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Abstract

The concept of volition undergirds much of our understanding about human actions, yet surprisingly little is known about the biological origins of volition, why humans believe their actions result from 'free will', and what factors differentiate voluntary from involuntary or subconscious actions. Given recent advances in techniques for dissecting neural circuit dynamics, the time is ripe to launch a new research program to reveal the neural circuit basis for volition and harness this understanding for groundbreaking technologies of military importance.

Toward this end, my lab built a robotic microscope (termed the 'Octopus microscope') that can visualize and manipulate neural dynamics concurrently in 4 areas of the brain's motor circuitry in awake behaving rodents or primates. By studying animals performing voluntary, involuntary, or subconscious movements, we aim in Objective 1 to identify the neural signals and brain area interactions that differentiate classes of movements performed with different levels of volition, and how repeated practice can transform volitional actions into skills or habits that can be executed subconsciously. The resulting understanding of volition will have profound scientific and philosophical implications and yield revolutionary technological applications.

These applications will include: (i) brain-machine interfaces (BMIs) that allow the brain to direct machine actions across a range of volitional levels; (ii) learning algorithms and artificial neural networks (ANNs) that better capture the human capacity for hierarchical forms of action planning, learning, cognition and motor control across different time-scales and contexts; (iii) neuroscience-based methods to optimally shape the ingrained habits and intentional actions of human operators; (iv) robots whose dexterous movements, actions, planning and learning capacities better approximate human capabilities.

To initiate such applications, we will create: (a) all-optical BMIs allowing an animal to control a machine in both a subconscious and a voluntary manner (Objective 2); (b) ANNs embodying the dynamics and principles we identify for joint volitional and subconscious action control (Objective 3).

Overall, this innovative research plan promises to re-shape thinking in multiple disciplines and yield several high-impact technologies; it is thus ideally suited for the VBFF Program.