INVASIVE BCIS

Towards Neural Prosthetics

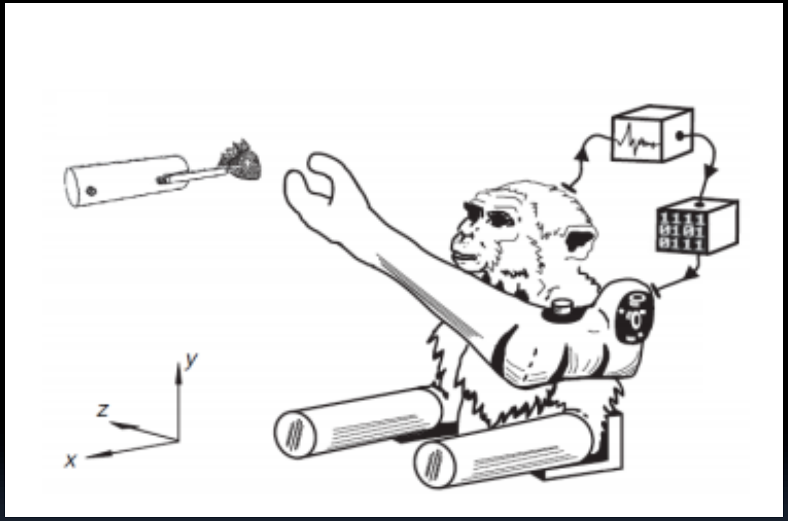
Papers

- Prosthetic Arm and Hand Control
  - *Cortical control of a prosthetic arm for self-feeding.* *Velliste M et al. Nature 2008.*
- Cursor and Robotic Control using a Multi-Electrode Array Implant
  - *Neuronal ensemble control of prosthetic devices by a human with tetraplegia.* *Hochberg LR et al. Nature. 2006.*

Experiment

- Monkeys used responses from primary motor cortex neurons to control a prosthetic arm and gripper in a continuous self-feeding task
  - The monkey had to move the prosthetic arm to arbitrary locations in the 3D workspace in front of it where food was presented.
  - The animal then had to close the gripper to grab the piece of food, move the arm to its mouth and open the gripper to retrieve the food.
  - in addition to 3D position, also proportionally controlled the distance between the two “fingers” on the gripper to open or close it

Control of a Prosthetic Arm and Gripper for Self-Feeding.



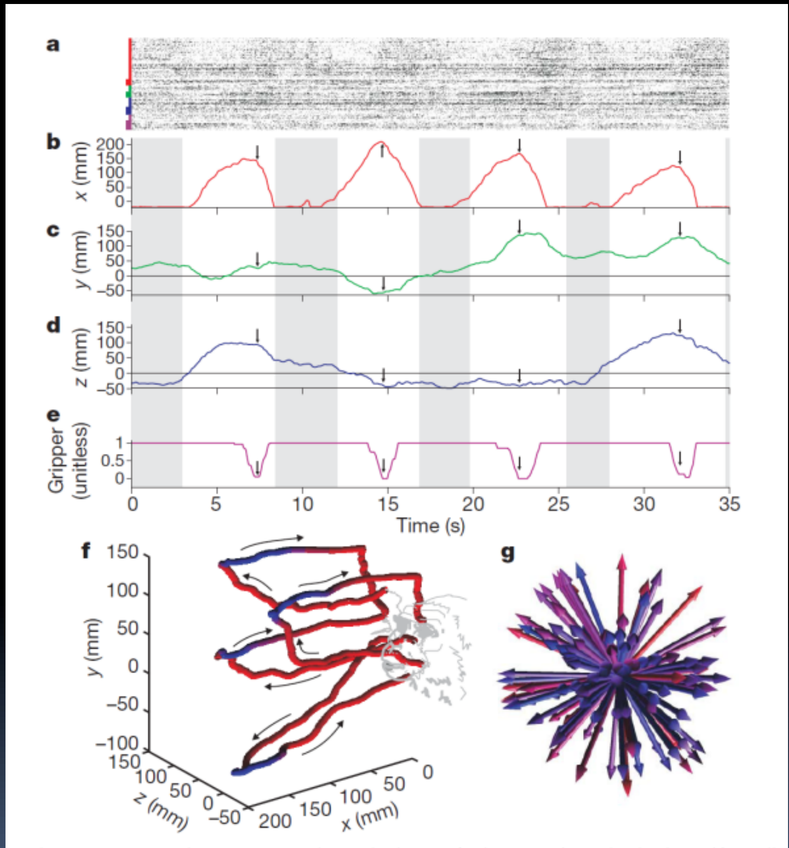
- The monkey's arms were restrained and a prosthetic arm was positioned next to its shoulder.
- Spikes recorded from multielectrode arrays implanted in primary motor cortex were processed and used to control the 3D arm velocity and the gripper aperture velocity in real time.
- Food targets were presented at arbitrary positions in the 3D workspace in front of the animal.

Video

Success Rate

- One monkey performed 2 days of this continuous self-feeding task with a combined success rate of 61% using 116 primary cortex neurons.
- For the positioning portion of the task the success rate was 98%.
- The monkey also moved the arm in unexpected ways such as to lick the gripper fingers and to push food.

Neural Responses and Prosthetic Arm/Gripper Trajectories.

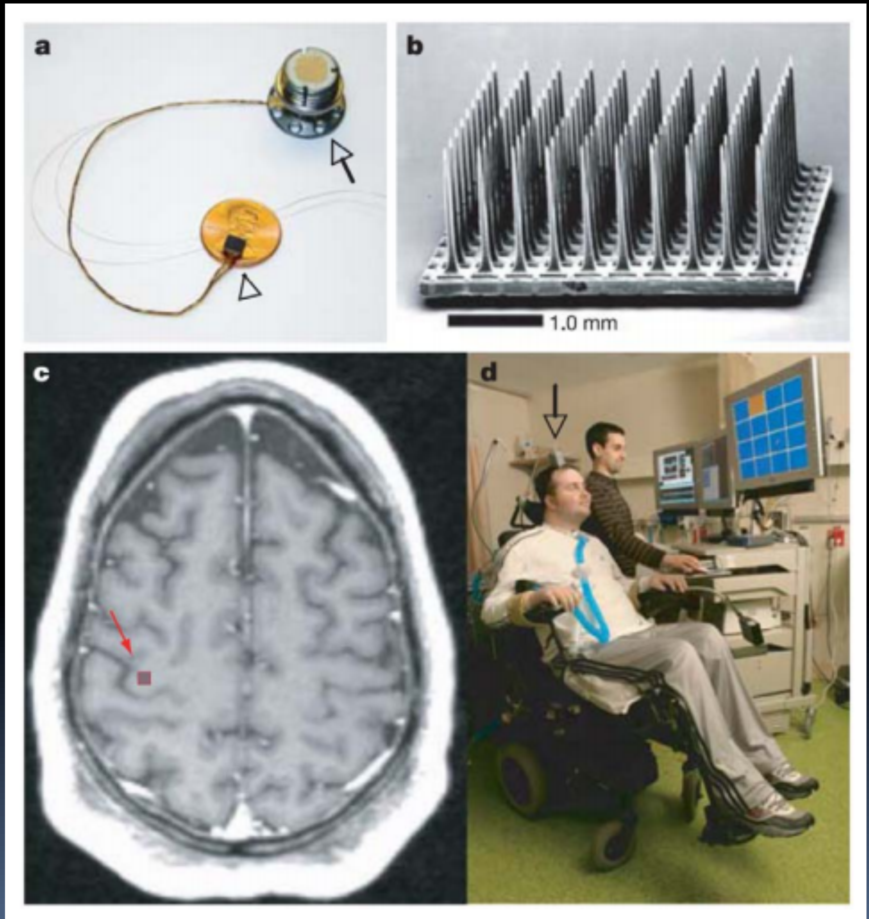


- (a) Spike trains from 116 neurons used for controlling the arm and gripper in 4 successful trials.
  - Each row represents spikes from one neuron, rows being grouped by major tuning preference
- (b) through (d) show X, Y, and Z components of arm endpoint position
- (e) Gripper aperture
- (f) Arm trajectories for the same four trials
- (g) 4D preferred directions of the 116 neurons.

Translating BCIs to Humans

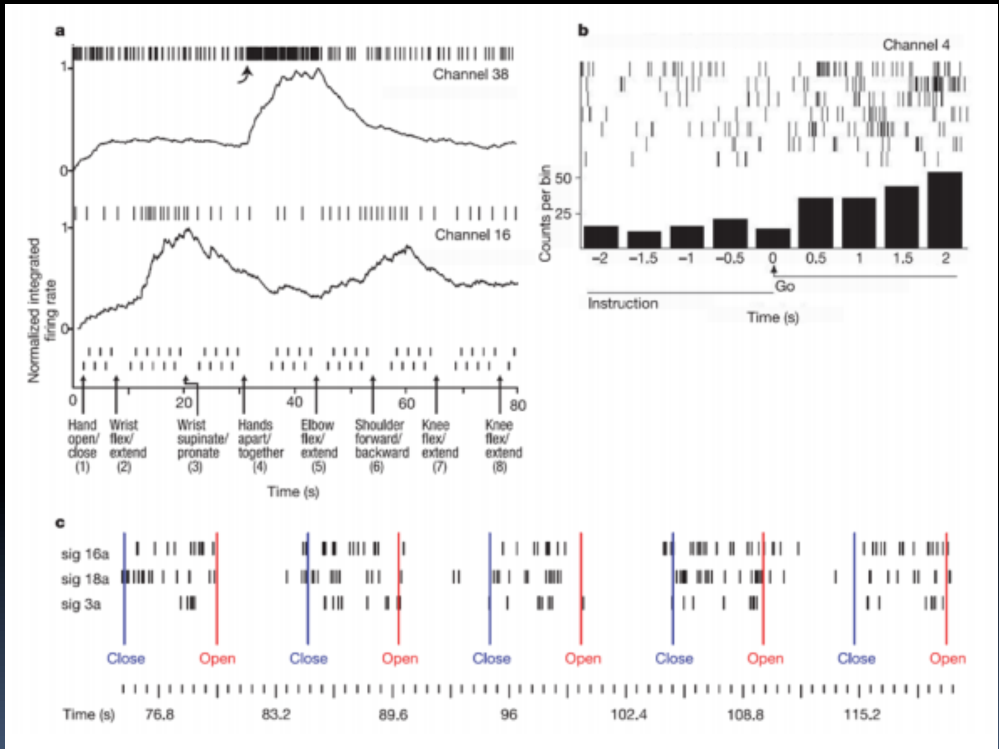
- Electrode array with 100 silicon microelectrodes was implanted in the arm area of primary motor cortex of a tetraplegic human.
- Addressed whether motor intention could still modulate cortical activity years after spinal cord injury and in the absence of hand motion.
- Researchers found that neurons in primary motor cortex can be modulated by imagined limb motions

Invasive BCI in a Human



- (a) The electrode array shown on a US penny with a ribbon cable to a percutaneous pedestal that is secured to the skull via surgery.
- (b) Close up view of the 10 × 10 electrode array.
- (c) MRI image of the brain of participant.
- (d) The subject sitting in a wheelchair looking at the computer screen and moving the neural cursor towards the orange square in a 16-target 'grid' task.

Response of human motor cortical neurons for imagined and actual movements.



- (a) Spikes and integrated firing rates from two simultaneously recorded neurons.
- (b) Seven spike trains from a neuron elicited for seven different movements, along with histograms showing the total number of spikes in each bin.
- (c) Spike trains from three neurons in response to a text instruction to open and close a hand.

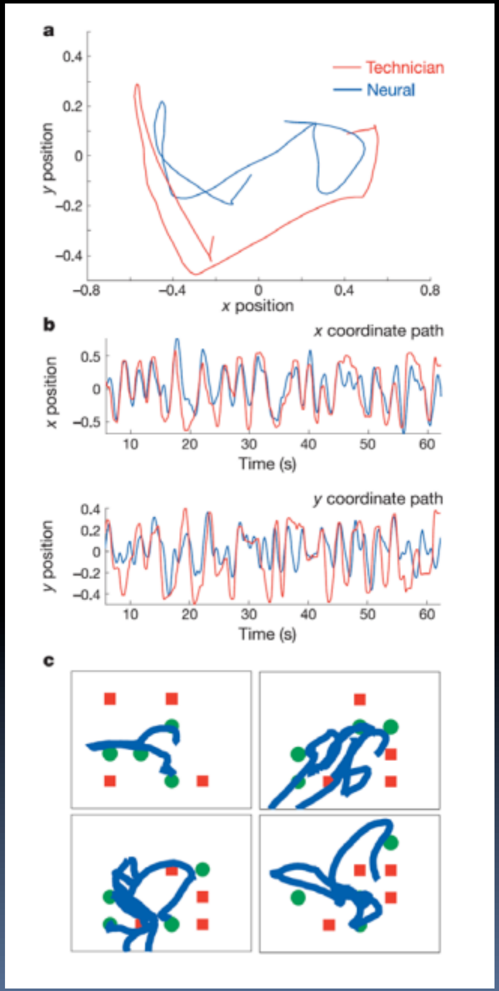
Experiment

- Given the diversity of neural responses observed for imagined actions, a linear filter method was used to translate neural activity into 2D cursor position.
- The subject was asked to imagine tracking a cursor on the screen which was controlled by a technician.
  - During this training session, the firing rates of up to 73 discriminated neurons over the past one second were linearly mapped onto technician-cursor position using a linear filter computed via the pseudoinverse technique.
  - In subsequent sessions, the predicted cursor position was plotted to provide visual feedback. The filter was updated in-between sessions

Success Rate

- The subject was able to move the cursor in the general direction of the technician's cursor movement as the cursor changed directions, but the tracking is only approximate.
- The correlation between the neural and technician-controlled cursor positions was found to be 0.56 ± 0.18 (x-coordinate) and 0.45 ± 0.15 (y-coordinate) over 6 sessions.

Cursor Control with an Implanted Human BCI



- (a) Trajectories of the technician controlled cursor and neurally-controlled cursor for a 5 second period
- (b) Comparison of x- and y coordinates of technician cursor and neural cursor for a 1 minute period.
- (c) Four examples of neural cursor control in a target acquisition and obstacle avoidance task

Complex Tasks

Using a Television

Playing Pong

Conclusions

- Rapidly evolving field
- Still a few concerns
  - Long term usage
  - continual tuning