Human Subthalamic Nucleus Neuronal Code for Action Switches and Movement Kinematics

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Introduction:

The subthalamic nucleus (STN) is theorized to globally suppress movement through connections with downstream basal ganglia structures. Current theories are supported by increased activity in STN neurons and increased beta oscillatory power when subjects withhold an uninitiated action plan. Modulation of the movement suppressive effects of STN is a potential mechanism of DBS therapy for Parkinson's disease. However, patients with Parkinson's disease have difficulty not only initiating movements, but also changing ongoing movements. We sought to determine the role of the STN in switching from one movement to another in patients with Parkinson's disease.

Methods:

We recorded neural activity in STN during implantation of DBS electrodes for Parkinson's disease while patients performed an extended reaching task where the movement trajectory changes in mid-action. During DBS surgery, patient hand movements were recorded using a stereoscopic camera enabling them to control a cursor on a screen. They completed trials consisting of planned and unplanned movements enabling determination of the effect of motor planning and execution as well as movement kinematics on neural responses in STN.

Results:

We recorded the activity of 39 neurons in 8 subjects, and show that the firing rate in a subset of STN neurons (n=18) decreases beginning >200 ms prior to unplanned action switches (p=0.003), contrary to prevalent theories. Background spiking activity decreases 100 ms prior to unplanned action switches (p=0.01). Further, beta oscillations do not show increased power or spiking entrainment during switches. A second STN subpopulation (n=16) encodes past and future movement speed and acceleration (R^2=0.48) and increases firing rate during medial movements (p=0.02).

Conclusions:

We report an inhomogeneous population neural code in STN, with one sub-population encoding movement kinematics and direction and another encoding unexpected action switches. We suggest an elaborate neural code in STN that contributes to planning actions and changing the plans.