Direct cortical control of 3D neuroprosthetic devices

Taylor, Tillery & Schwartz

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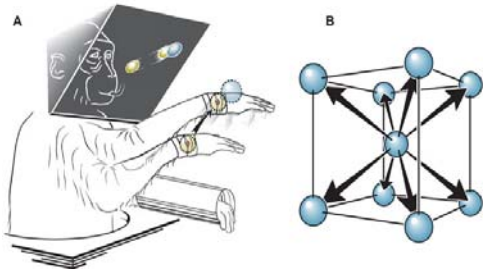
Background

- Prediction of intended movement by cortical activity: 2 approaches
  - "open-loop": offline trajectory recreation based on cortical activity, no feedback of neuronal activity
  - "closed-loop": online trajectory recreation, subject receives feedback of neuronal activity
- Authors compared the two approaches when only small numbers of neurons were sampled

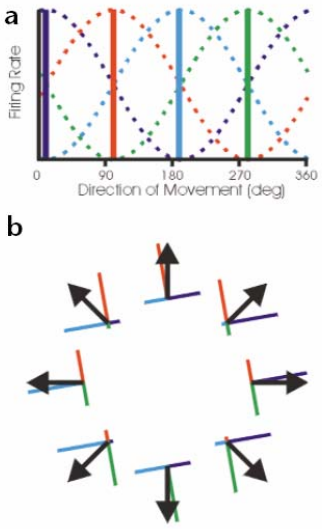
Methods (I)

- Task
  - reach targets in a 3-D virtual environment
- Recording
  - chronic electrode array
  - L motor, premotor
- Decoding
  - population vector
  - approx. 18 cells



Population vector

- Preferred direction
- Single neurons ‘vote’ using their firing rates
- ‘Final vote’ calculated by vectorial summation of individual preferred directions weighted by individual firing rate
- Each cell’s contribution scaled by:
  - its quality of tuning
  - expected magnitude of movements



Hand-control (open loop trajectories)

- Beginning of each day, new baseline data
- Slightly-different brain-to-cursor movement relation each day
- Fairly stable waveforms across days
- Encoded trajectories were calculated offline

Brain-control (closed loop trajectories)

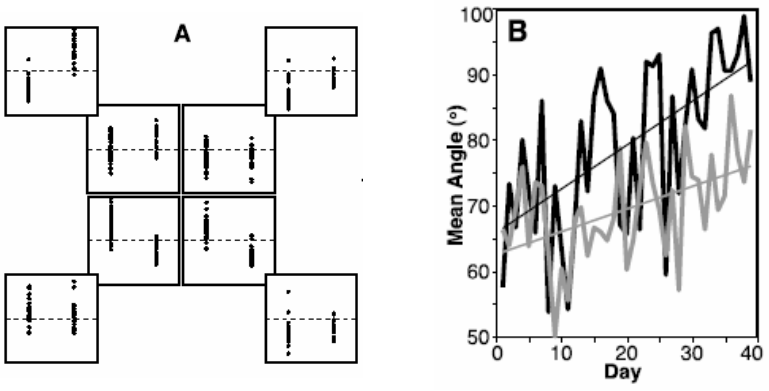
- Subjects used visual feedback to make online error correction
- More accurate than open-loop trajectories
- Subjects learned the new day-to-day relations
- Brain control was tested in both slow and rapid movements with comparable results

Closed-loop brain-controlled trajectories	M1	M2	both
% Targets hit	52 ± 14	46 ± 18	49 ± 17
% Time in correct octant	36 ± 9	34 ± 11	35 ± 11
Open-loop brain-predicted trajectories	M1	M2	both
% Targets hit	32 ± 11	23 ± 5	27 ± 9
% Time in correct octant	23 ± 9	23 ± 9	23 ± 9

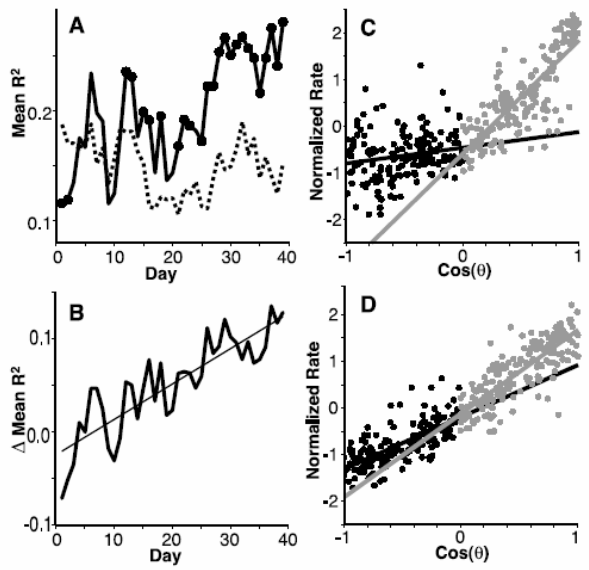
Co-adaptive algorithm

- In the clinical setting, initial tuning properties will not be available
- Start with random initial preferred directions
- Iteratively refine “preferred direction” of each cell, based on difference between calculated cursor position (in 3D space) and desired cursor position

Gradual change in cells’ tuning properties



Gradual change in cells' tuning quality & performance



Testing novel targets