Voluntary Movement I.

Psychophysical principles & Neural control of reaching and grasping

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Introduction

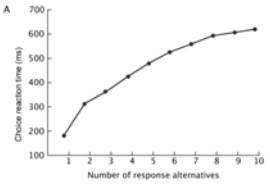
- **Reflex and voluntary movements are sensorimotor transformations.**
  - Feedforward vs. feedback control.
- **Reflex control differs from voluntary control**
  - Spatial organization of reflexes reflects hard-wired connections vs. behavioral demands and context: decisions. Voluntary movements are organized to be appropriate to address behavioral goal: kinematic vs. dynamic transformations - internal models.
  - Reflex latency & duration reflect mainly fixed neuromuscular constraints: conduction, transmission, contraction. These, also influence timing of voluntary movement, but information processing and accuracy constraints are the critical reaction time and movement duration.
  - Neural organization of voluntary movements is highly dependent on learning and plasticity. Adaptability is critical over long term.

Today

1. **Voluntary movements require decisions and information processing: Latency and duration:**
   - Reaction time.
   - Parallel processing.
   - Speed-accuracy tradeoffs.
2. **Sensorimotor transformations in reaching and grasping.**
   - Kinematics: visuomotor transformations. Movement vectors
   - Dynamics: internal models.
   - Role of vision and proprioception in feedback and feedforward control
3. **Organization of motor cortical areas for reaching and grasping**
   - Multiple motor areas
   - Somatotopic organization
   - Redundancy

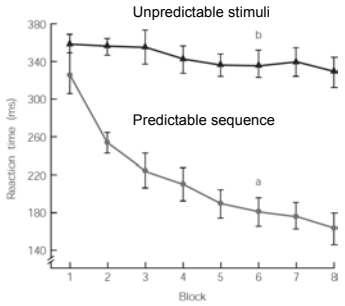
Latency or "Reaction time" depends on decision

Reaction time paradigm
• Warning -> cue= go signal
•Simple RT: *single or predictable cue Subject knows what response to make in advance*
•Choice: *multiple unpredictable cues (e.g. colors, symbols, spatial locations) each requiring different responses.*

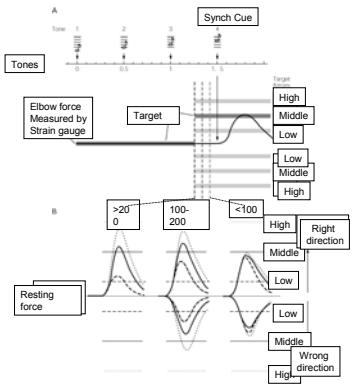


Stage theory of reaction time

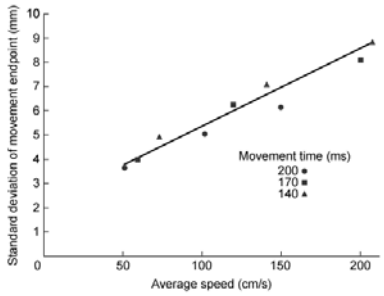
"Reaction time" depends on practice and learning



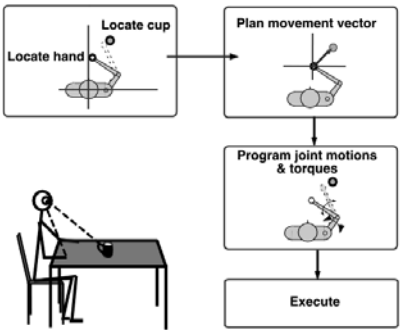
Response features can be processed in parallel



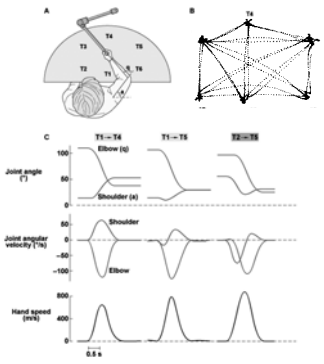
Speed-Accuracy tradeoff (Fitts' law)
Error varies with speed



Reaching reflects several sensorimotor transformations
kinematic and dynamic planning

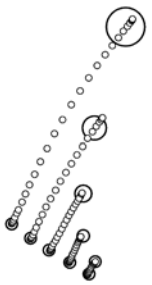


Reaching:
hand and joint kinematics are planned independently

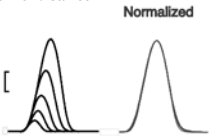


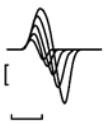
Extent and direction are planned in advance

Paths are straight



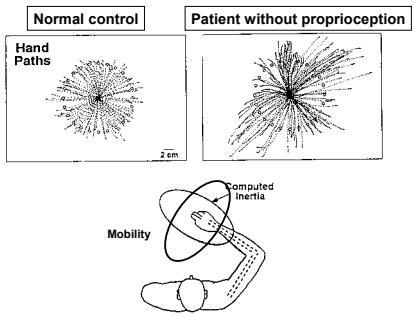
Hand trajectories:
Speed & acceleration
Scale with distance



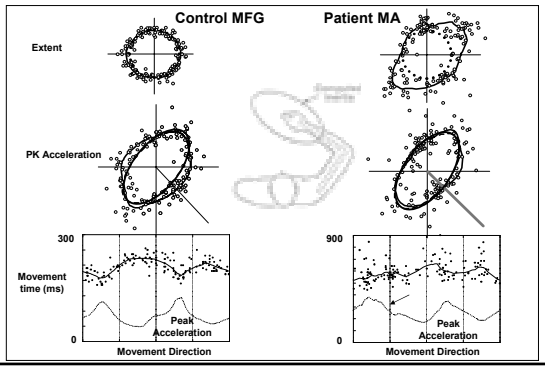


Reaching involves scaling a 'trajectory primitive' to target distance.
Learned scaling factors & reference frame

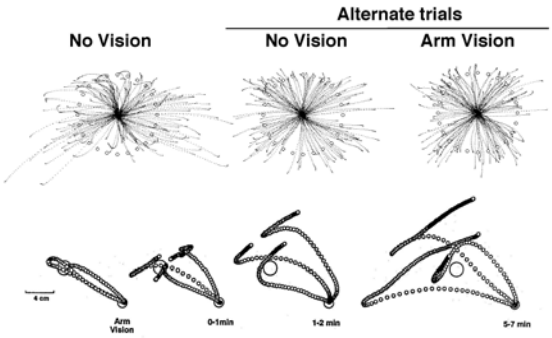
Accuracy requires knowledge of mechanical properties of the limbs ("the plant"): role of proprioception



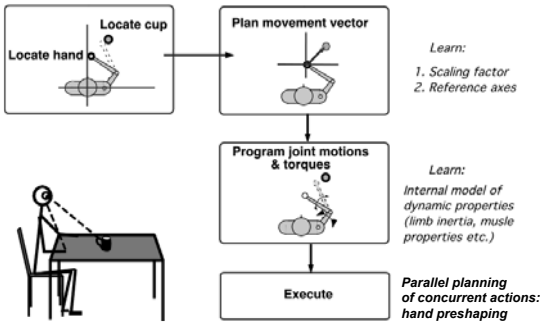
Directional variations in inertial resistance are corrected by compensatory variations in movement time
Proprioception is critical



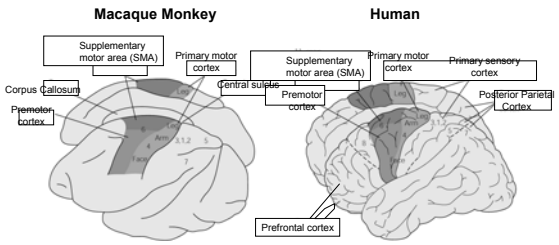
Proprioceptive information is used for feedforward control: *Internal models*



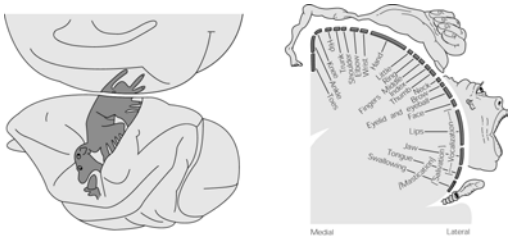
Reaching reflects several sensorimotor transformations *Kinematics and dynamics*

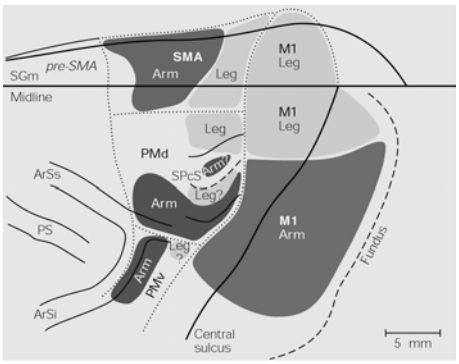


Motor areas of the brain



Somatotopic organization revieled by electrical stimulation of the cortical surface

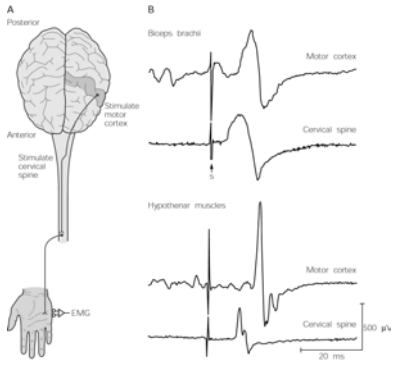




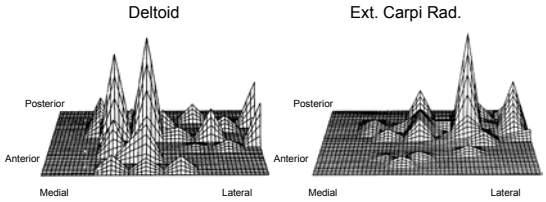
Electrical stimulation is medically useful
Early experiments

"Whoa! That was a good one! Try it, Hobbs — just poke his brain right where my finger is."

Electrical stimulation is medically useful: More recent experiments



Representation of individual muscles is patchy and distributed



Cell activity associated with movement of individual digits is broadly distributed: convergence of spinal projections