

Behavioral Neuroscience:

The NeuroPsychological approach

Rony Paz

What is the NeuroPsychological approach?

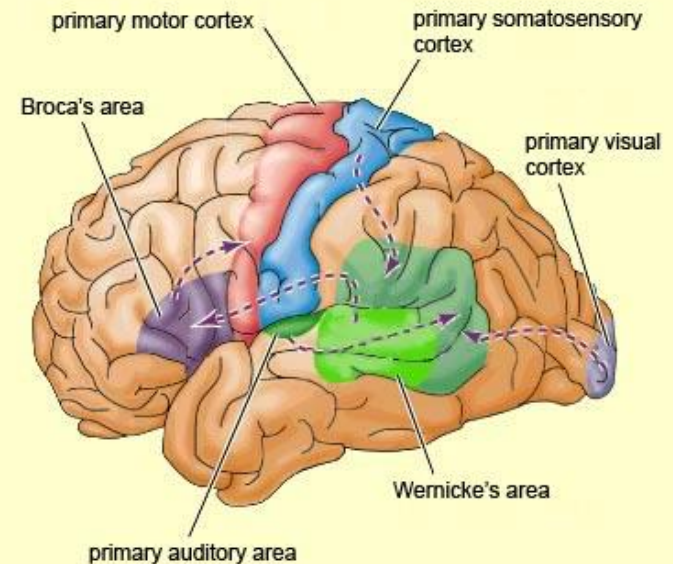
- **Neuropsychology** is the basic scientific discipline that studies the structure and function of the brain related to specific psychological processes and overt behaviors.
- The use of *artificial* well-controlled tasks.
- Why?
 - Well-controlled
 - Pre-planned quantification
 - We observed something, now lets do it properly
 - Target Human behavior
- For example:
 - Sensation and perception
 - **Control of movement**
 - **Learning** and memory
 - Decision making
 - Emotions
 - Consciousness

Active and Passive approaches

- The active approach manipulates the brain and observes behavior.
 - Stimulation
 - Lesions
 - Pharmacological intervention
 - Genetic manipulations
- The passive approach manipulates behavior and observes the brain.
 - Trained behaviors
 - Observing patients

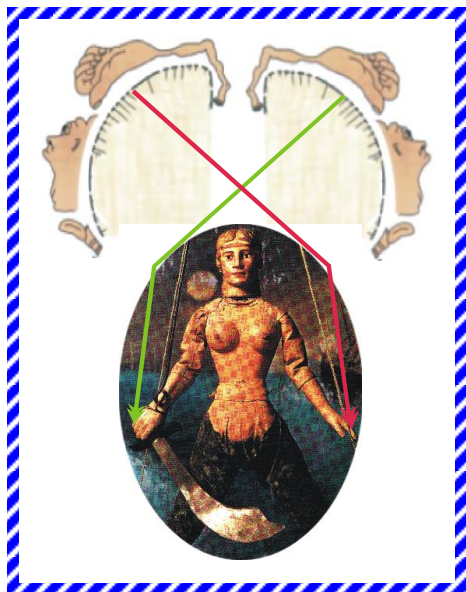
Speech and language

- Paul Broca (French physician, 1824-1880), discovered, by post-mortem operations, that a brain area in the **left hemisphere** causes deficits in speech production (“Tan”, Syphilis).
- Karl Wernicke (German physician, 1848-1905), discovered another brain area that causes deficits in language comprehension.

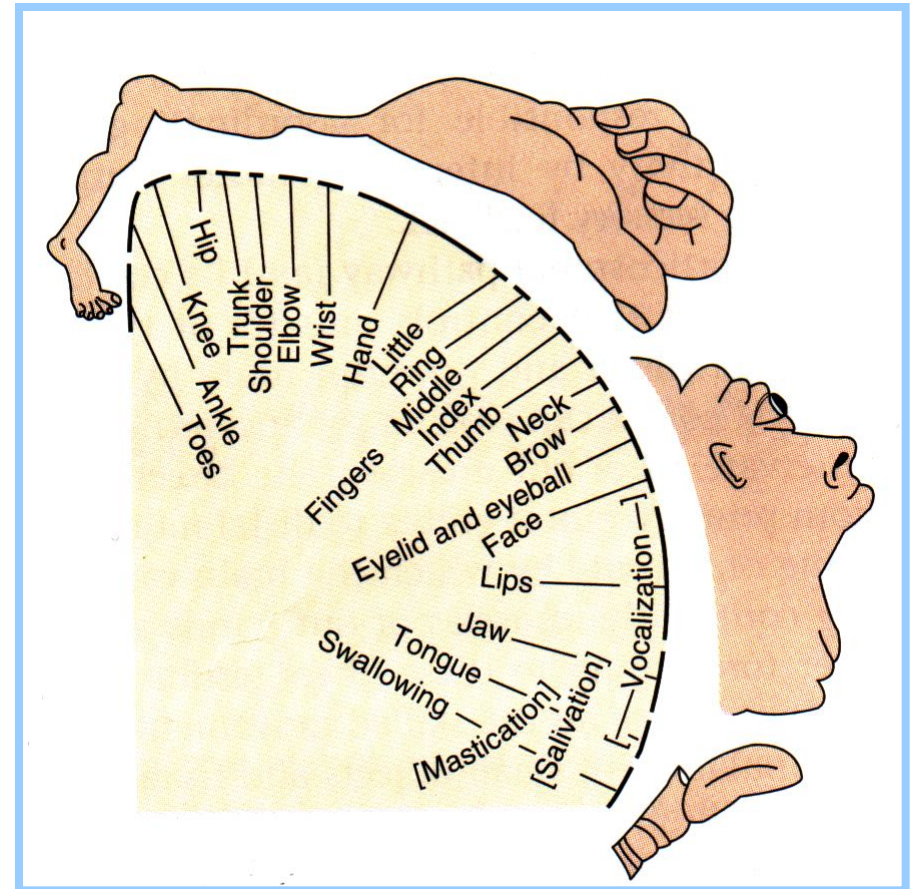
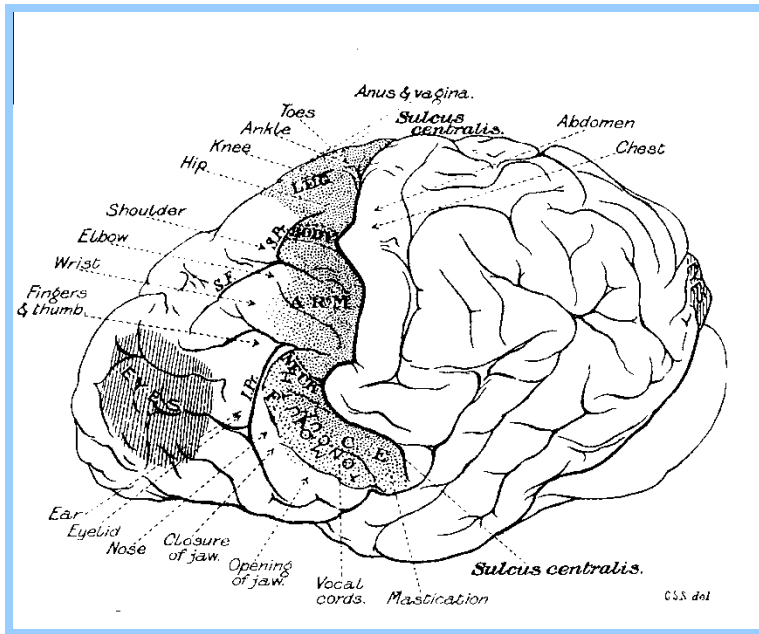


Lateralization

- Wilder G. Penfield, the “*greatest living Canadian*”, a Neurosurgeon.
- Together with Herbert Jasper, treated epileptic patients by destroying neurons.
- Before that, he applied stimulation to different brain areas to probe the epileptic loci.
- One main finding was that each hemisphere controls (efferent nerves) and gets sensory inputs (afferent nerves) from the ***contralateral*** side of the body.
- How is it linked to language?

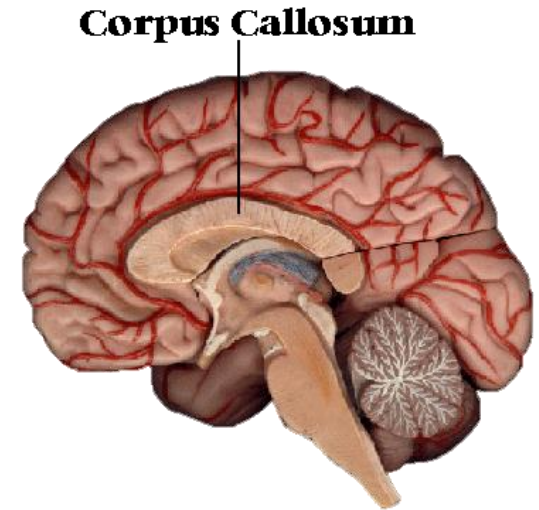
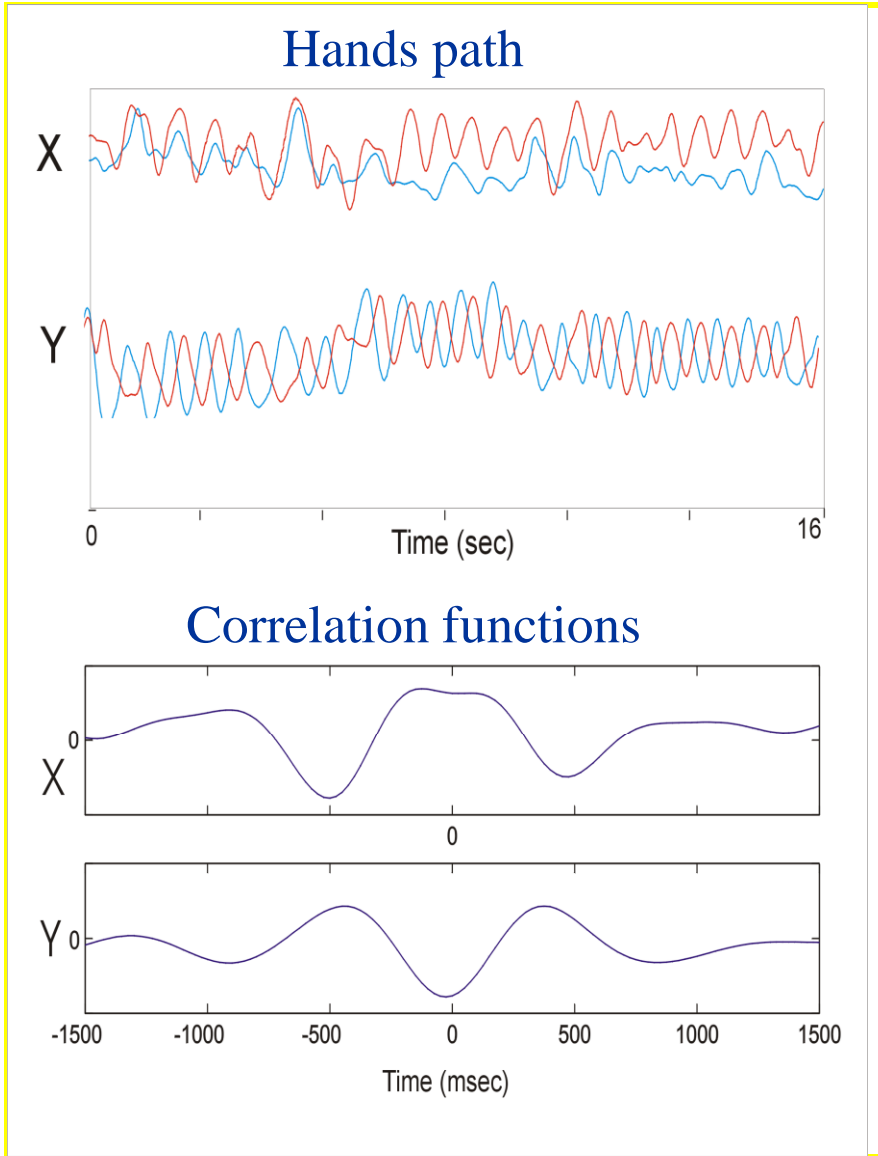


Somatotopic representation: Homunculus?

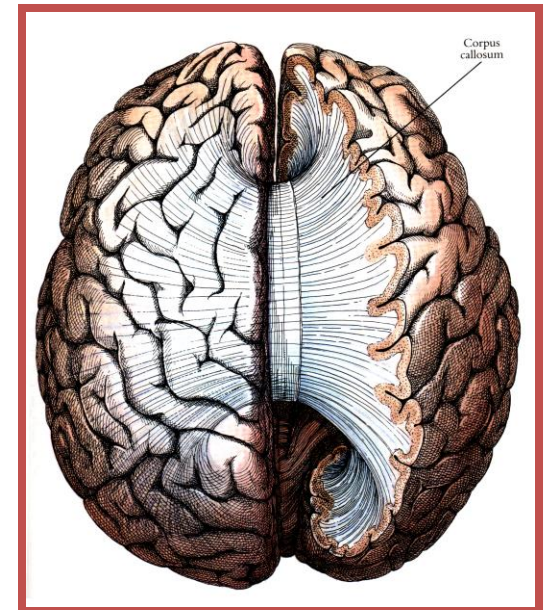


- A mosaic broadly overlapping muscle representations, with each part repeated

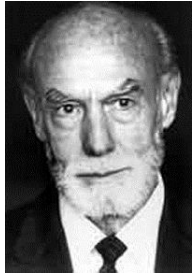
Natural movements are coupled



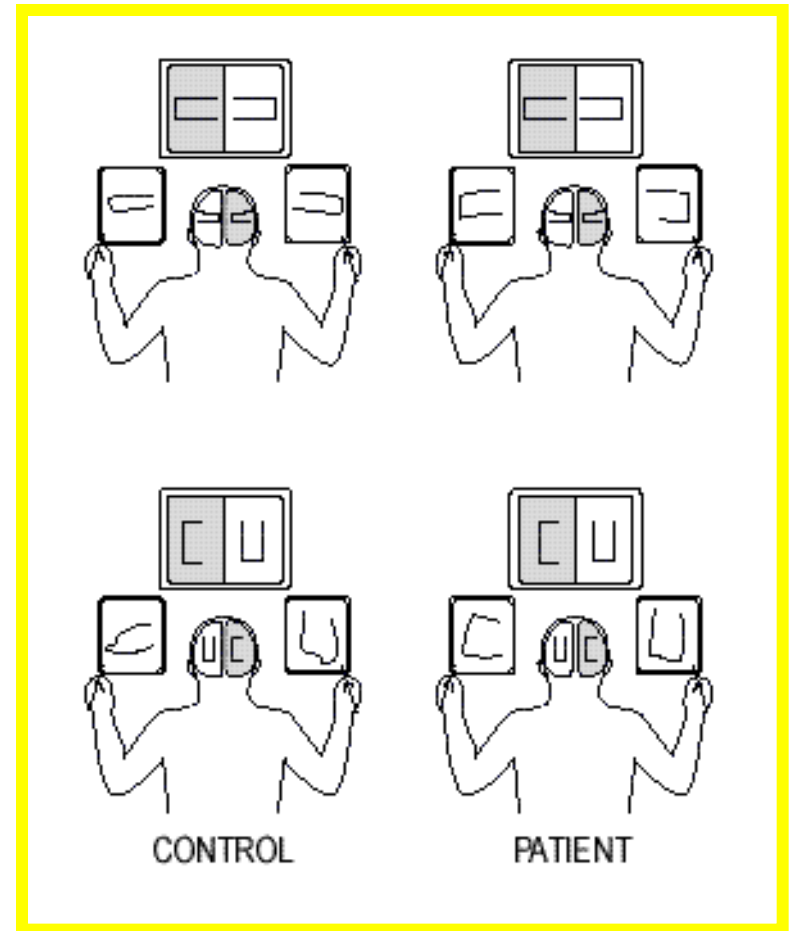
Coupled oscillators



Decoupling can help, sometimes



- Roger W. Sperry (1913-94, Nobel), **Athlete scholarship**, died from ALS.
- & Michael S. Gazzaniga
- Observed split-brain patients (removed corpus-callosum) and found that each hemisphere is a conscious system in its own right, even in conflicting mental processes.
- Object in the left visual field, will not be vocally named, but can be handled with left hand.
- Reasoning and calculation with the left hemisphere



Voluntary movement: Reaching

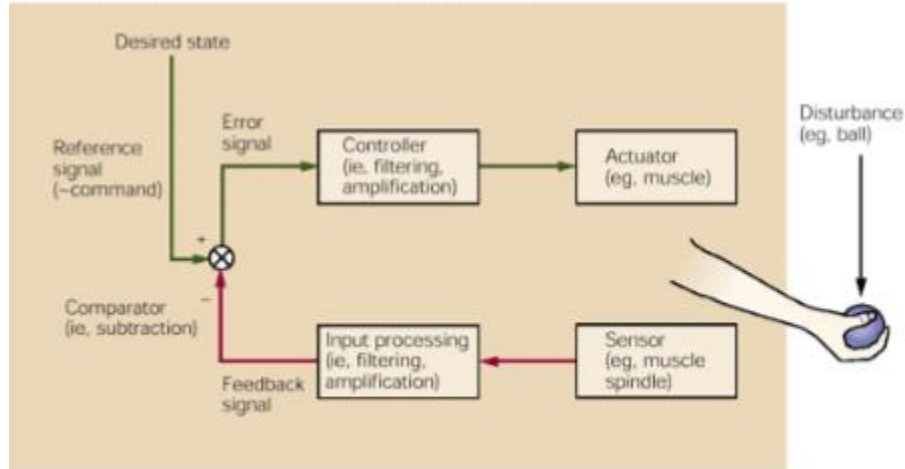
Why reaching?

- Daily
- Fast movements (120ms)
- Specific to mammals and mainly to primates
- A crucial advantage of our ancestors
- Easy to study in a lab

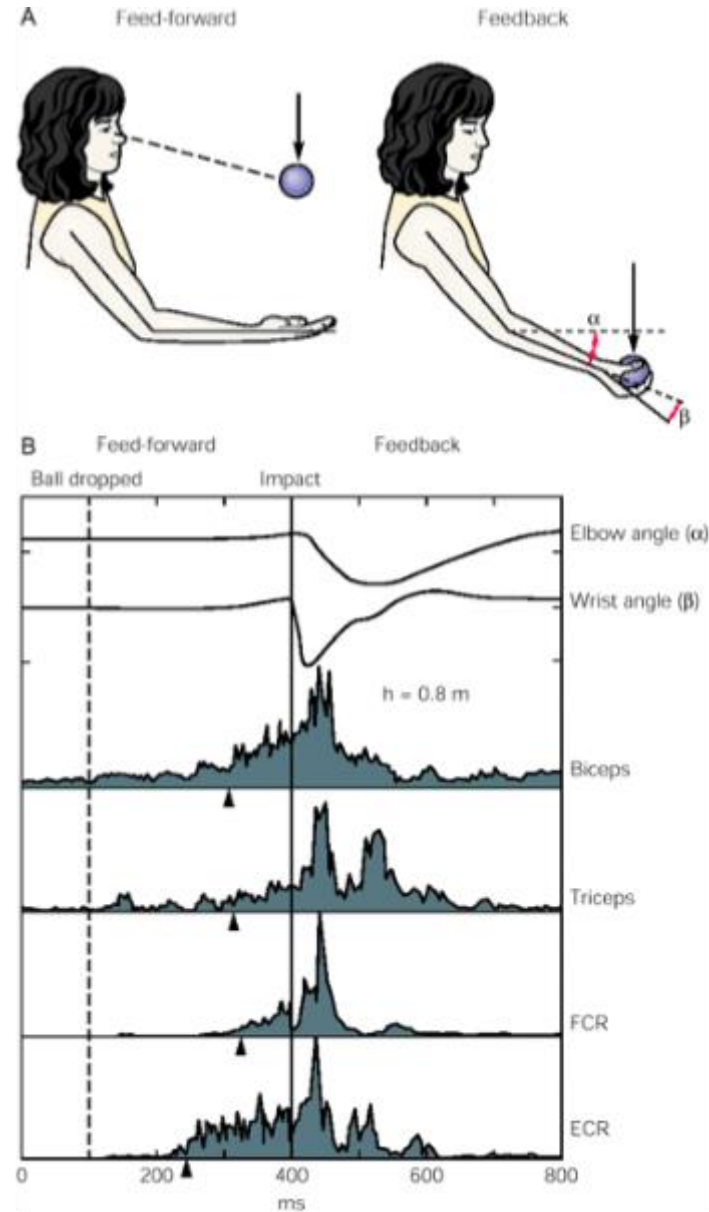
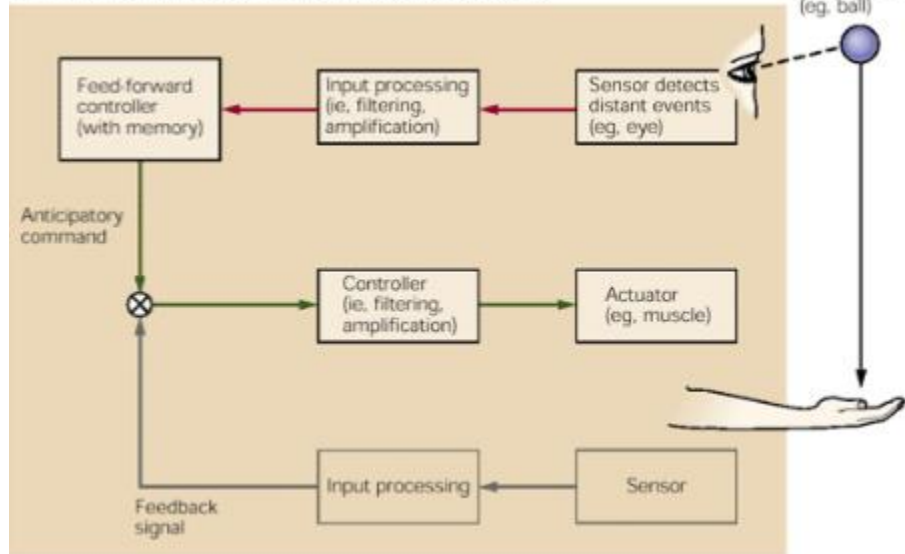


Feedforward and feedback control

A Feedback control: command specifies desired state



B Feed-forward control: command specifies response



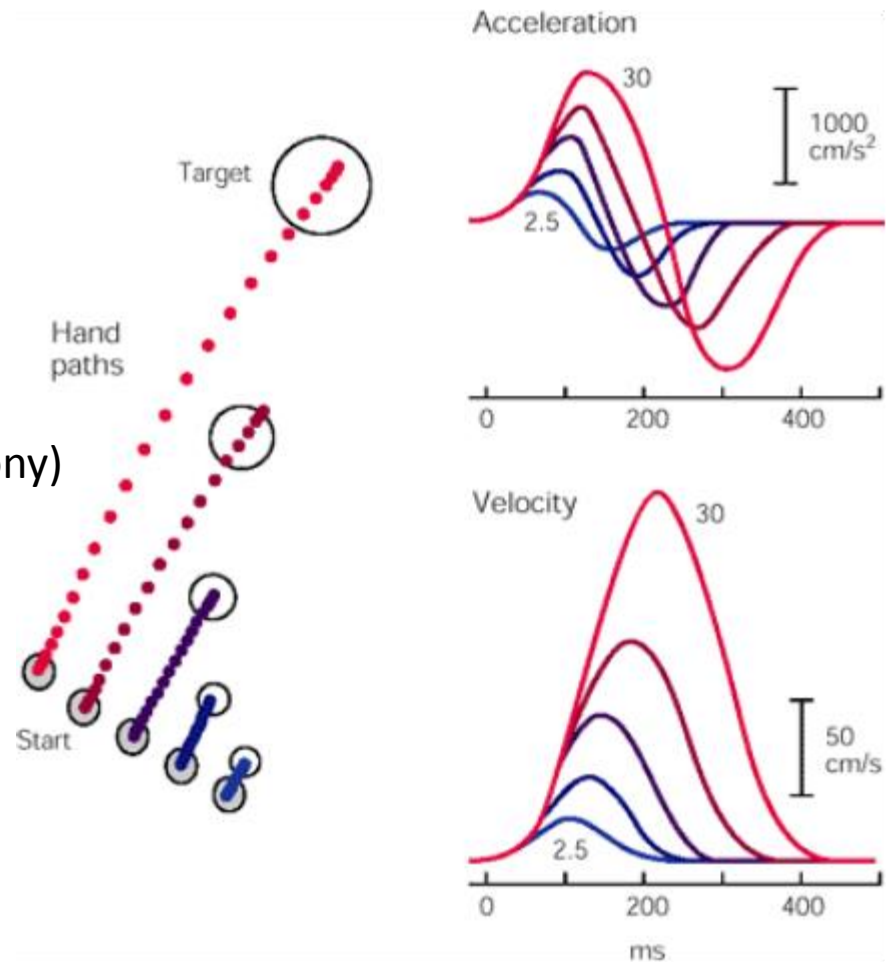
The motor program- trajectories and kinematics

Straight with bell-shaped velocity profile

Is there online visual feedback?

No - scaling of acceleration and speed

Invariant time for each components (Isochrony)

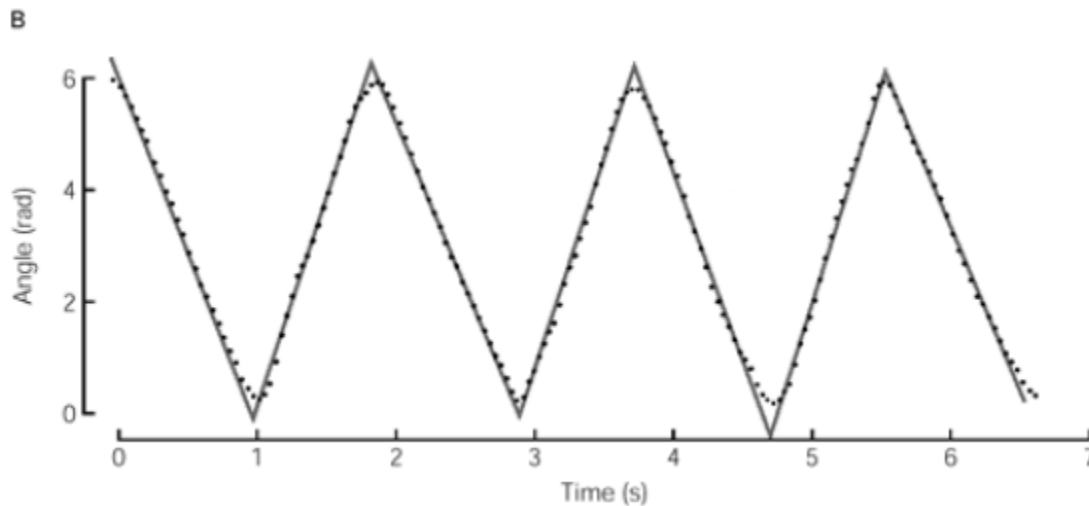
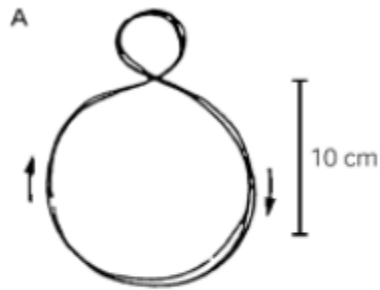


Building blocks – segmentation into primitives

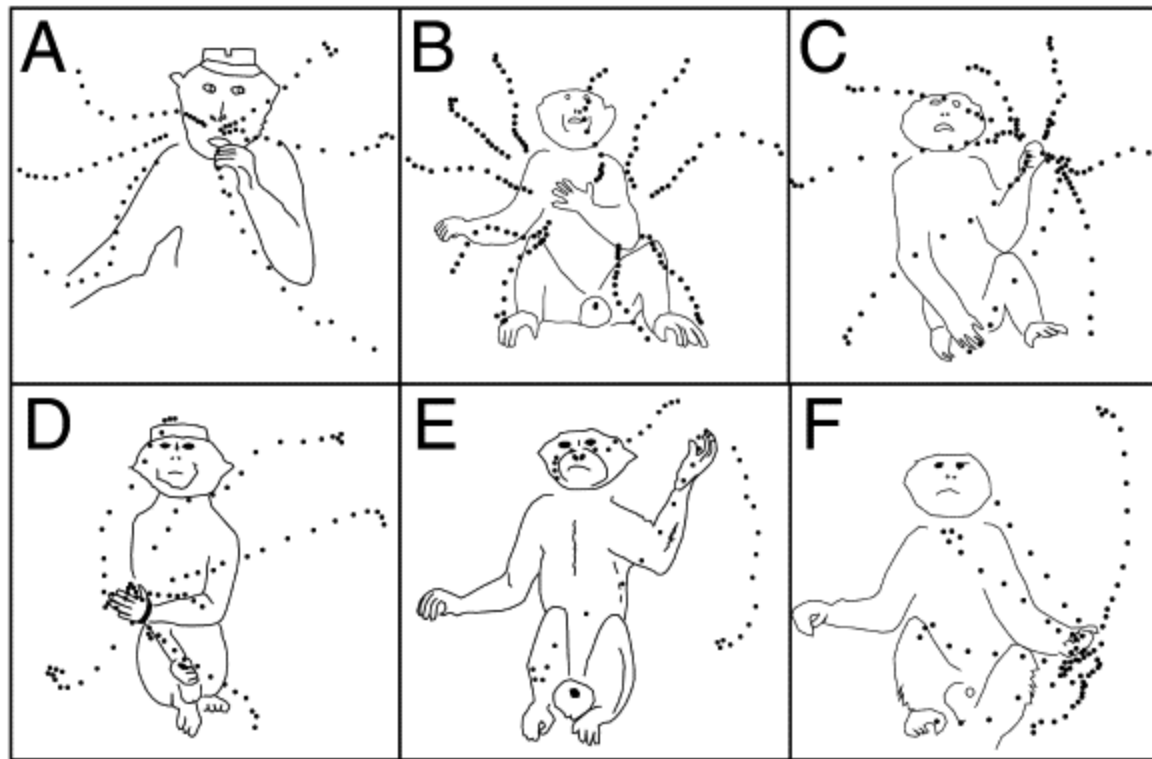
Isogony (equal angles)

Isochrony (duration independent of length)

$2/3$ power law: speed as a function of curvature



Stable behavioral gestures



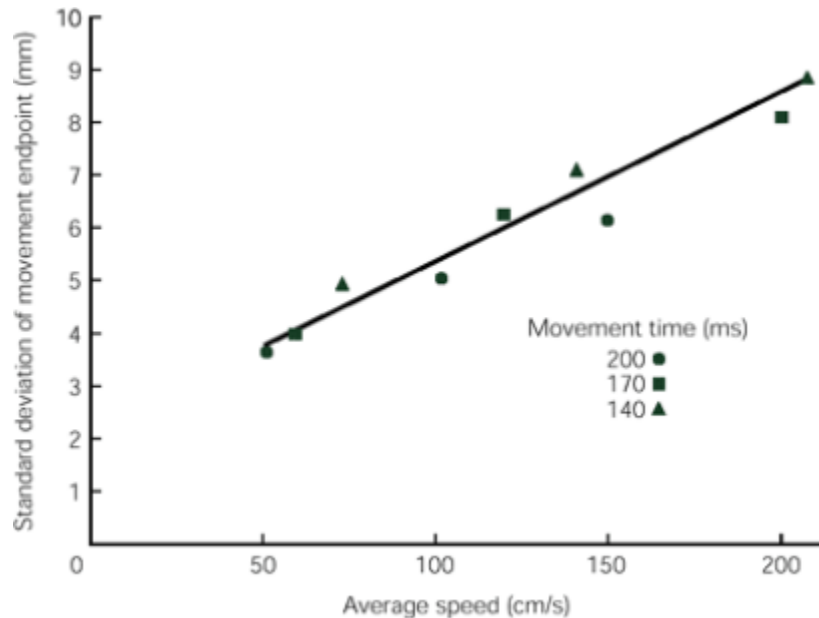
Motor programs and Invariants

Motor equivalence
(Donald Hebb,
1904-85)

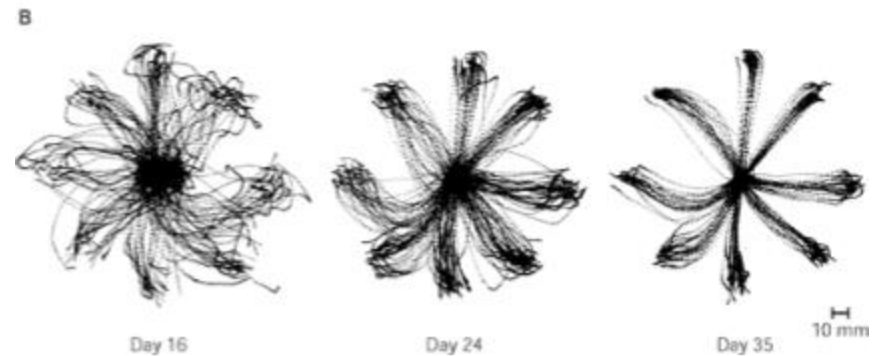
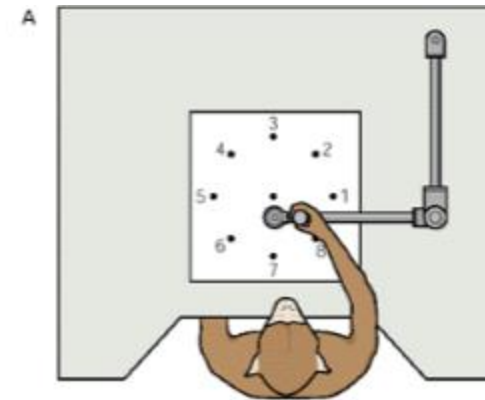


- A Able was I ere I saw Elba
- B Able was I ere I saw Elba
- C Able was I ere I saw Elba
- D Able was I ere I saw Elba
- E Able was I ere I saw Elba

Speed – accuracy tradeoff

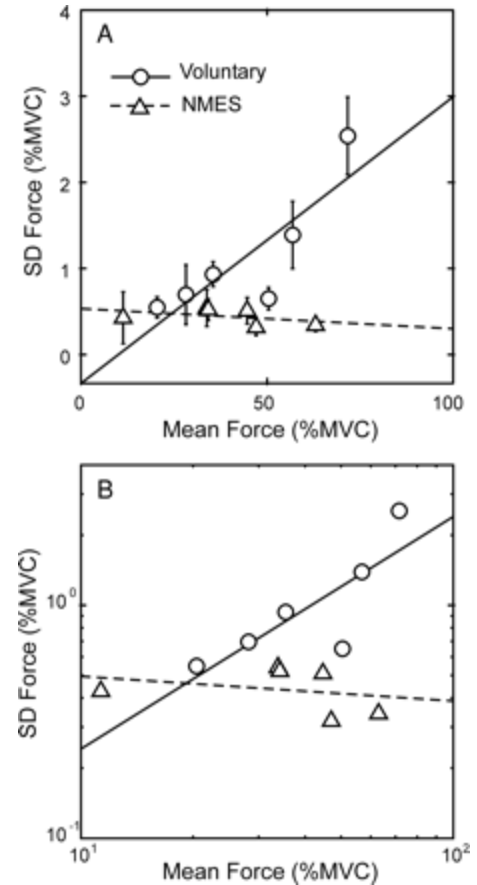
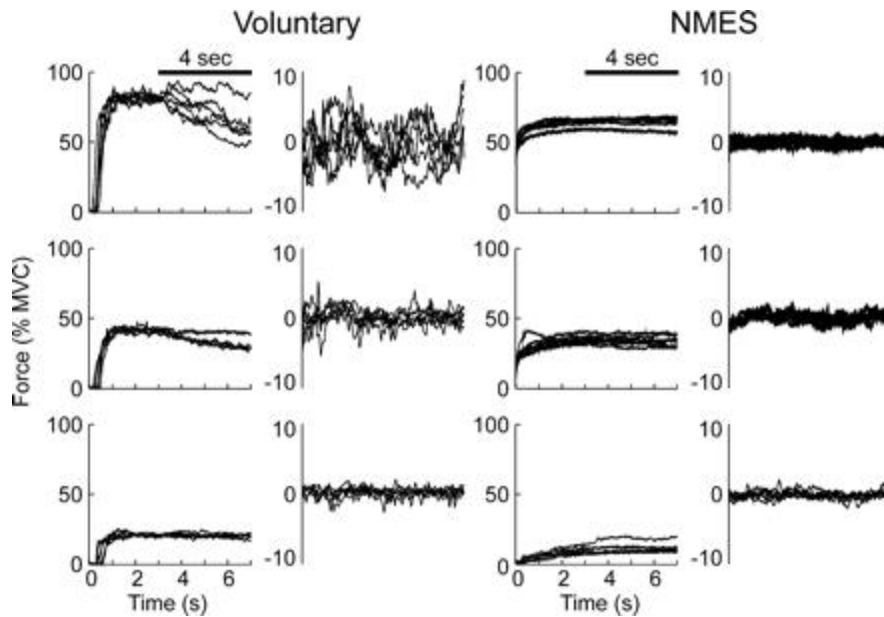


- Less time for feedback corrections?
- No, even without sensory feedback
- Why then?



Variability of the components
But which?

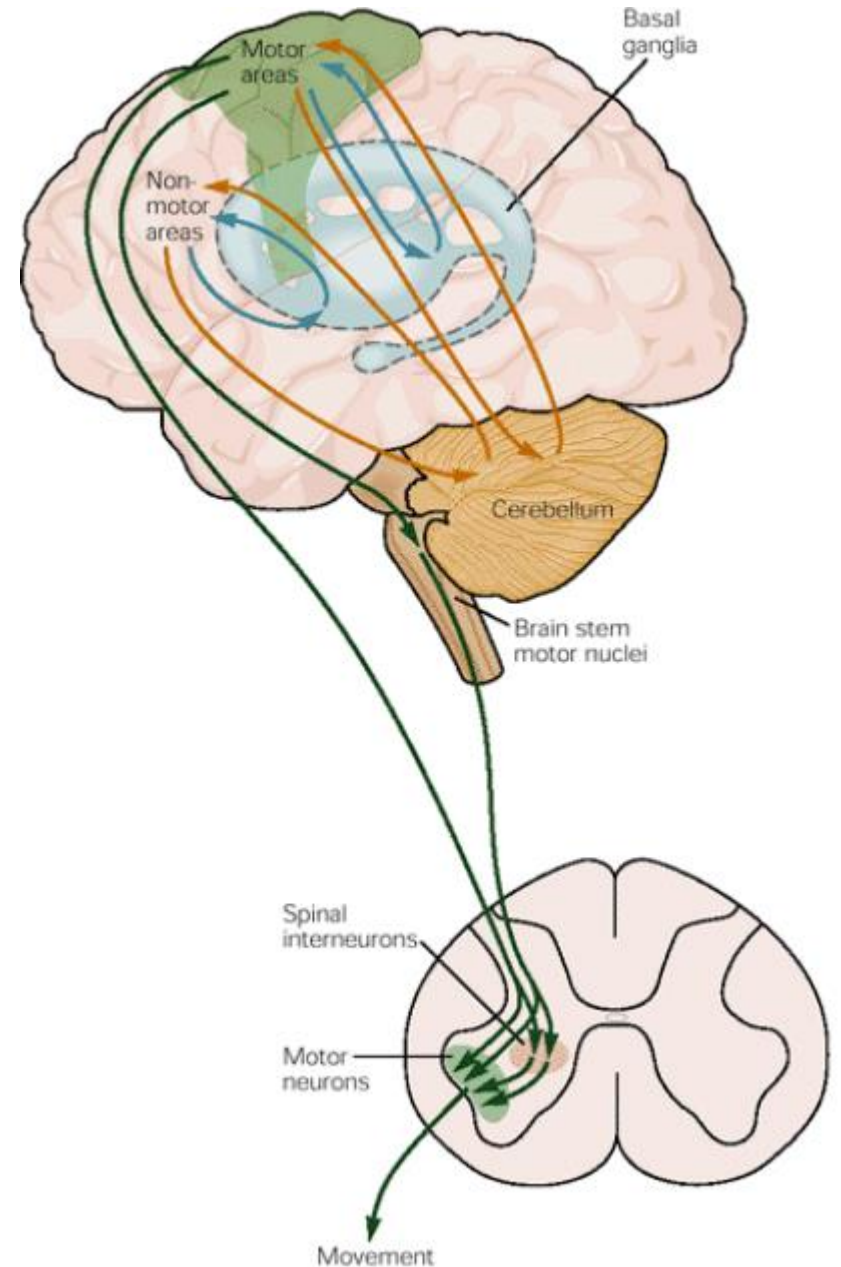
Neurons are noisy channels, not muscles



Components of the motor system

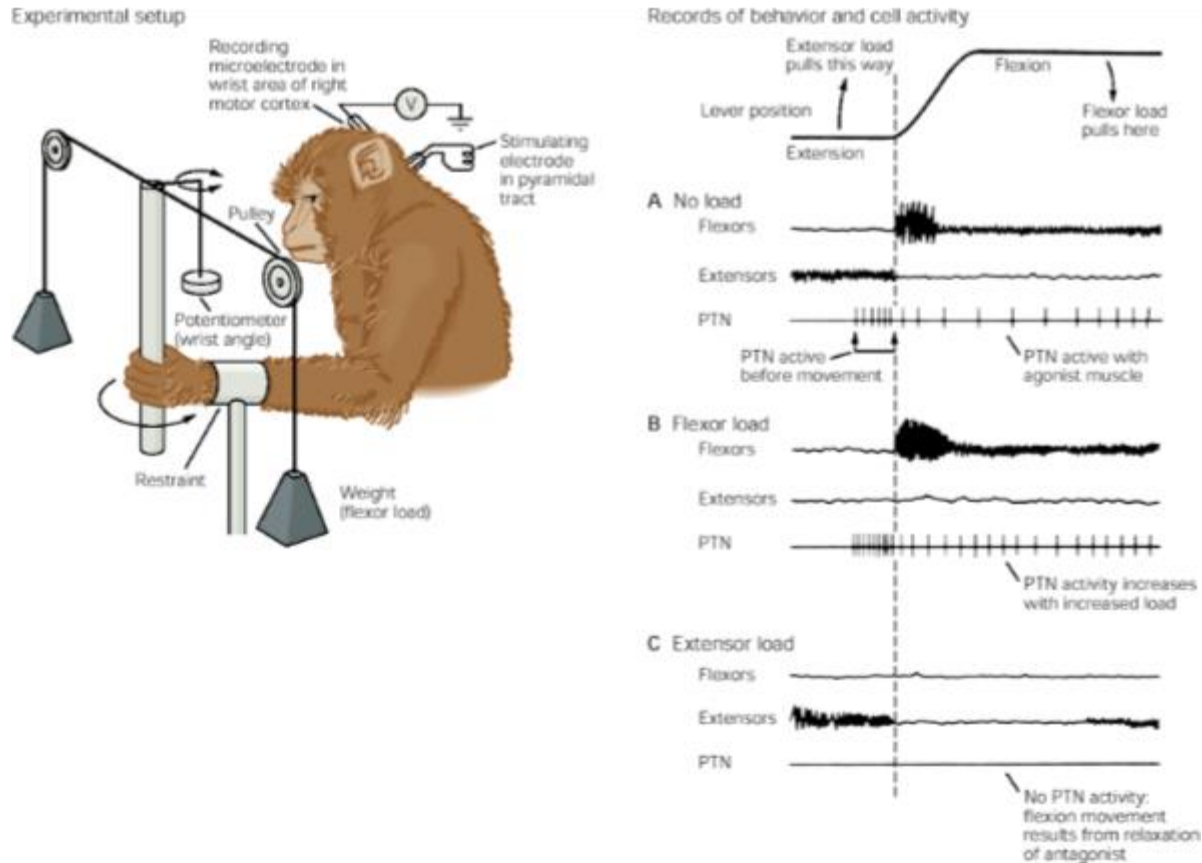
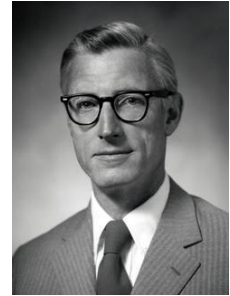
Hierarchical organization

- Cortex
- Cerebellum
- Basal-ganglia
- Brain stem
- Spinal cord
- Muscles



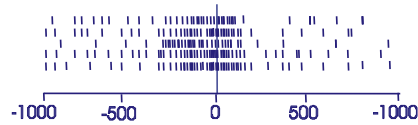
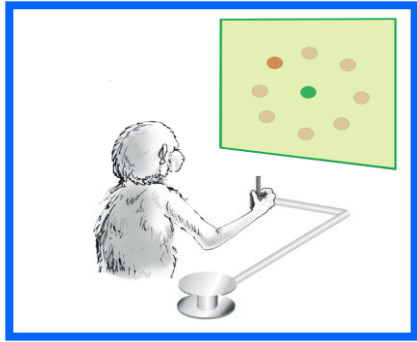
Coding of force

Edward V. Evarts (1926-85), pioneered single-unit recordings during behavior

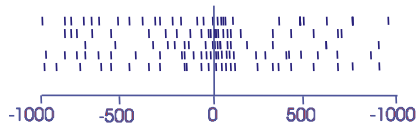
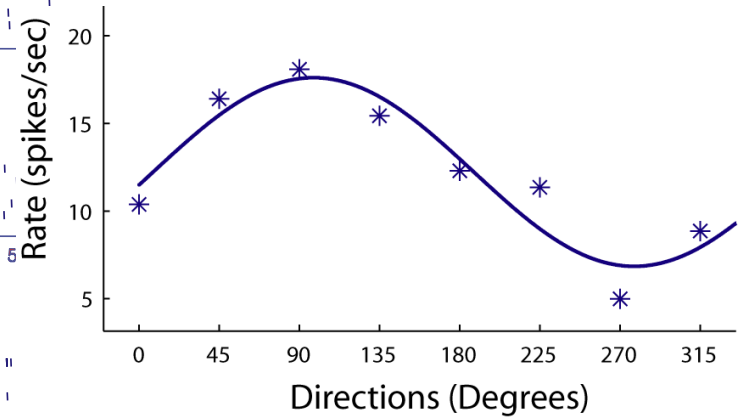
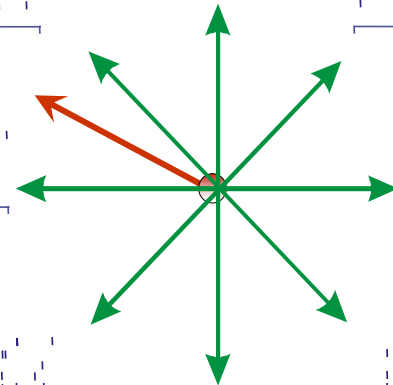
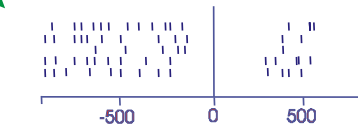
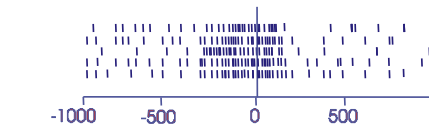
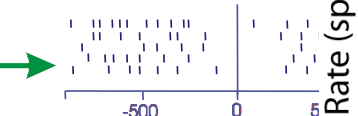
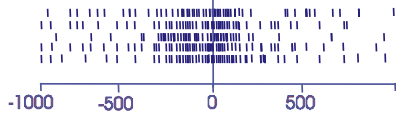
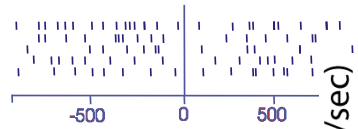
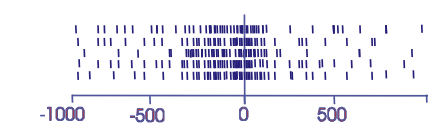


Coding of direction

Apostolos Georgopoulos , 1982



$$fr_i(\overline{MD}) \approx b_i + k_i \cos(\theta_i - \theta_{MD})$$

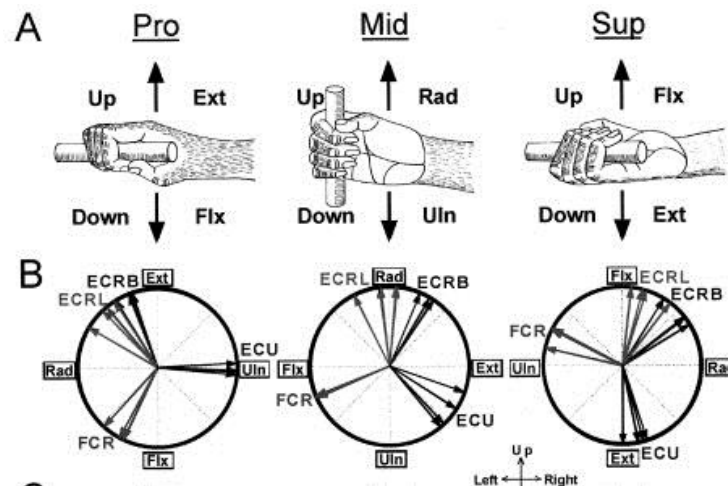


So, does M1 code for kinematics or dynamics?

Kinematic transformation: to transform a target position into a command to the skeletal system to move the hand i.e. to convert between coordinate systems;

Dynamic transformation: relate motor commands to the motion of the system; in the reaching task here considered, the forces applied changed the system without changing the kinematics.

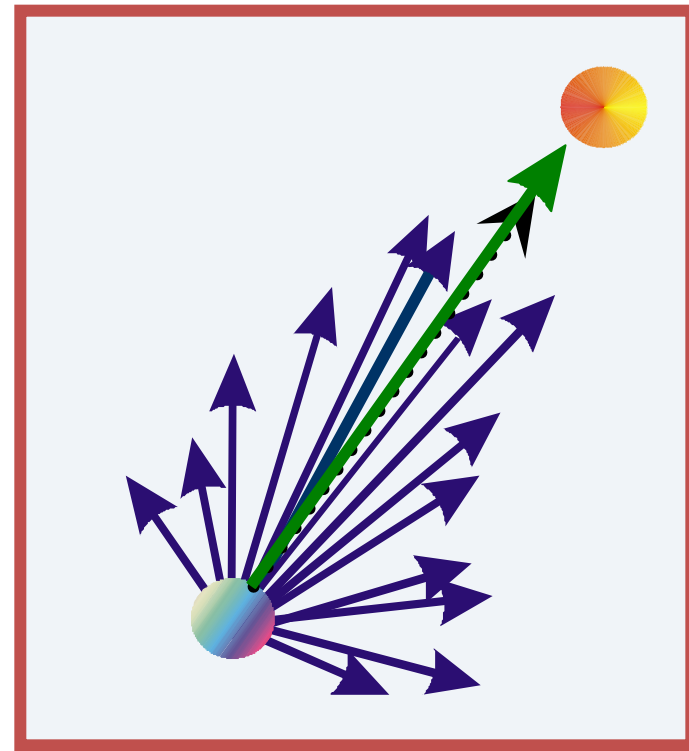
How can we test this?



From neurons to something useful: the population vector

If:

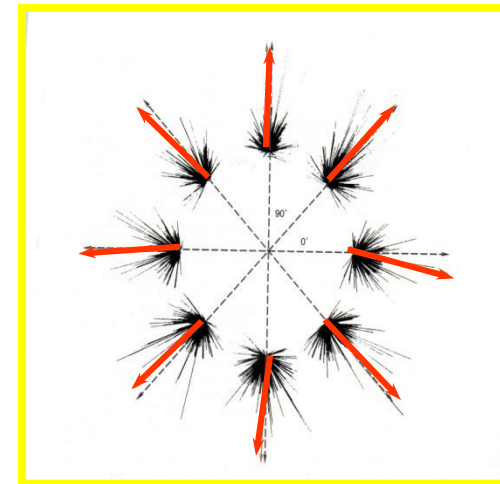
- Many cells “care” about direction of movement
- Cells are tuned “cosine like” with a preferred direction
- Preferred directions are uniformly distributed



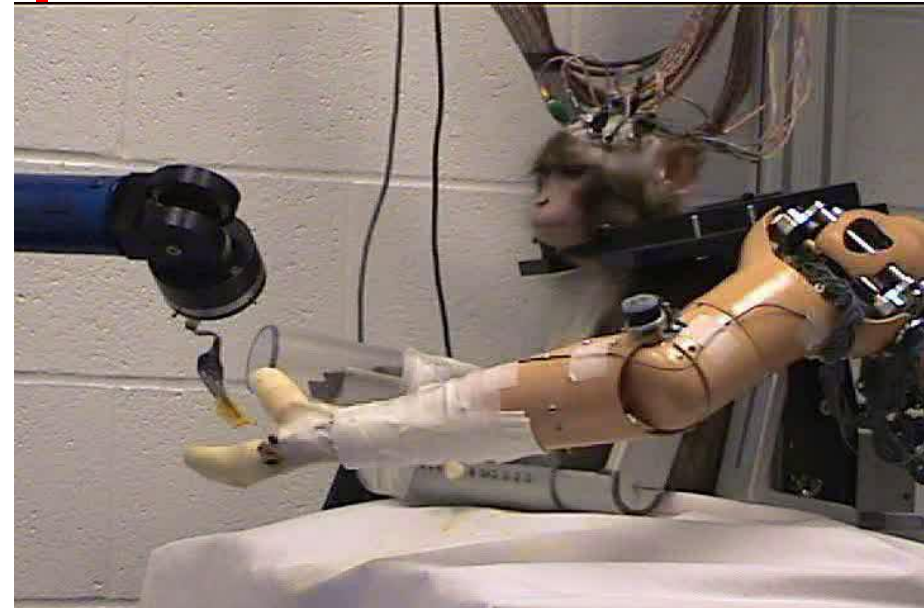
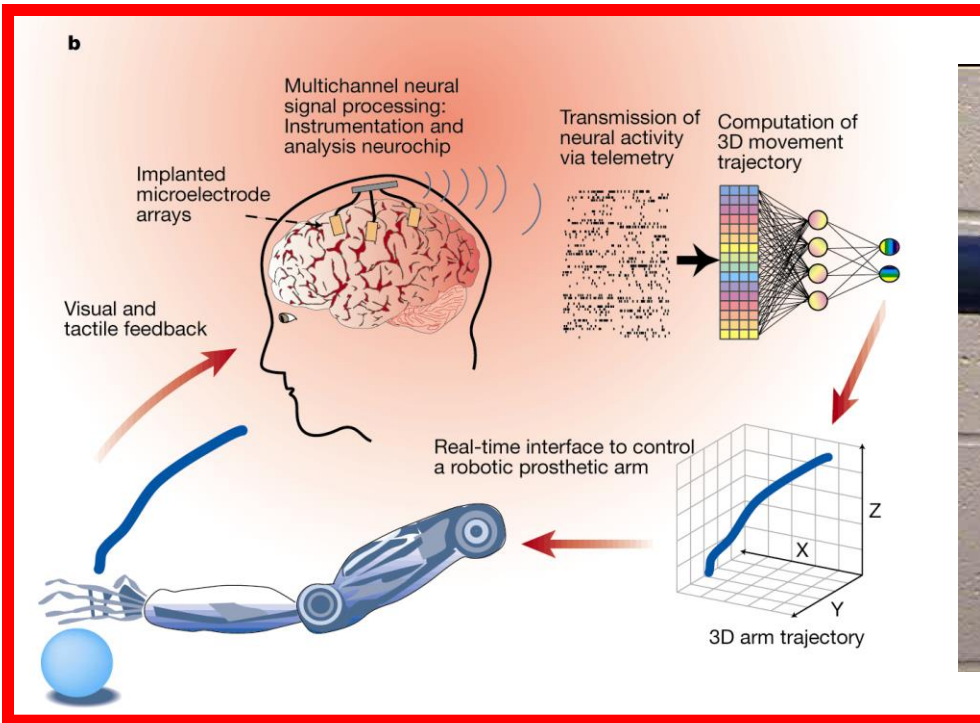
$$\overline{MD} \approx PV = \sum_{i=1}^N w_i \overline{C}_i$$

Then:

The actual movement can be estimated in Cartesian coordinates by a linear combination of weighting the preferred directions with the actual firing rate

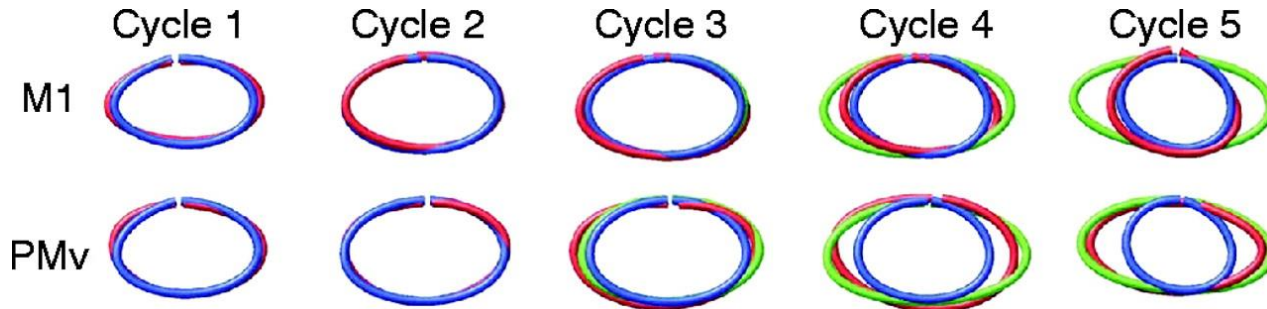
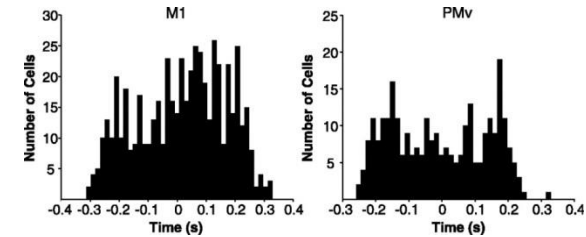
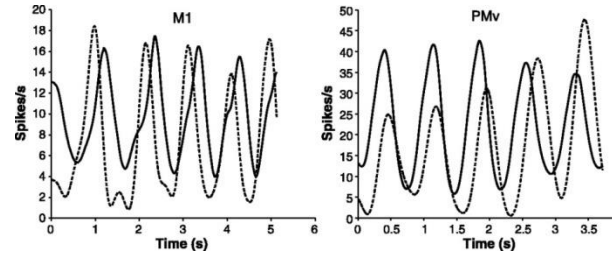


Brain-machine interfaces: Neural prostheses



Andy Schwartz

Representation of plan and execution



Illusion task trajectories. Top row is five cycles from M1 units. Bottom row is from the PMv. The hand trajectory is blue, cursor trajectory is green, and neural trajectory is red. Each displayed trajectory is the mean across five repetitions