CLOSED LOOP BRAIN-MACHINE INTERFACES

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Over the past 5 years, we have demonstrated, for the first time, that simultaneously recorded populations of single neurons in the motor cortices of rats and monkeys can be electronically "decoded" and used to directly control a robot arm. In the first study, populations of up to 46 single neurons were simultaneously recorded in the primary motor cortex of rats initially trained to obtain water by pressing a lever to move a robot arm. Next, electronic techniques were used to transform the movement related information recorded in the motor cortex into an electronic output capable of controlling the robot arm in real time. In experiments, the rats first controlled the robot (and got their water) by moving by moving the lever, but this robot control was then suddenly switched to the brain-derived signal. Most rats were able to routinely use this motor cortex population function to position the robot arm under the water dropper and obtain their water. Over continued trials, the ability of the brain-derived signal to control the robot arm became increasingly independent of the forelimb movement, with which it was normally associated. These results therefore demonstrated the feasibility of using neuronal population activity to control external devices

Next, we demonstrated the feasibility of brain-controlled robotics in monkeys trained either to move a manipulandum or to reach to a target in 3D space. Neural populations were recorded throughout the arm areas of the frontal and parietal cortices. Using multivariate regression techniques to decode the neural population vectors, the animals were able to use their brain signals to move a robot arm in both 1D and 3D spaces with the same trajectory as their hand. Accuracy improved generally with increased numbers of recorded neurons, approximating a slowly saturating hyperbolic curve.

Because these results suggested the feasibility of using brain-derived signals to restore movement in spinal cord injured patients, we are now investigating the possibility of bringing tactile and proprioceptive feedback from a brain-controlled robot back to the brain by stimulating in the somatosensory system through implanted multi-electrodes. Initial studies have shown that stimulation in the somatosensory cortex of rats can be used to deliver virtual conditioned stimulus cues. These animals are trained, using medial forebrain bundle stimulus rewards, to turn in the direction of the part of the body that receives a perceptible virtual stimulus, generally producing an illusion of being touched on the left or right side of the face. When a remote controlled stimulator is attached on the rat's backpack, it can be remotely guided to traverse a wide range of indoor and outdoor terrains, including stairs, ladders, trees and rubble piles. In conclusion, these studies suggest feasibility of using electronic technology to transmit information bi-directionally between the brain and external machines.