ME 328: Medical Robotics
Winter 2019

Lecture 14: Prosthetics

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Updates

Office hours by appointment

Project:

- Sign up for meeting with teaching team on March 4
- Supporting data due on Friday, Mar. 1 at 4 pm
- Peer review form to be posted

Tour Friday

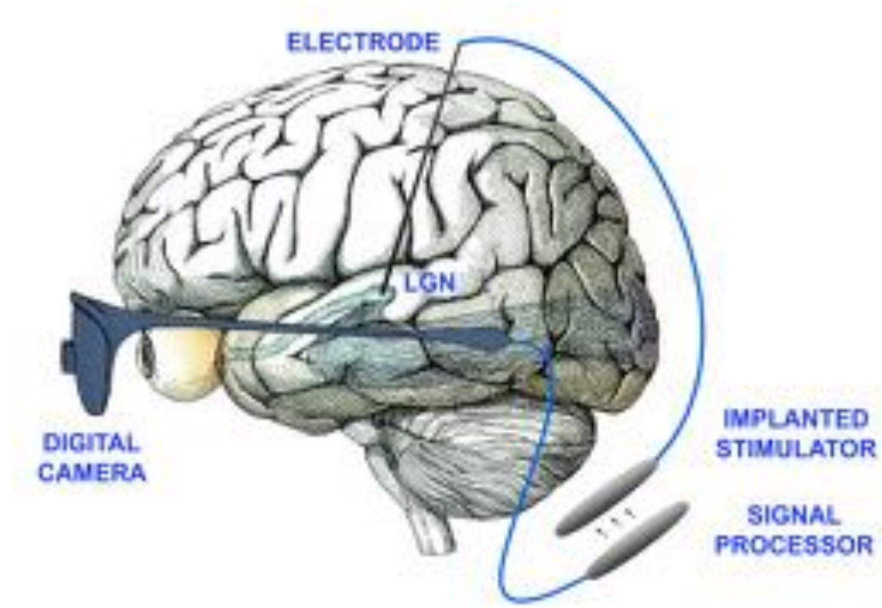
- Intuitive Surgical Mar. 1 (meet on campus at 1:15, arrive at 2:00) https://tinyurl.com/IntuitiveSurgicalTour
- Drivers, look for an email with your destination assignment
- Drivers taking other people will be reimbursed by mileage

Types of Prostheses

prostheses

artificial devices that replace injured or diseased body parts

Ocular prosthesis



Visual prosthesis

Artificial kidney

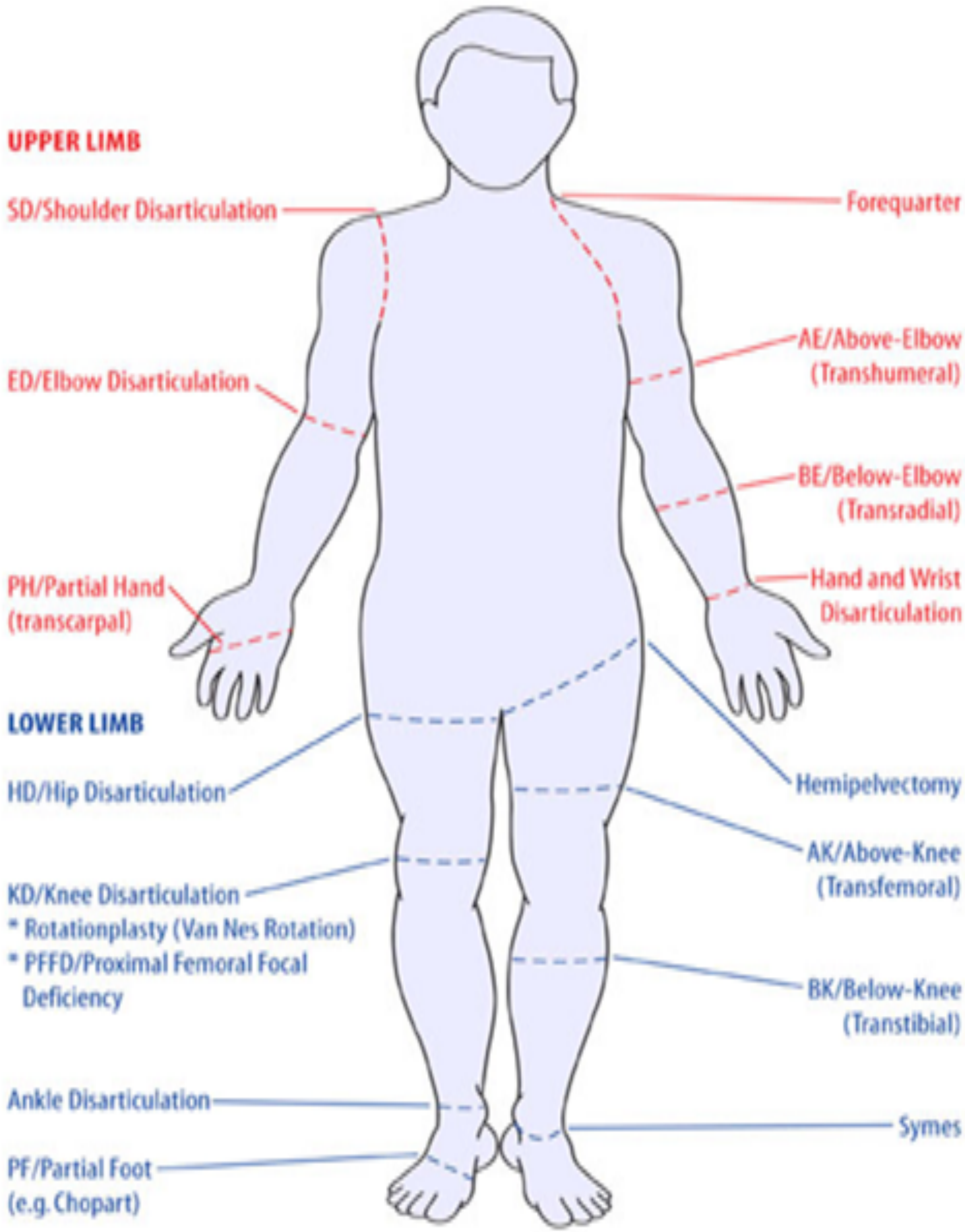
Also: Craniofacial (hemifacial, auricular, nasal, dental), neck (larynx substitutes, trachea and upper esophageal replacements), internal organs (bladder, stomach, heart), etc.

limb prostheses

purposes range from cosmesis to function

reasons for amputation

- Trauma
- Burns
- Peripheral Vascular Disease
- Malignant Tumors
- Neurologic Conditions
- Infections
- Congenital Deformities


UPPER LIMB
SD/Shoulder Disarticulation
Forequarter
ED/Elbow Disarticulation
AE/Above-Elbow
(Transhumeral)
BE/Below-Elbow
(Transradial)
PH/Partial Hand
(transcarpal)
Hand and Wrist
Disarticulation
LOWER LIMB
HD/Hip Disarticulation
Hemipelvectomy
AK/Above-Knee
(Transfemoral)
KD/Knee Disarticulation
* Rotationplasty (Van Nes Rotation)
* PFFD/Proximal Femoral Focal
Deficiency
BK/Below-Knee
(Transtibial)
Ankle Disarticulation
Symes
PF/Partial Foot
(e.g. Chopart)

limb prostheses

Upper extremity:

- forequarter
- shoulder disarticulation
- transhumeral prosthesis
- elbow disarticulation
- transradial prosthesis
- wrist disarticulation
- full hand
- partial hand
- finger
- partial finger

Lower extremity:

- hip disarticulation
- transfemoral prosthesis
- knee disarticulation
- transtibial prosthesis
- Syme's amputation (through ankle joint)
- foot
- partial foot
- toe

PROSTHETICS LOWER EXTREMITY

BELOW KNEE

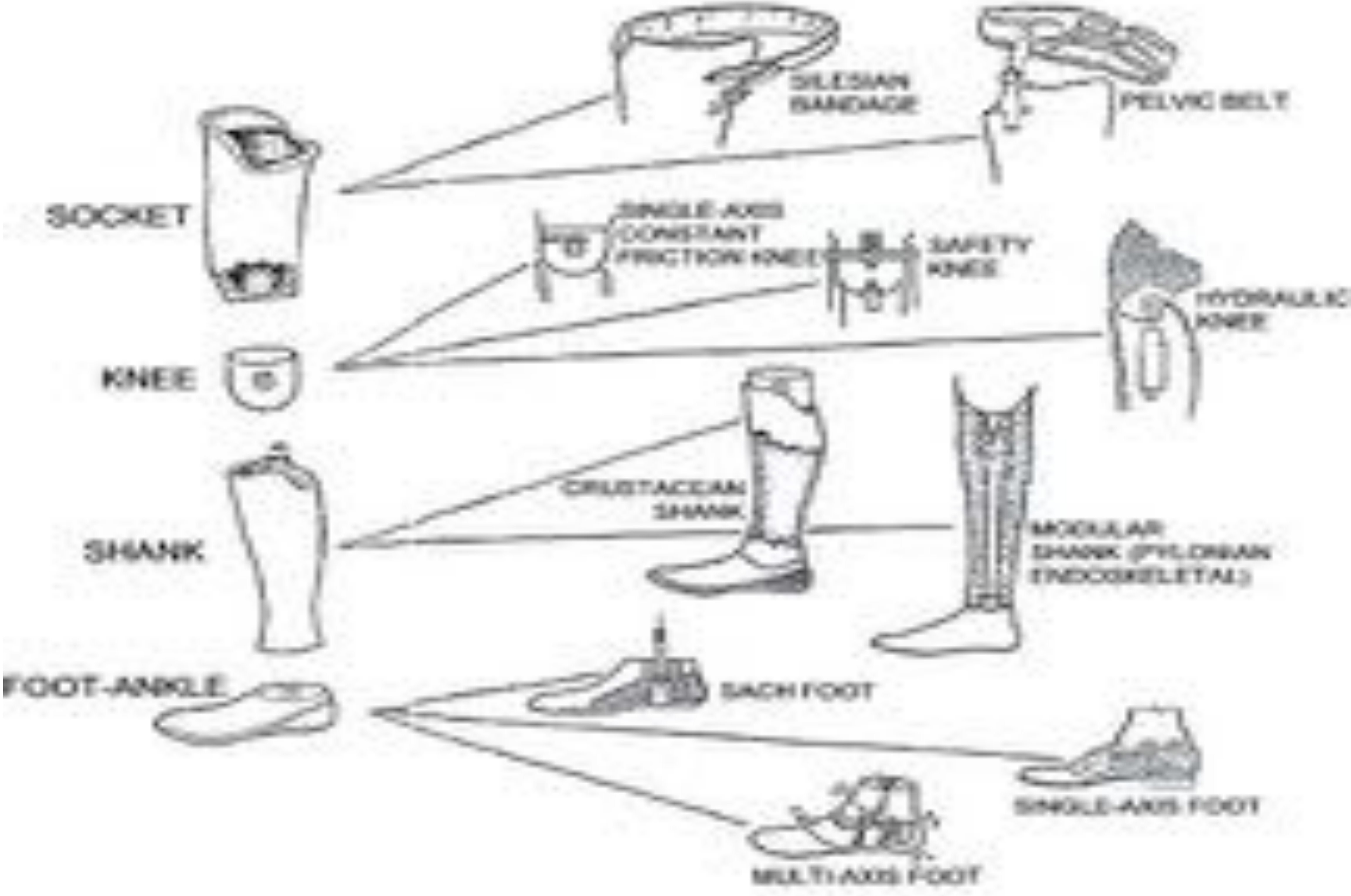
KNEE DISARTICULATION

ABOVE KNEE

HIP DISARTICULATION

Prosthesis Design and Control

components



SILESIAN BANDAGE
PELVIC BELT
SOCKET
SINGLE-AXIS CONSTANT FRICTION KNEE
SAFETY KNEE
HYDRAULIC KNEE
KNEE
CRUSTACEAN SHANK
SHANK
MODULAR SHANK (PYLON AN ENDOSKELETAL)
FOOT-ANKLE
SACH FOOT
SINGLE-AXIS FOOT
MULTI-AXIS FOOT

types of prosthesis control

No control

Cable operated (body powered)

Myoelectric

Robotic

myoelectric prosthesis control:

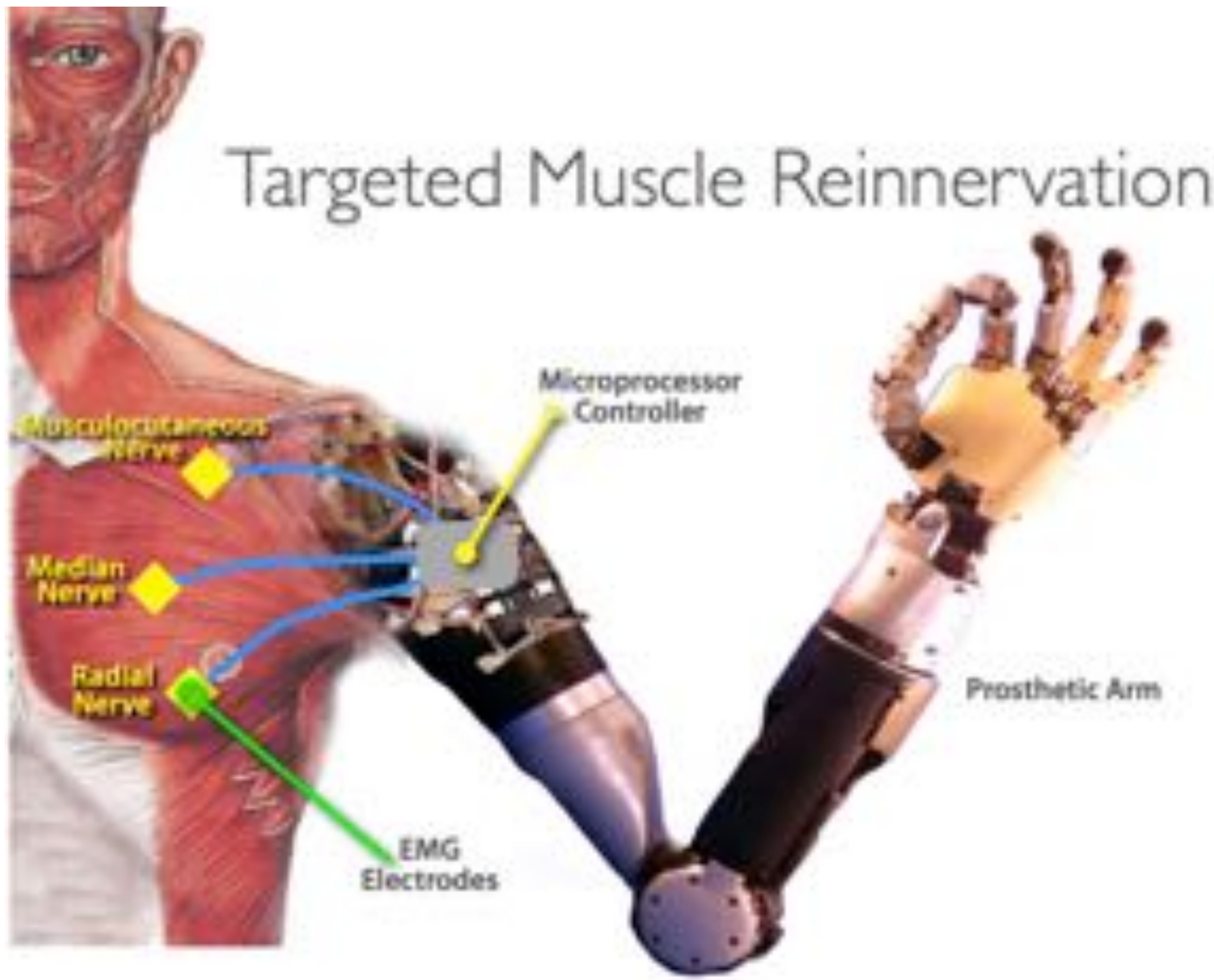
- Electrodes pick up microvolts of electricity produced by contractions in the muscles of the residual limb.

- Signals are amplified and thereafter they activate the motor

- In operating a hand there may be two electrodes, one on extensor muscles and one of flexor muscles groups, for opening and closing the hand

robotic prosthesis control: peripheral invasive

robotic prosthesis control: targeted muscle reinnervation



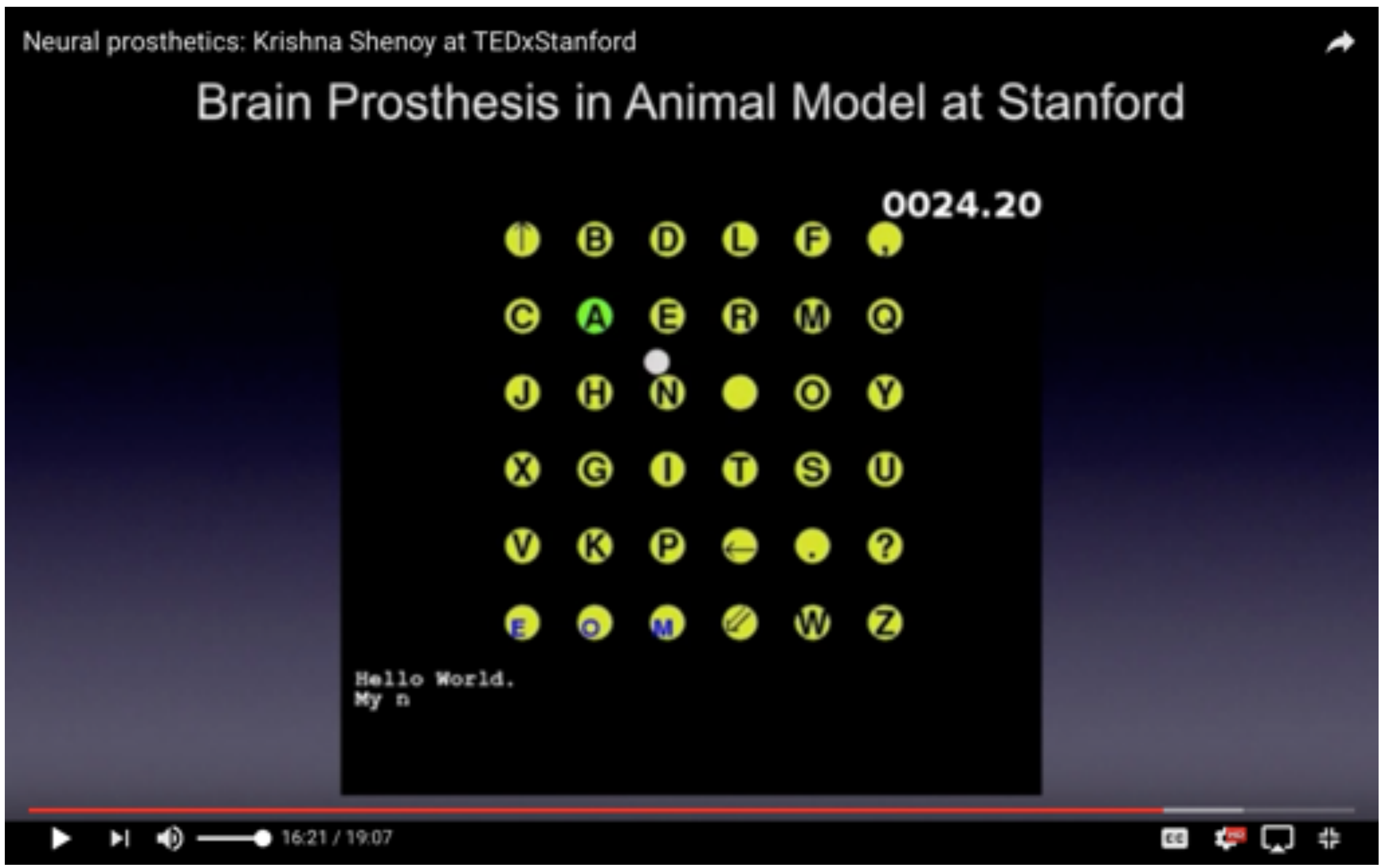
Courtesy of The Rehabilitation Institute of Chicago and DEKA
(http://www.youtube.com/watch?v=ddInW6sm7JE)

robotic prosthesis control: targeted muscle reinnervation

- Provides an **organized** afferent pathway
  - Offers strong causal link between sensation and perception
  - Minimizes need for CNS plasticity
- Provides a **natural** afferent pathway
  - Near-normal thresholds for temperature, light touch, sharp/dull and pressure have been demonstrated
- Yet, there are many challenges and unknowns:
  - Density and types of mechanoreceptors in reinnervated skin unknown
  - No evidence of kinesthetic sensing
  - Relevance to proprioception unclear
  - Sensation of fingerpads has not been reported
  - Relationship to reinnervated muscle unclear

robotic prosthesis control: brain implant

robotic prosthesis control: brain implant

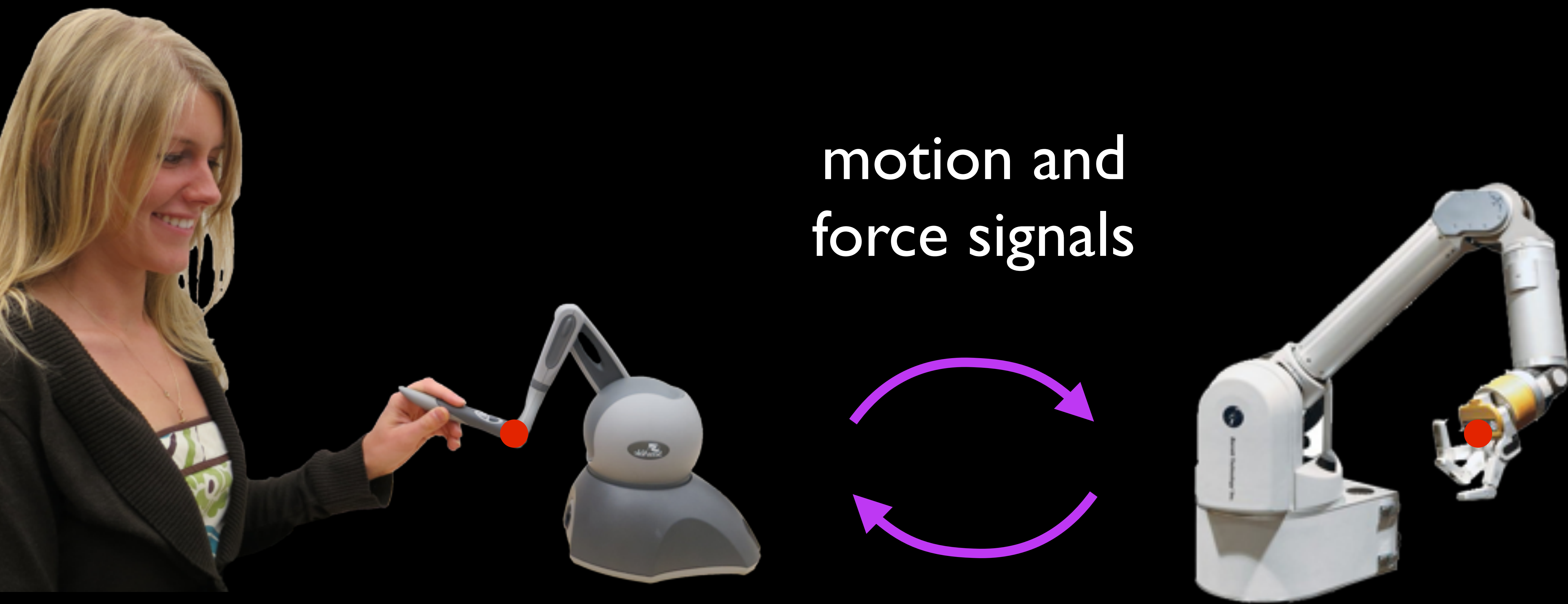


https://www.youtube.com/watch?v=ZuATvhIcUU4 discussion:

what are additional design challenges and potential solutions?

Human Sensorimotor Control Considerations

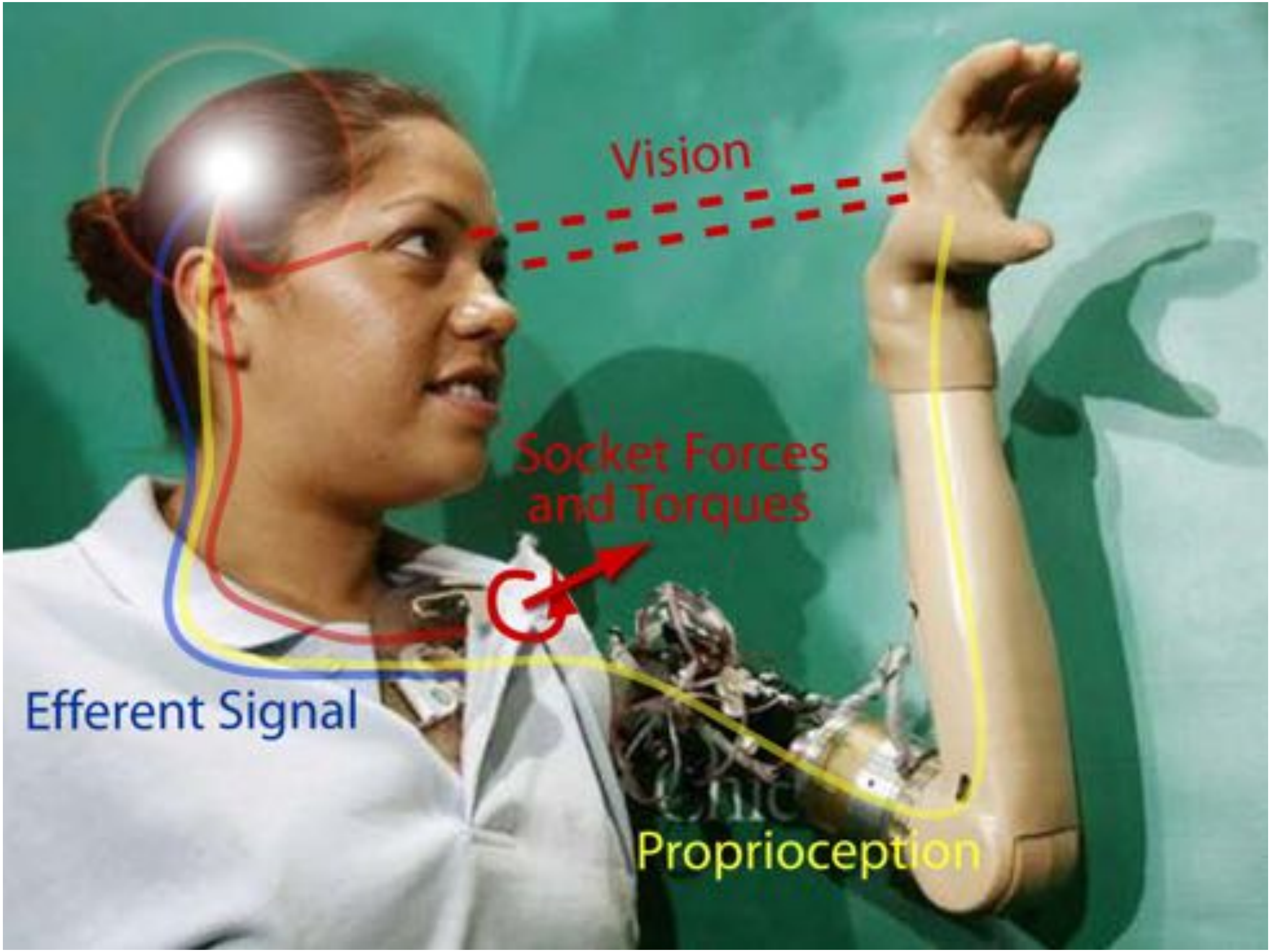
Comparison to Teleoperation



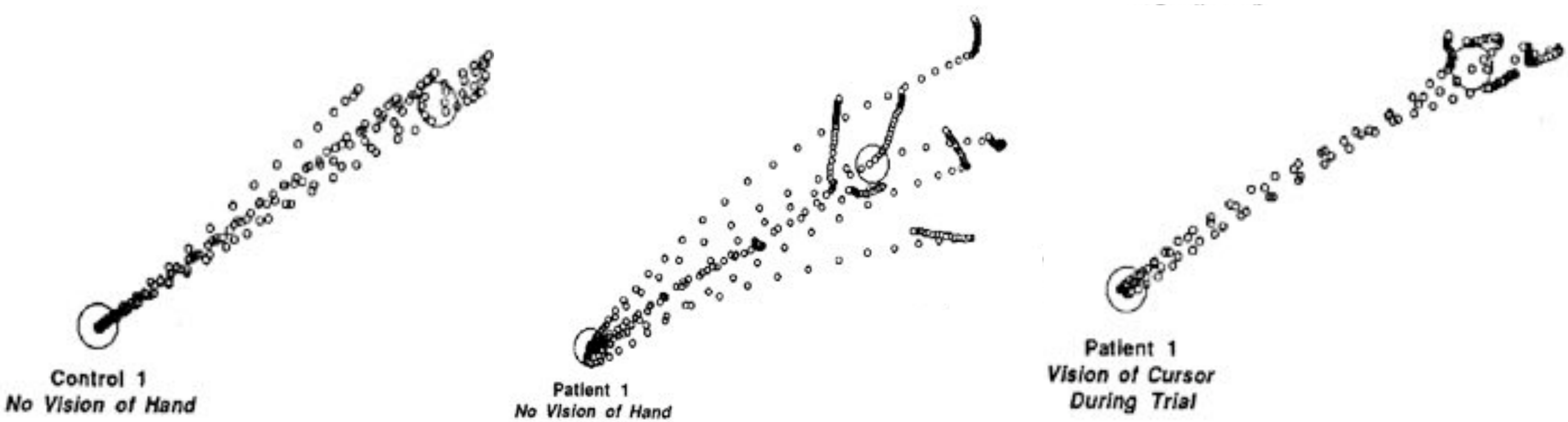
Transradial Electric-Powered Prosthesis User Preferences

Rank Order of Priority	Item Name
1	Fingers could bend
2	Thumb moved out to side
3	Required less visual attention to perform functions
4	Thumb could touch each finger individually
5	Could hold small objects better
6	Wrist rotated terminal device
7	Could hold large objects better
8	Could use it in vigorous activities
9	Wrist moved terminal device up and down
10	Middle joint of thumb could bend

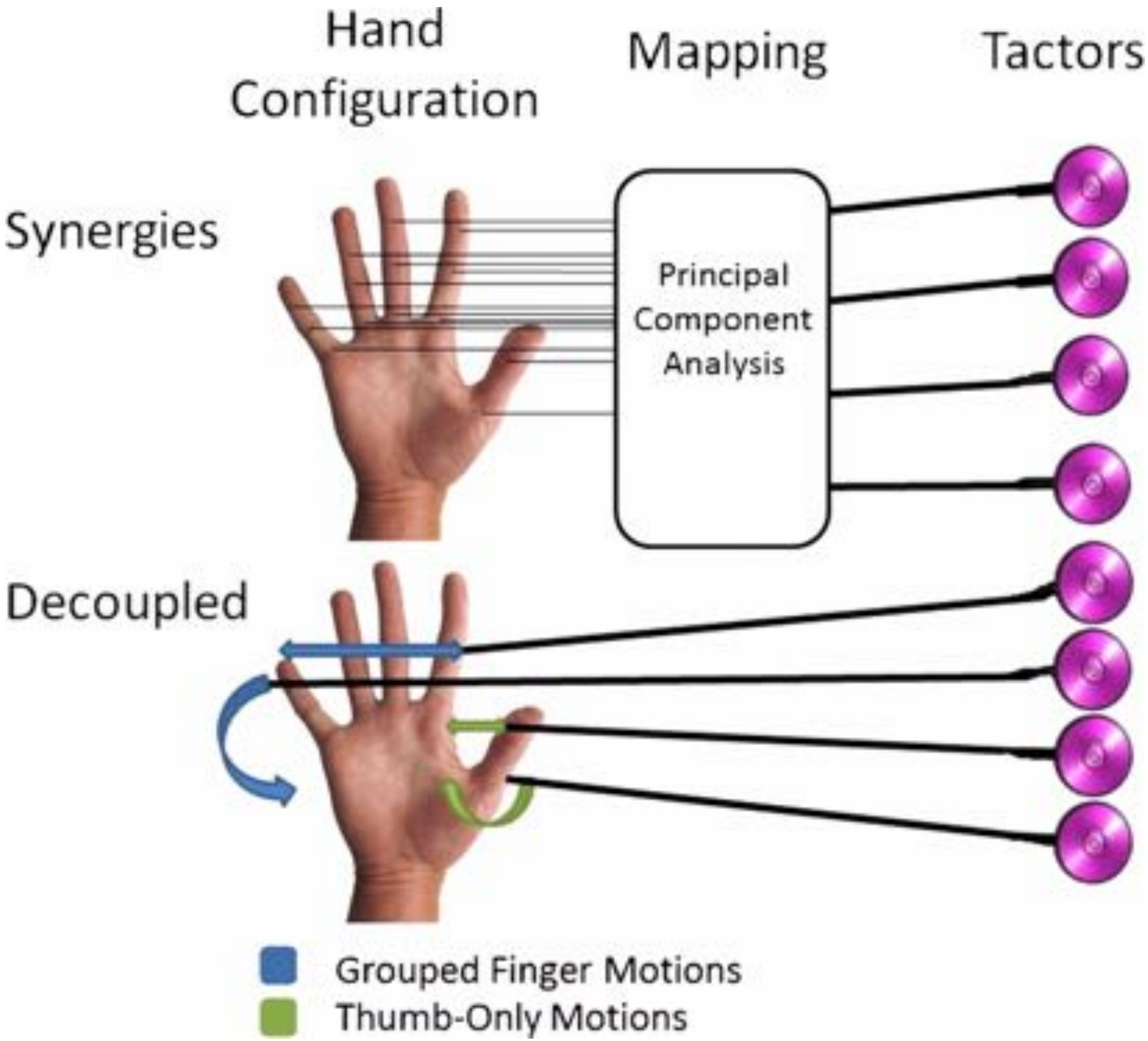
* D. J. Atkins, D. C, Y. Heard, and W. H. Donovan, "Epidemiologic overview of individuals with upper-limb loss and their reported research priorities," J. Prosthetics and Orthotics, vol. 8:1, pp. 2-11, 1996.


Vision
Socket Forces
and Torques
Efferent Signal
Proprioception

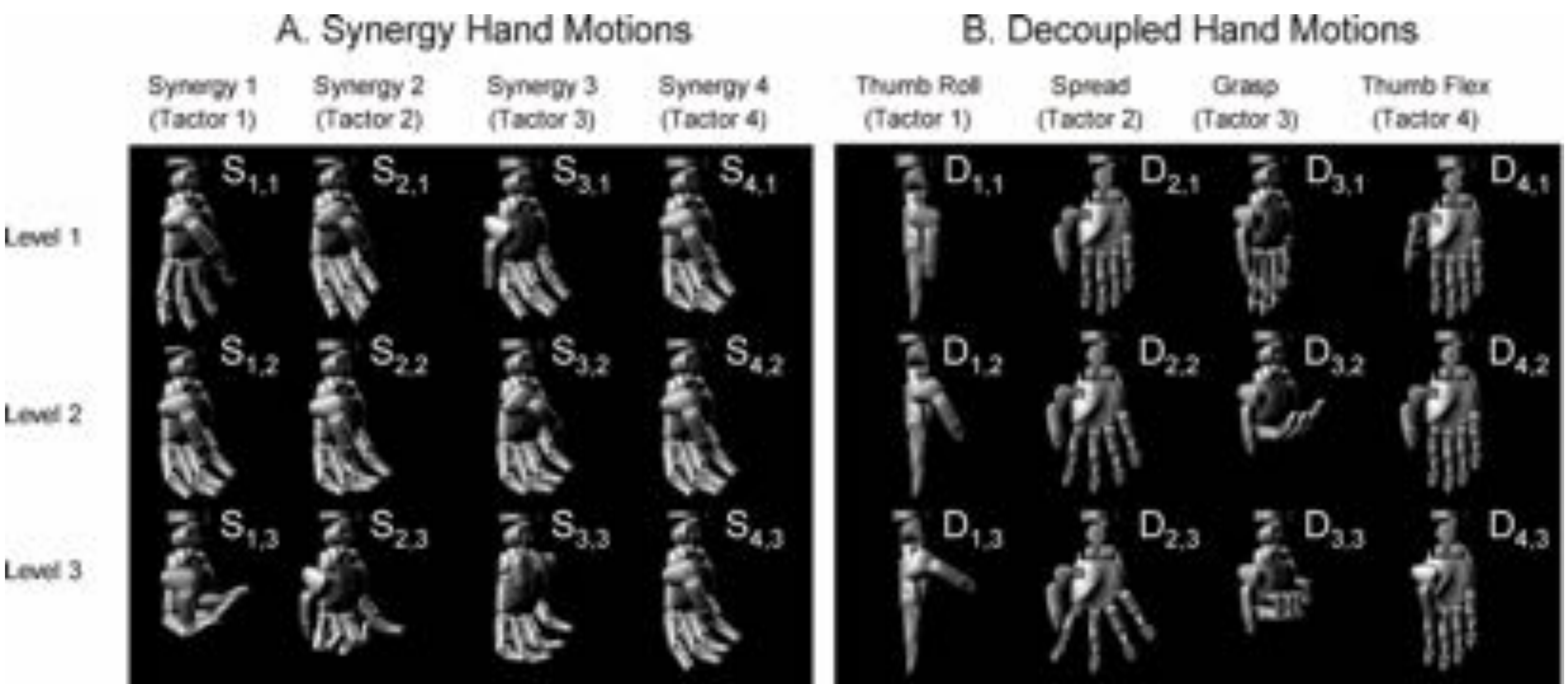
role of vision and proprioception



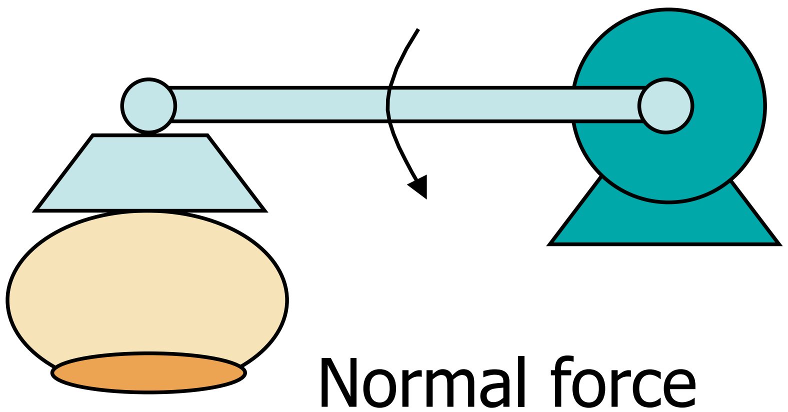
C. Ghez, et al., Cold Spring Harbor Symp. Quant. Biol., 1990.



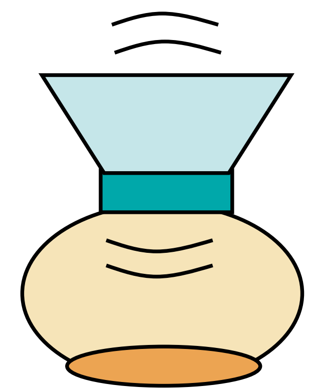
Hand
Configuration
Mapping
Tactors
Synergies
Principal
Component
Analysis
Decoupled
Grouped Finger Motions
Thumb-Only Motions


A. Synergy Hand Motions
B. Decoupled Hand Motions
Synergy 1 (Tactor 1)
Synergy 2 (Tactor 2)
Synergy 3 (Tactor 3)
Synergy 4 (Tactor 4)
Thumb Roll (Tactor 1)
Spread (Tactor 2)
Grasp (Tactor 3)
Thumb Flex (Tactor 4)
Level 1
Level 2
Level 3
$S_{1,1}$ $S_{2,1}$ $S_{3,1}$ $S_{4,1}$
$S_{1,2}$ $S_{2,2}$ $S_{3,2}$ $S_{4,2}$
$S_{1,3}$ $S_{2,3}$ $S_{3,3}$ $S_{4,3}$
$D_{1,1}$ $D_{2,1}$ $D_{3,1}$ $D_{4,1}$
$D_{1,2}$ $D_{2,2}$ $D_{3,2}$ $D_{4,2}$
$D_{1,3}$ $D_{2,3}$ $D_{3,3}$ $D_{4,3}$

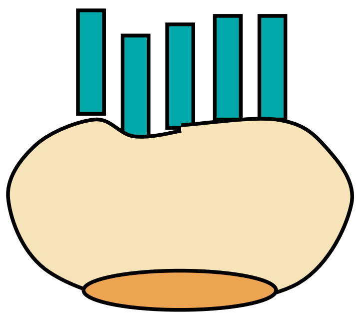
haptic feedback



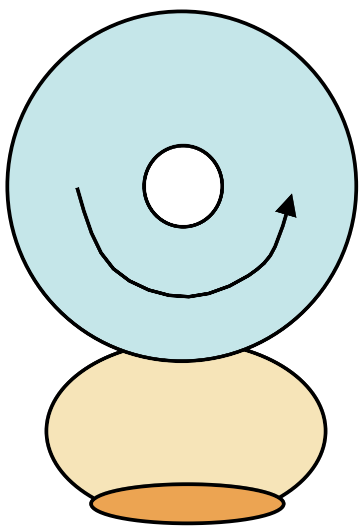
Normal force
(e.g. “force reflecting” interface)



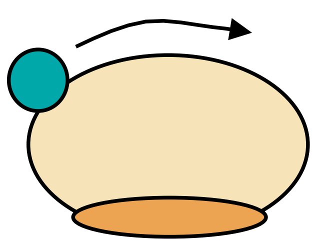
Vibration
(e.g., voicecoil)



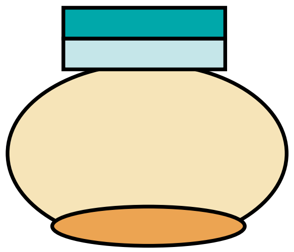
Local Shape
(e.g. pin array)



Shear
(e.g., rotating wheel)



Contact Location
(e.g. moving roller)



Thermal
(e.g. Pelletier)

images courtesy Ed Colgate, Northwestern University discussion:

what are additional sensorimotor control challenges and potential solutions?

future of prosthetics:

- Solving problems of cost, power, weight
- Direct human sensorimotor control
- Autonomy (or partial autonomy)
- Other ideas?