ShanghAI Lecture Series

15 November 2012, 10:00 AM CET

Design Principles for Intelligent Rehabilitation Robots

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Disadvantage of Manual Training

For the Therapist

- Physically exhausting
- Ergonomically inconvenient

↓

For the Patient

- Limited training duration
- Gait pattern not optimal

SCI Center, Balgrist

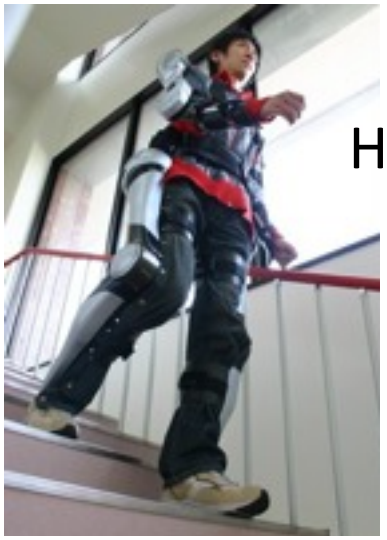
Human-Robot Gait Rehabilitation

Gait Rehabilitation "Robots"

GaitTrainer

G-EO

Haptic Walker



HAL

Auto ambulator

ARMin III

Exoskeletal Robot with 7 Degrees of Freedom

ETH Zurich/Balgrist, Hocoma AG

Nef, Riener et al. 2006-2011

Arm Rehabilitation Robots

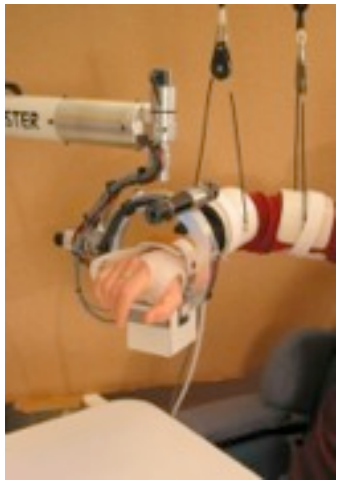
MIT Manus

Bi-Manu-Track

MGA

Salford PMA

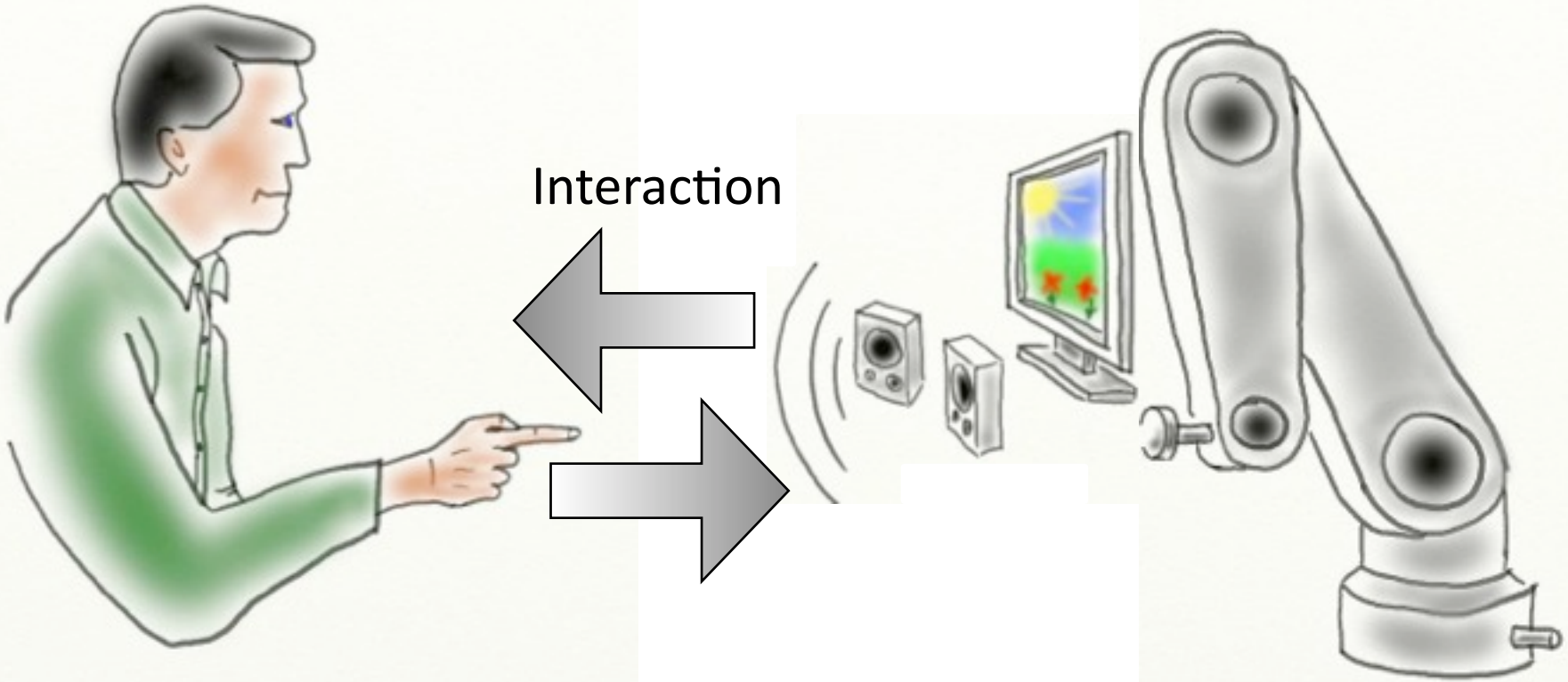
Haptic Master, GENTLE/s



PERCRO Exoskeleton

KIST Arm

Sensory-Motor Interaction

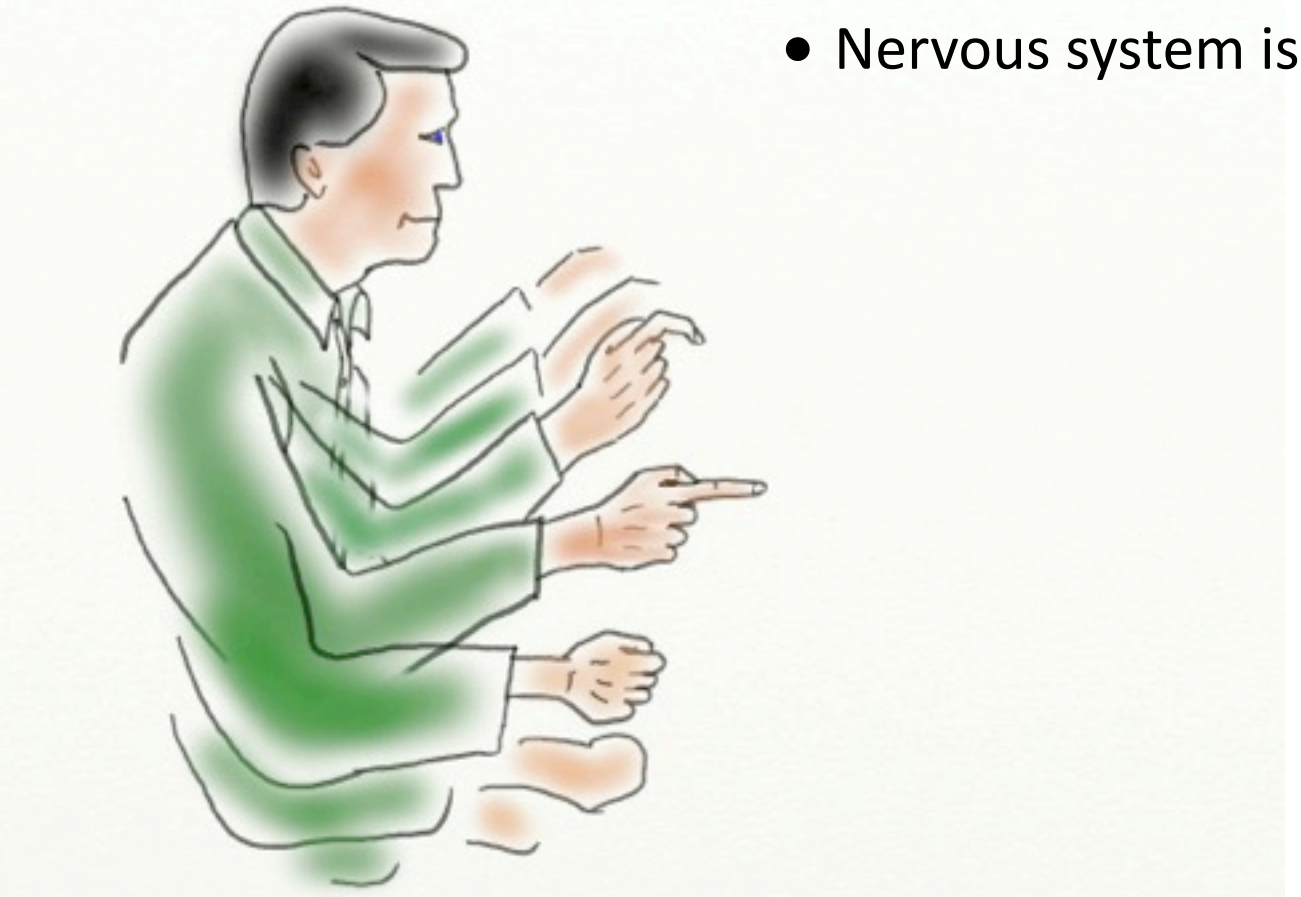


Focus: Exoskeleletons for Clinical Rehabilitation

Setups: Lokomat, ARMin

Sensory-Motor Characteristics

To Be Known about Human Physiology



- Nervous system is plastic

Sensory-Motor Characteristics

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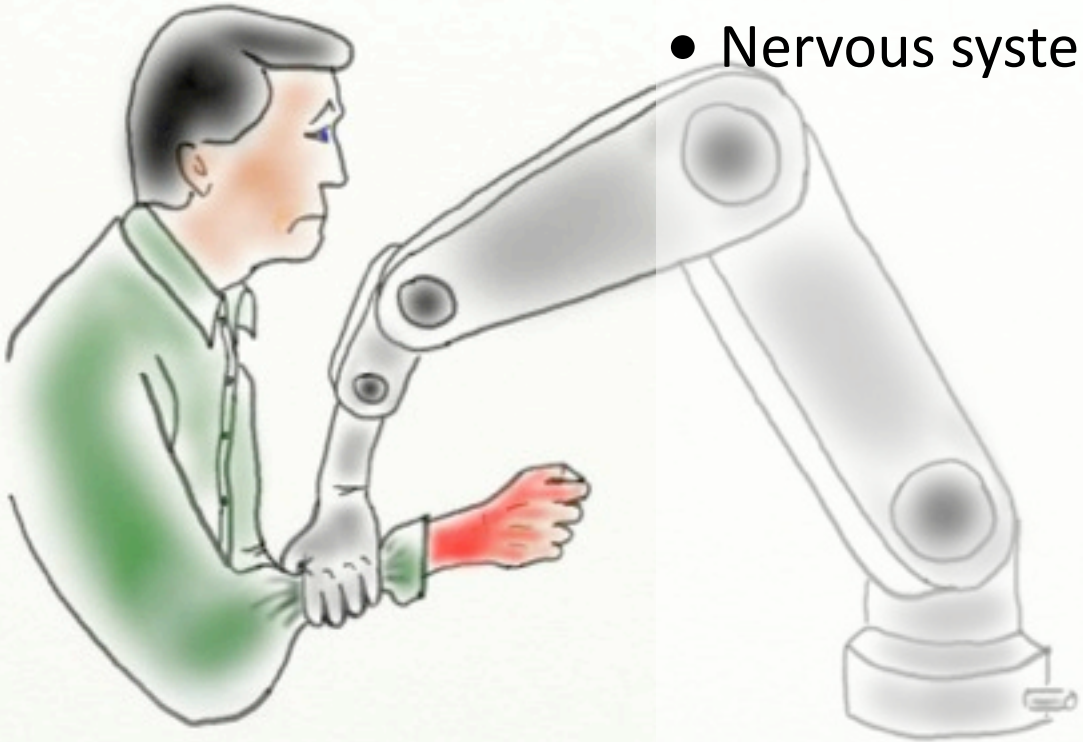

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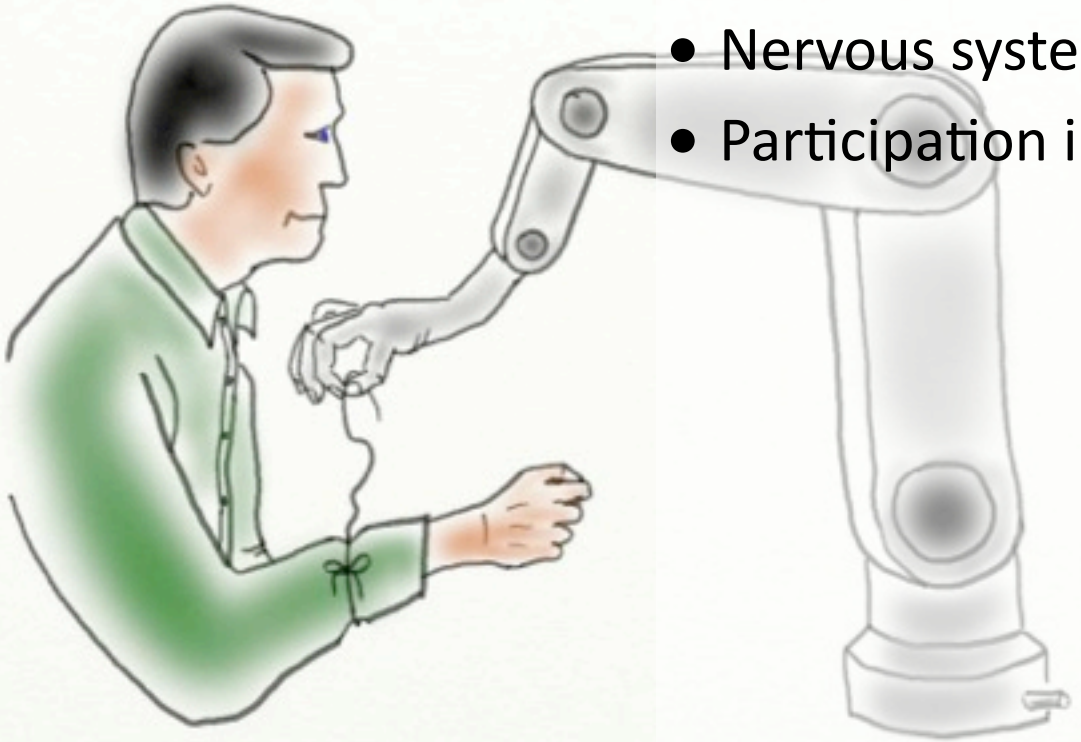


- Nervous system is plastic
- Participation increases plasticity

Passive *vs* Active Training

Limitations of Passive Training of Healthy Subjects

- Physical guidance hinders motor learning of walking balance

Domingo & Ferris, 2009

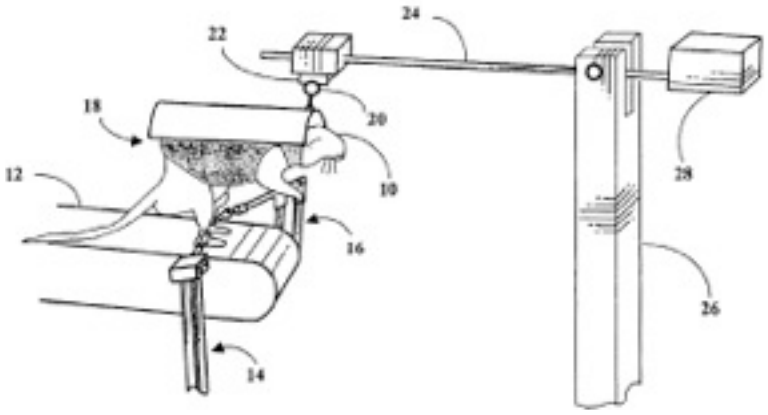
- High frequency guiding is detrimental for learning of arm movements (guidance hypothesis)

Winstein et al. 1994; Marchal-Crespo & Reinkensmeyer 2008

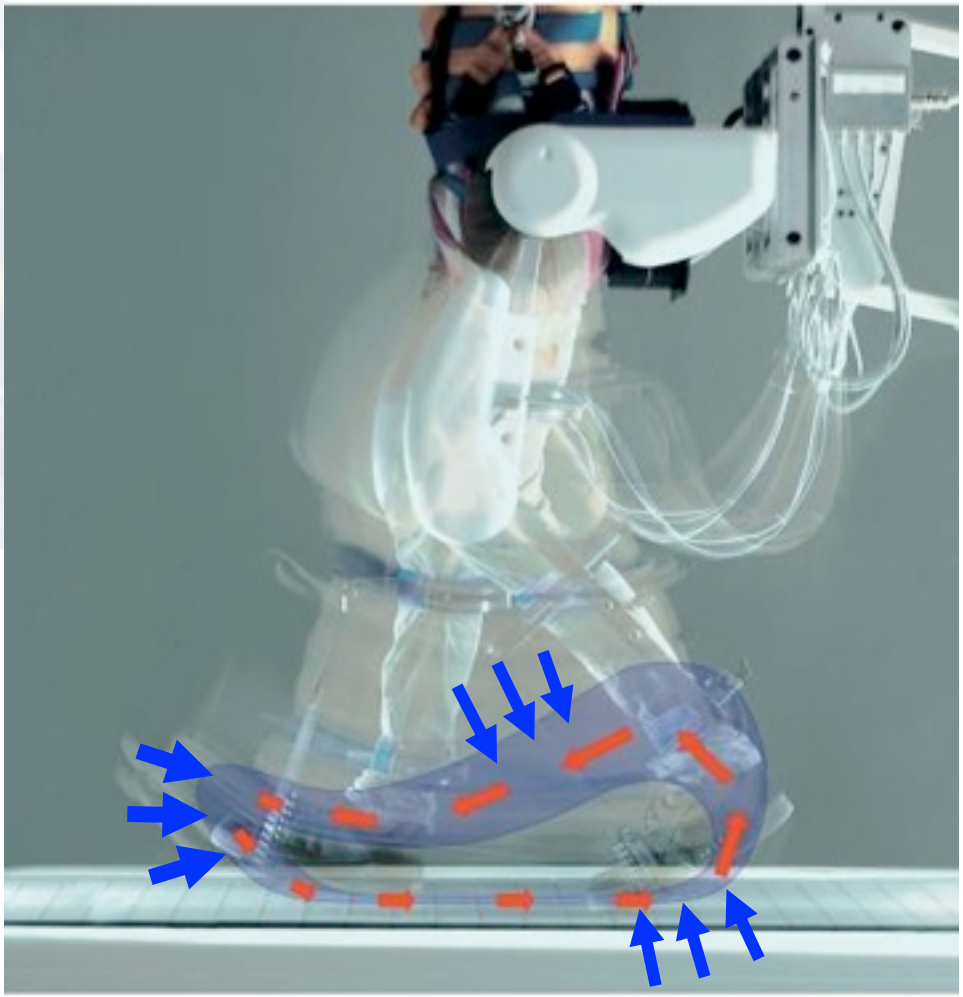
Assist-as-Needed Training (ANN)

- AAN shows higher level of recovery step number, periodicity, and consistency (27 mice)

Cai et al. 2006



Lokomat: Patient-Cooperative Control



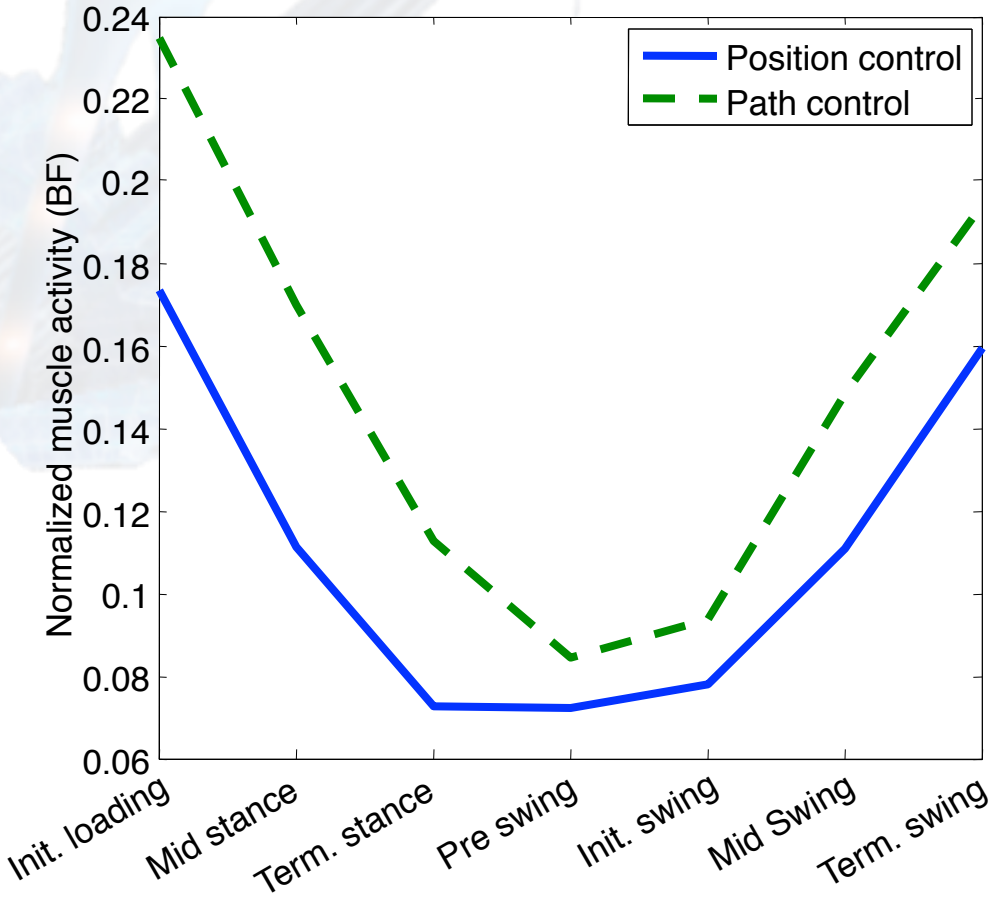
Duschau-Wicke, Vallery, Riener 2009, 2010, 2011

Path Control

- Robot behaves assistive, corrective or transparent, when needed
- Free timing for patient
- Support patient, but do not restrict patient

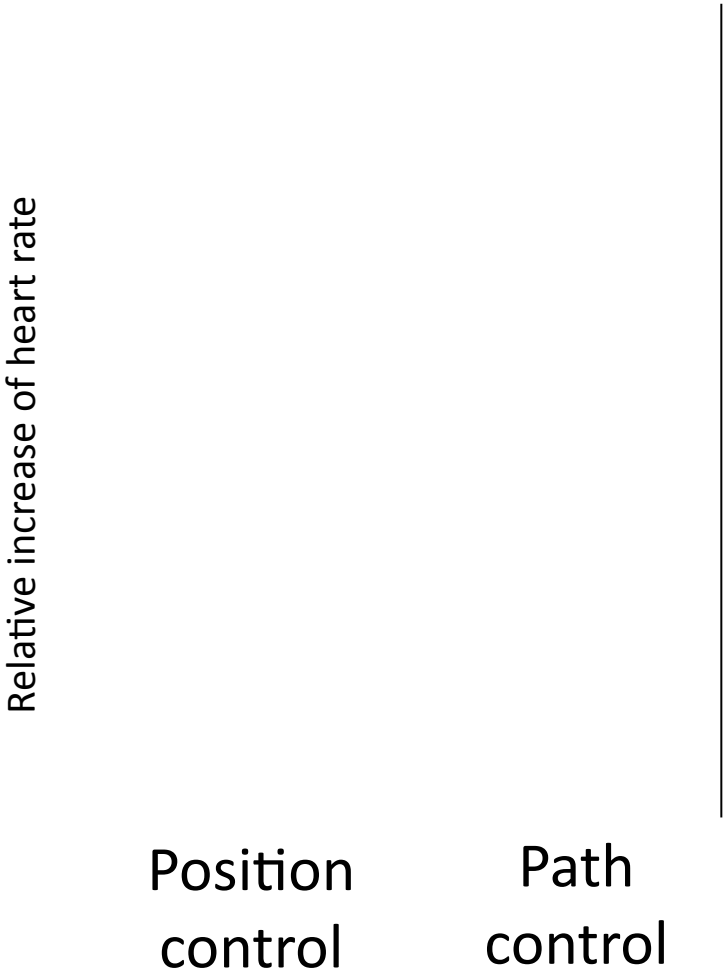
Path Control Increases Participation

Muscle Activity



11 incomplete SCI subjects

Heart Rate



Sensory-Motor Characteristics

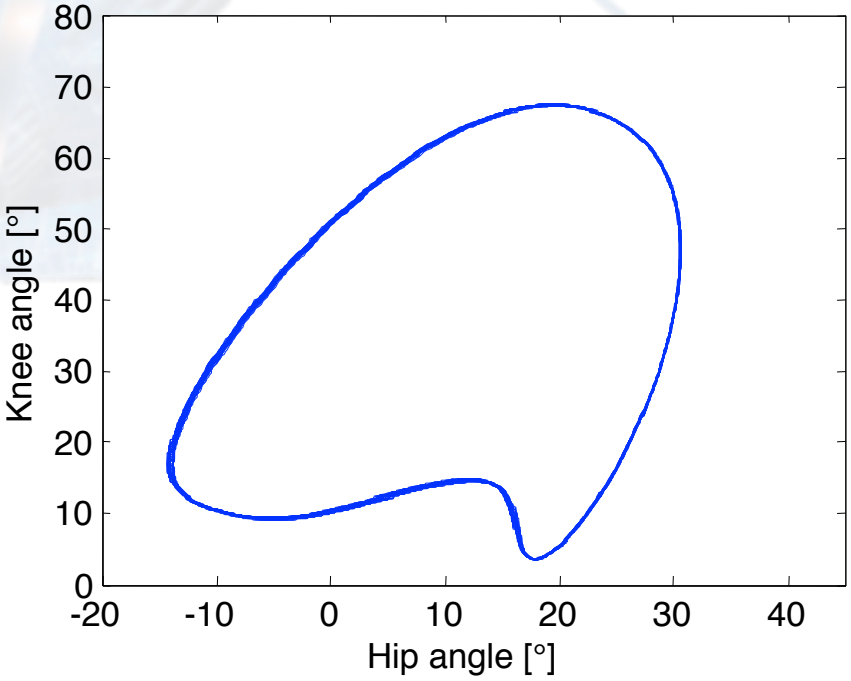
To Be Known about Human Physiology

- Nervous system is plastic
- Participation increases plasticity
- Repetition without repetition

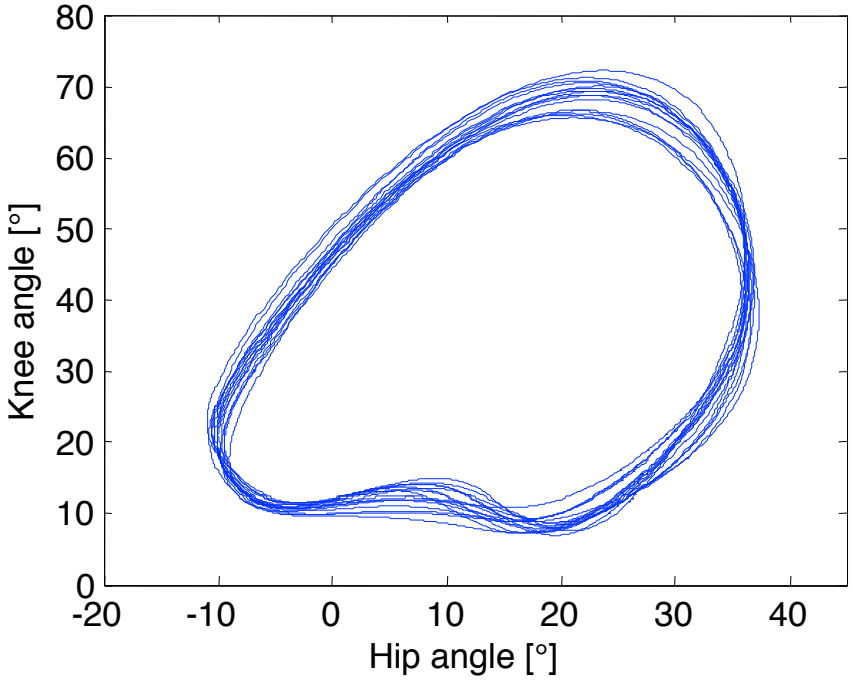
Path Control Enhances Variability

“Repetition without Repetition”

Position Control



Path Control



Sensory-Motor Characteristics

To Be Known about Human Physiology

- Nervous system is plastic
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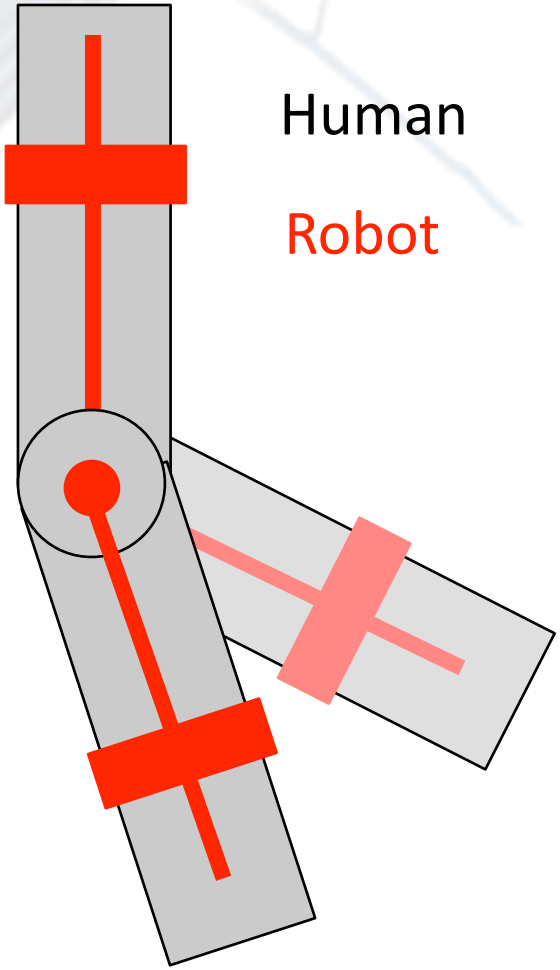
- Provide large ROM, avoid joint stress

Main Problem with Exoskeletons

Alignment of Robotic and Human Joints



Human

Robot

Main Problem with Exoskeletons

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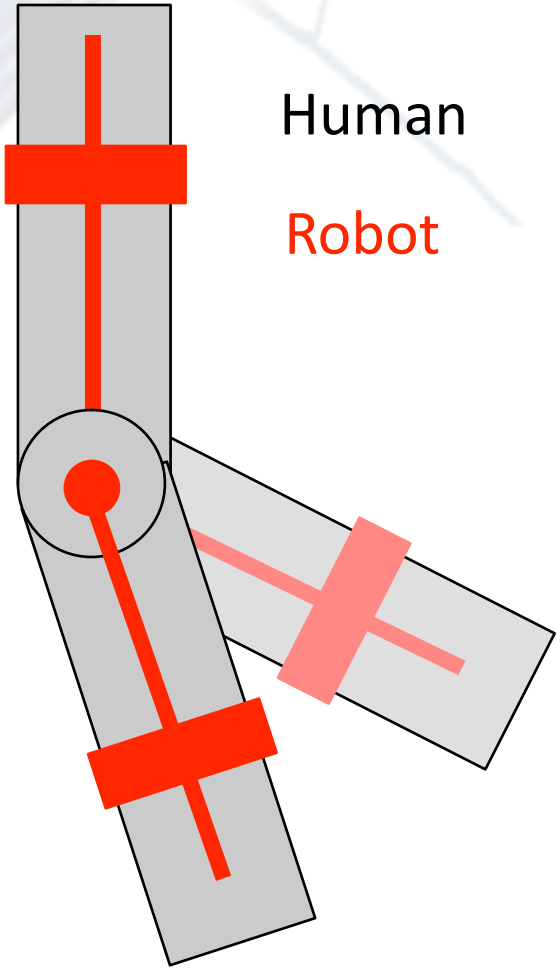

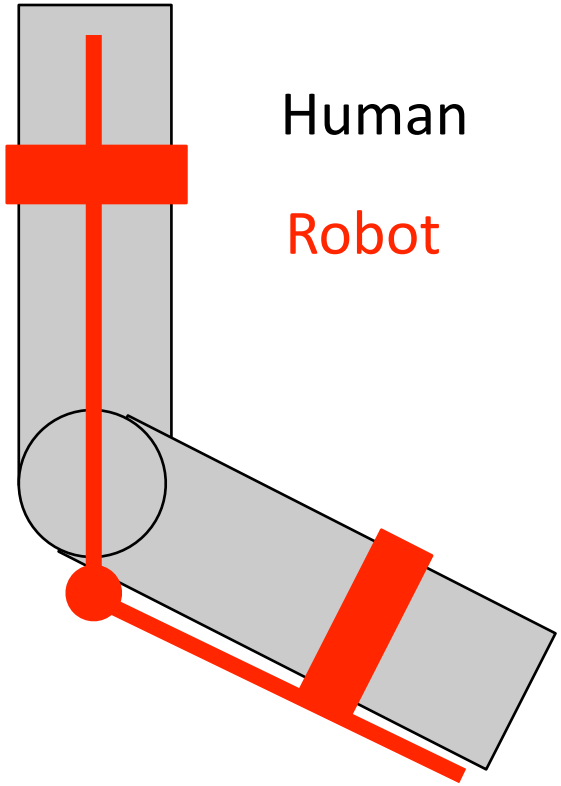

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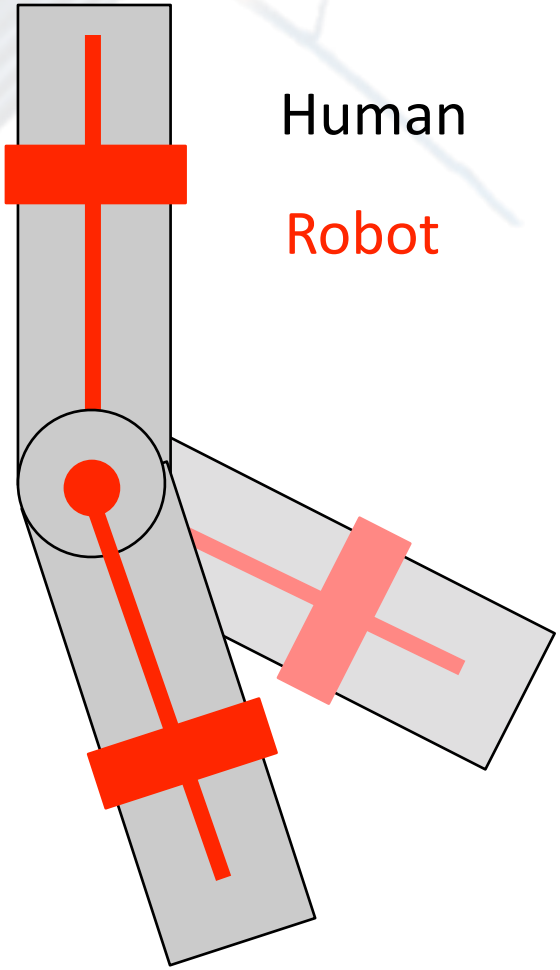
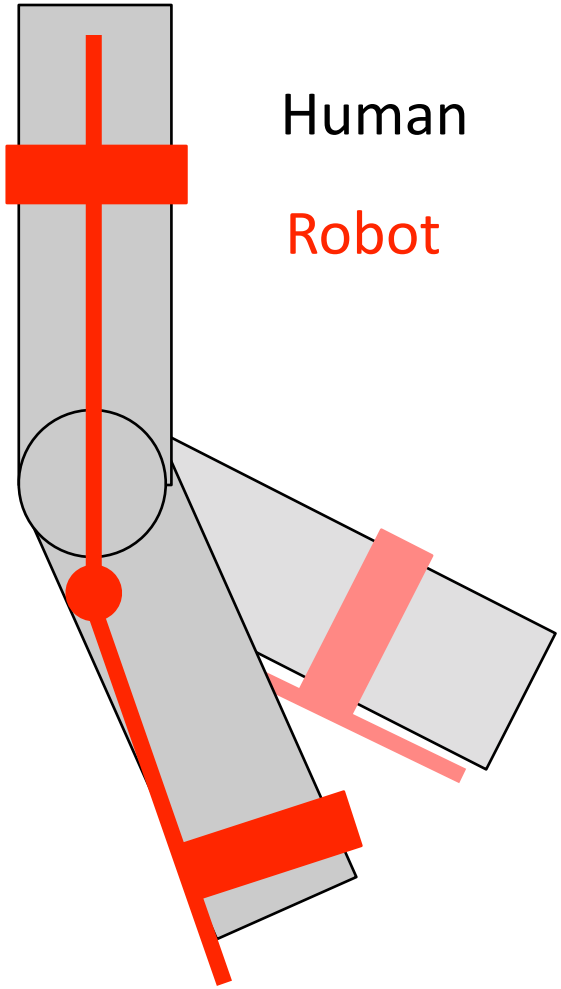
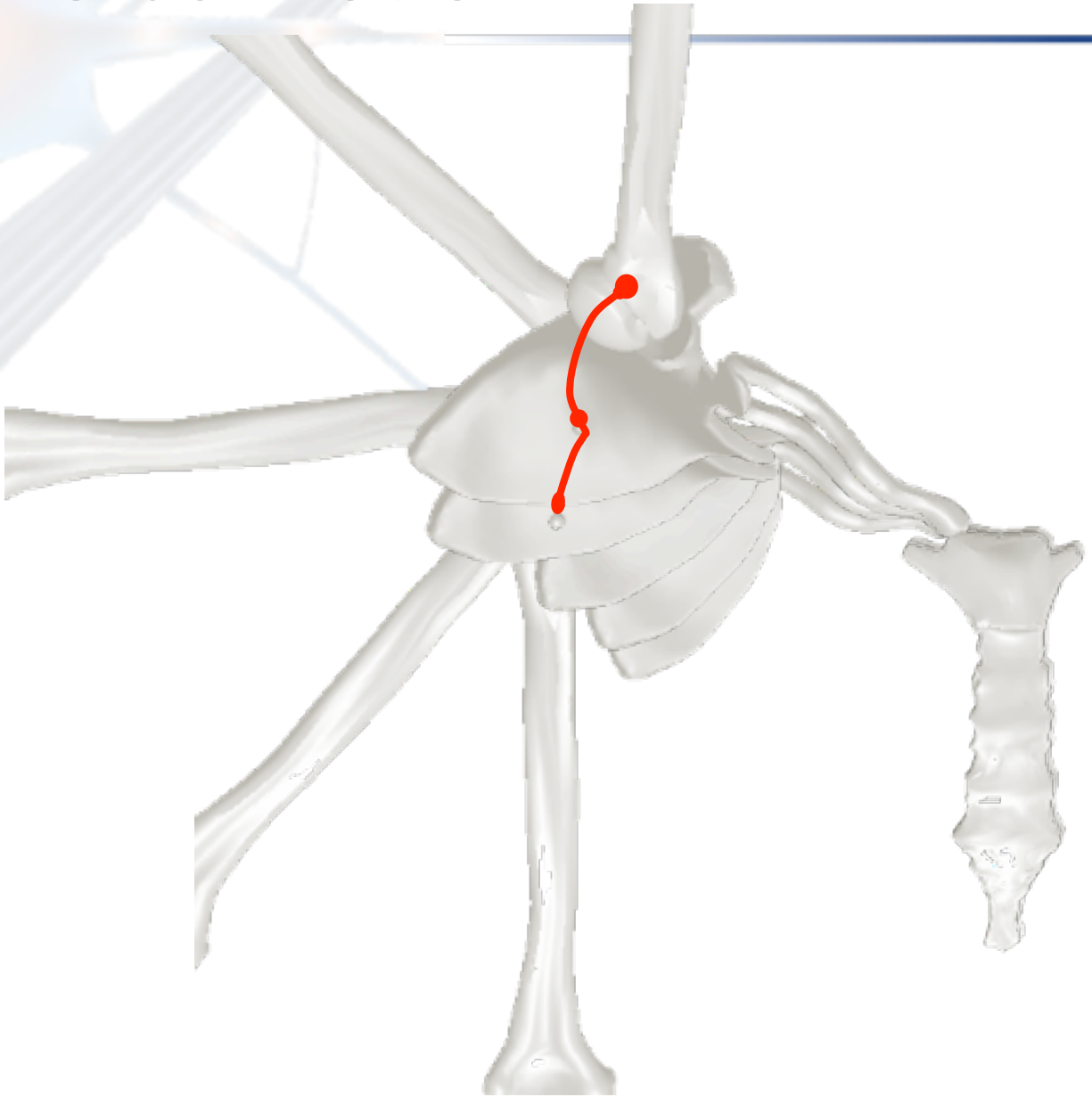




Humerus Motion



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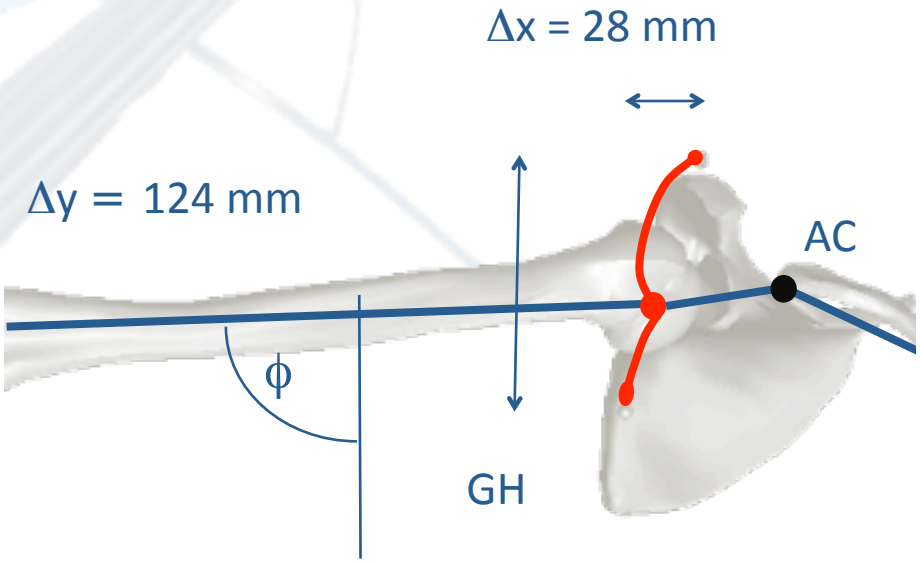
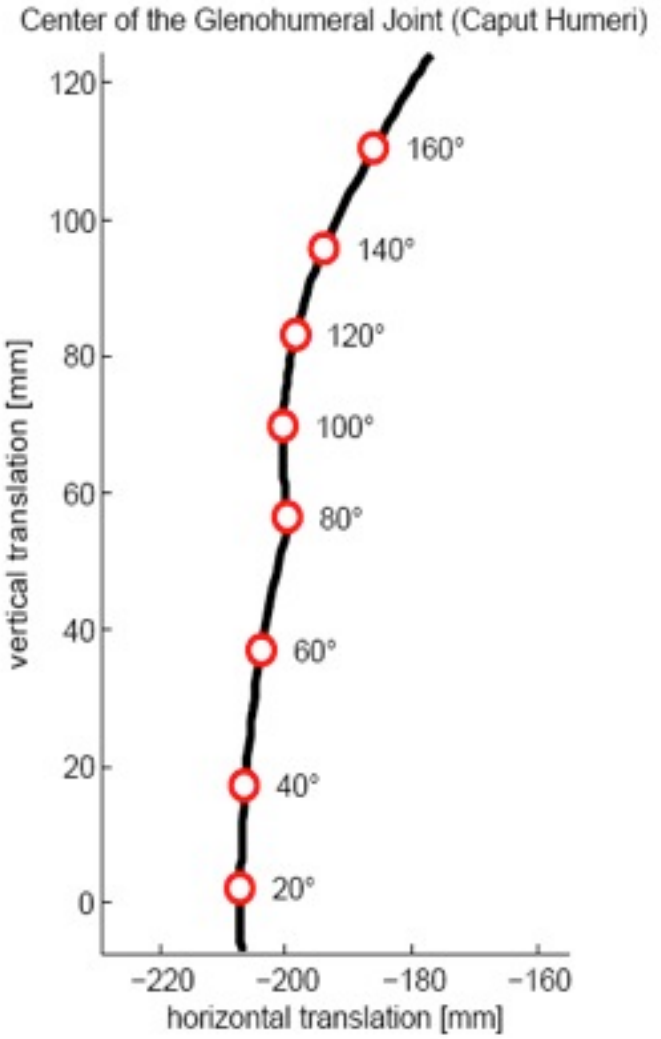
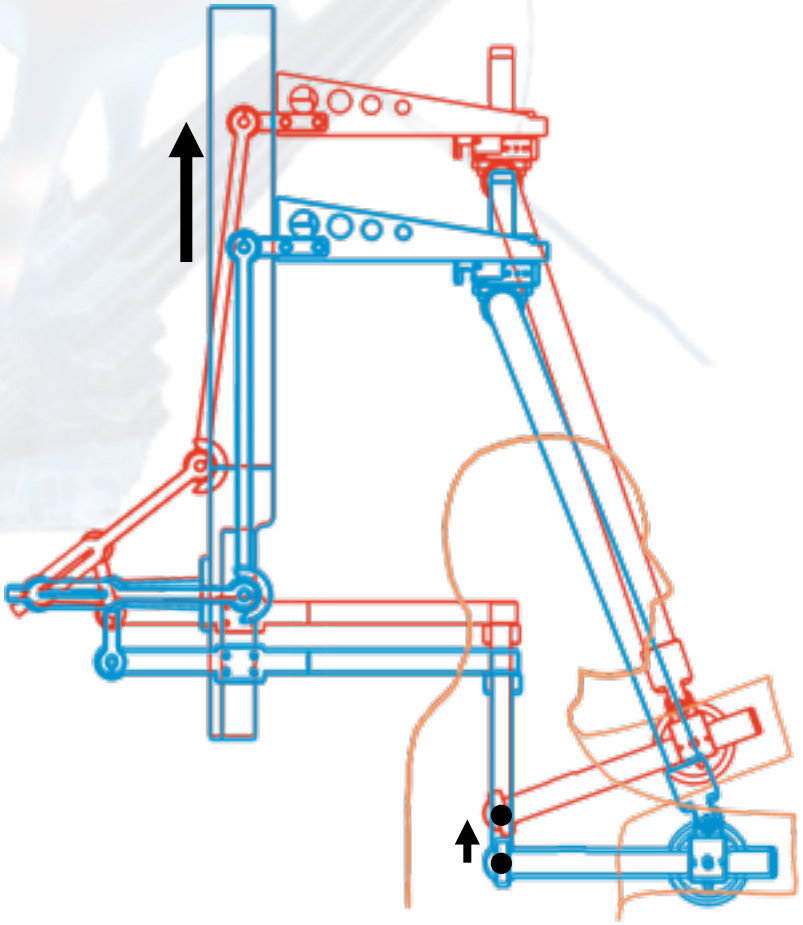
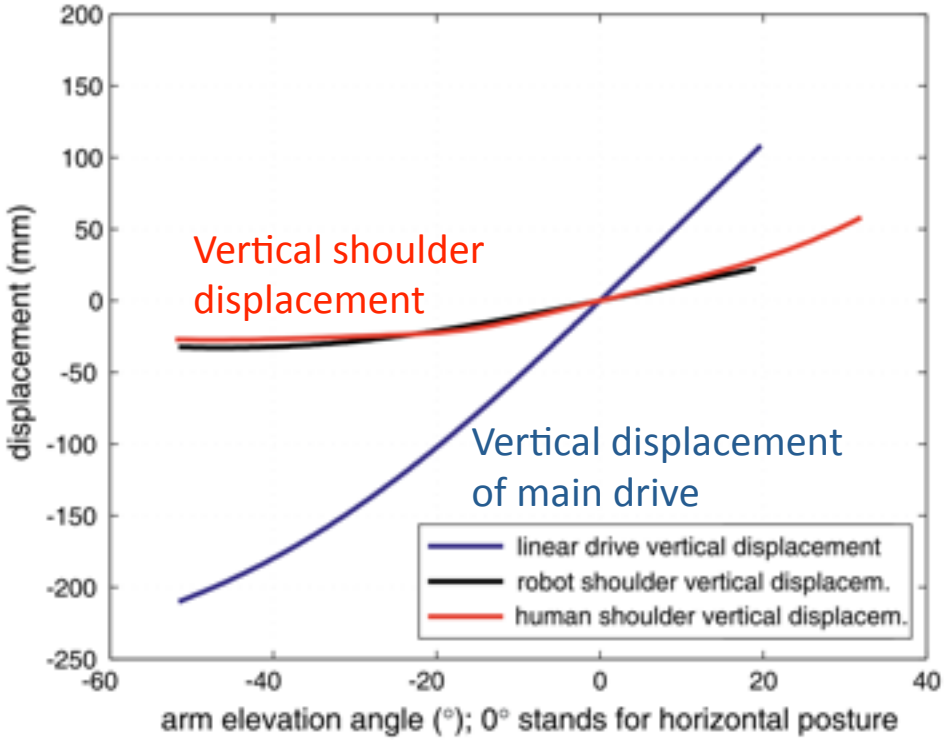




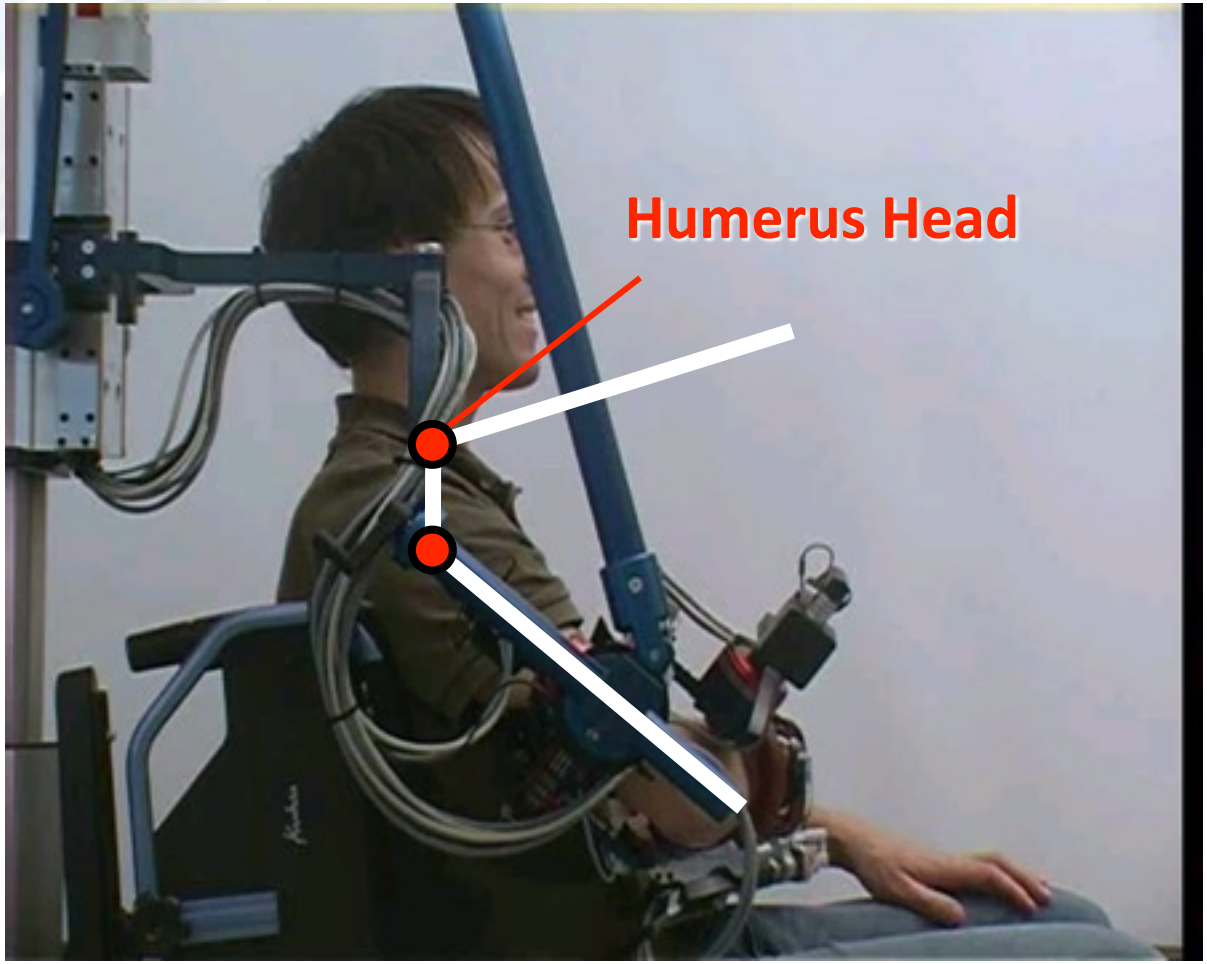
Body height: 1.7 m

ARMin II Shoulder Kinematics





ARMin III: Novel Shoulder Actuation



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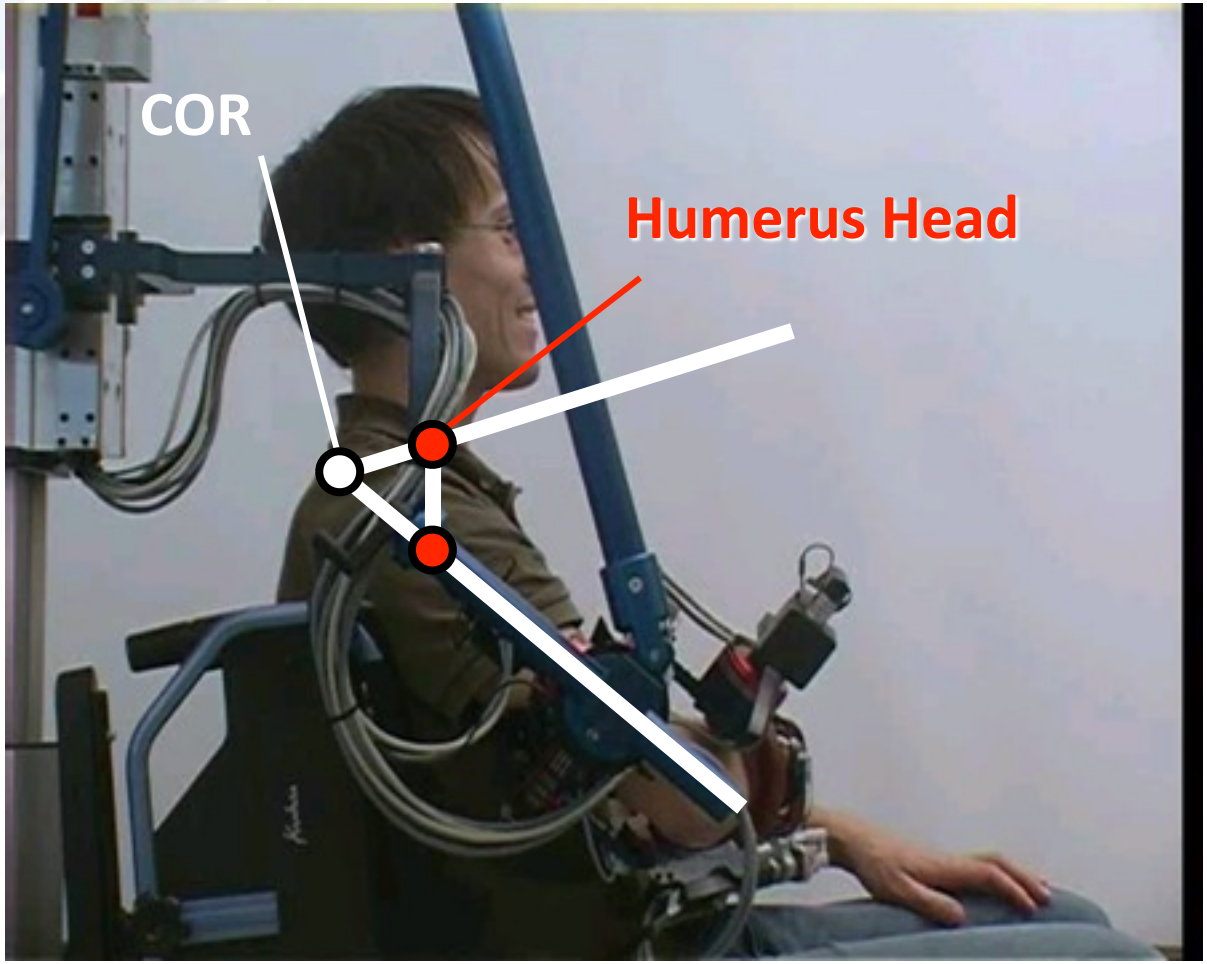

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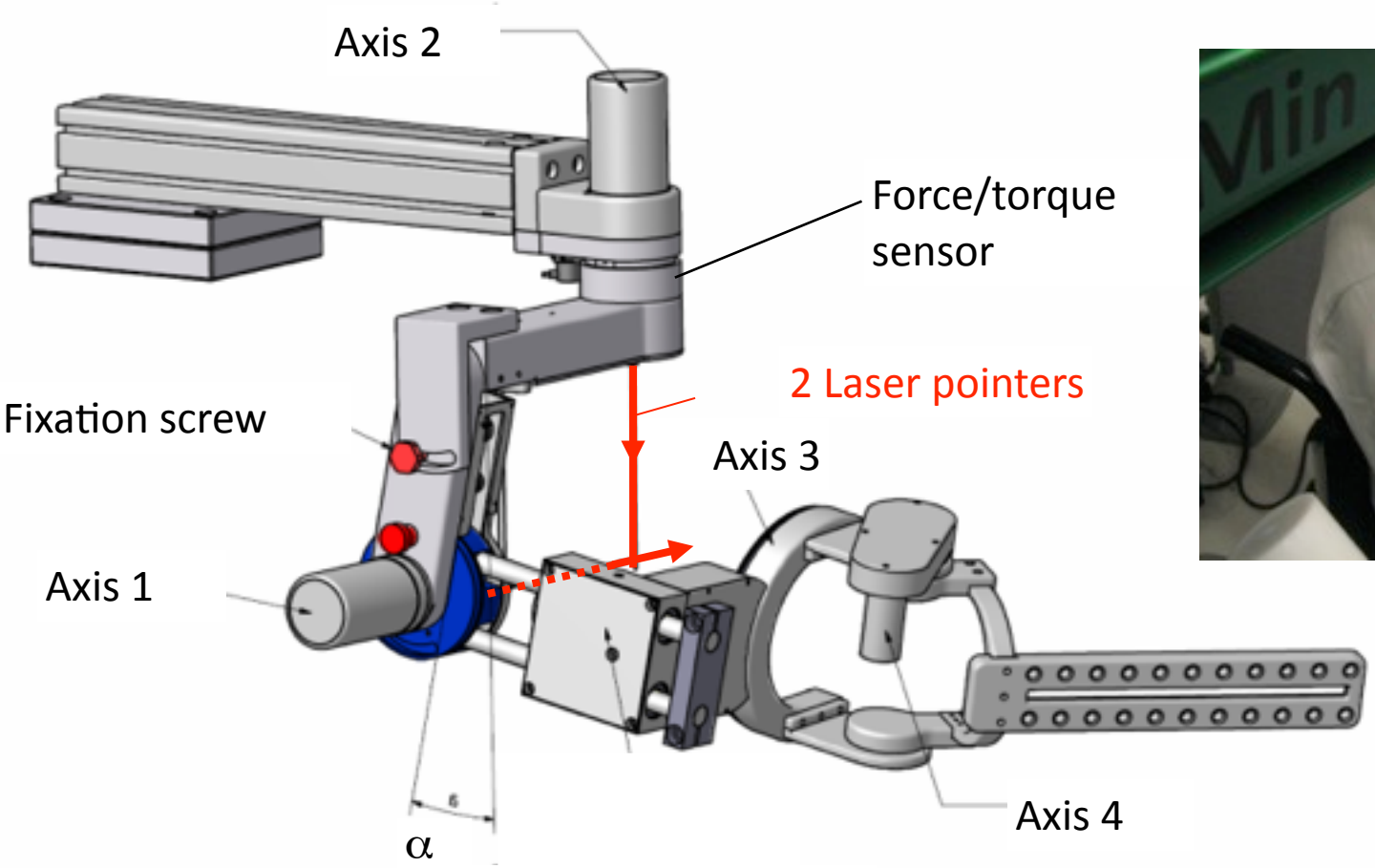

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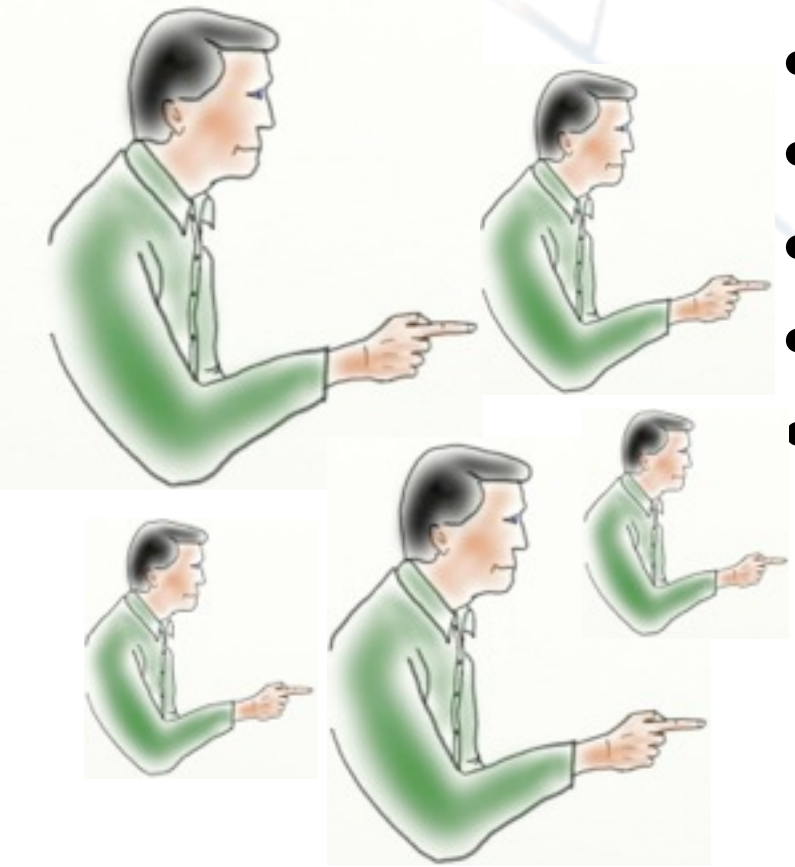

- Nervous system is plastic
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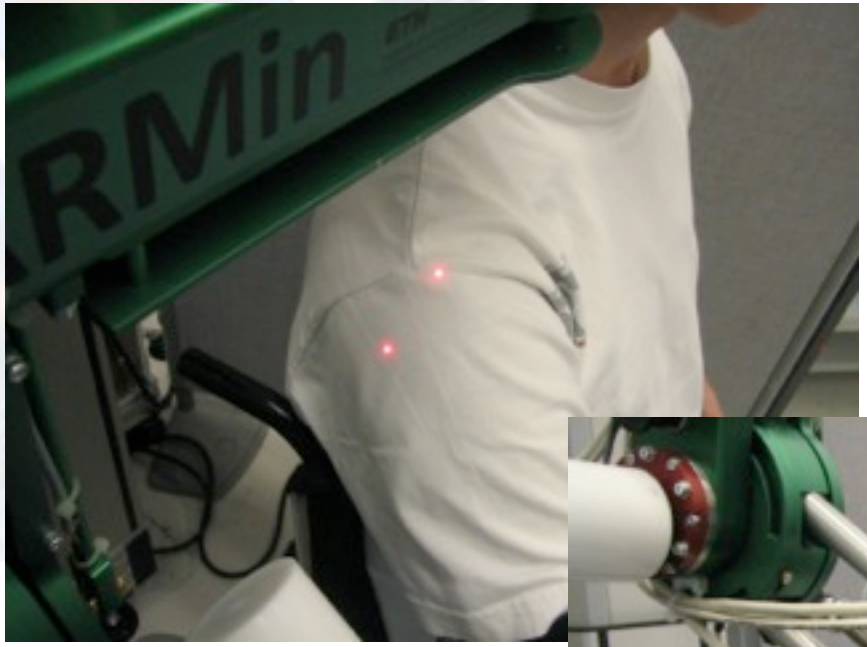
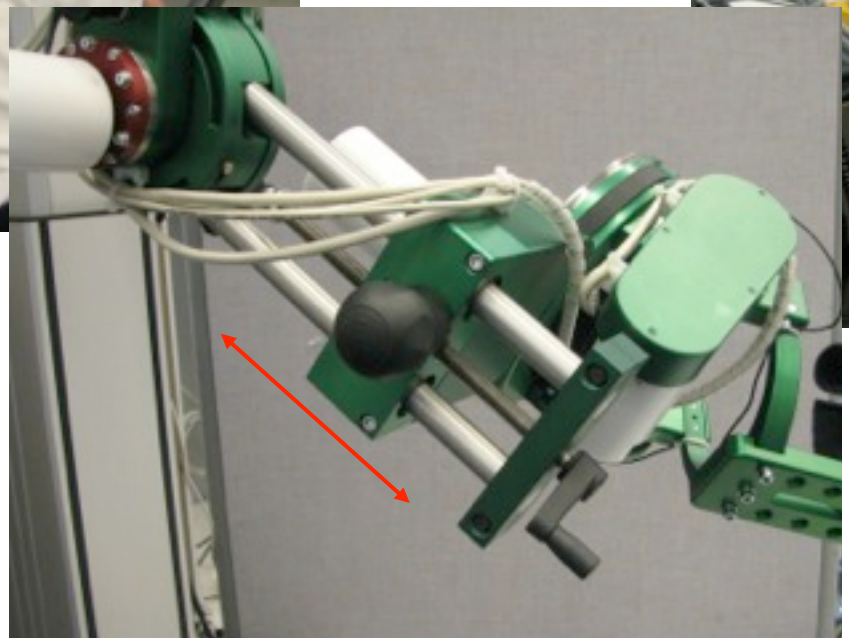
- Provide large ROM, avoid joint stress
- Each patient is different

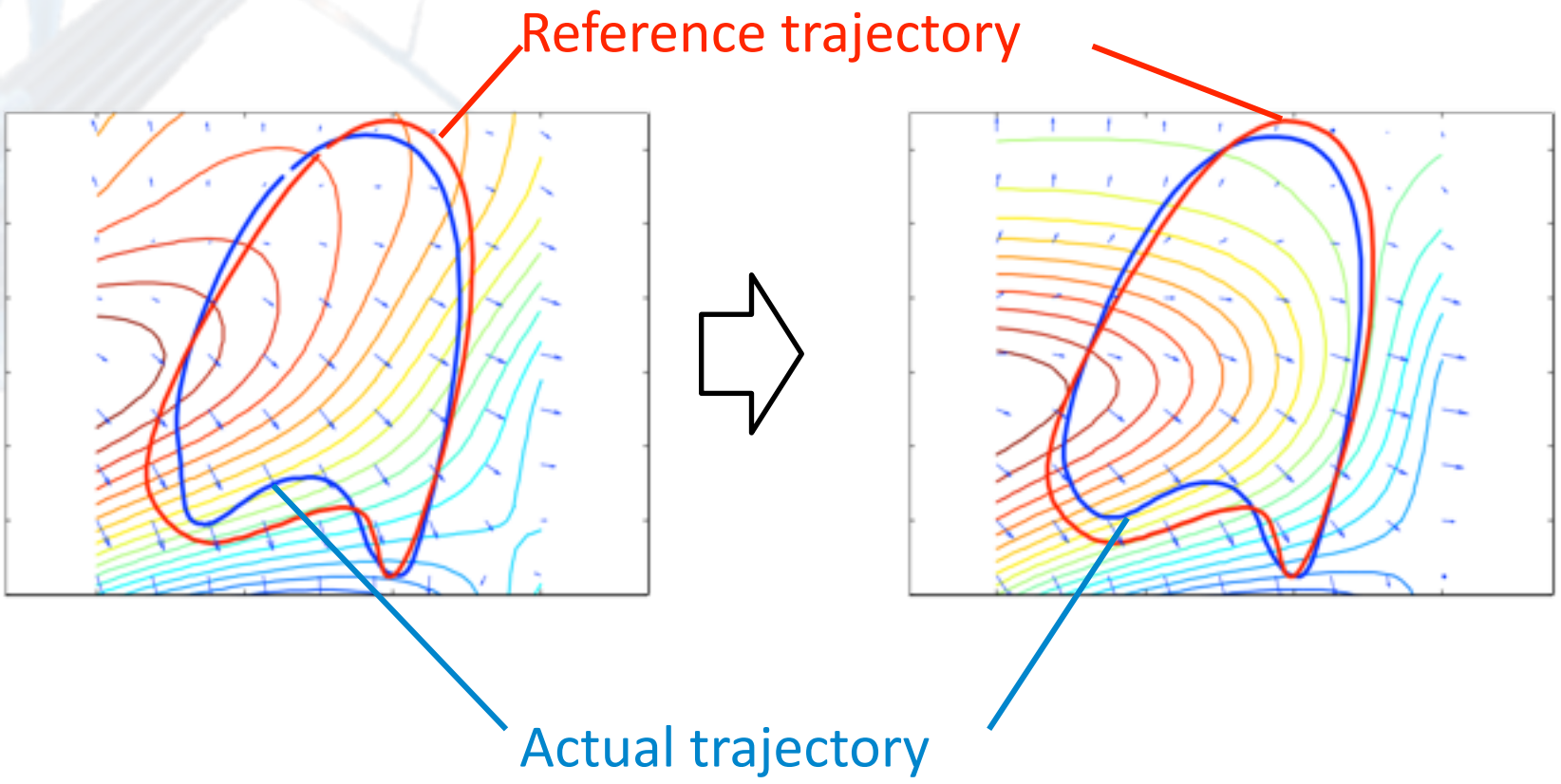
ARMin III: Adjustments





Lokomat: Adaptive Force Field

Adapt Field with a Iterative Learning Controller



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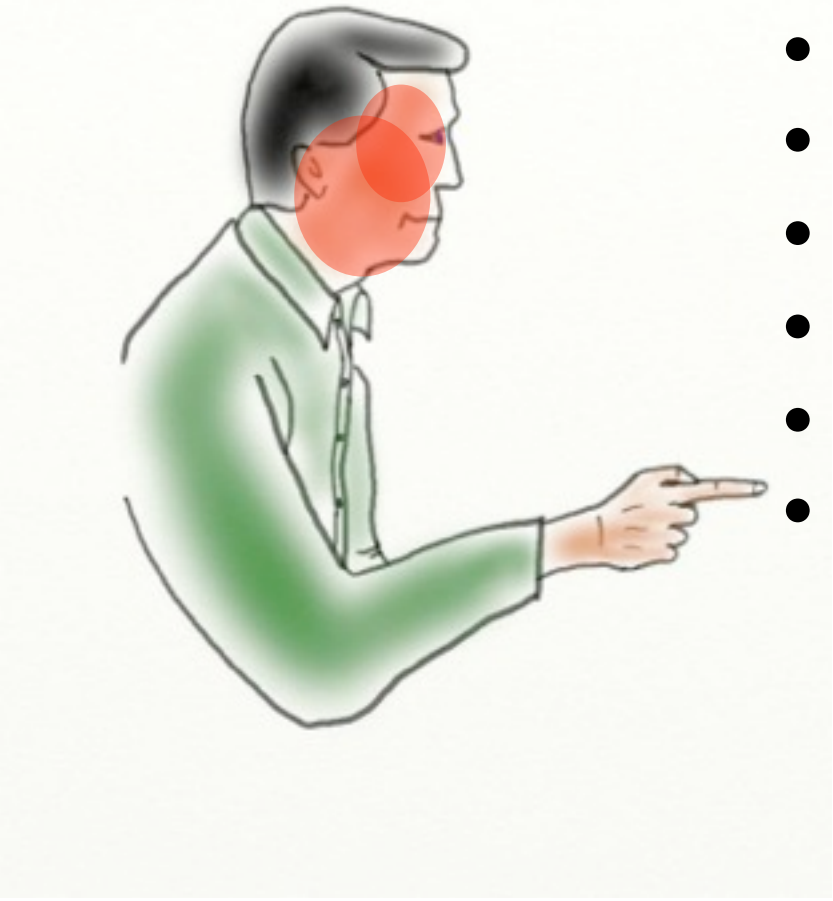

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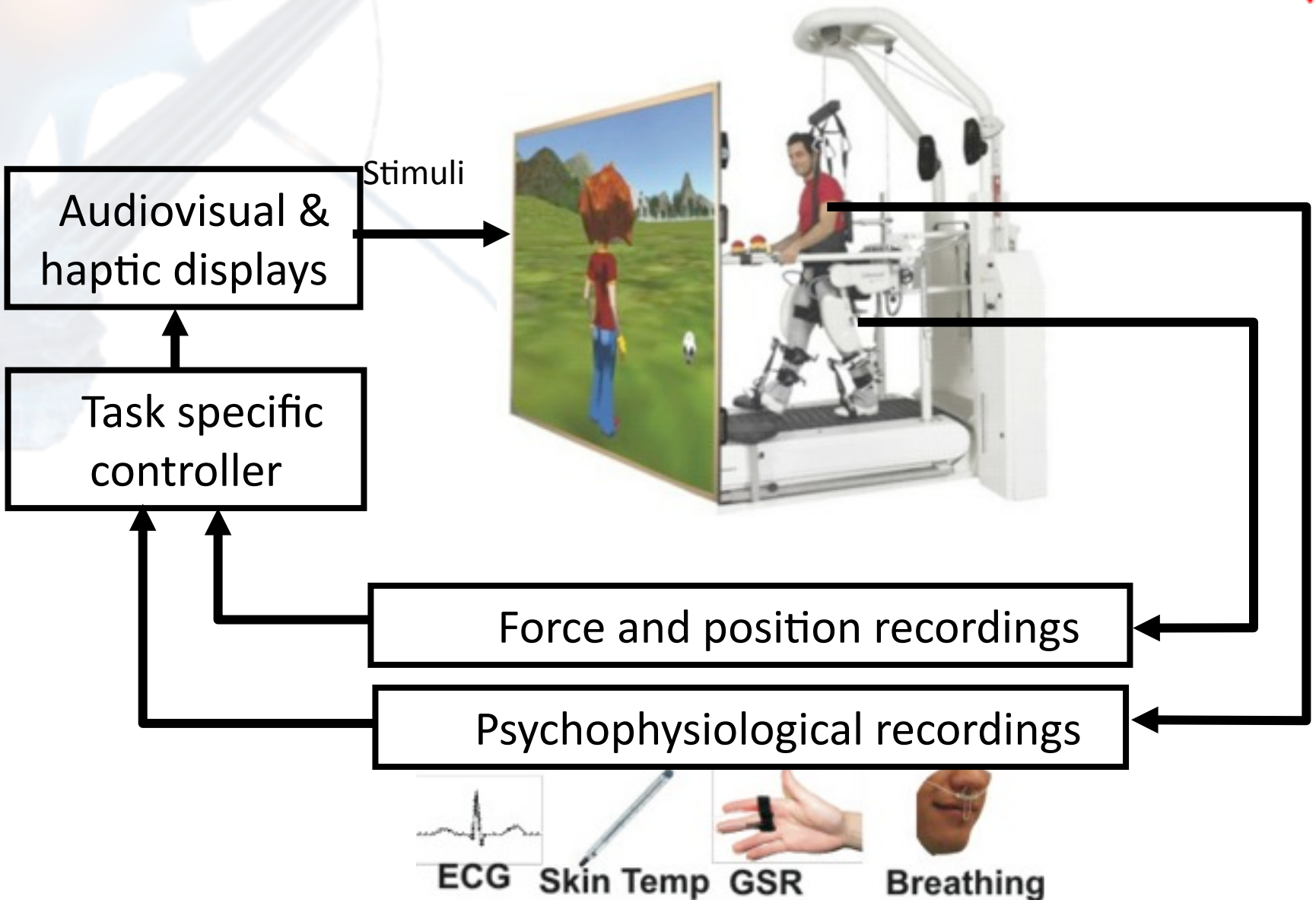
- Each patient is different
- Motivation increases plasticity

Human-Robot Cooperation



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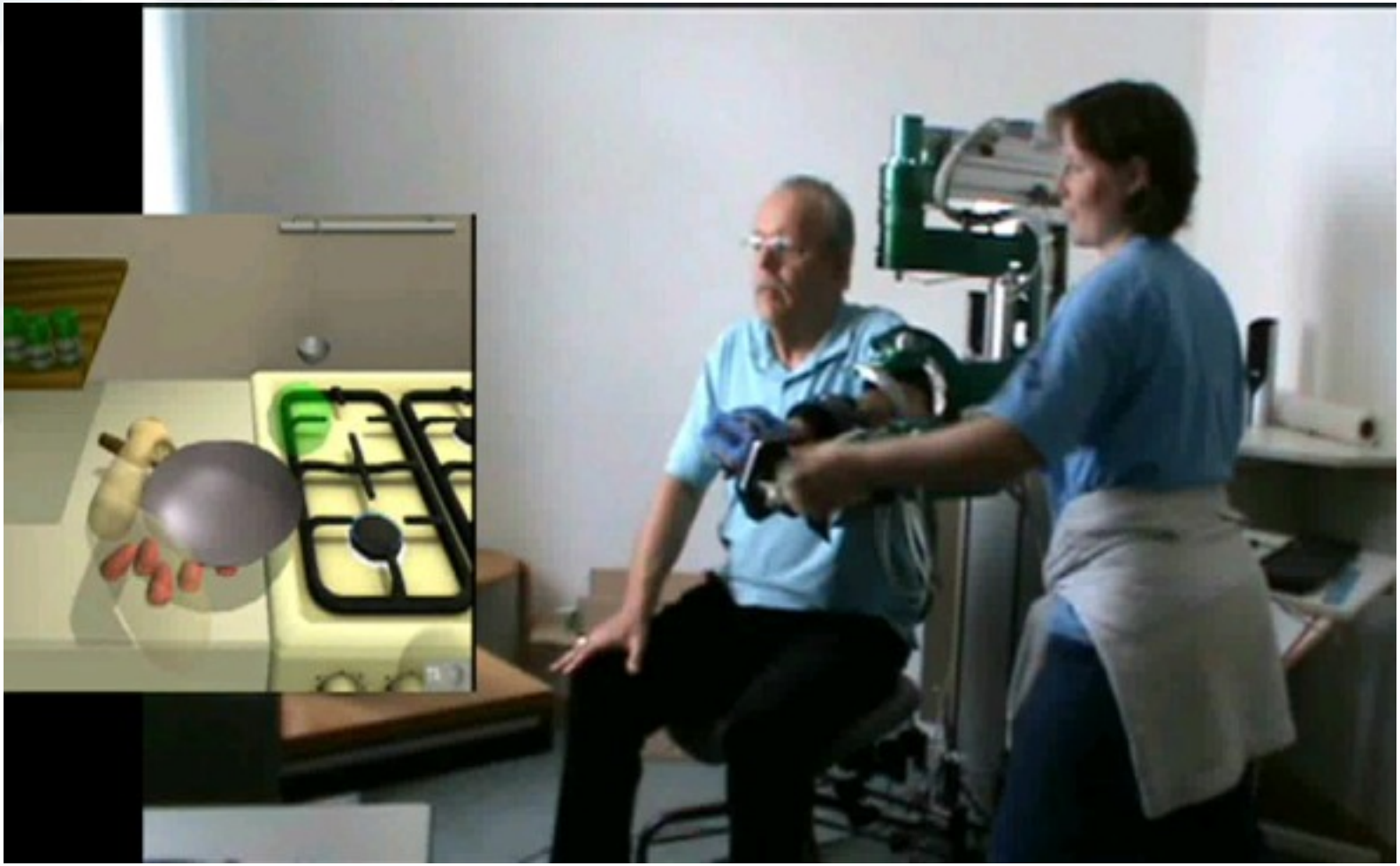
- Train activities of daily living

Task Specific Training

Chronic Stroke Patient (FMA=26)



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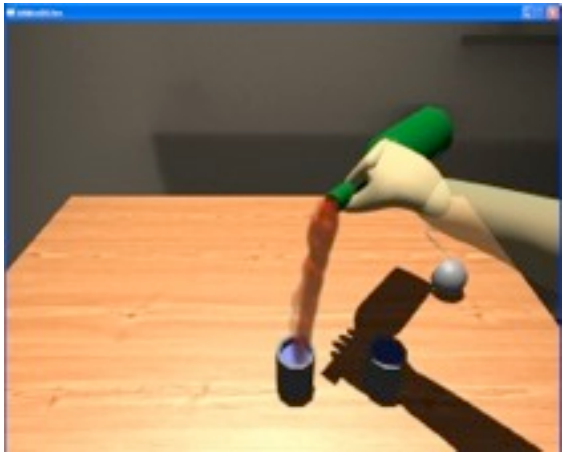

Conclusion and Outlook

Taking into Account Human Physiology

- Robots can allow efficient & intensive & individual training
- Robot can cooperate to keep the patient active
- Robots can motivate the patient

Chances

- Improve health status and quality of life (patients)
- Reduce workload of clinical staff (therapists, nurses)

To do

- Clinical evaluation studies on patients