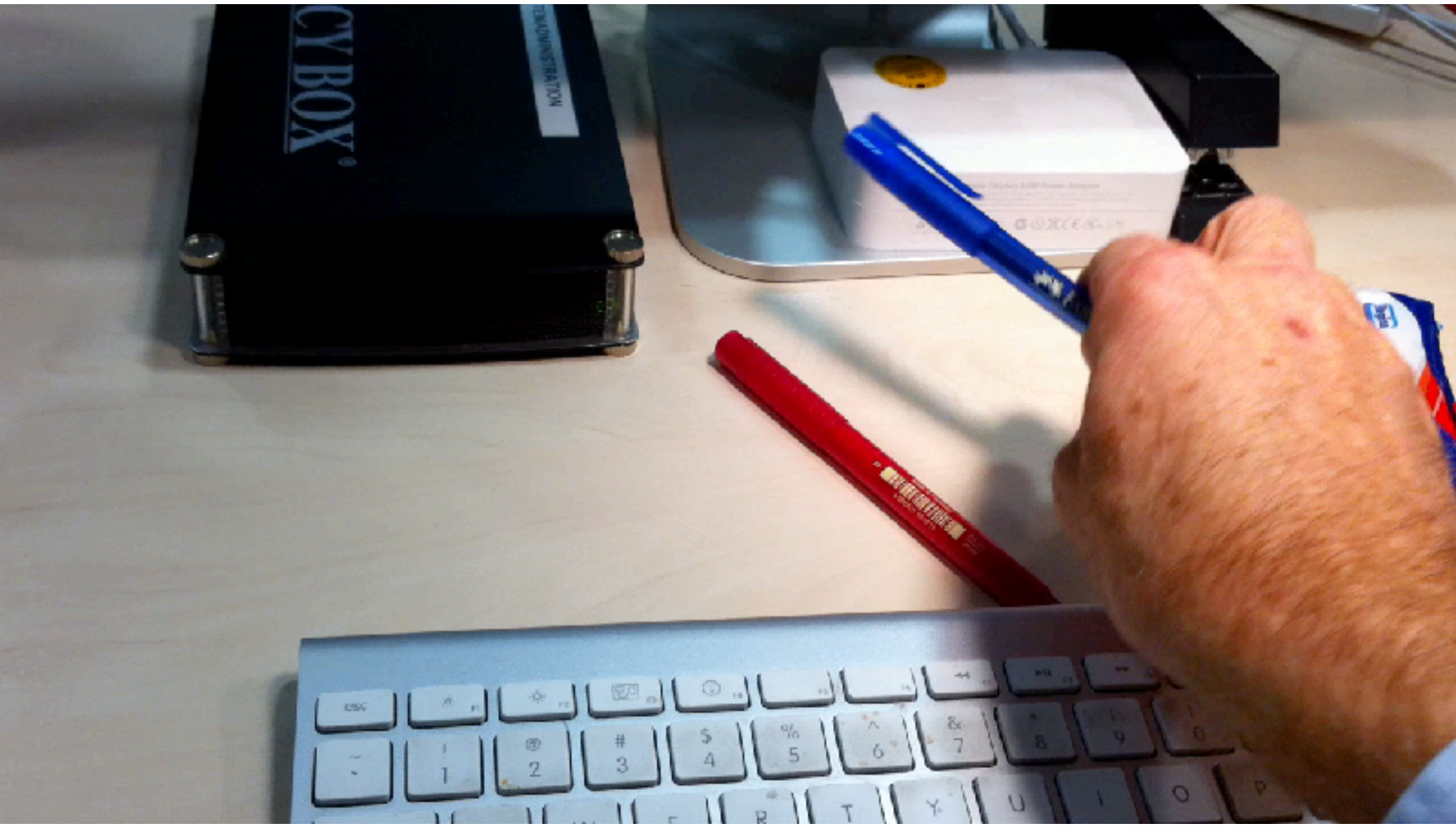
Autonomous Robotics: Action, Perception and Cognition: Analogies with nervous systems

Gregor Schöner
Institute for Neural Computation
Theory of Cognitive Systems
gregor.schoener@rub.de

Human movement



Human movement

- “homo faber”: we are the skillful species who make things
- using fluent sequences of movement, linked on-line to sensory information
- multiple motor skills which can be adapted and be performed concurrently
- excellent fast scene perception
- fine (compliant) manipulation skills

Human movement generation

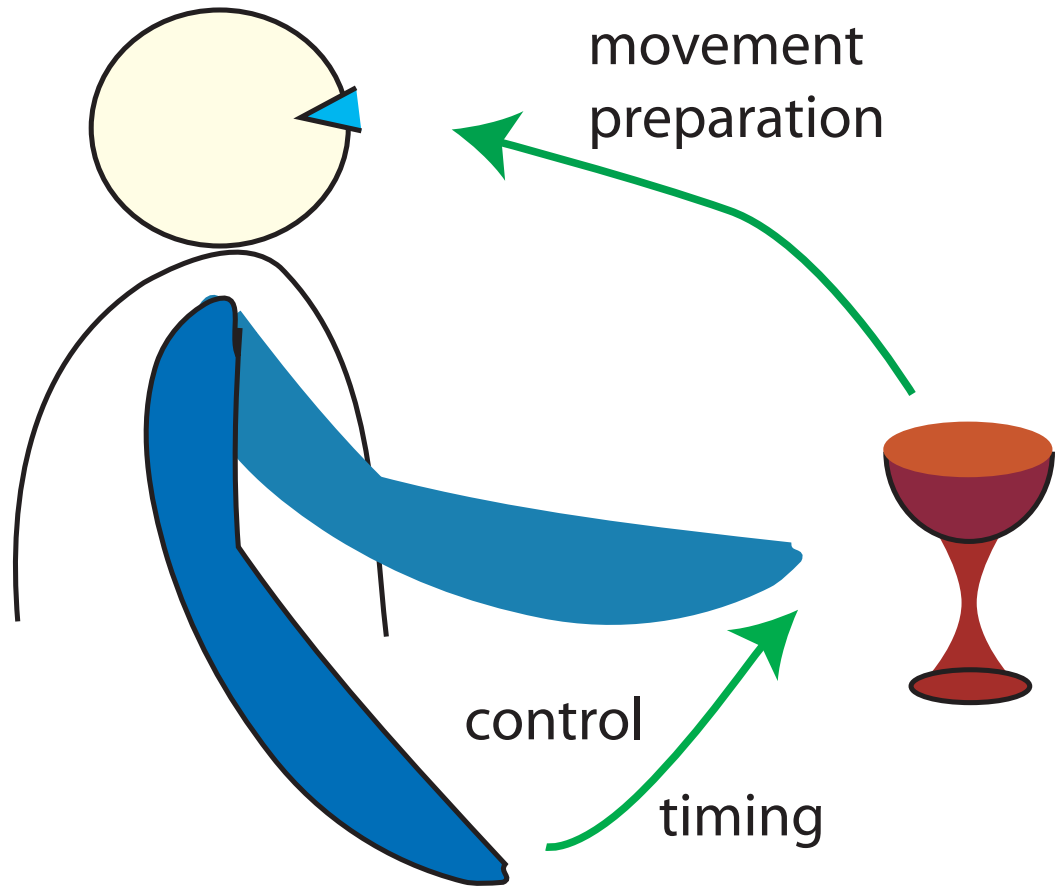
- posture/balance
  - involuntary... automatic
- locomotion
- navigating: moving through space
  - stepping
- rhythmic (dance, music)
  - voluntary
- whole body skills, sports
- reach, grasp, manipulate
  - object oriented
- speech articulatory movement

What is “motor control”?

- ... the neural processes underlying movement generation of organisms…
- “movement generation”
- [neurally controlled movement…
  - not the tropisms and transport phenomena of biological mobility in plants, amoebae, etc.
  - not falling from a tower ;=)

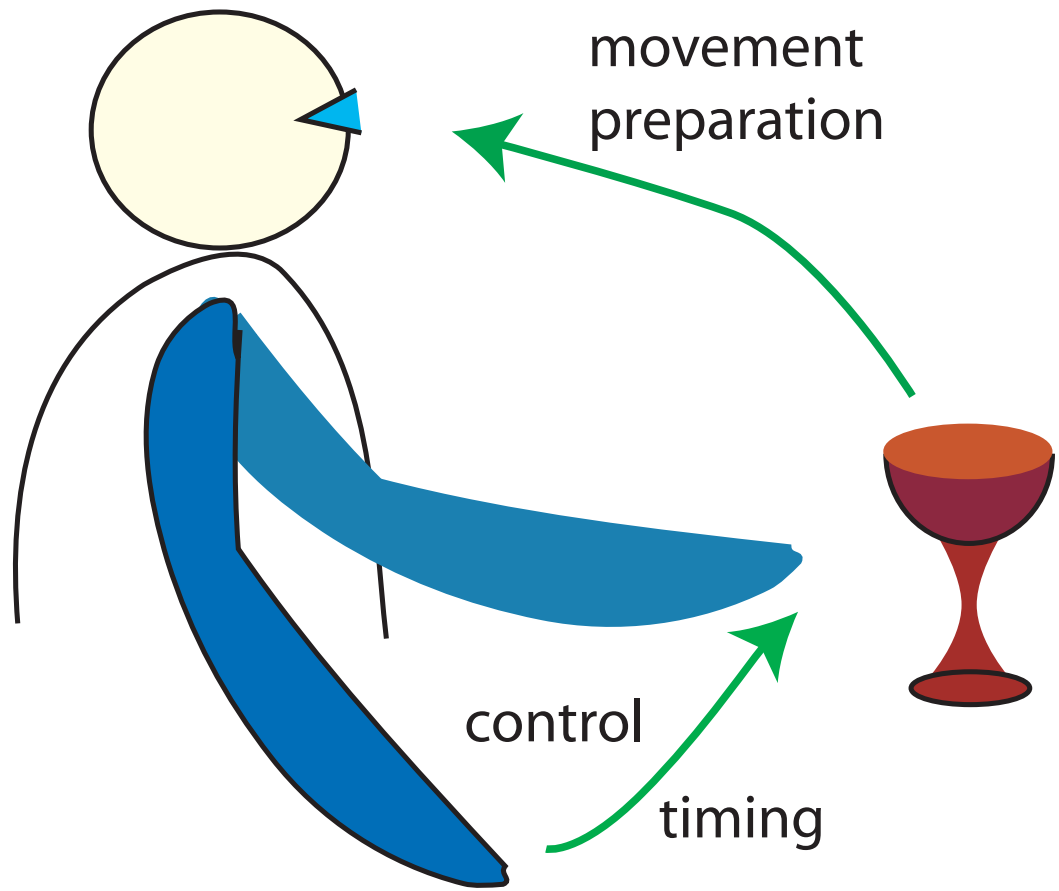
What is entailed in generating an object-oriented movement?

- scene and object perception
- movement preparation
- movement initiation and termination
- movement timing and coordination
- control
- degree of freedom problem



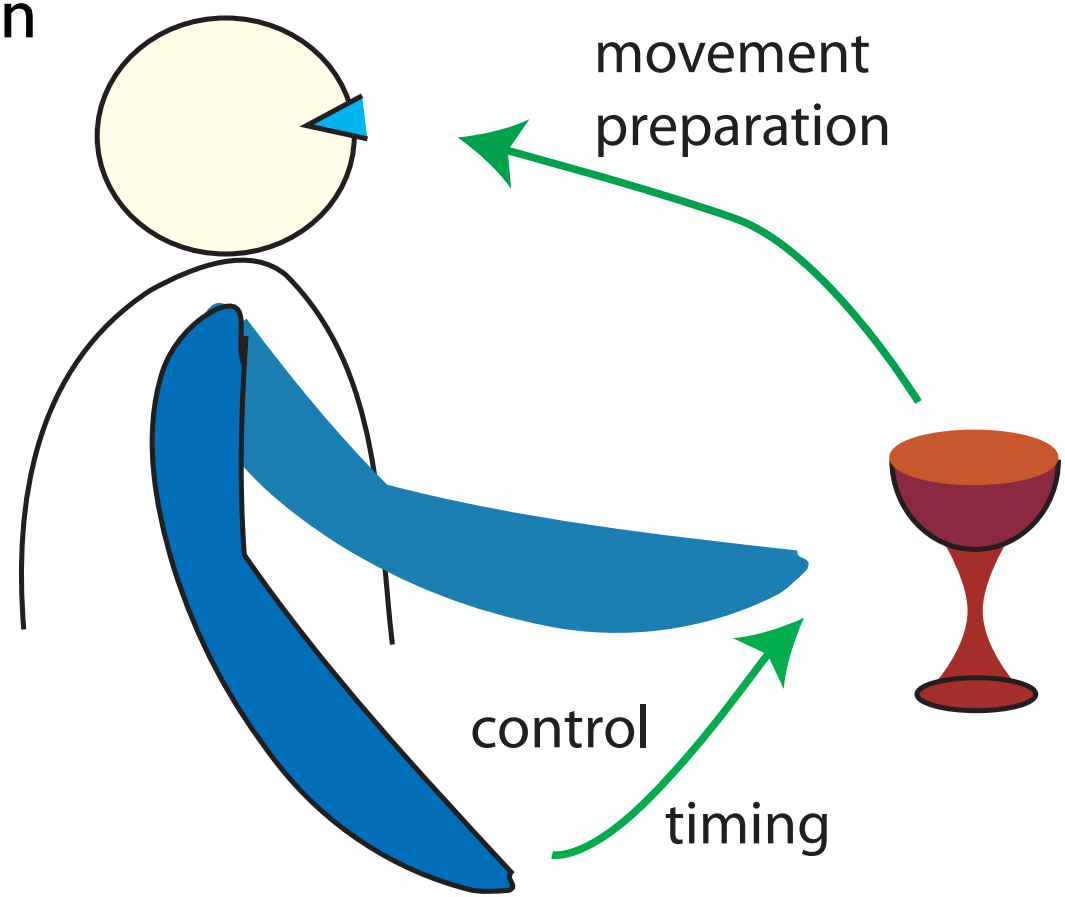
What is entailed in generating an object-oriented movement?

- sequential organization of movement: behavioral organization
- goals, motivation, problem solving
- memory, spatial maps
- adaptation
- skill learning



What is entailed in generating an object-oriented movement?

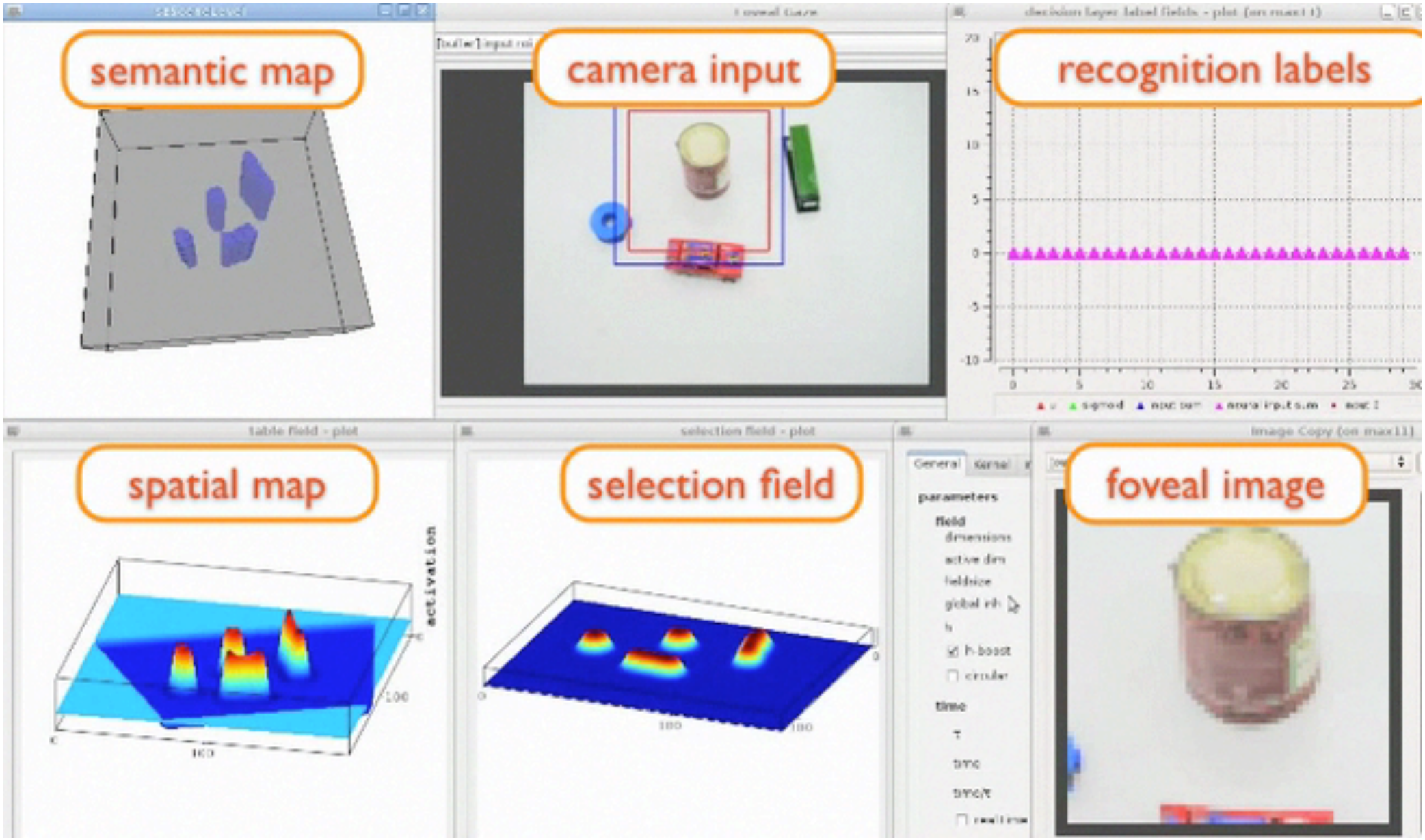
- => spans perception, cognition and control
- … difficult to isolate any individual process, which is why movement is hard to study
- critical to understand integration



Neural computation: learning from analogies with the human nervous system

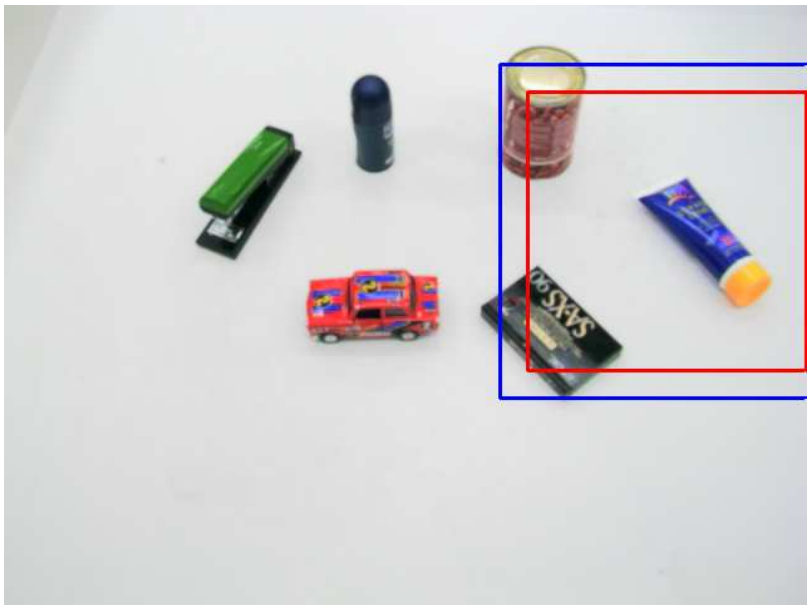
(1) visual cognition

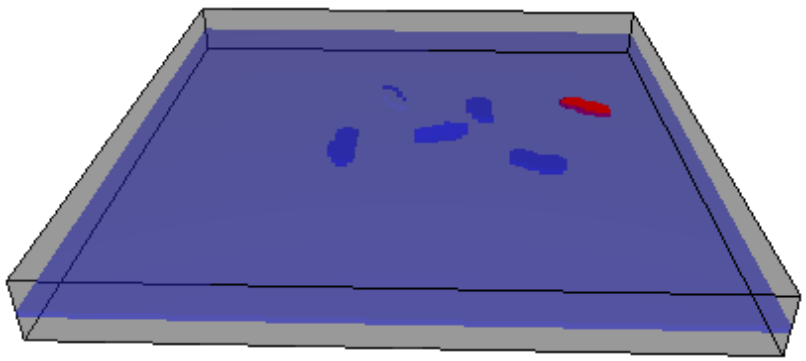
- feature maps, within neural activation controls the attentional foreground
- and that are continuously linked to sensory input …
- sequences of attentional selection decisions generate scene representations

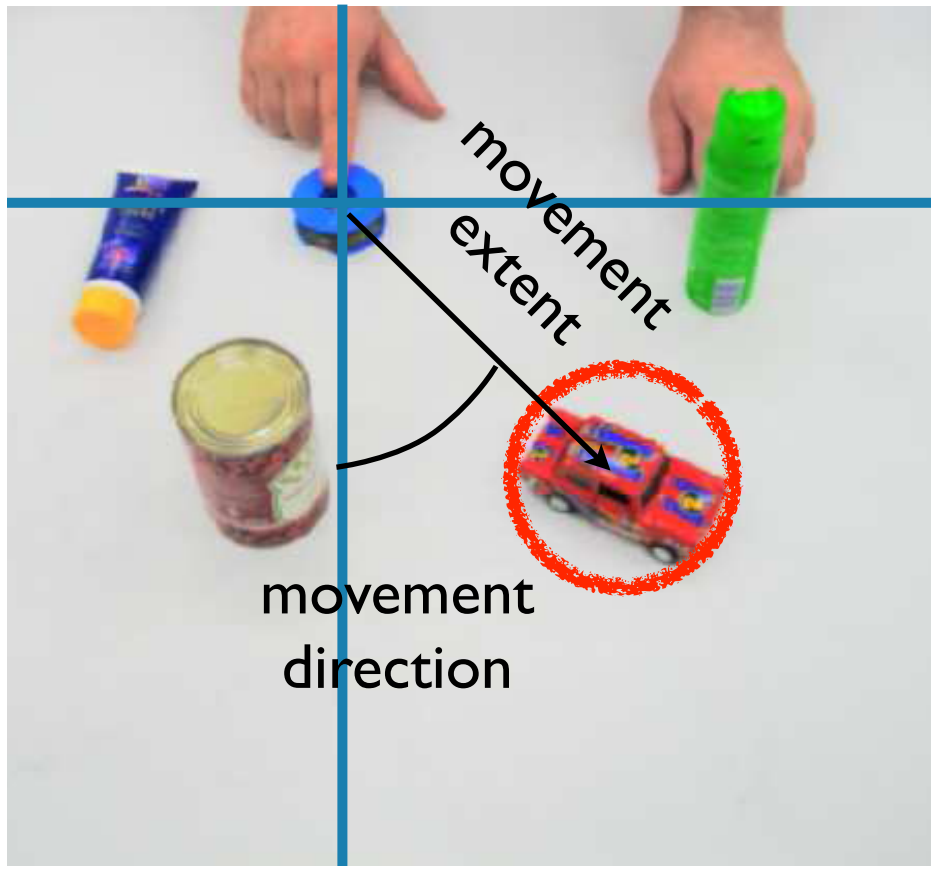

semantic map
camera input
recognition labels
spatial map
selection field
foveal image

(2) movement planning

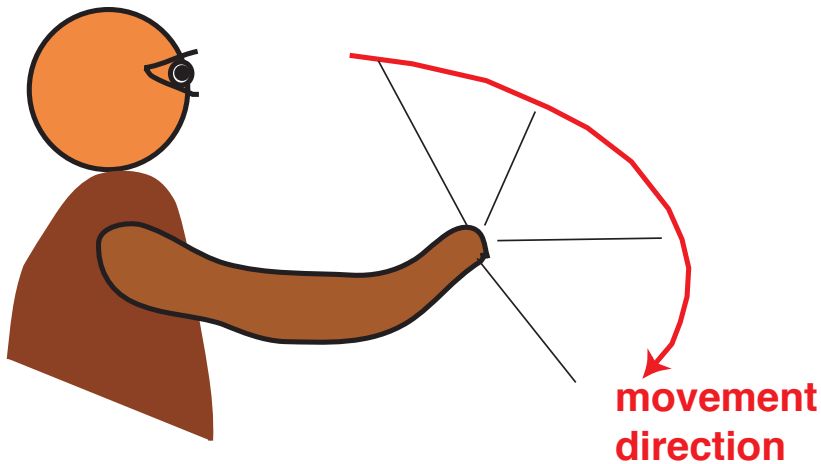
- is driven by scene representation

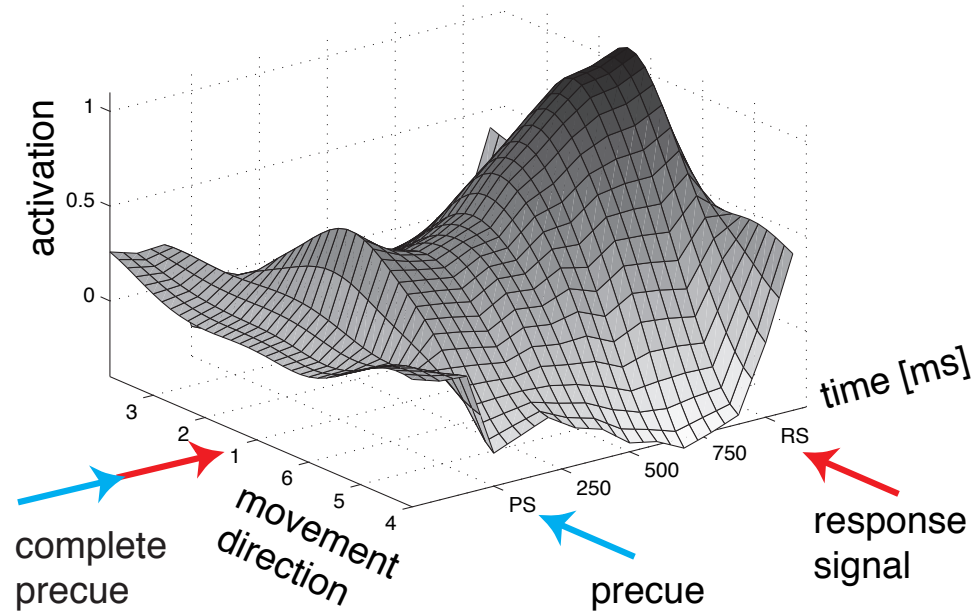


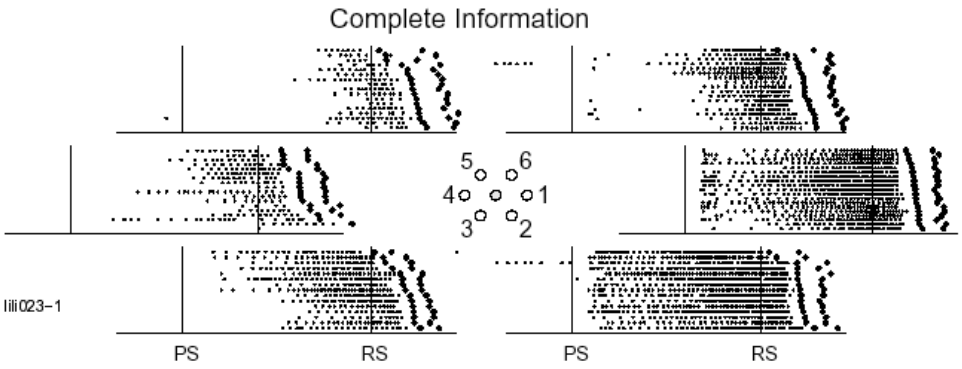


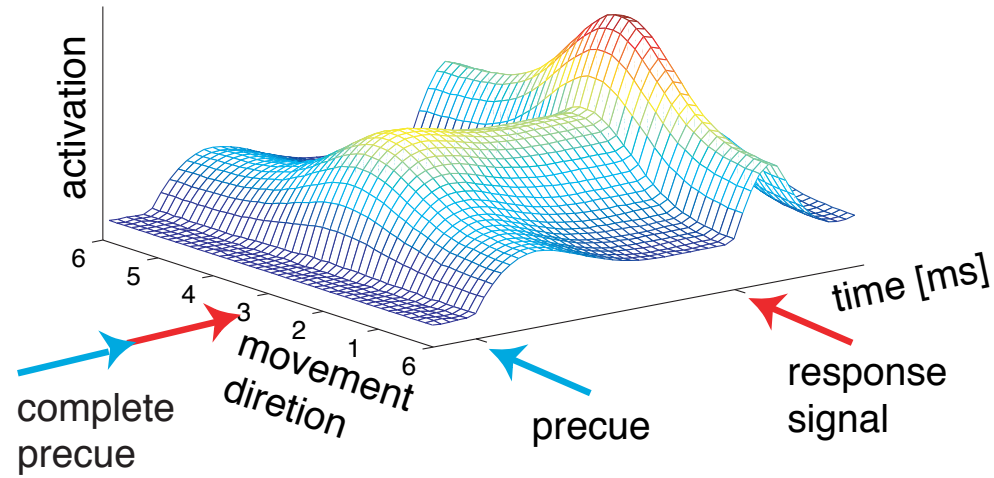


… based on neural activation fields



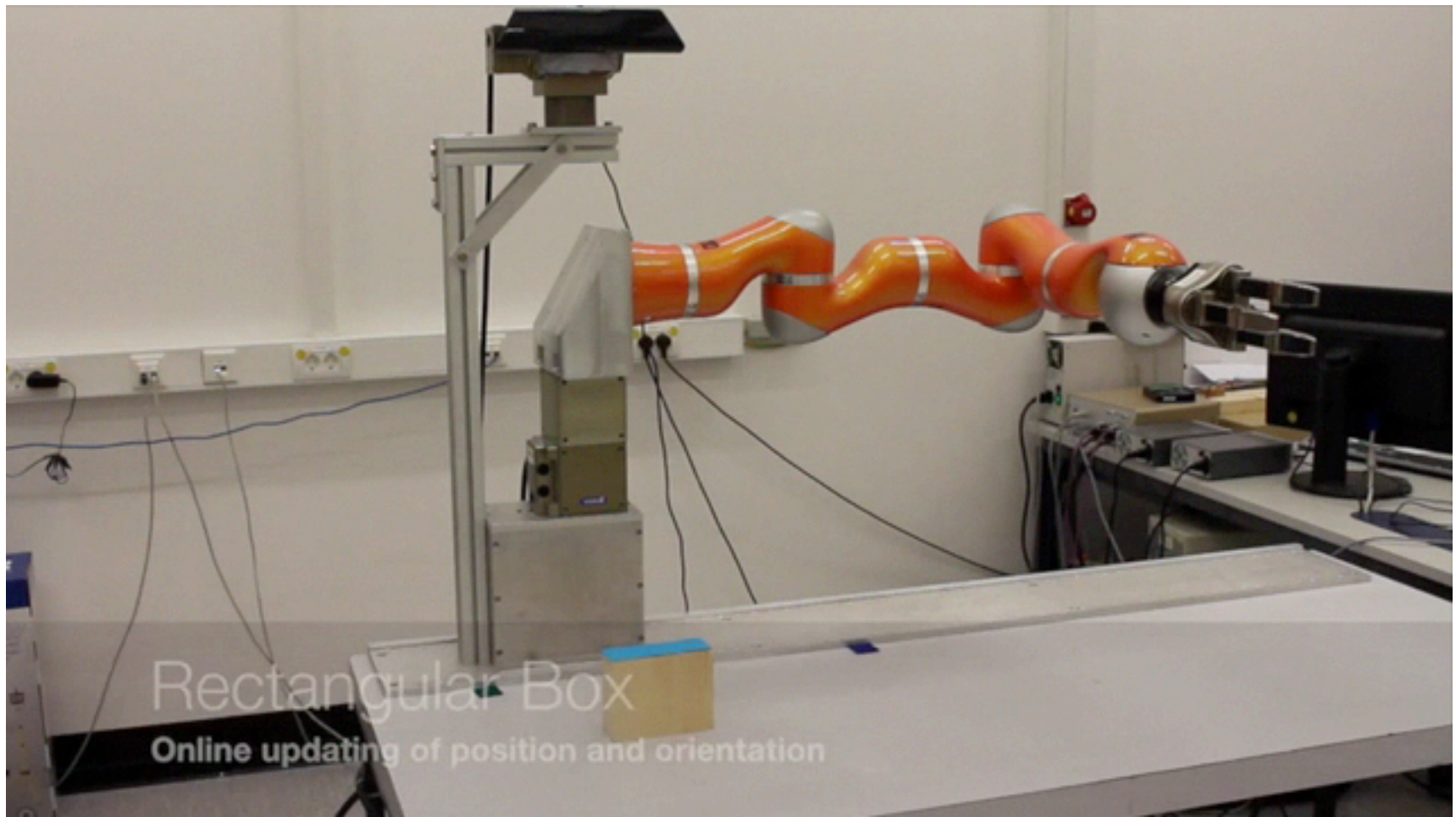






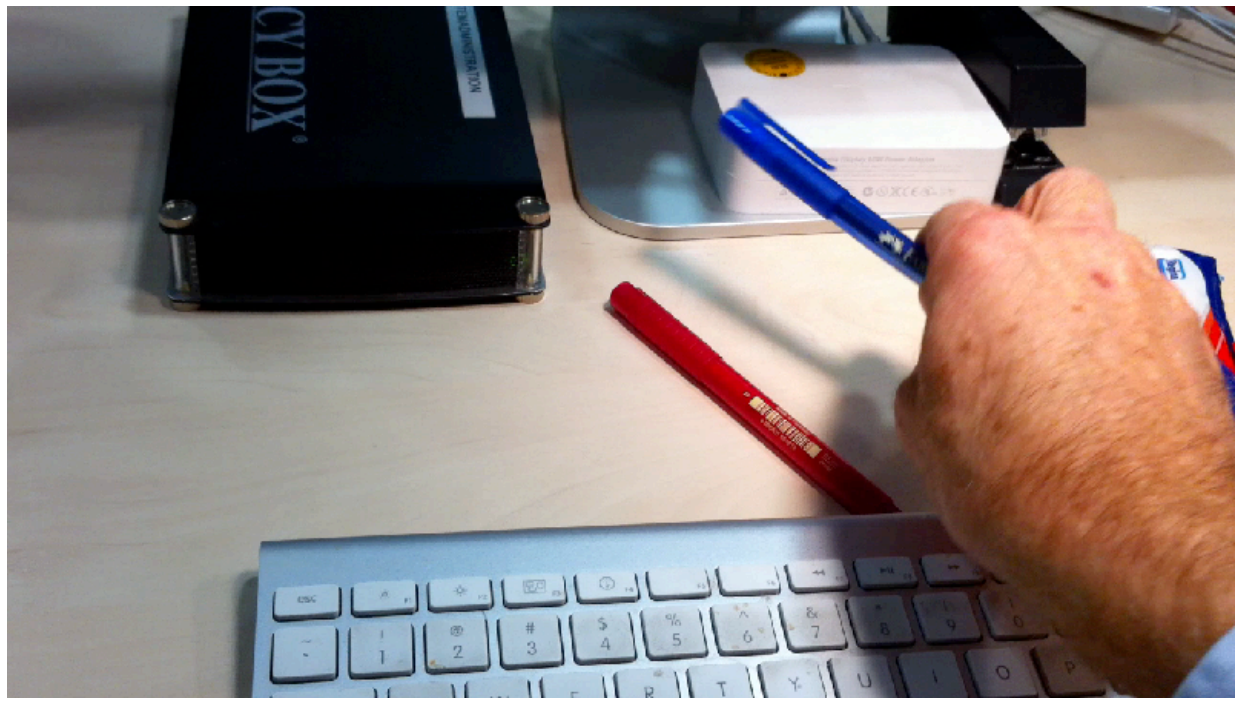
Bastian, Riehle, Schöner, European Journal of Neuroscience, Vol. 18, 2047-2058 (2003)

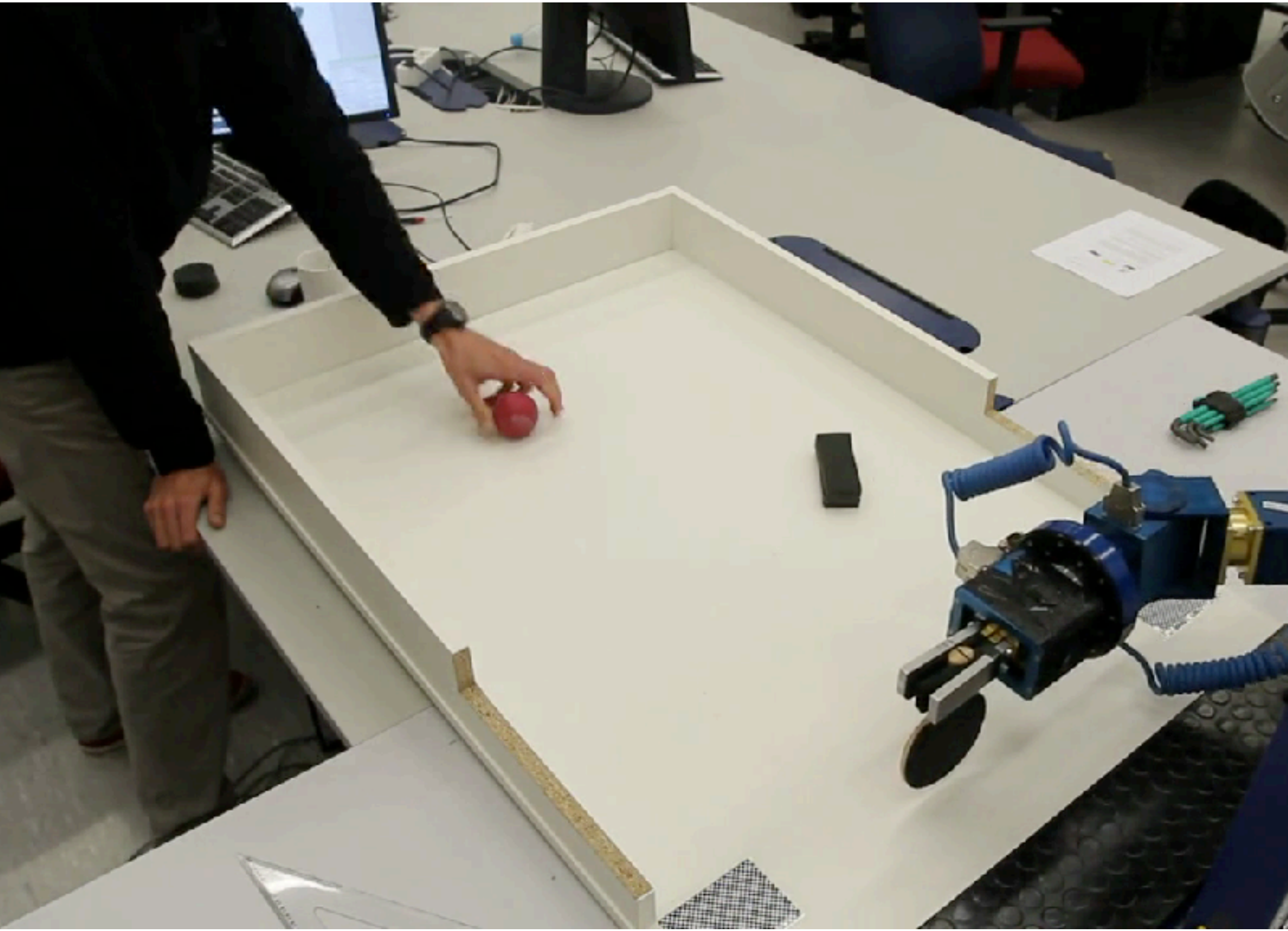
… online updating



(3) timing and coordination

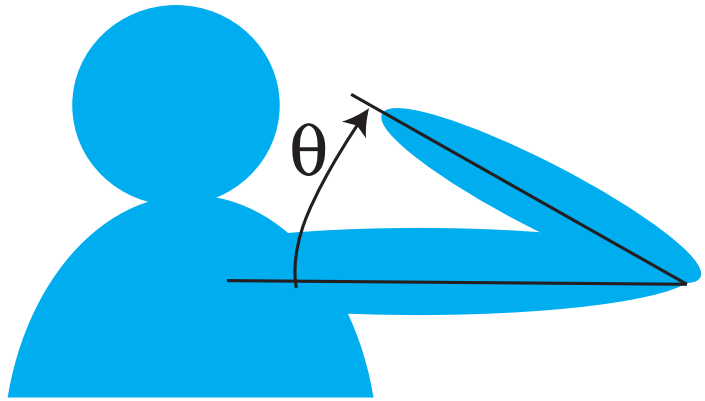
- all movement is coordinated, timed, and multi-sensory…

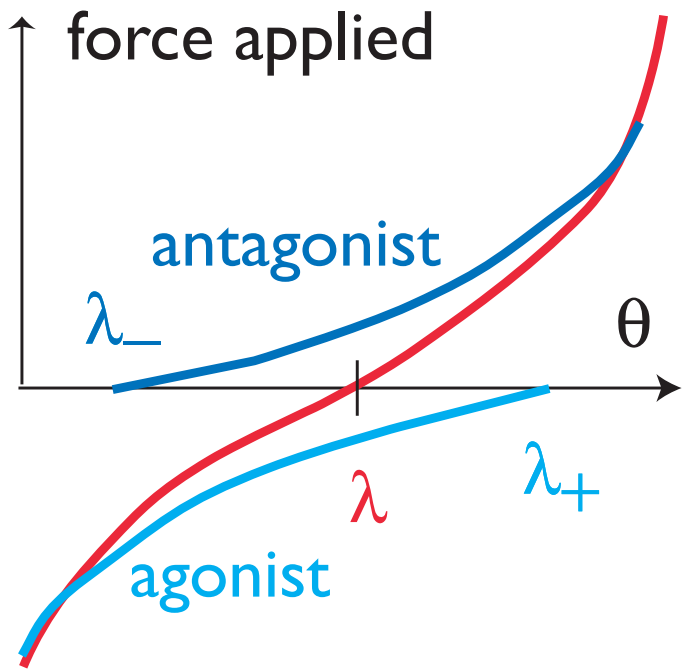


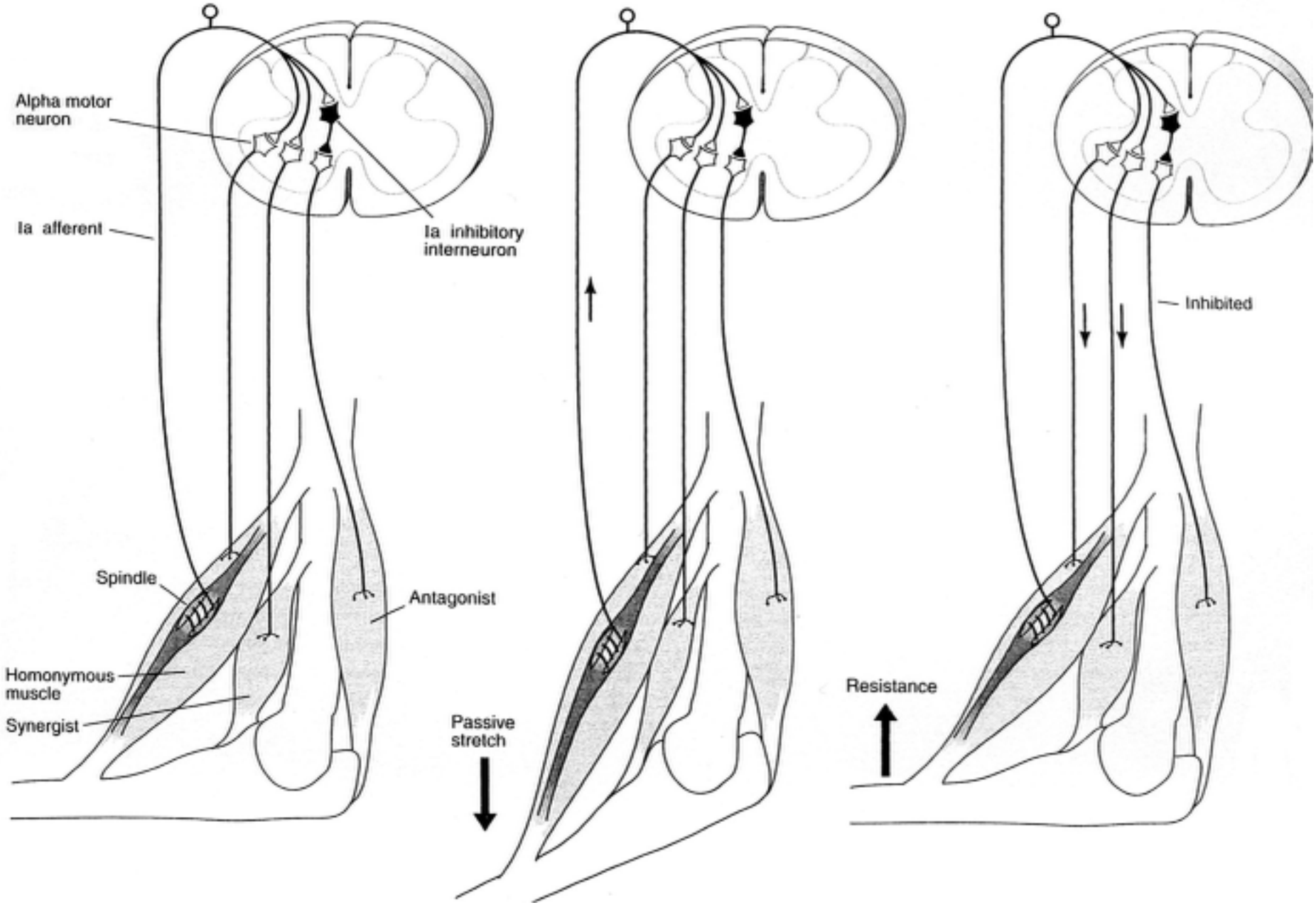


(4) muscles

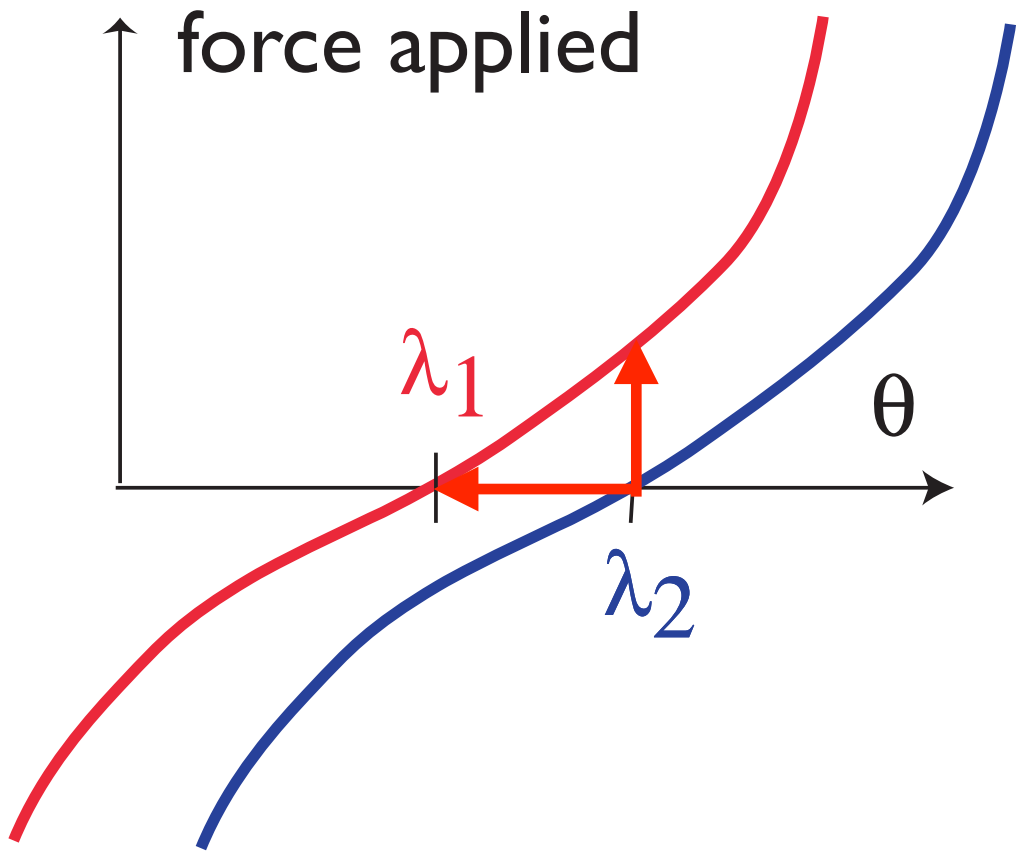
- are tunable (dampened) springs





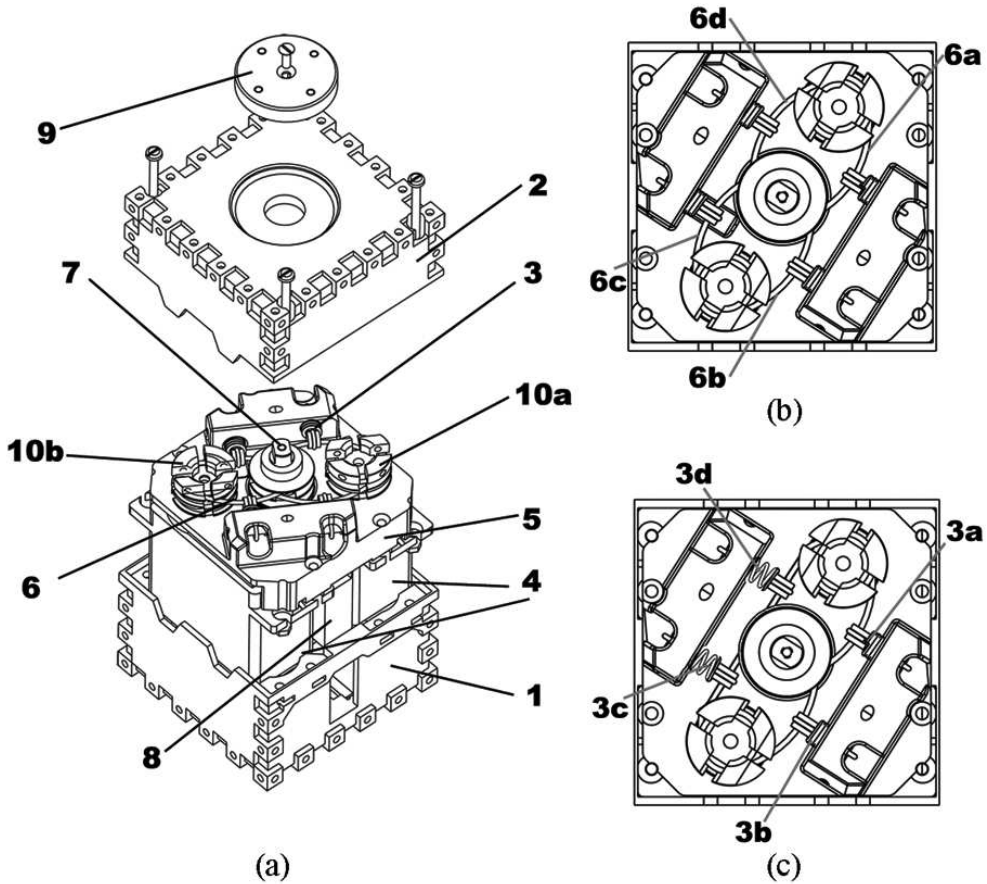

Alpha motor neuron
Ia afferent
Ia inhibitory interneuron
Spindle
Antagonist
Homonymous muscle
Synergist
Passive stretch
Inhibited
Resistance

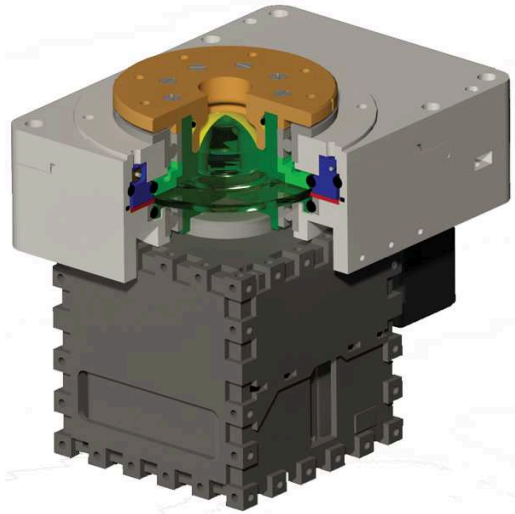
- muscle activation and force result from spatial command

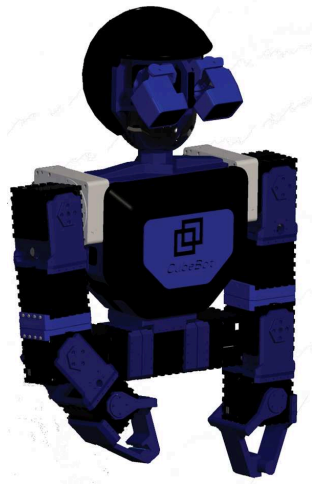


research

- active elastic actuators







[Antonio Bicchi]

why autonomous robots?

autonomous robots as demonstrators of neural function

- to show that neural process models are capable of generating the modeled behavior based on real sensory information …
- such proof of function as a source of heuristics
  - discover problems that are often overlooked (e.g., coordinate transforms)
  - discover non-problems that need not be solved to achieve a function
  - confront the problem of synthesis or integration…