Point-and-click cursor control using intracortical neural interface systems in a human with tetraplegia

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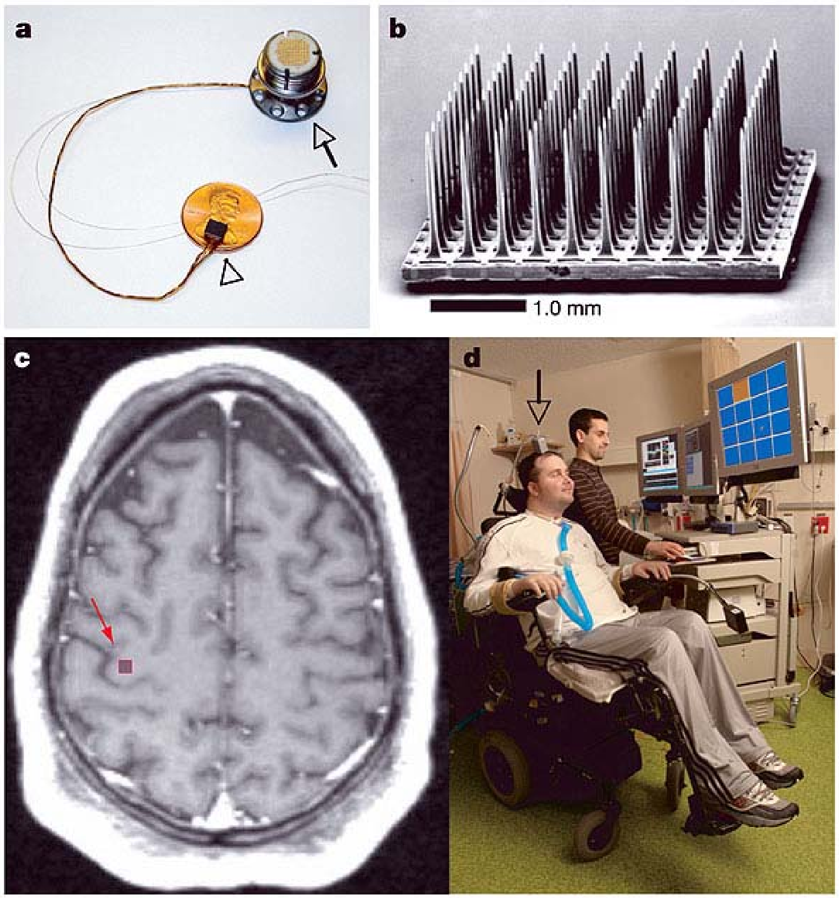
Intracortical human neural prosthesis BrainGate^{TM} pilot trials



Hochberg et al. Nature 2006

- Motor signals in MI activity after paralysis
- Control external devices
  - e.g. computer cursor
- Position decoding by linear regression
- Unsteady cursor movements
- No click

Challenge: Practical interfaces

- Steady and accurate cursor movements ?
- Simultaneously decode continuous (point) and discrete (click) signals from the same neural population of humans ?
  - Non-human studies:
    - Darmanjian et al (IEEE/ RSJ, 2003)
    - Wood et al (EMBS, 2004)
- How to train paralyzed humans and decoding algorithms for “point” and “click” ?

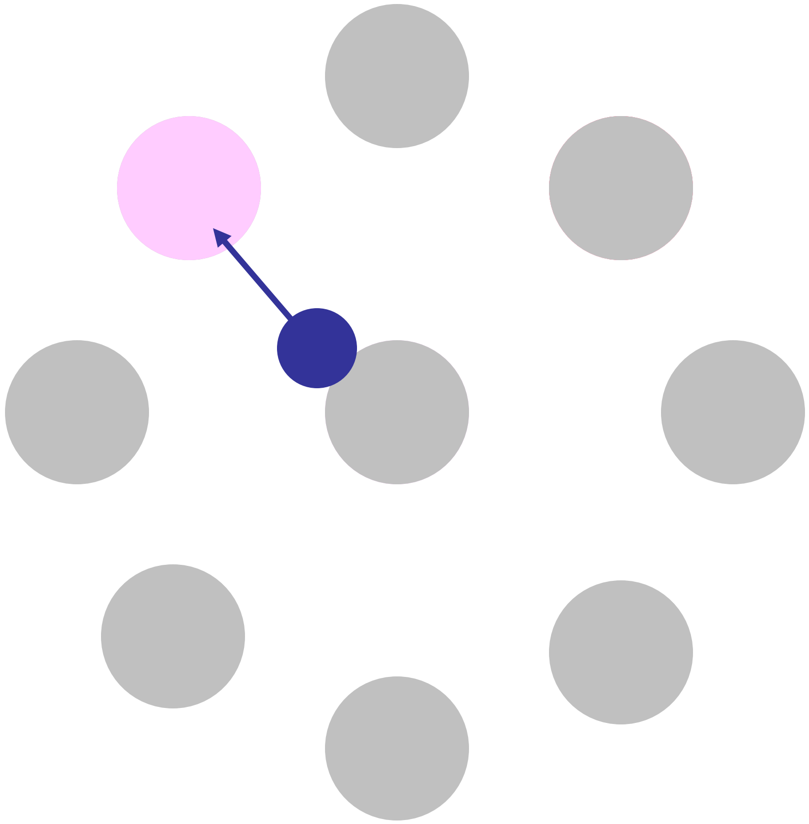
Human Participant

- 52-year-old female
- Brainstem stroke
- 9 years prior to trial enrollment
- Microelectrode array was implanted in November 2005

Donoghue et al. SfN 2006

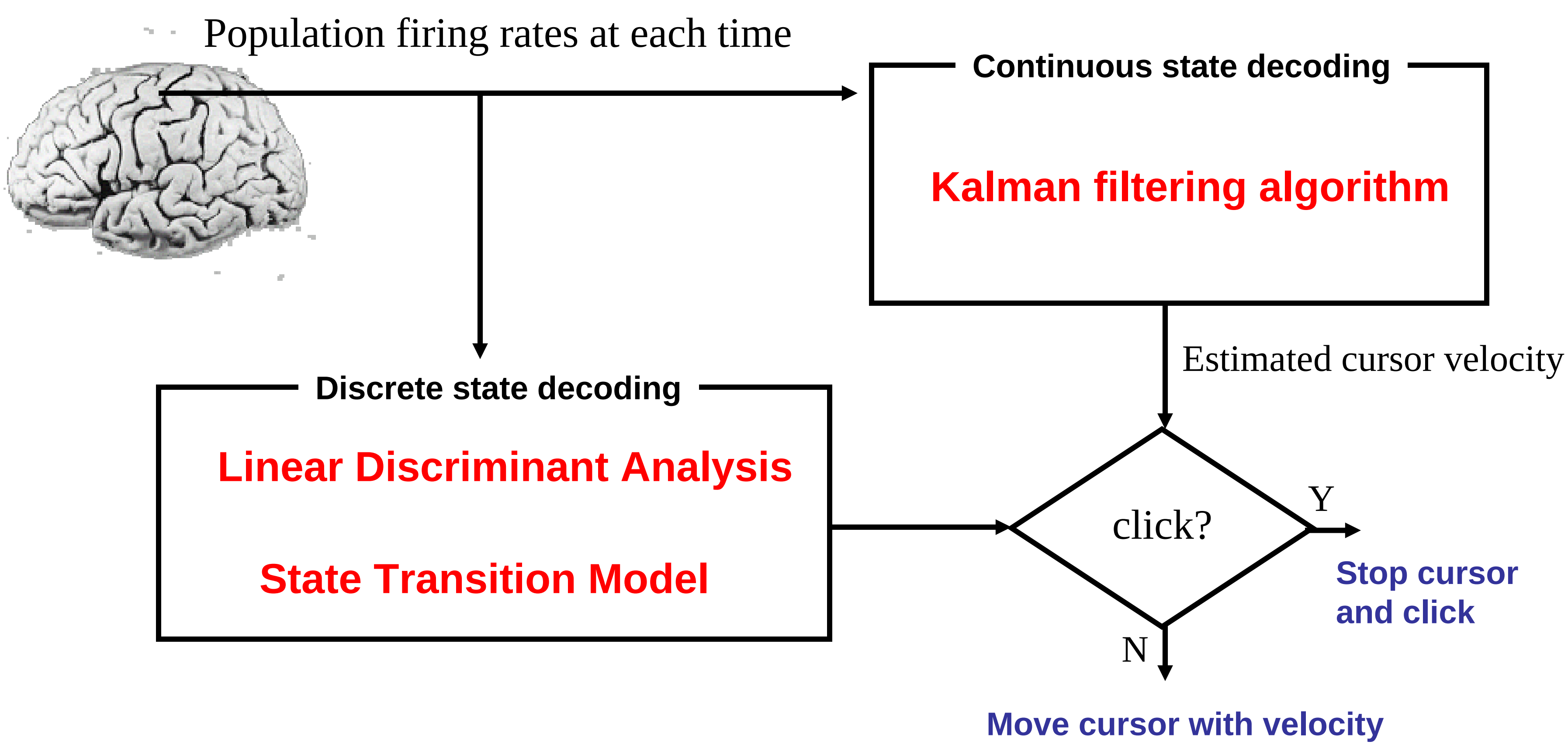
Point-and-click performance

- 8 center-out target acquisition task
- Point-and-click within timeout
- Move back to center



- Demonstration of closed-loop cursor control performance: 292 trial day after implantation
- Demo: movie

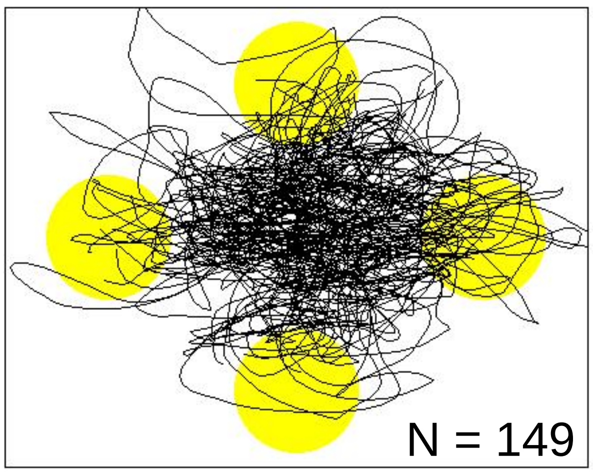
Continuous and discrete decoding



Stable and accurate cursor control

Position decoding

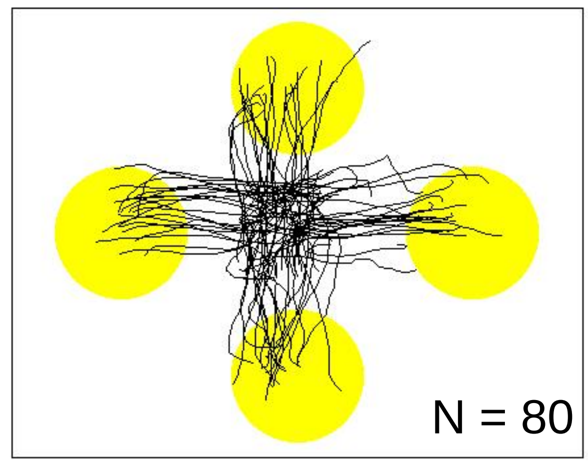
Linear filter



OLD

Velocity decoding

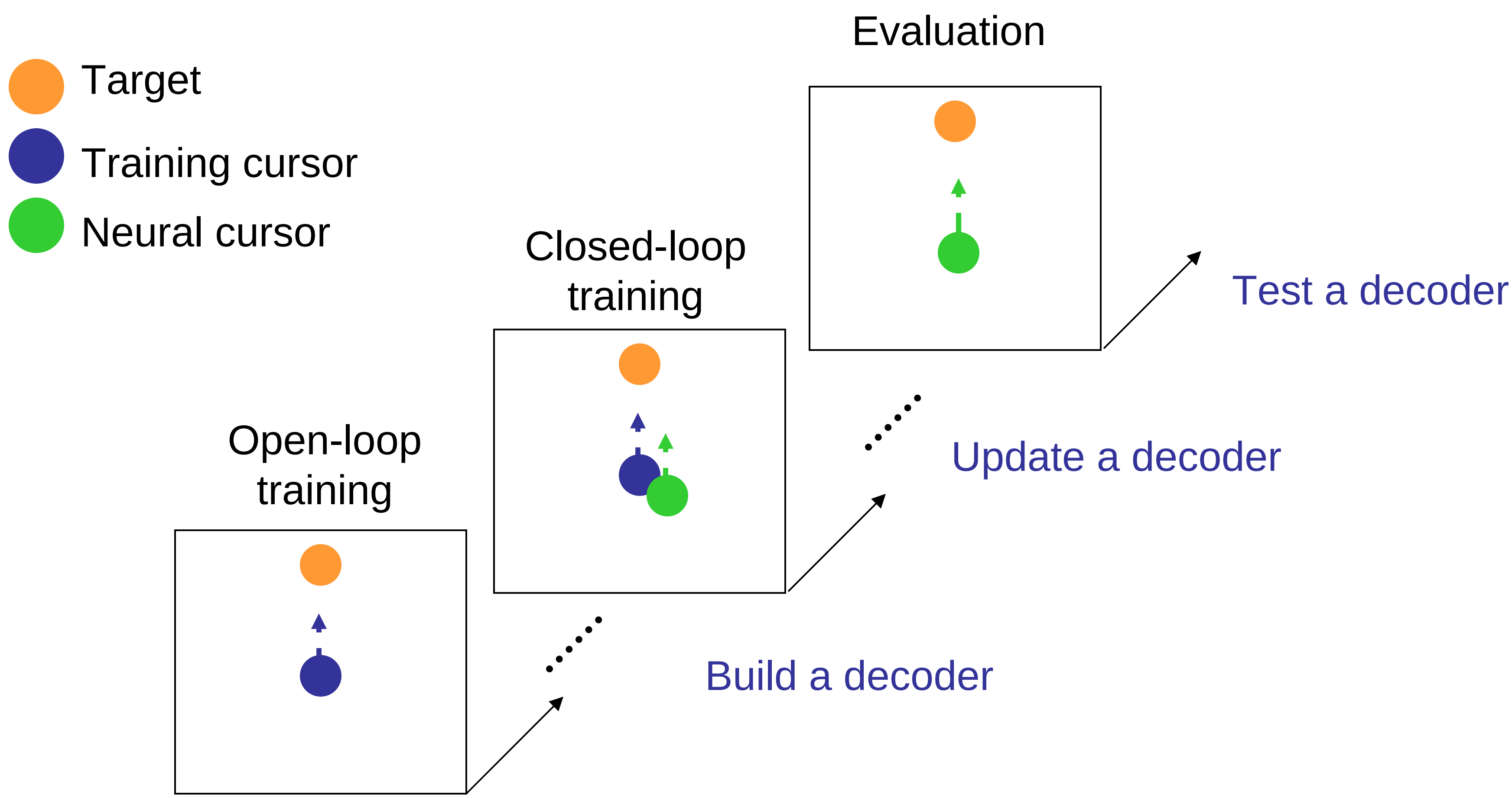
Kalman filter



NEW

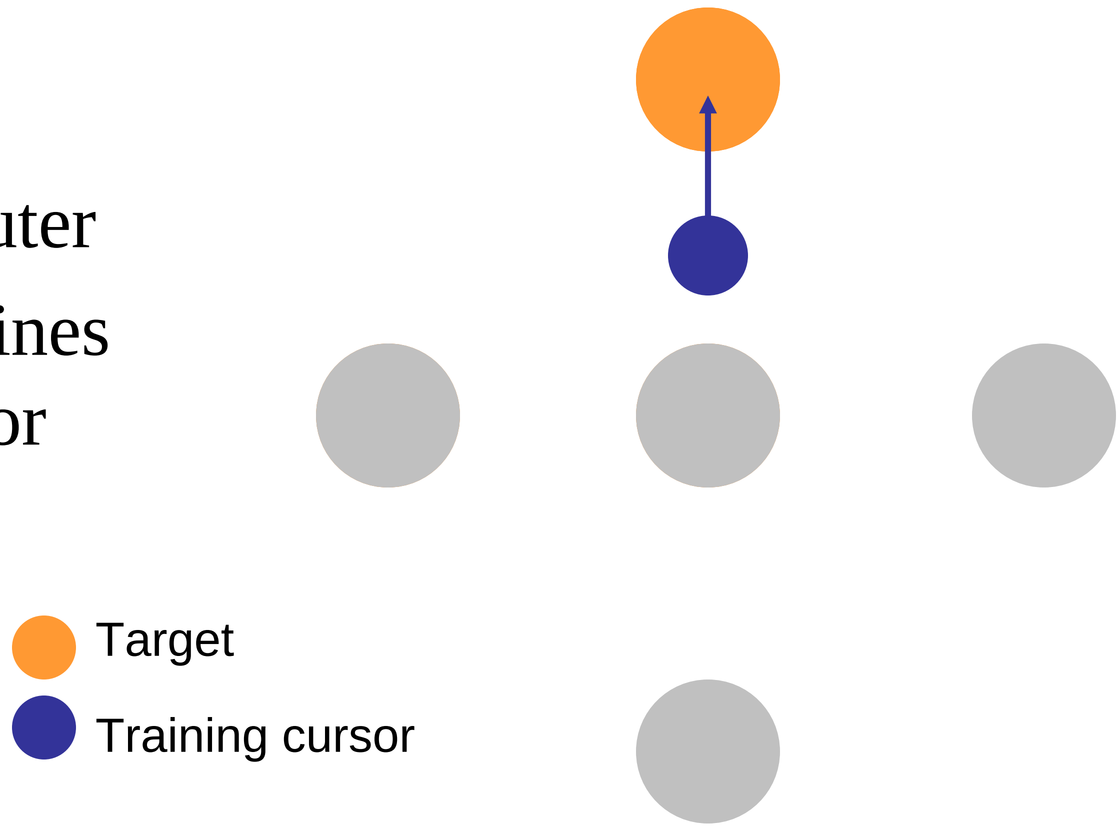
Kim et al. SfN 2006

Training Paradigm



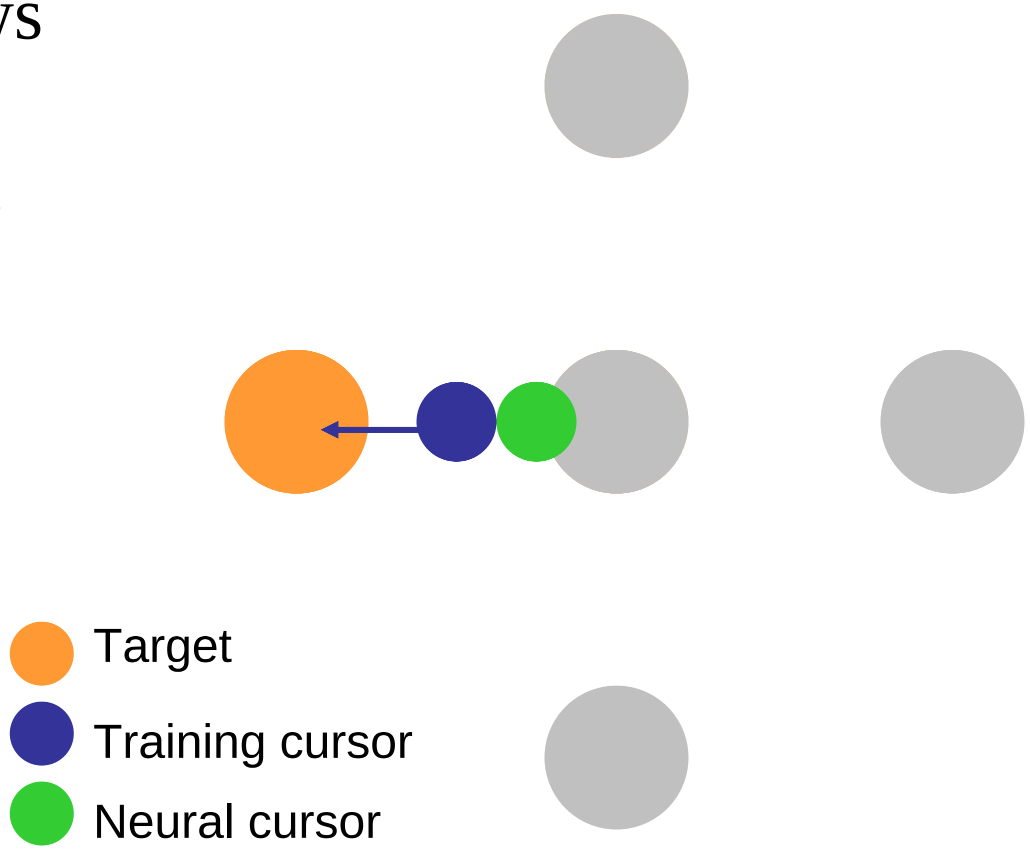
Training – Continuous state

- Open-loop training
  - Center-out task
  - Training cursor moved by computer
  - Participant imagines the training cursor movement



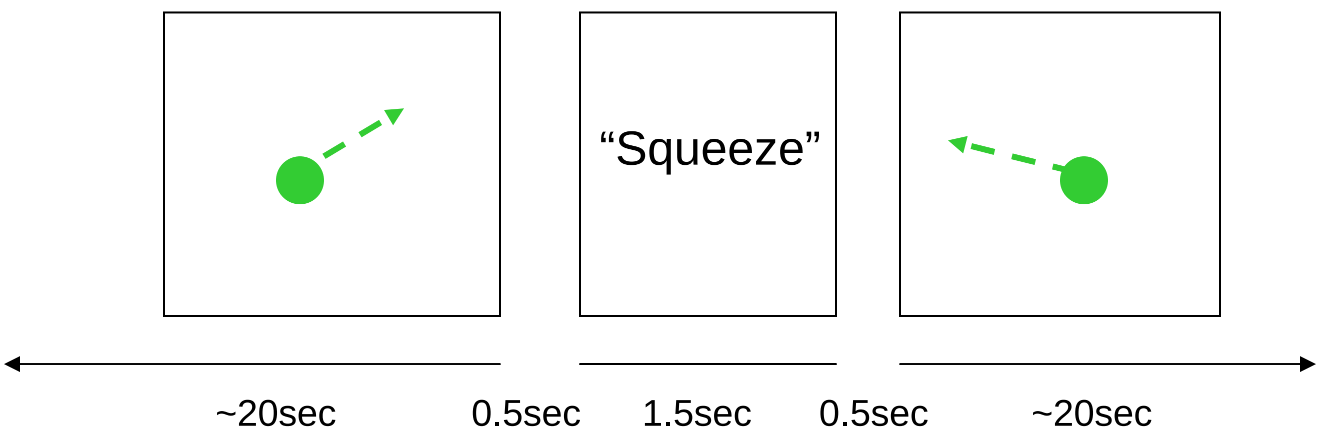
Training – Continuous state

- Closed-loop training
  - Neural cursor follows training cursor
  - Participant imagines the training cursor movement
  - Visual feedback of the neural cursor



Training – Discrete state

- Movements vs click
  - Click motion = “squeeze”
  - Squeeze between movements



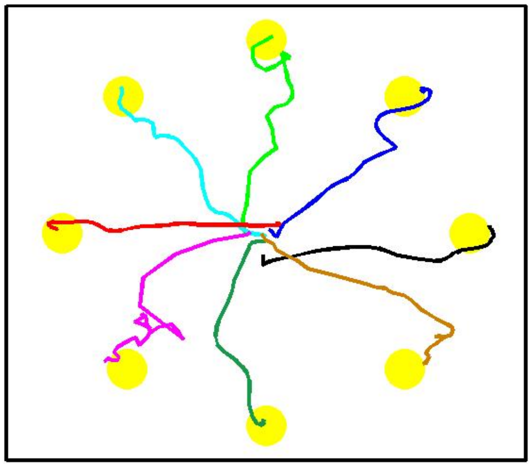
Results

- 3 sessions: 292, 301, 303 days after implant
- # neurons: N = 37, 38, 57
- 10-min evaluation period

Mean neural cursor paths

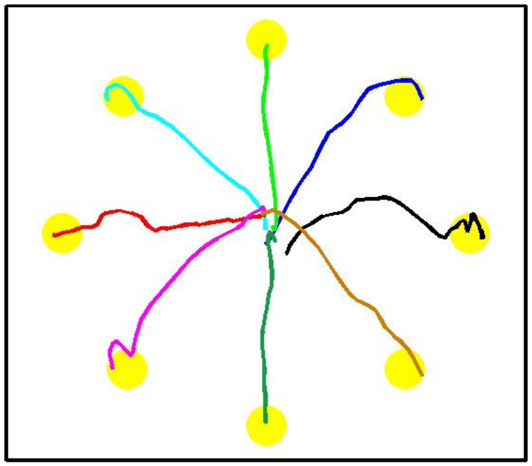
Session 1

N = 37



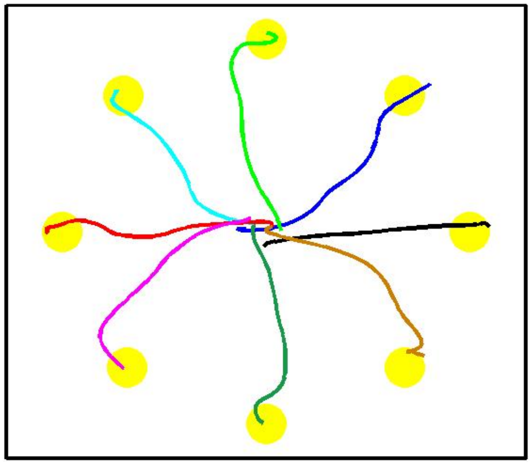
Session 2

N = 38

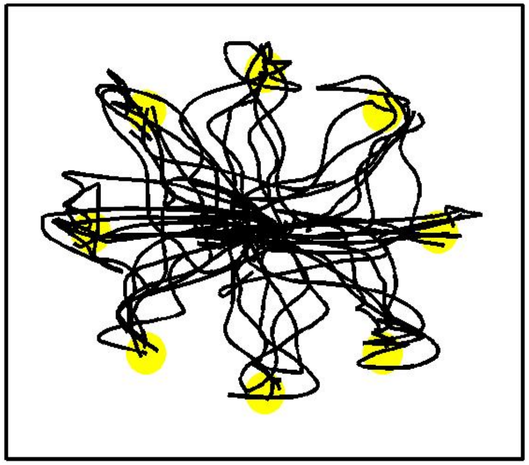


Session 3

N = 57



Session 3

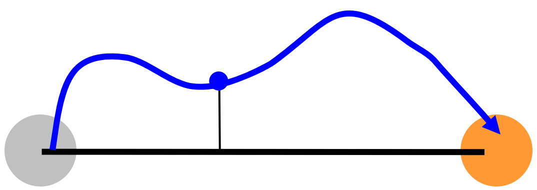


Performance Quantification

Metric	Sesssion 1 (n = 37)	Session 2 (n = 38)	Session 3 (n = 57)	Avg.
ER(%)	0 (30s)	0 (30s)	3.9 (9s)	
MT(s)	7.89	6.10	5.70	**6.43**

ER: Error Rate (timeout period)
MT: Mean Movement Time

Movement Variability



Tetraplegia	Parkinson's Disease			Essential Hand Tremor		
NIS	**Mouse**	**Trackball**	**Joystick**	**Mouse**	**Trackball**	**Joystick**
16.73(mm)	15.39	18.08	19.98	18.84	21.95	26.23

* Screen size ~ 366mm x 305mm

Contributions

- Continuous and discrete motor signals could be simultaneously decoded from the same neural population in a human with tetraplegia
- Steady and accurate cursor control
- Develop a training paradigm for paralyzed humans and decoding algorithms for point-and-click

Acknowledgements

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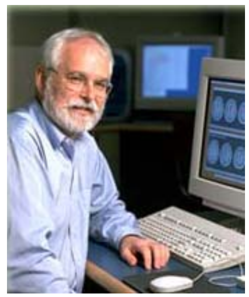

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