Motive: A BCI Odyssey

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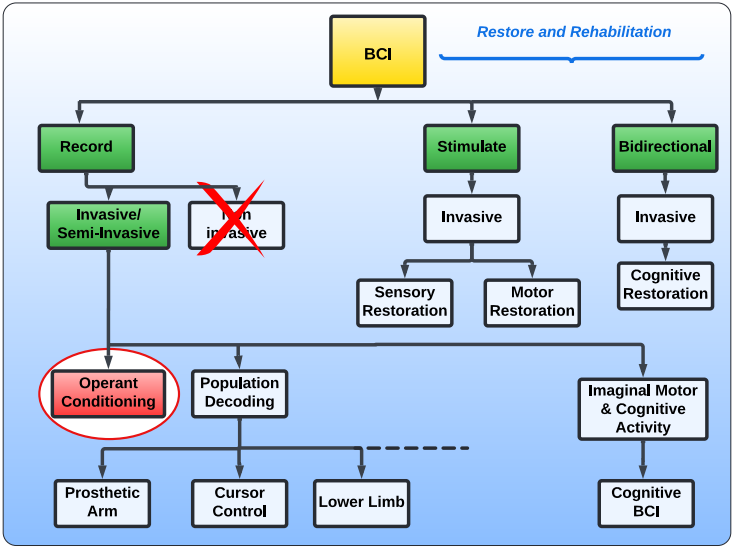


I. Operant Conditioning (Fetz,1969) [1]

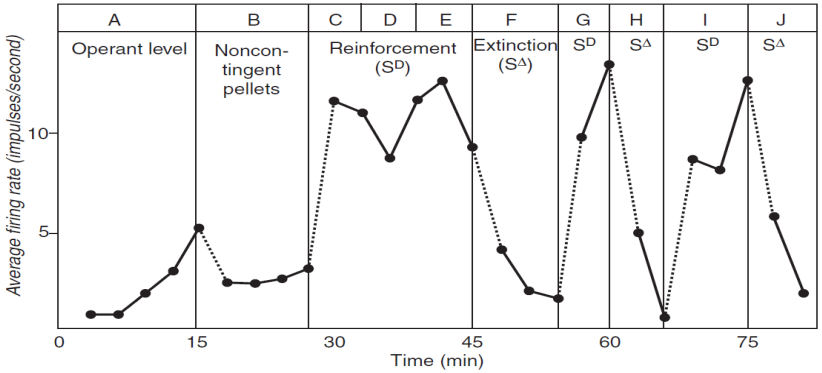


Figure: Monkey learned to increase the firing rate of the recorded cortical neuron to defect the needle past the threshold and obtain the reward. Different time: Operant level - Initially, Noncontingent period - Reward uncorrelated with neuron's firing rate, Reinforcement - Reward correlated firing rate

Operant Conditioning

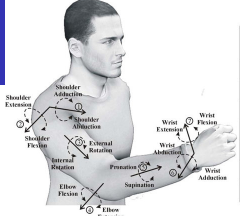
Advantages

- Relies on the brain's remarkable ability to adapt (**Neuroplasticity**)
- Does not require complex machine-learning algorithms.

Drawback

- User requires a considerable amount of practice.
- Difficult/impossible to achieve control over complex devices.

Decoding Arm Movement



Joint	Anatomic Angles	SAM Angles
1	-50/180 °	-10/180°
2	-45/180°	-20/180°
3	-80/90°	-50/90°
4	0/145°	0/110°
5	-90/85°	-90/85°
6	-15/30°	-15/30°
7	-70/80°	-30/80°

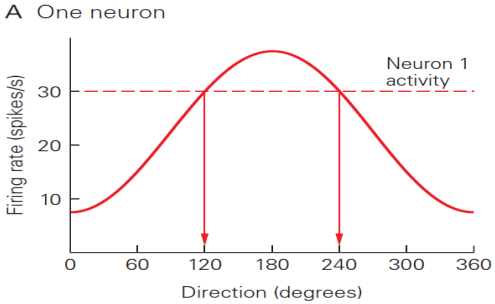


Figure: **Neuron Activity is related to Movement direction via cosine function known as "Tuning Curve".** If these neurons fire at 30 spikes per second, the intended movement direction could be either 120° or 240°

Decoding Arm Movement

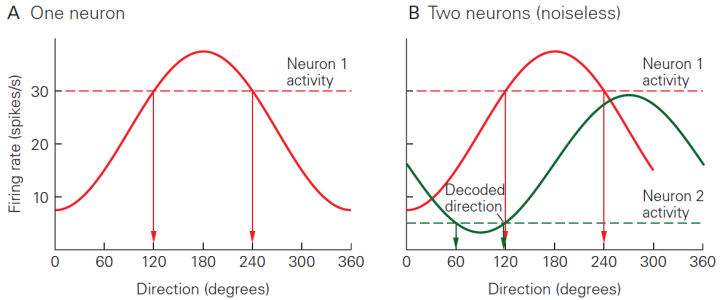


Figure: The only movement direction consistent with the activity of both neurons is120°.

"The More The Merrier"

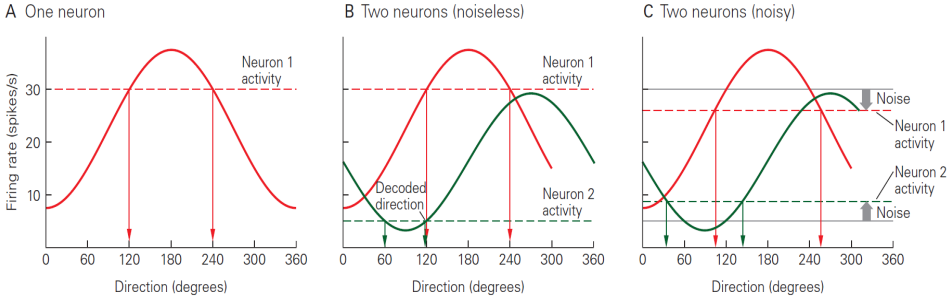
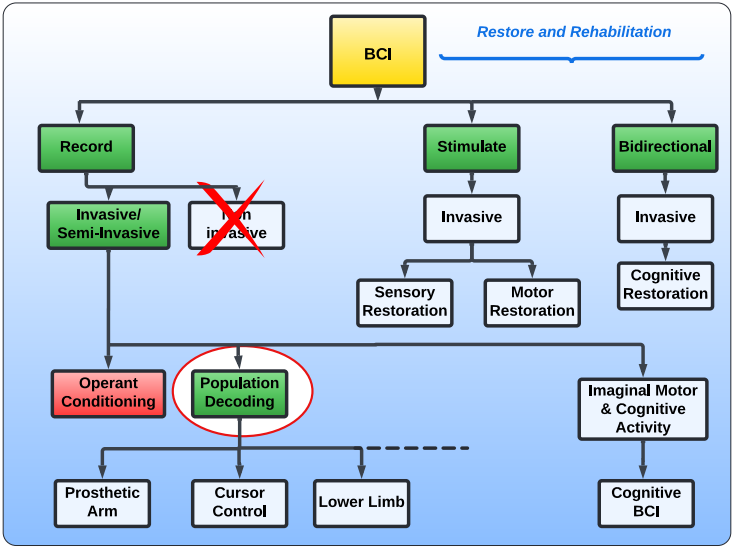
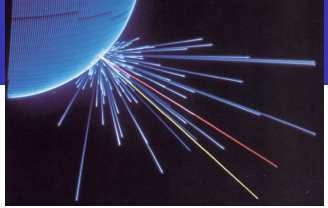


Figure: Because the neural activity is"noisy", it is usually not possible to conclusively determine the movement direction from the activity of two neurons. **The movement direction can be decoded even more accurately as the number of neurons increases.**

Probable Applications of BCI



II. Population Vector Decoding [2]



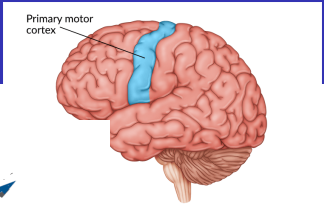
- Neurons preferred direction is direction of movement for which the neuron shows the highest level of activity (i.e., peak of curves) & is known as **"pushing vector"**
- Population vector algorithm (PVA) is one of the earliest decoding algorithms and most of the pioneering work is done in the same.

Population Vector Algorithm (PVA)

$$\hat{d} = \sum_i \mathbf{p}_i \left(\frac{r - r_0}{r_{\max}} \right)_i$$

- where, d is predicted direction of movement, p_i is preferred direction of movement
- r is each neuron's firing rate, r_0 is baseline firing rate & r_{max} is maximum average firing rate

Population Vector Algorithm



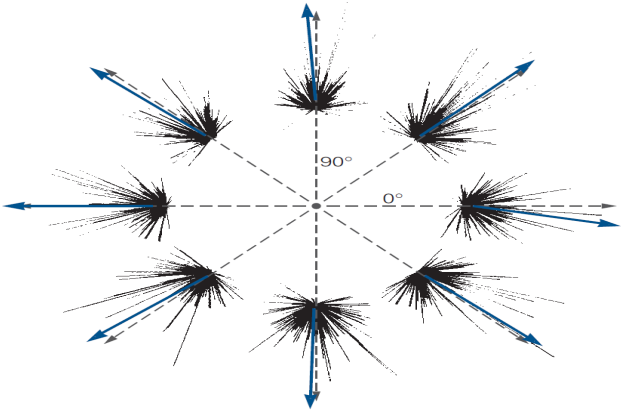


Figure: Comparison of motor cortex population vectors with actual arm movement directions Actual arm movements were along the 8 radially outward directions(dashed arrow) in multiples of 45°. A solid arrow indicates the sum of each group of vectors.(From Eric Kandel 1991)

Motor Cortex

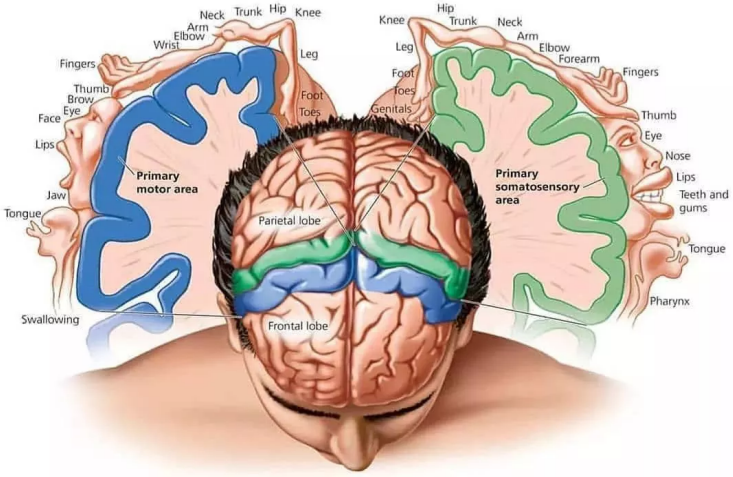
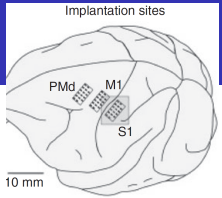


Figure: The primary motor and somatosensory regions https://medizzy.com/feed/32384308

Motor & Communication BMI



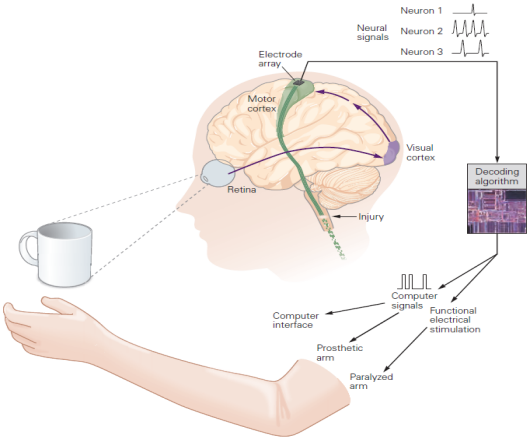


Figure: Electrode arrays implanted in brain regions such as **primary motor cortex (M1)**, **dorsol premotor (PMd)** and **ventral premotor (PMv)**, or **somatosensory cortex (S1)**.

Note: Closed-loop BCI is not to be confused with Bidirectional BCI

References

[1] Eberhard E. Fetz. "Operant Conditioning of Cortical Unit Activity". In: *Science* 163.3870 (Feb. 1969), pp. 955–958. ISSN: 00368075. DOI: 10.1126/SCIENCE.163.3870.955.

[2] A. P. Georgopoulos, R. E. Kettner, and A. B. Schwartz. "Primate motor cortex and free arm movements to visual targets in three-dimensional space. II. Coding of the direction of movement by a neuronal population". In: *The Journal of neuroscience : the official journal of the Society for Neuroscience* 8.8 (1988), pp. 2928–2937. ISSN: 0270-6474. DOI: 10.1523/JNEUROSCI.08-08-02928.1988.

Thank You!