Cognitive Control Signals for Neural Prosthetics

Musallam et al. 2004

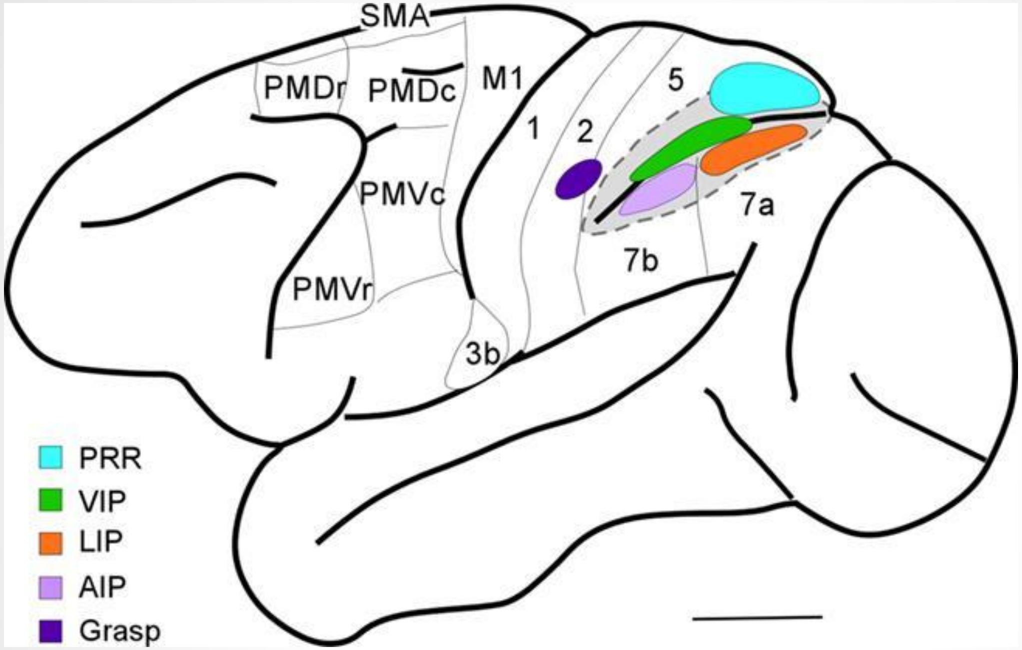
Background

- Previous work focused on decoding online intended trajectories from motor cortex activity
- This study explores using higher-level cognitive signals to predict intended movement and expected value

Significance

- Signals related to planning are independent of visual or online intended movements
- Command abstraction allows for smart prosthetics to compute trajectories

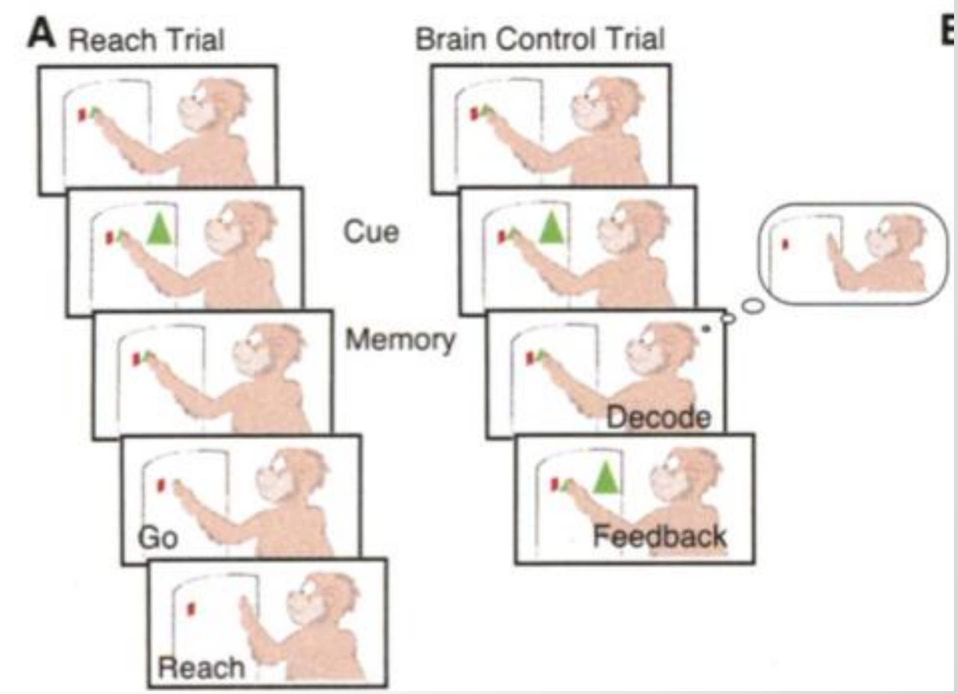
Pathway for visually guided movement



- Extrastriate visual cortex -> parietal reach region (PRR) -> Pmd (dorsal premotor cortex) -> primary motor cortex
- Parietal reach region is activated when animals plan but withhold movement

Data collection

- Reach segment to collect database
- Monkeys reach for flashed cue after a "memory period"
- Controlled for hand and eye movements
- "Brain control" segment to decode cursor position



Database update

- Adaptive versus frozen database
- Frozen database contains only reach trials
- Adaptive contains 30 most recent successful trials (eventually all brain control segment)

"Training sets for cognitive prosthetics can be obtained in paralyzed patients who do not have the ability to reach"?

Decoding of brain control trials

- Project spike train from memory period onto family of Haar wavelets
- Wavelet coefficients provide unique neural signature, used to find greatest P(s|r)

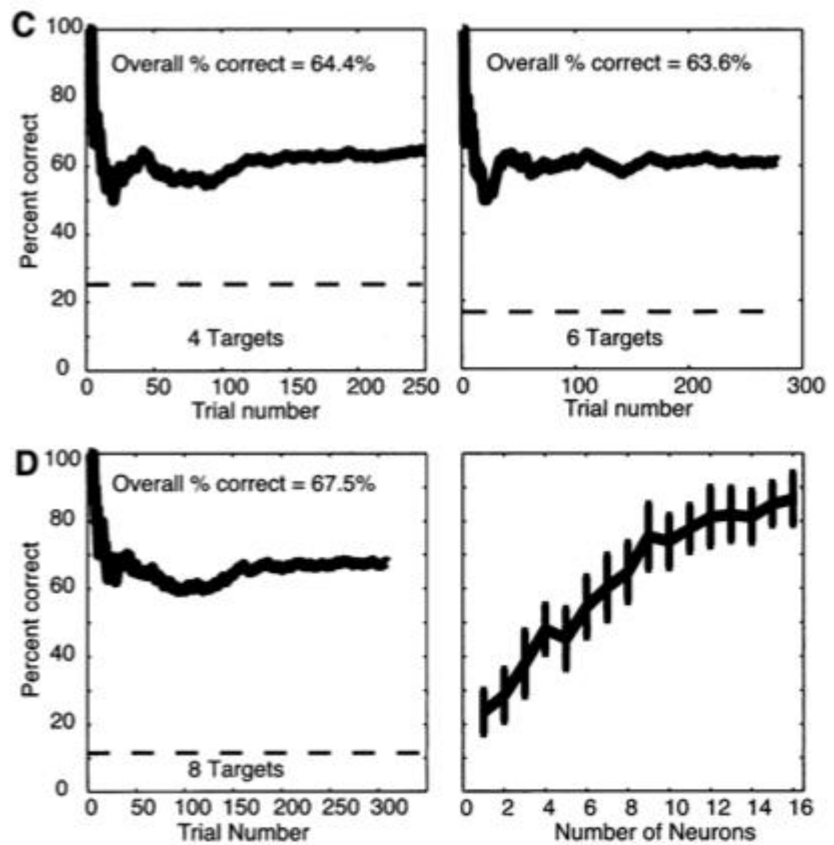
$$P(s \mid r) = \frac{P(r \mid s) P(s)}{P(r)}$$

$$\psi(t) = \begin{cases} 1 & 0 \le t < 1/2, \\ -1 & 1/2 \le t < 1, \\ 0 & \text{otherwise.} \end{cases}$$

Result of decode performance

PRR

PMd

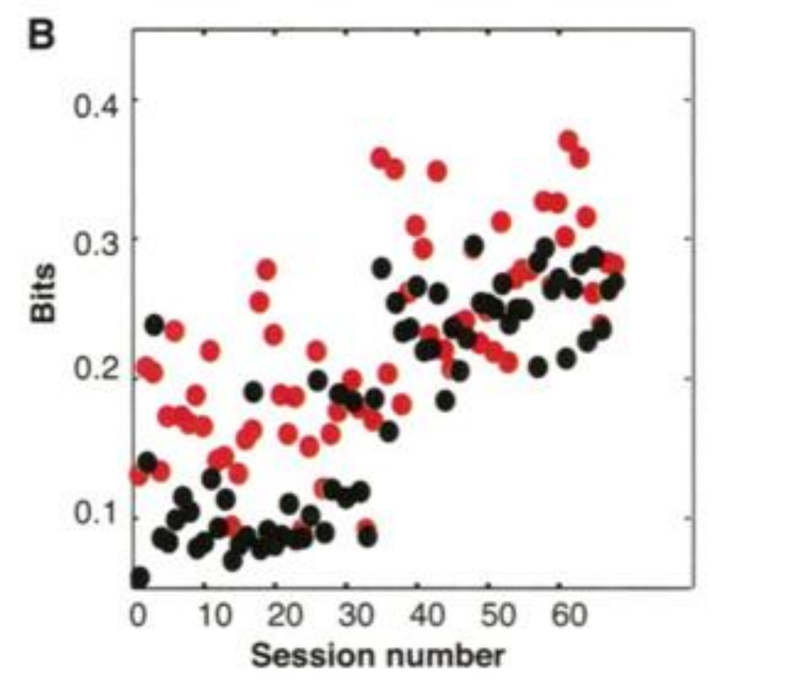


E

	Monkey S	NS	Monkey C	NS	Monkey O	NS
4 Targets	45.0 (10.5)	62	34.2 (5.0)	81	43.2 (17.1)	13
5 Targets	48.1 (7.3)	10	30.6 (2.9)	7	59.3 (0.2)	2
6 Targets	37.1 (11.1)	10	25.6 (5.8)	2	31.2 (14.7)	6
*4 Targets	75.2	1				
*8 Targets	68.2 (1.3)	2				

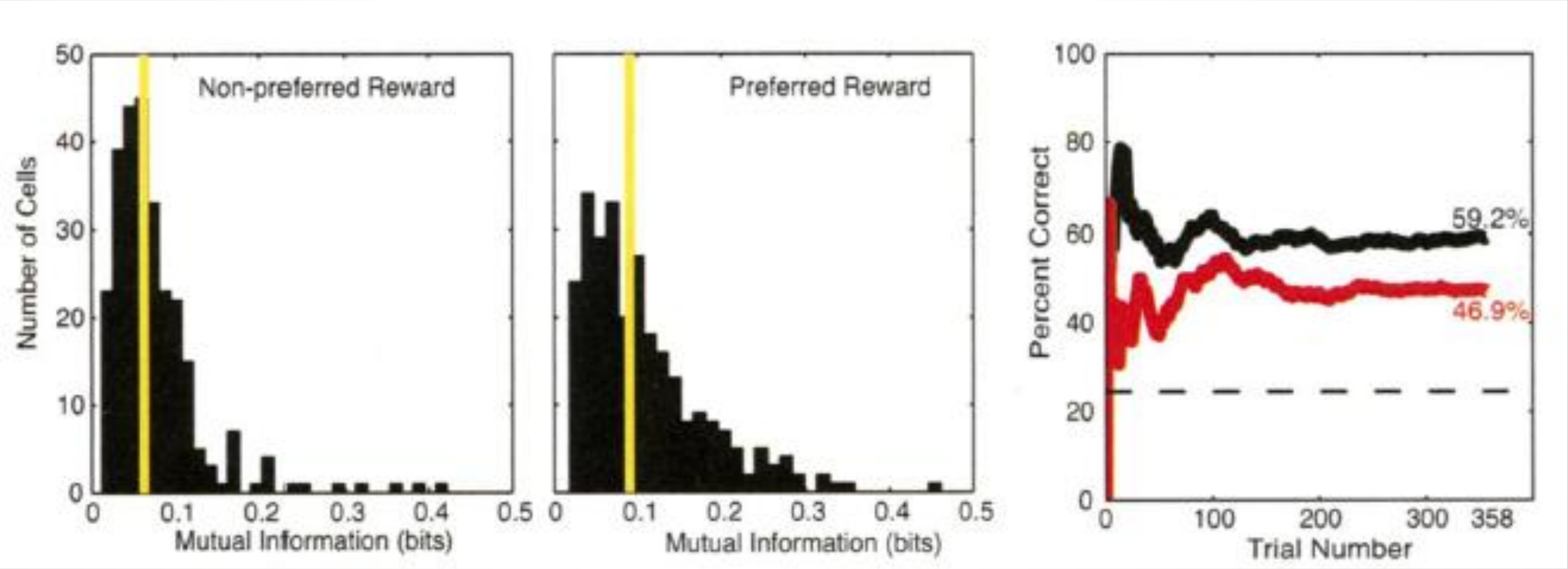
Mutual information of cells

- Mutual information quantifies degree of spatial tuning, where s is target direction and r is response

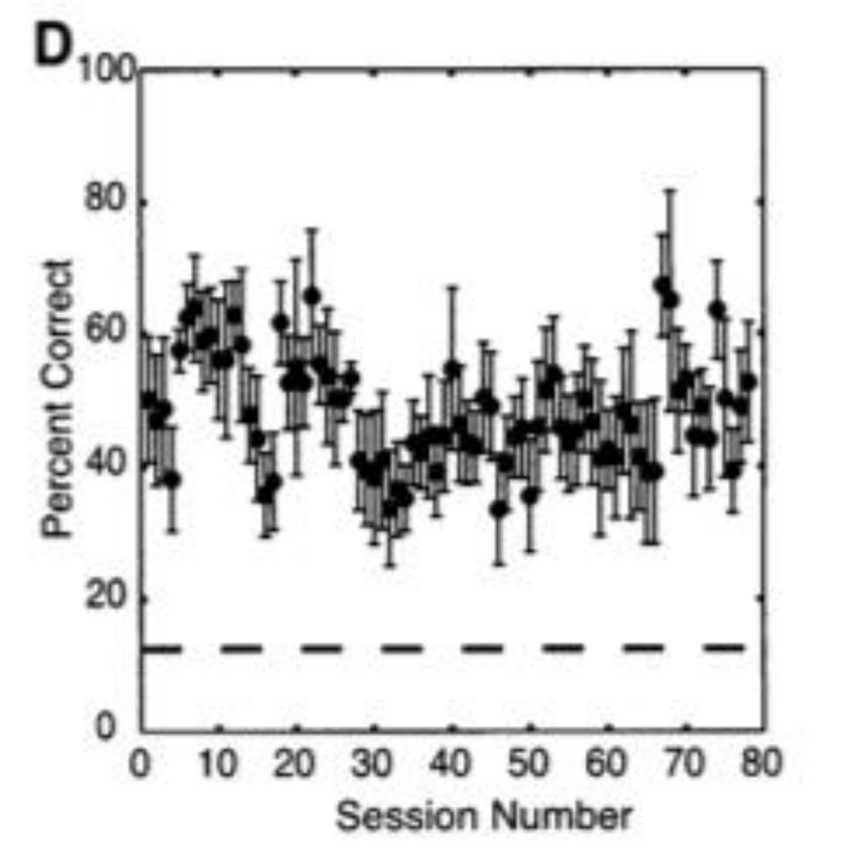


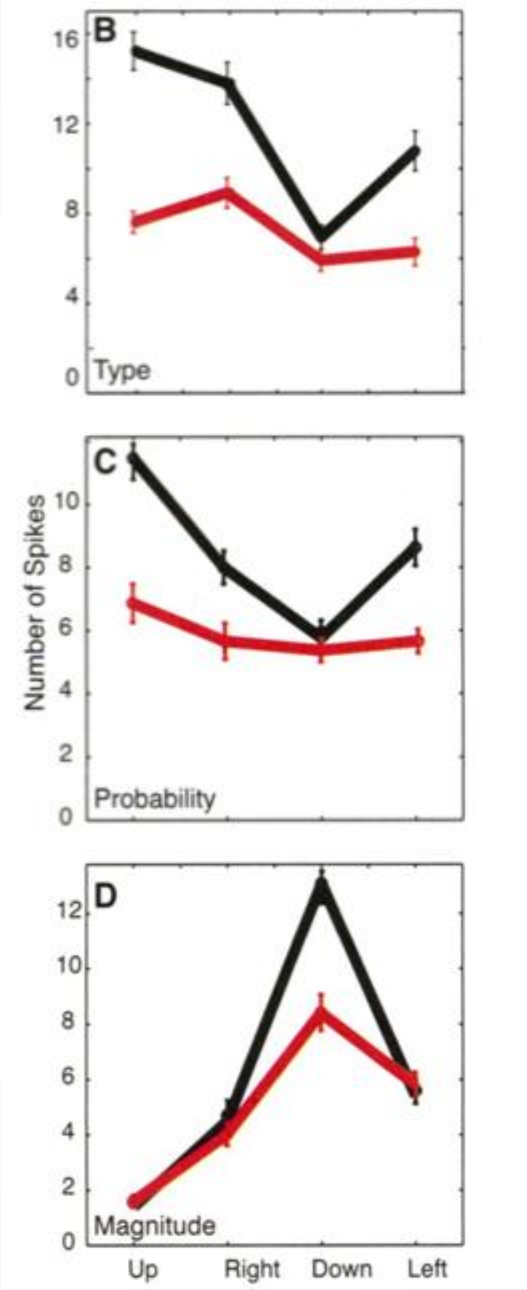
$$I(r,s) = \sum_{r,s} P(r,s) \log \frac{P(r,s)}{P(r)P(s)}$$

Increased mutual information with higher expected value and decoding success



Simultaneous decode





Discussion

-investigate time course of plasticity and degeneration in PRR vs. PMd

-investigate time course of accuracy when starting with brain control data rather than reach segment data and how to update error trials

-finer scale of expected values to see if the exact expected value can be decoded from the memory period

-allow free eye movements and update activity within map of space of PRR to separate this signal from the movement intent