioural system are described by its relative error to a baseline level, its phase velocity and the phase plane diagrams. It enables the analysis of behaviour as on-going active processes, rather than as discrete correlational entities.

The delayed conditioned approach paradigm is essentially a servomechanism-like paradigm. It can readily be studied in the context of control theory analysis. It was used to study the role of the frontal striatal system and the cerebellar control system in temporal and delay conditioning.

64male adult Albino rats were trained in the delayed conditioned approach behaviour and then divided into 9 groups. Four experimental groups received bilateral electrolytic lesions either to the frontal pole, the head of the caudate nucleus, the posterior caudate nucleus or and the dentato-interposed nuclei respectively. There were a corresponding 4 sham lesioned groups and 1 normal control group.

Results showed that bilateral electrolytic lesions in the head and the posterior aspect of the caudate nucleus produced temporary impairment in the initiation

of conditioned approach paradigm. Subsequently,tthe head of caudate nucleus lesioned group evolved into a hard limit cycle, no longer sensitive to changes in reinforcement contingencies. In contrast the posterior caudate nucleus lesioned group showed functionary recovery from an initial impairment on the DCA. The group with frontal pole lesions showed temporary shift toward shorter response latencies, suggesting the posibility of hyper-reactivity to CS presentations. Lesions in the dentato-interposed nucleus produced permanently ataxic Ss, but their performance on the conditioned approach paradigm was essentially the same as those of the normal control Ss.

The results were discussed with references to the concept of act inhibition, the initiation and control of conditioned behaviour and of possible motivational variables.

Chapter 1

Review of Literature

Traditionally, the relationship between brain structures and behaviour relies mainly on techniques which assume that behavioural systems are discrete, static entities. Inter actions between the central nervous system (CNS) and behaviour are described in correlational terms.

Alternatively, the application of control theory and techniques allows behavioural systems to be studied as servomechanism-like systems which are in the continnual process of establishing active stability and equilibrium.

while correlational data yield abundant information on the modes of CNS function and behaviour , they do not provide adequate information where behaviours are essentially viewed as on-going, active processes. The study of timing function,ie. temporal discrimination and delay conditioning (eg. Skinner, 1938, 1946; Wilson and Keller, 1953; Laties, Weiss, Clark and Reynolds, 1965; Reynolds , 1966) is one of the topics in point.

Review of recent literature suggests the existence of two major hypotheses concerning the neurophysiological substrates underlying delay response and temporal discrimination. One hypothesis states that 'timimg' is a function of the cortical inhibitory processes (hypothesis I), while the other postulates that 'timimg' is a function of the cerebellar postural mechanisms (hypothesis II).

The present study attempts to study the relative role of the two proposed neural mechanisms. Using the control theory approach anaylsis, it attempts to evaluate the characteristics of the cortical and cerebellar neuronal systems as active, on-going processes in their adjustments to various levels of demand in ' timing ' of behaviour.

Historical Background

Literature supporting hypothesis I : delayed respon and temporal discrimination as a function of cortical inhibitory processes.

The 1936 paper published by Jacobsen precipitated the search for the neurological mechanisms for prefrontal lobe-lesion-induced impairment on delayed response tasks. After bilateral prefrontal lobectomies, his monkeys showed a severe and permanent impairment on Hunter's delayed response test in the Wisconsin General Test Apparatus(WGTA), delayed alternation, go-no-go tests, sensory discrimination, discrimination reversal, and to a lesser extent, avoidance training. The majority of results favors the concept of the "frontal lobe system" proposed by Rosvold and Szwarcbart (1964) which included the dorsolateral prefrontal cortex, the anteriodorsal aspect of the head of the caudate nucleus, the subthalamus (and possibly the hippocampus) as components of the cortical inhibitory system responsible for delayed response performance (Battig ,Rosvold and Mishkin, 1962;Divac,1968(a),(b); Divac ,Rosvold and Szwarcbart, 1967; Fox,Kimble & Lickey,1964; Gross,1963(a), hompsom,(d); Gross et al,1962,1964; Hansing Schwartzbaum and Thompson,1968; Konorski ,1959,1961,1964,1967; Mishkin ,Prockop and Rosvold ,1962; Pribrim,1955; Rosvolt & Szwarcbart,1962,1964; Stamm,1968,1969,1970; Stamm and Rosen, 1969; elc). It should be noted, however, that Hunter's "delayed response" involves restraint of S by the experimenter as well as self-restraint. It thus is somewhat different from Pavlovian DR.

Anatomical evidence

Anatomical studies have shown the existence of neuronal pathways among these cortical and subcortical structures. In the young and adult albino rats, Webster (1961) performed localized cortical ablations via suction or thermocoagulation and subsequently traced the pattern of retrograde degeneration traced, using the Golgi rapid method, Marchi's method and the Nauta method. Webster showed that all rats with cortical ablations exhibited striatal degeneration. "Changes in the position of the lesion produce changes in the locations of the region of the striatum found to contain degeneration. The striatal degeneration is more widespread dorsally than nearer the pallidum". There were no axonal termination in the pallidum. In addition,the striatal degeneration was considered terminal because the Nauta & Gygax (1954) method showed complex nests of degenerating axons around striatal cells. Some of the cortico-striate fibers were collaterals of axons in the internal capsule. Most importantly, Webster described that the cortico-striate projection is topographically well organized in both anterior posterior and mediolateral planes, and is derived from widespread areas of the cortex, probably including the auditory and visual areas. With cats Webster (1965) identified a similar arrangement with the exception that the rat the striatum is not divided into caudate nucleus and putamen, while the cat striatum is. In both studies the author failed to observe striate-cortical projections. Similar results were found in monkeys by Nauta(1964), and Burandt (1961). Kamp and Powell(1970) studied the cortico-striate connections in adult macaque monkeys. Using Nauta technique, they found that: (1) all parts of the cortex send fibers to the striatum in topographically well organized fashion. In the frontal lobe the cortex of the medial surface projects dorsally in the striatum, that of the lateral surface laterally and the orbital surface medially. (2) Posteriorly the arrangement is modified in relation to the development of the temporal lobe. (3) Projections from the somatosensory and motor area is large while that from the visual area is the smallest. (4) The sensorimotor and frontal association cortex are related to the caudate nucleus (and, in particular, to the large part of the head and the parietotemporal lobe to the body and tail of the nucleus. Kemp specifically pointed out that "there is topographic projections but multiple innervation from different cortical areas upon one striatal region". Kemp et al's (1970;1968) studies are in agreement with those by Carman et al (1965), Nauta (1964) and Divic et al (1967).

Indirectly, Mettler, Hovde and Grundfest (1952), and Harman (1954) found a decrease in the volume of the caudate nucleus in monkeys after extirpation of the premotor and orbital cortex. But Ermolenko(1969) was the first to report direct striato-cortical projections. Using cats as subjects, Ermolenko performed electro-coagulation of the rostral part of the head of the right caudate nucleus. The brains were fixed in 10% formaline and sectioned ten days later with Nissl's method. He found that there is direct projection from the rostral part of the head of the caudate nucleus to the prefrontal orbital, anterior limbic 32 and secondary somatosensory cortical areas. Preterminal degeneration of axons from the head of the caudate nucleus was found in the ipsilateral cortical area 6. Destruction of the rostro-central part of the head produced degeneration in the anterior part of sigmoid gyrus. Destruction of the rostro-medio-ventral part of the head produced degeneration in the anterior part of area 4. Projection of the dorso-medial and central areas of the rostral part of the head of the caudate on the frontal cortex partially