Contribution of subcortical structures to cognition assessed with invasive electrophysiology in humans

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Implantation of deep brain stimulation (DBS) electrodes via stereotactic neurosurgery has become a standard procedure for the treatment of Parkinson’s disease. More recently, the range of neuropsychiatric conditions and the possible target structures suitable for DBS have greatly increased. The former include obsessive compulsive disease, depression, obesity, tremor, dystonia, Tourette’s syndrome and cluster-headache. In this article we argue that several of the target structures for DBS (nucleus accumbens, posterior inferior hypothalamus, nucleus subthalamicus, nuclei in the thalamus, globus pallidus internus, nucleus pedunculopontinus) are located at strategic positions within brain circuits related to motivational behaviors, learning, and motor regulation. Recording from DBS electrodes either during the operation or post-operatively from externalized leads while the patient is performing cognitive tasks tapping the functions of the respective circuits provides a new window on the brain mechanisms underlying these functions. This is exemplified by a study of a patient suffering from obsessive-compulsive disease from whom we recorded in a flanker task designed to assess action monitoring processes while he received a DBS electrode in the right nucleus accumbens. Clear error-related modulations were obtained from the target structure, demonstrating a role of the nucleus accumbens in action monitoring. Based on recent conceptualizations of several different functional loops and on neuroimaging results we suggest further lines of research using this new window on brain functions.

Keywords: deep brain stimulation, action monitoring, motivation, subcortical nuclei, memory, nucleus accumbens, nucleus subthalamicus, electrophysiology

INTRODUCTION

The first two decades of cognitive neuroscience have been a success story that is intimately linked to the development of sophisticated models of cognitive functions but no less so to the improvements in brain imaging procedures. Functional magnetic resonance imaging (fMRI) and surface electrophysiology (event-related potentials and time-frequency analyzed EEG) have provided a detailed picture of the brain mechanisms underlying cognition. On the other hand, there are still a number of remaining scotomata in our view on the brain, for example the relative blindness of EEG-derived measures to activity coming from subcortical structures and the low temporal resolution of fMRI limiting its use for chronometric analyses.

Recently, the implantation of electrodes for deep brain stimulation (DBS) of subcortical nuclei as a