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Review

Some highlights of research on the effects of caudate nucleus lesions over the past 200 years

Norman M. White*

Department of Psychology, McGill University, 1205 Dr Penfield Avenue, Montreal, QC H3A 1B1, Canada

A R T I C L E I N F O

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A B S T R A C T

This review describes experiments on the effects of caudate nucleus lesions on behavior in monkeys, cats and rats. Early work on monkeys and cats focused on the relationship of the caudate to the cortex in motor control, leading to the idea that the caudate serves to inhibit behaviors initiated by the cortex. However, investigation of this hypothesis with systematic behavioral testing in all three species did not support this idea; rather, these studies provided evidence that caudate lesions affect memory functions. Two main types of memory tasks were affected. One type involved reinforced stimulus–response (S–R) associations, the other involved spatial information, response–reinforcer contingencies, or working memory. Recent evidence, mainly from rats, suggests that the dorsolateral part of the caudoputamen is central to the processing and consolidation of memory for reinforced S–R associations, and that the more medial and anterior parts of the same structure are part of a neural circuit that (in some cases) also includes the hippocampus, and mediates relational information and certain forms of working memory. The possibility that the spatial distribution of the patch and matrix compartments within the caudoputamen underlies these regional differences is discussed.

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* Tel.: +1 514 398 6082; fax: +1 514 398 4896.
E-mail address: norman.white@mcgill.ca.

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1. Introduction

The first person to make a lesion of the caudate nucleus may have been Lopoldo Caldini. In 1786 Caldini reported on his experiments using a probe with red dye on the tip to manipulate the brains of dogs, lambs and goats. Some of these manipulations resulted in seizures followed by deficits in voluntary movement. These behavioral effects were later correlated with the presence of red dye in the corpus striatum (or, caudate nucleus). Unilateral manipulations resulted in contralateral hemiplegia and an arched posture turned towards the side of the lesion. Caldini concluded that the corpus striatum was involved in voluntary movement ([1], p. 216).

Stereotaxic techniques were first used to guide stimulation and lesions of the caudate nucleus in monkeys by Wilson [2]. Observing few effects, he concluded that the structure had little motor function and was largely unexcitable. He argued that it had a “steadying effect” on motor performance when its output combined with that of the motor cortex, but that the latter structure was the true source of voluntary motor movements. Kennard [3] replicated these findings for small lesions, but found that large lesions of the striatum resulted in tremors during voluntary movement. She also found that combined damage to area 6 of the cortex and to the striatum produced severe tremor during complex voluntary movement. Kennard concluded that the striatum exerted control of motor function by exercising an inhibitory effect on the output of the motor cortex.

This idea was furthered by studies in which cocaine, a local anesthetic, was applied to the nucleus. Unilateral inactivation of the caudate produced by cocainization produced circus (turning) movements towards the side of the inactivation. Combined cocainization of the caudate and the vestibular organ exacerbated this symptom. These experiments, by Delmas-Marsalet and by Bergouignan and Verger are described in a well-known paper by Mettler [4] who reported that caudate lesions produced a “leaping or forward movement”, which he argued was a specific symptom of “motor release”, originating the oft-repeated notion that it is a “classic inhibitory structure”. According to Mettler, the turning movements produced by unilateral lesions are due to unilateral motor release, “one-half of the pattern of cursive hyperkinesia”. With bilateral lesions, Mettler described “obstinate progression”, a strong tendency for the animal to move forward and to resist attempts to impede this movement. Mettler also wrote that “It is difficult to escape the suspicion that animals with striatal injuries suffer from some variety of vestibular disturbance” ([4], p. 252).

Study of the relationship between the caudate and the cortex, and a debate about which structure is important for controlling motor function was the main theme of research on the caudate nucleus during the first half of the 20th century. Attention was focused on the relationship of the caudate and the frontal cortex by the discovery of direct connections between them [5,6]. Studies of more “cognitive” functions of the caudate mainly began after the middle of the century, and some of these are considered in the next section.

1.1. A note on nomenclature

In primates and ungulates the caudate nucleus is usually divided into at least two separate parts, the head (or dorsal anterior part) and the tail (the ventral posterior part). Some workers also distinguish between two anterior parts, the head and the body. The caudate nucleus as a whole is considered to be closely related to the putamen, which is separated from the head of the caudate by the internal capsule. The two structures together were and often still are referred to as the corpus striatum or, to distinguish them from other striated structures, the neostriatum.

Another term, basal ganglia, refers to the neostriatum, together with certain other structures, variously including lenticular nucleus, subthalamic nucleus, globus pallidus, substantia nigra, nucleus accumbens (or ventral striatum) and amygdala. However, sometimes the term basal ganglia is used to refer to the caudate and putamen exclusively.

In rats it is possible to distinguish between the head (anterior) and tail (posterior) parts of the neostriatum, but the internal capsule does not exist (the descending motor fibers course through the