Interview for Advanced Robotic Systems

ICRA, Hongkong, 2nd June 2014

Novel Robots for Gait and Arm Rehabilitation

Prof. Dr. Robert Riener

Sensory-Motor Systems Lab

Institute of Robotics and Intelligent Systems, ETH Zurich

University Hospital Balgrist, University of Zurich

SMS Lab: 2 Affiliations, 2 Locations

ETH Zurich

Institute for Robotics
and Intelligent Systems

IRIS

University Hospital Balgrist

Spinal Cord Injury Center

uniklinik
balgrist

Disadvantage of Manual Training

For the Therapist

- Physically exhausting
- Ergonomically inconvenient

↓

For the Patient

- Limited training duration
- Gait pattern not optimal

SCI Center, Balgrist University Hospital, Zurich

Challenges & Chances

What Are the Challenges in Rehabilitation?

1. Patients need intensive training to benefit from neuroplastic effects, even in the presence of pharmaceutical factors

2. Number of patients increases due to demographic shift

3. There is a shortage of personnel for rehabilitation and care

=> Chances: Application of Robotics

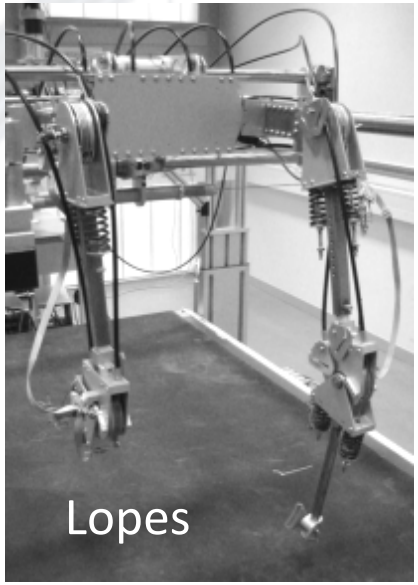
Robot-Aided Gait Training

Lokomat

Balgrist,
Hocoma AG

Current Robotic Plattforms for Neurorehabilitation

Gait Rehabilitation "Robots"



GaitTrainer

Haptic Walker

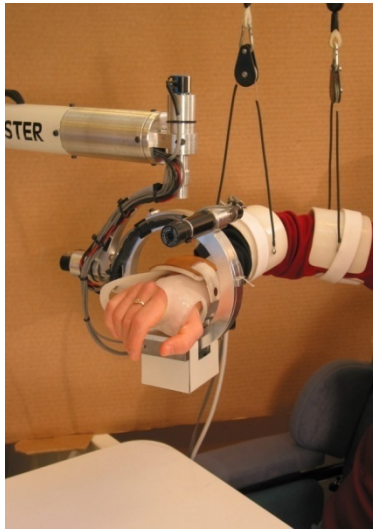
Hand/Arm Rehabilitation "Robots"

MIT Manus

Bi-Manu-Track

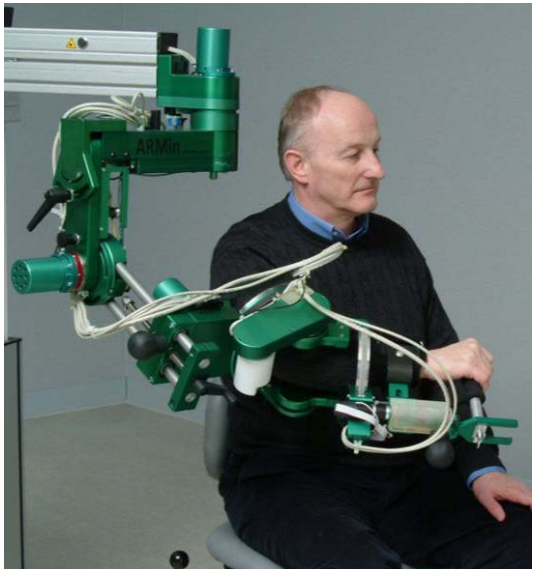
MGA

Haptic Master, GENTLE/s



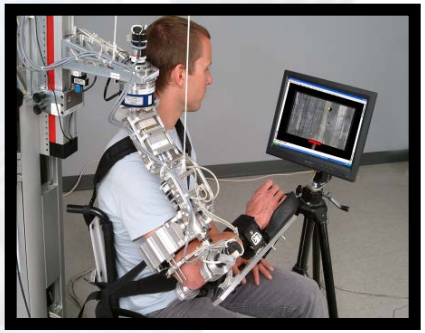
Armeo Series

ARMin

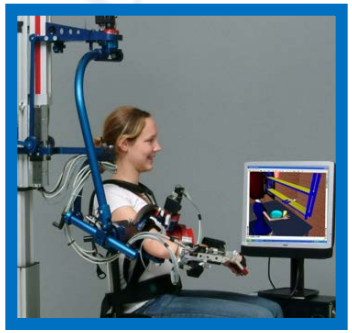


ARMin History

4 Axes



6 Axes



ARMin I ***ARMin II***

2005 2006 2007 2008 2009 2010 2011 2012

Pilot study I (n=10)

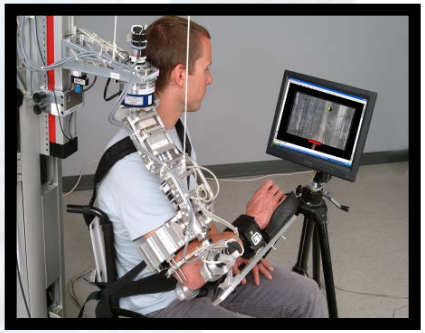
Pilot study II

Single case studies I, chronic stroke (n=3)

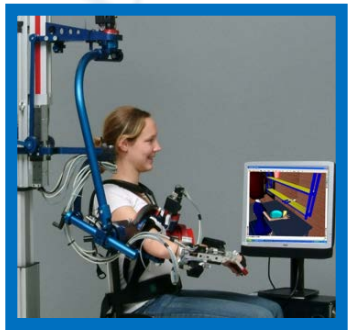
Single case studies II, chronic stroke (n=4)

ARMin History

4 Axes



6 Axes



7 Axes

ARMin I ***ARMin II*** ***ARMin III***

2005 2006 2007 2008 2009 2010 2011 2012

Pilot study I (n=10)

Pilot study II

Pilot study III

Single case studies I, chronic stroke (n=3)

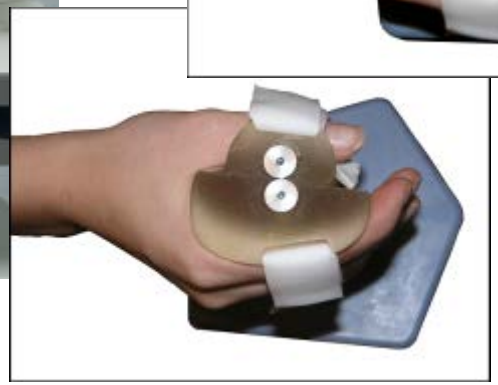
Single case studies II, chronic stroke (n=4)

Controlled clinical trial, chronic stroke (n=80)

Nef, Riener et al. 2006-2011

ARMin III

Exoskeletal Robot with 7 Degrees of Freedom



ETH Zurich/Balgrist, Hocoma AG

Nef, Riener et al. 2006-2011

Multicenter Randomized Clinical Trial

Hypothesis

"Patient-responsive ADL-related **robotic training** with ARMin is **more effective than conventional therapy** with respect to **motor functional recovery** of the affected arm of chronic hemiparetic **stroke** patients."

Multicenter Randomized Clinical Trial

Study Design

- Multicenter, randomized, controlled, clinical trial
- Four medical centers
- Total of 77 patients
- Patients with moderate to severe motor impairment of an upper limb (FMA 8 to 38) after stroke
- Chronic state (at least 6 months post-stroke)

Study Outcomes

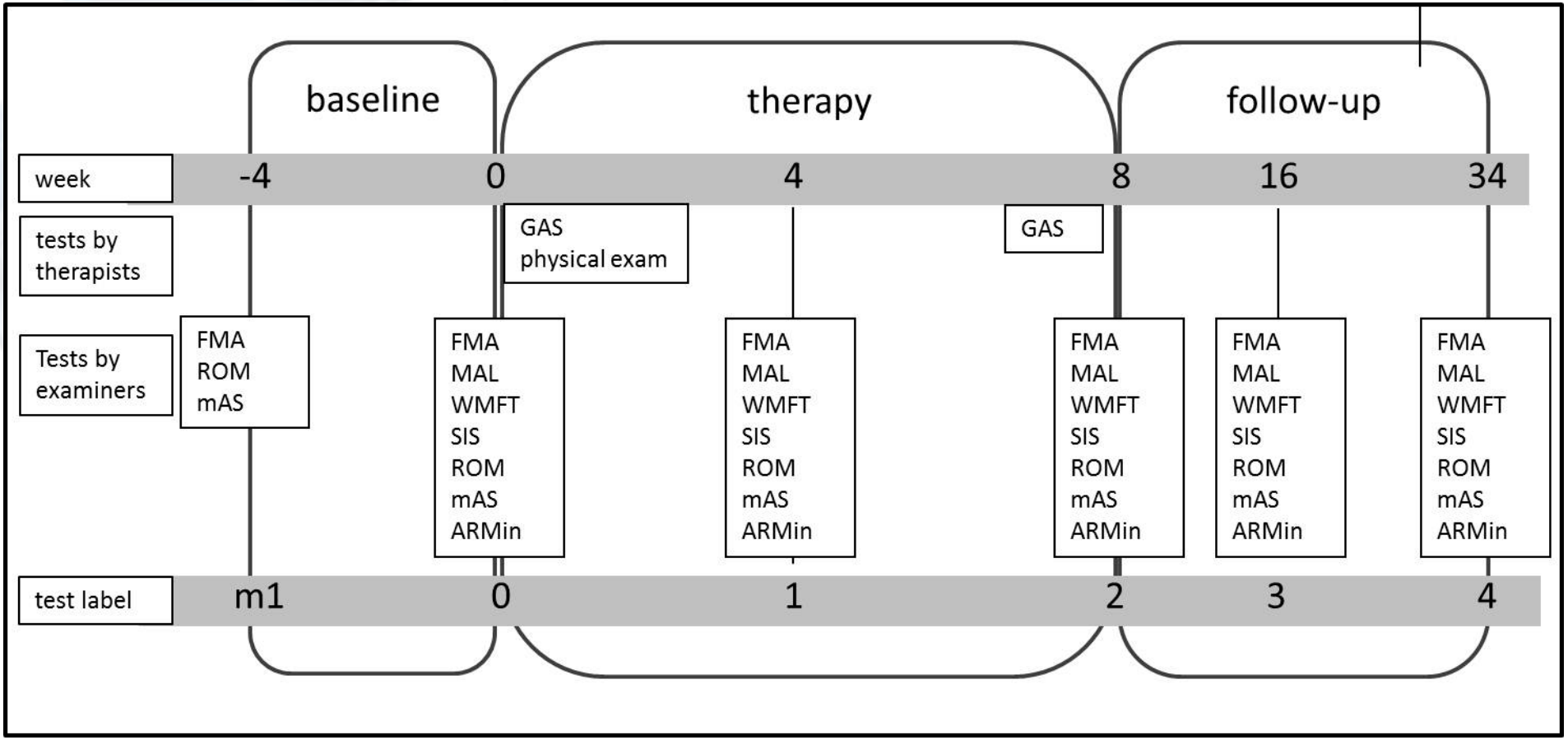
Primary Outcome

- Fugl-Meyer Assessment (FMA), impairment based, upper arm portion (max. 66 points)

Secondary Outcomes

- Wolf Motor Function Test (WMFT)
  - time
  - function
- Questionnaires
  - Stroke Impact Scale (SIS)
  - Motor Activity Log (MAL)
- Modified Ashworth-Skala (mAS)
- ROM, joint torques measured by ARMin

Time Course

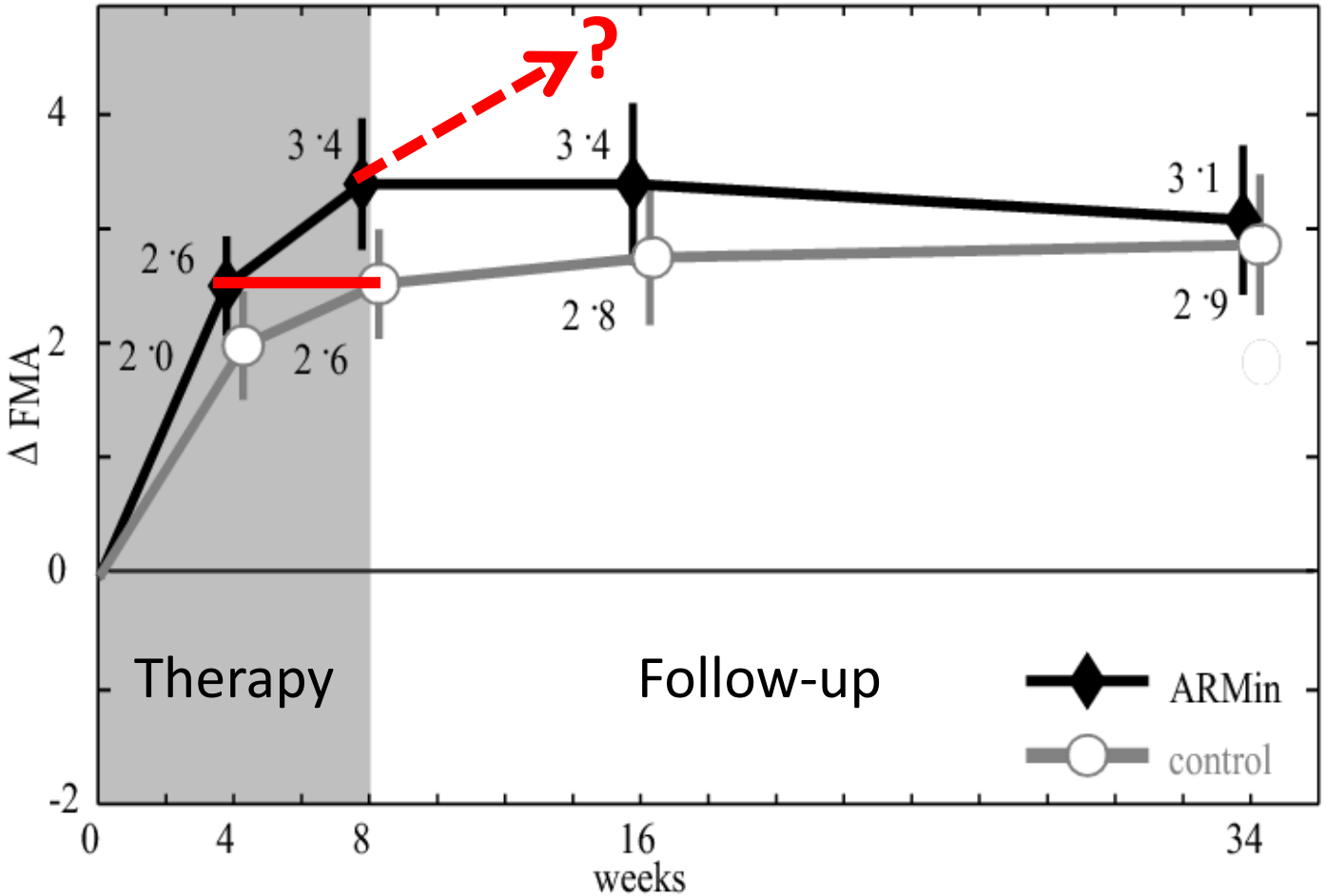

baseline
therapy
follow-up
week
-4
0
4
8
16
34
tests by therapists
GAS
physical exam
GAS
Tests by examiners
FMA
ROM
mAS
FMA
MAL
WMFT
SIS
ROM
mAS
ARMin
FMA
MAL
WMFT
SIS
ROM
mAS
ARMin
FMA
MAL
WMFT
SIS
ROM
mAS
ARMin
FMA
MAL
WMFT
SIS
ROM
mAS
ARMin
FMA
MAL
WMFT
SIS
ROM
mAS
ARMin
test label
m1
0
1
2
3
4

Therapy Session Modes

	Robot (ARMin)	Conventional (Control)
Minimum time	45 min	45 min
Therapy modes	Mobilisation (min. 10min)	Mobilisation
	Games (min. 10min)	Games
	ADL tasks (min. 10min)	ADL tasks
		«Others»

Change in FMA

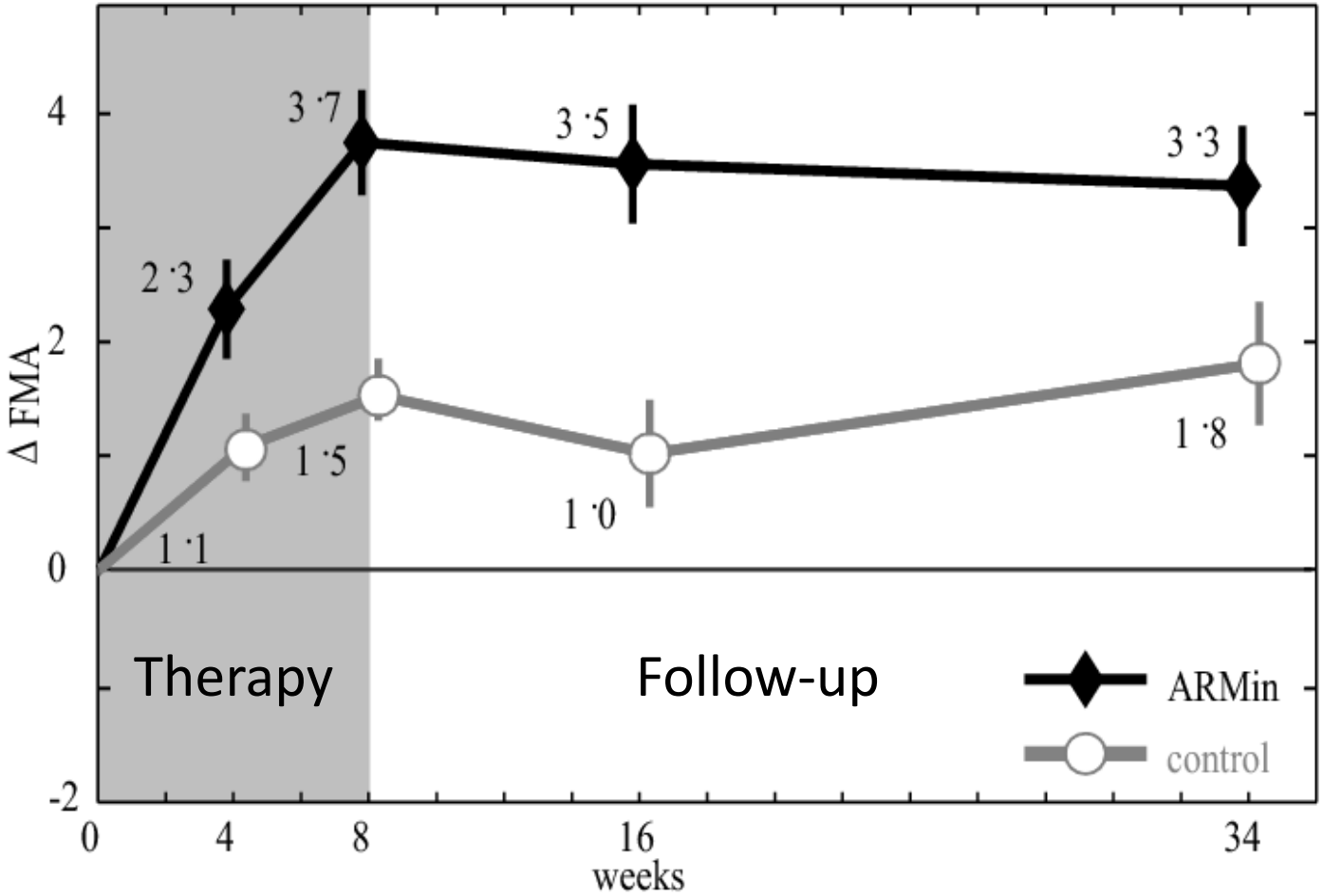
73 Patients (38 ARMin, 35 Control)



Klamroth, …, Riener, The Lancet Neurology, Dec. 2013

Change in FMA: Severe Cases

34 out of 73 Patients



Klamroth, …, Riener, The Lancet Neurology, Dec. 2013

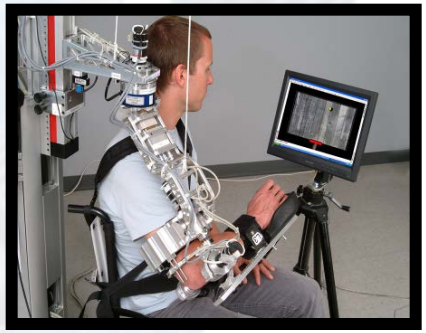
Conclusion from Clinical Study

- Patient-responsive ADL-related robotic training with ARMin is more effective than conventional therapy with respect to functional recovery.
- Particularly patients with severe impairment benefit from robotic therapy of the arm.
- Differences are clinically questionable.
- Were patients "too chronic"? Were robots stimulating too little and supporting too much?
- Future question: Where are the responders?

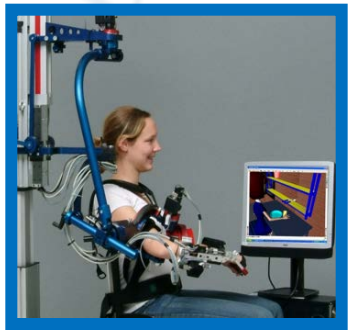
ARMin History

Hocoma

4 Axes



6 Axes



7 Axes

ARMin I ***ARMin II*** ***ARMin III*** ***ARMin IV***

2005 2006 2007 2008 2009 2010 2011 2012

Pilot study I (n=10)

Pilot study II

Pilot study III

Pilot study IV
novel assessment methods

Single case studies I, chronic stroke (n=3)

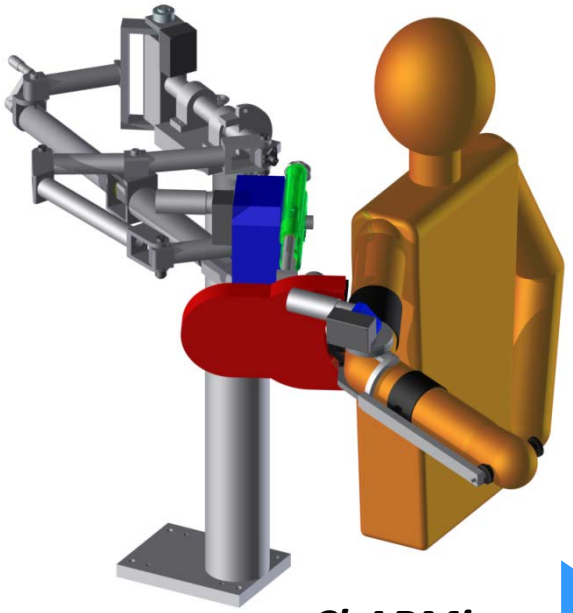
Single case studies II, chronic stroke (n=4)

Controlled clinical trial, chronic stroke (n=80)

Technology Transfer
Armeo®Power

Nef, Riener et al. 2006-2011

ARMin Histor



ARMin III ***ARMin IV*** ***ChARMin***

2008 2009 2010 2011 2012 2013 2014 …

Pilot study III

Pilot study IV
novel assessment
methods

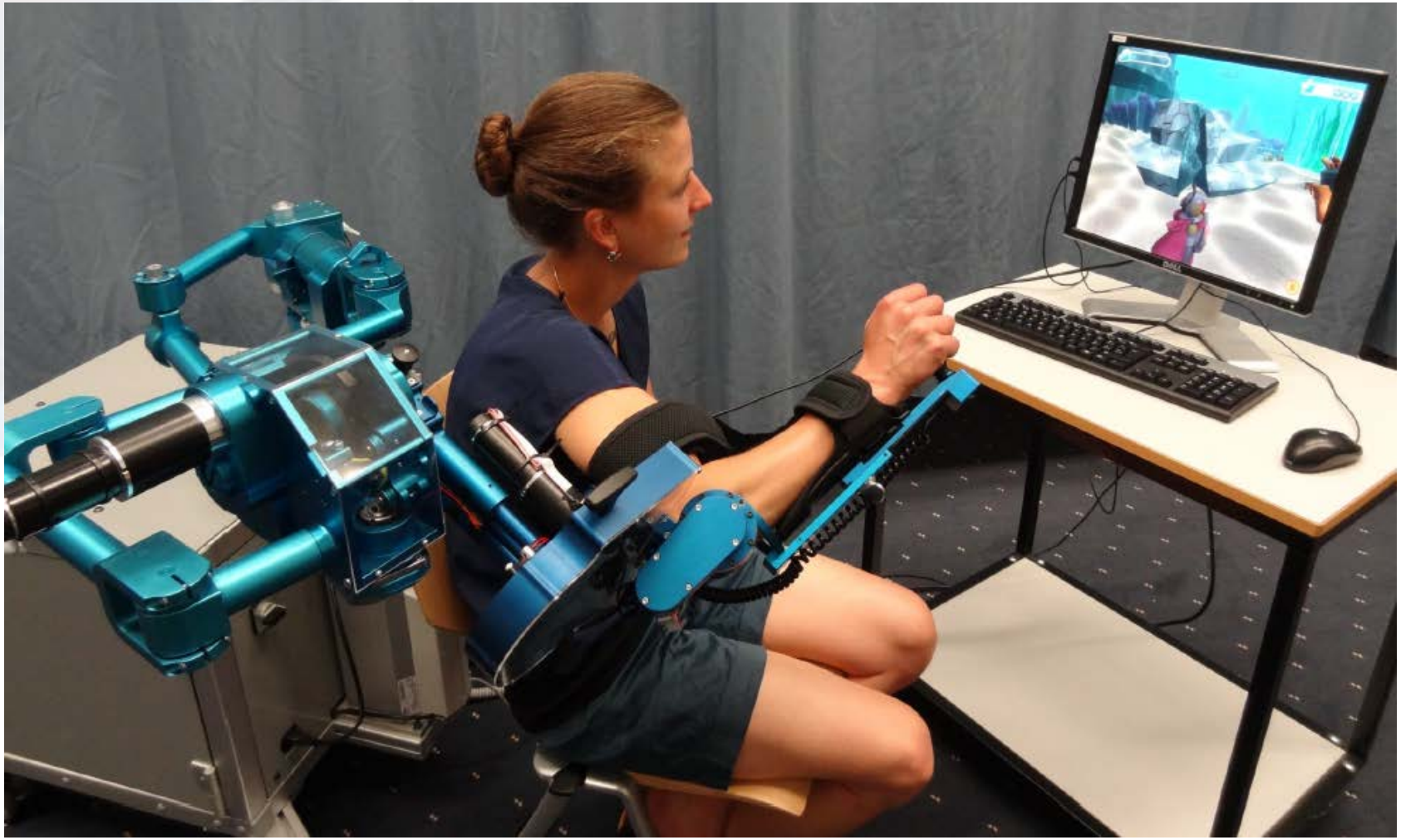
MR-compatible robotics

II,
4)

Controlled clinical trial,
chronic stroke (n=80)

Technology Transfer
Armeo®Power

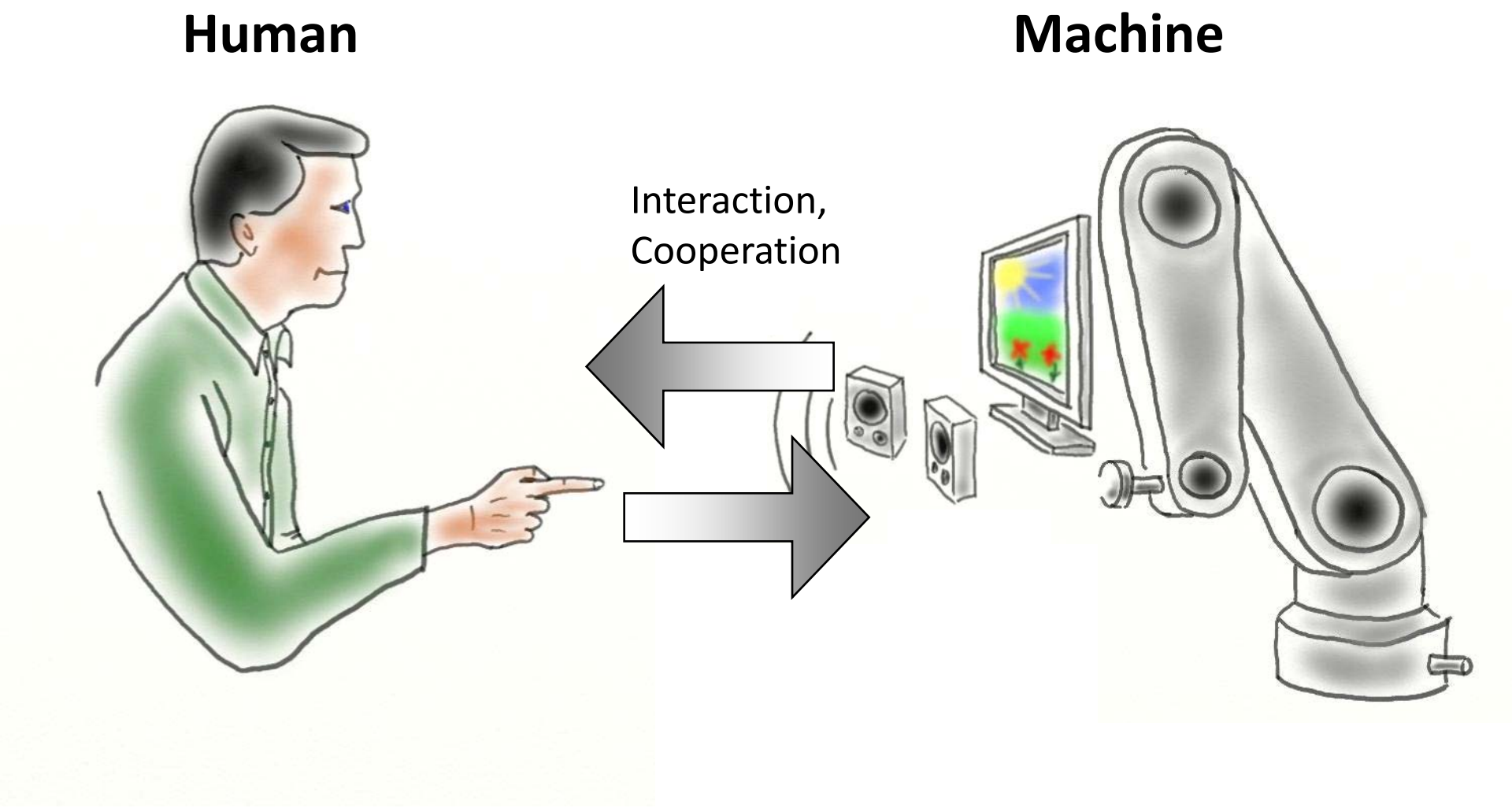
ChARMin Setup



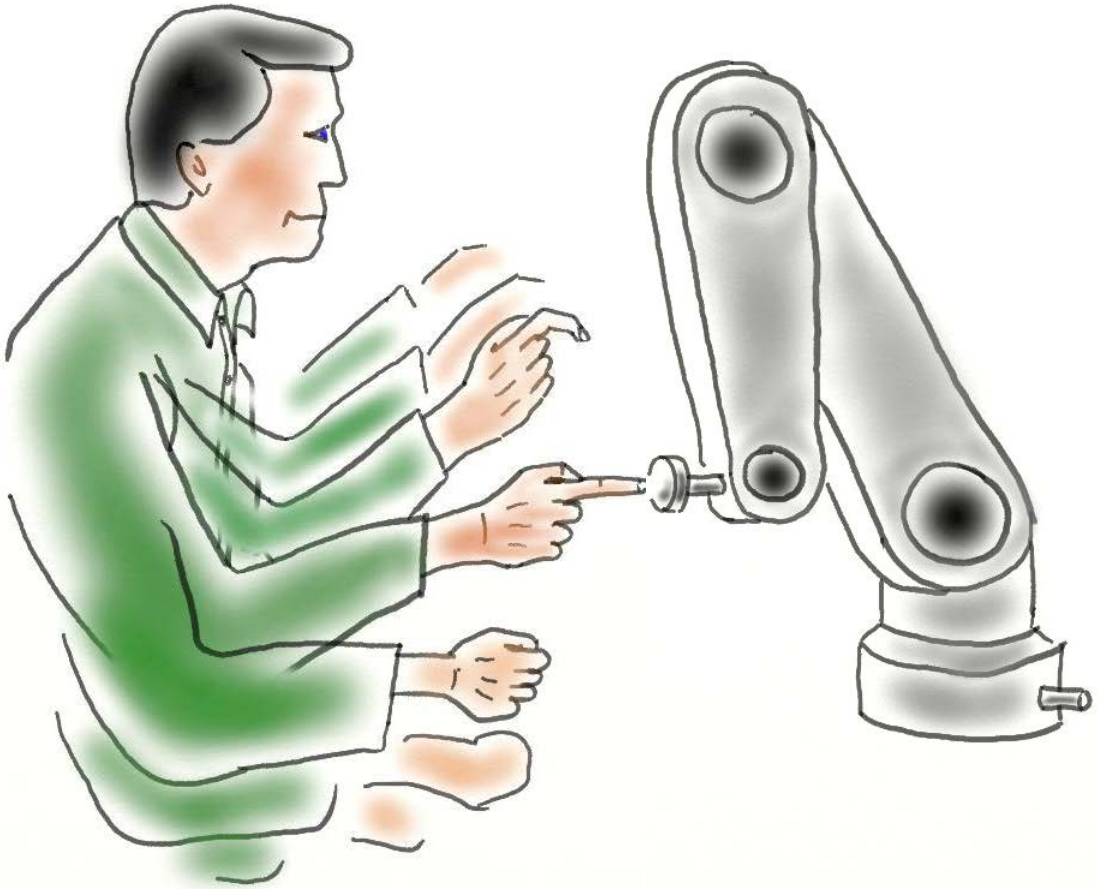
U. Keller, R. Riener & KiSpi Zurich

Human-Robot Interaction

Human-Robot Cooperation



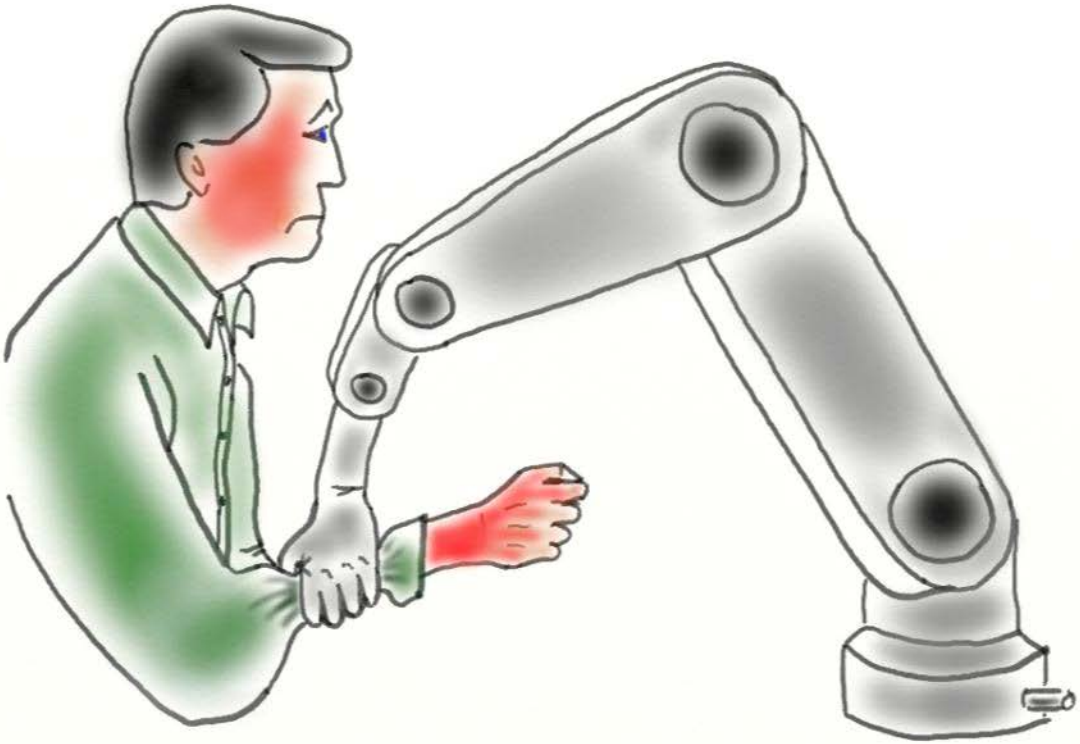
Human-Robot Cooperation



Key Features

- Intensive

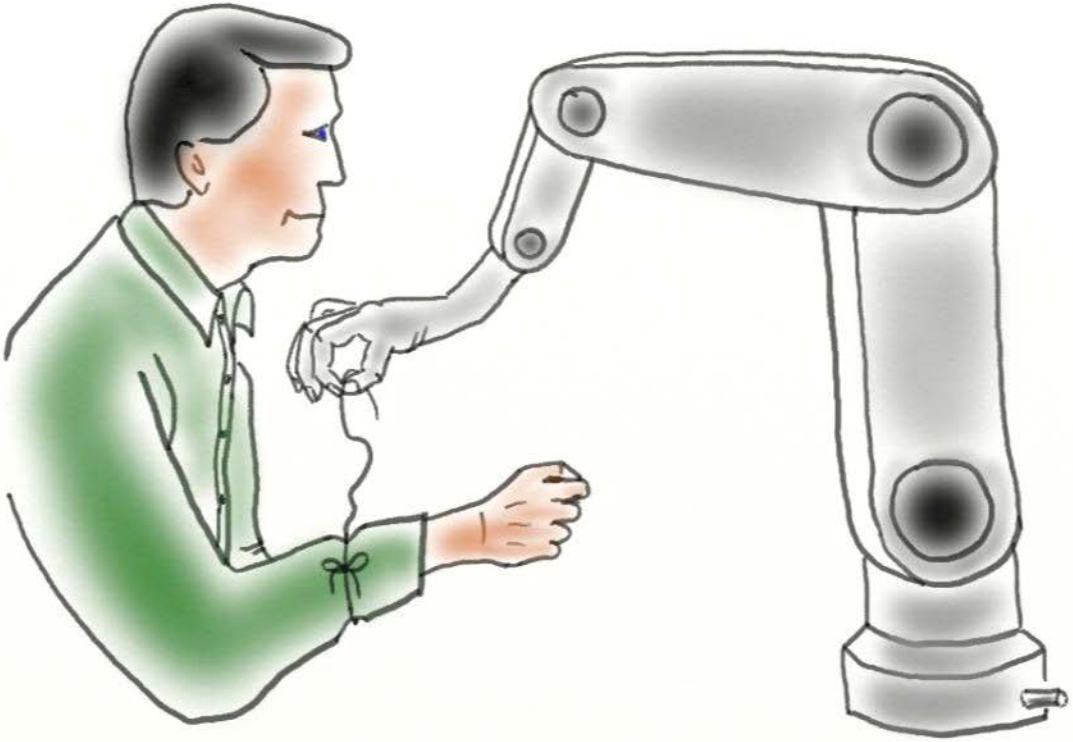
Human-Robot Cooperation



Key Features

- Intensive
- Guided?

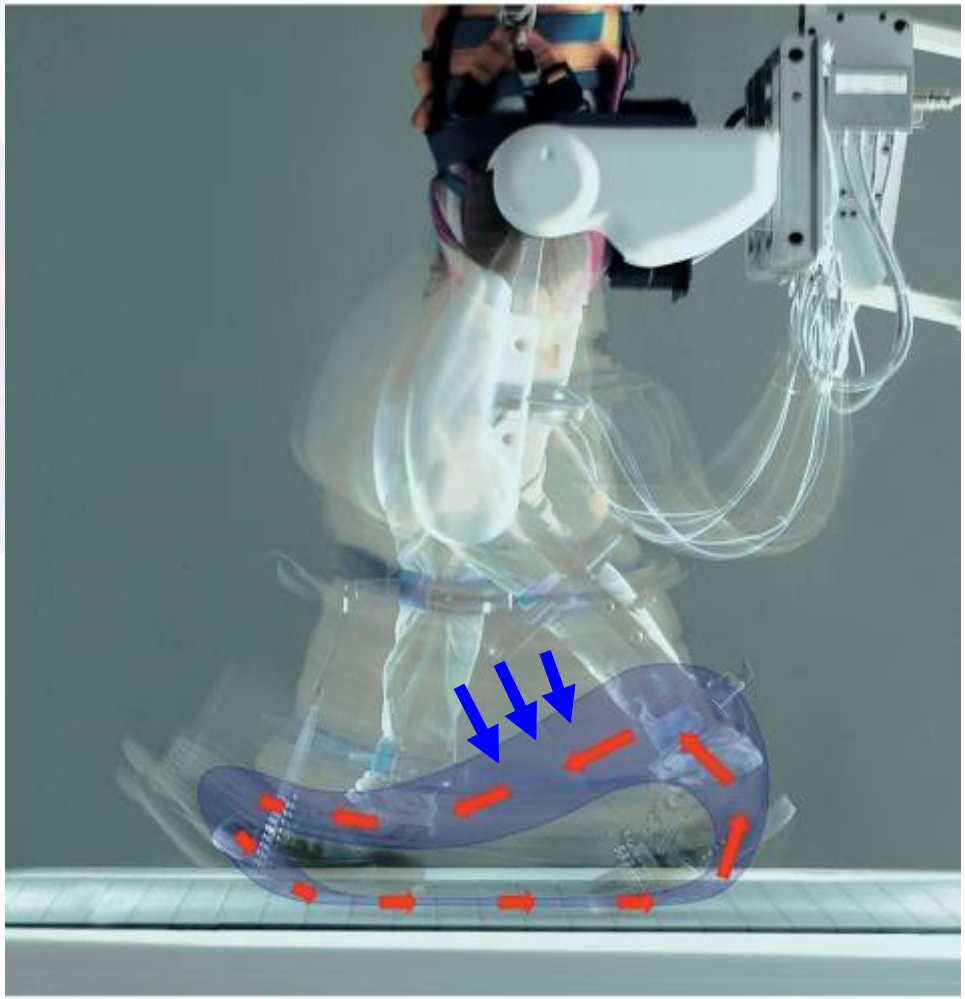
Human-Robot Cooperation



Key Features

- Intensive
- Cooperative
- Transparent

Mechanical Interaction



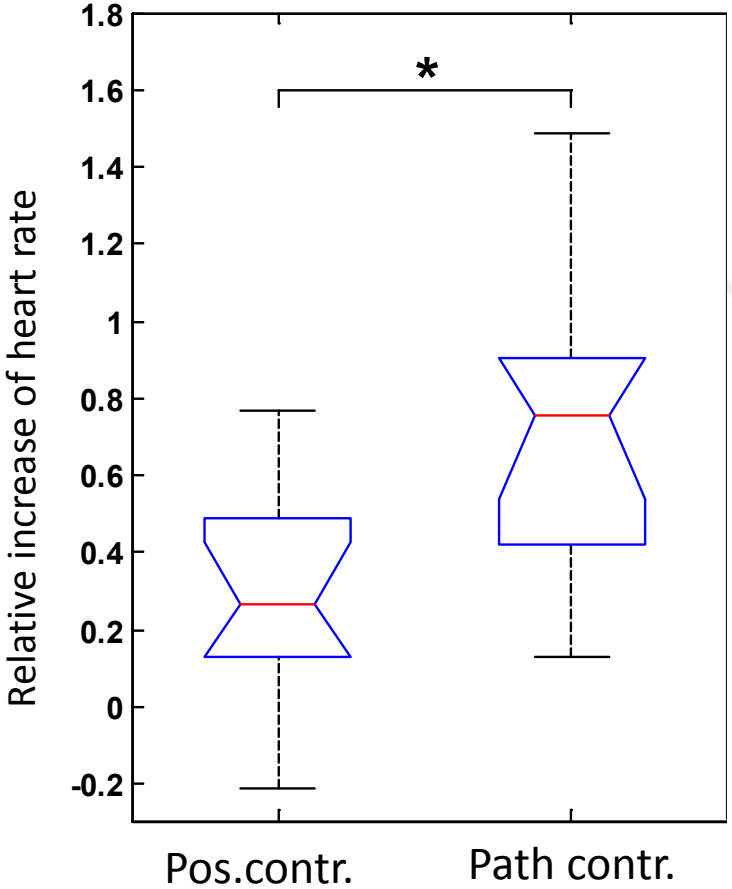
Duschau-Wicke, Vallery, Riener, et al.

Path Control

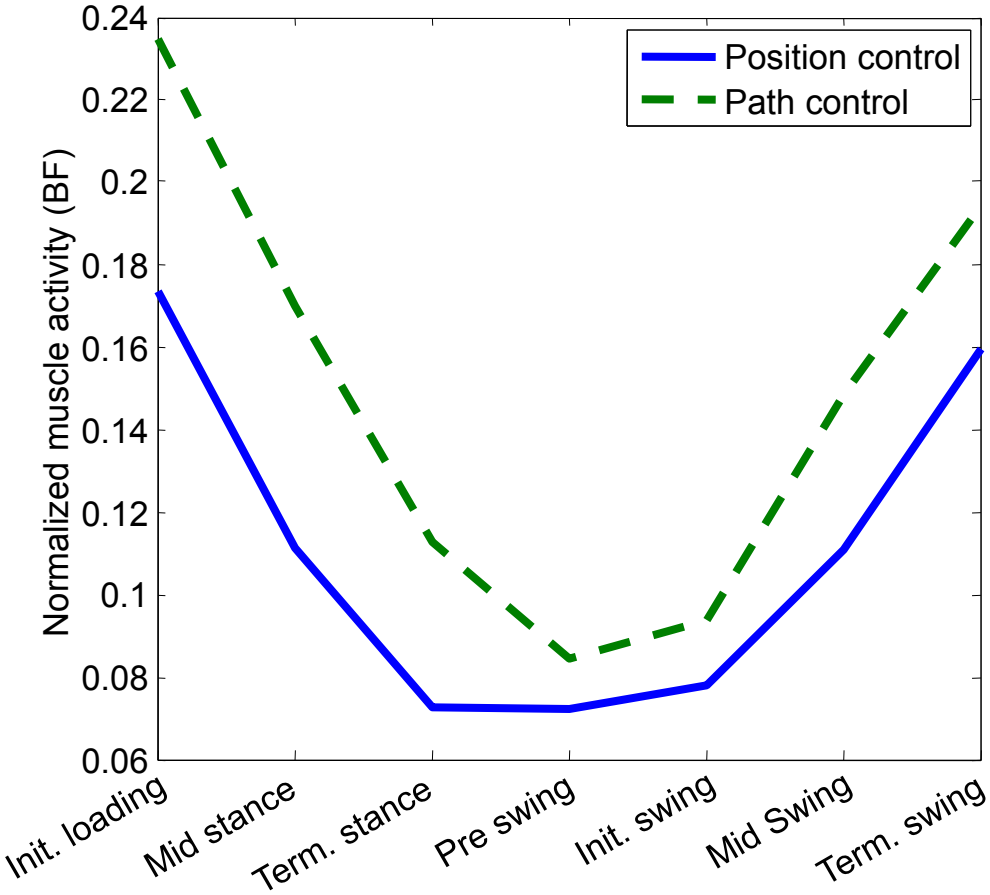
- Robot behaves assistive, corrective or transparent, when needed
- Free timing for patient
- Support patient, but do not restrict patient

Path Control Increases Participation

Heart Rate



Muscle Activity

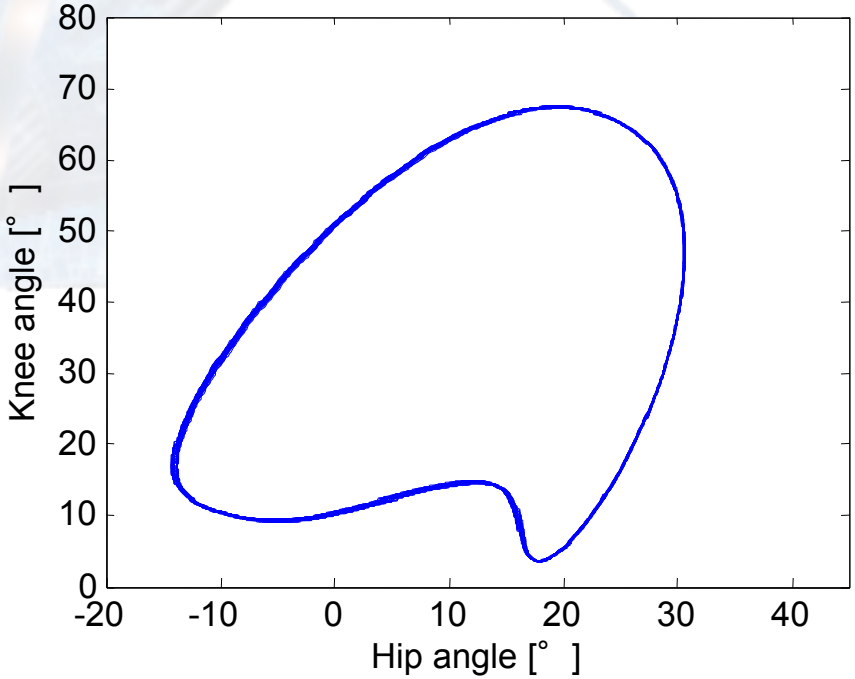


11 incomplete SCI subjects

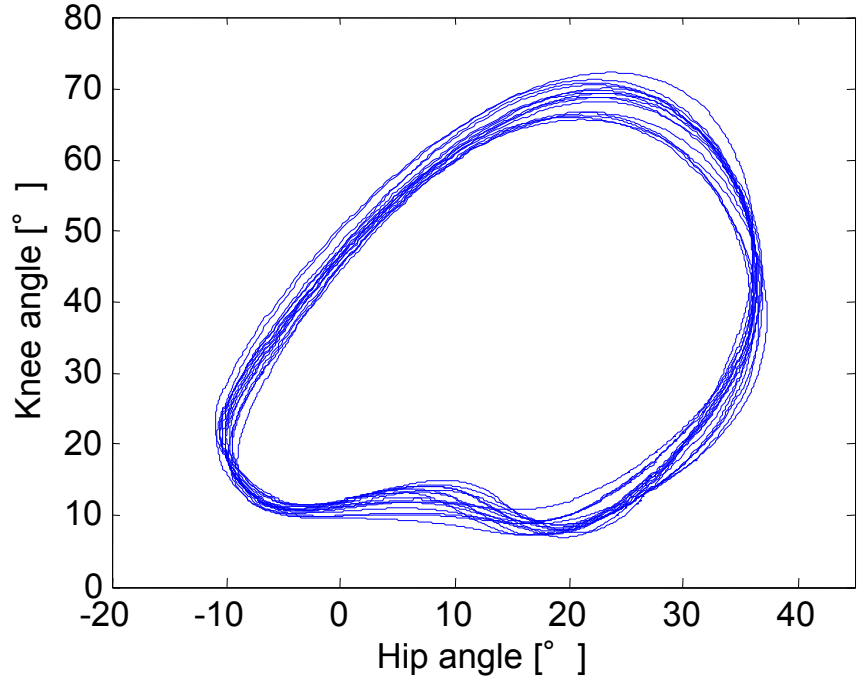
Path Control Enhances Variability

“Repetition without Repetition” (Bernstein)

Position Control

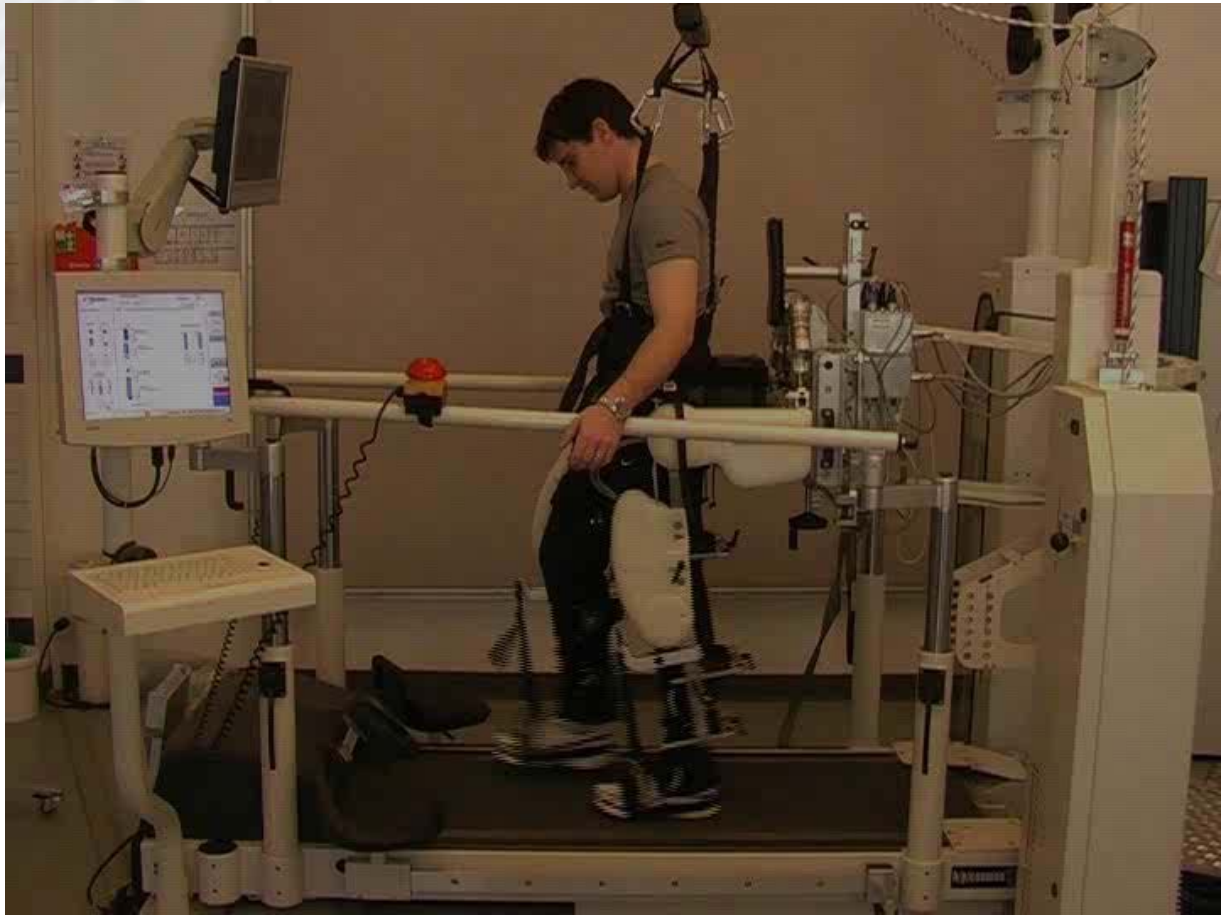


Path Control



Motivation During Gait Training

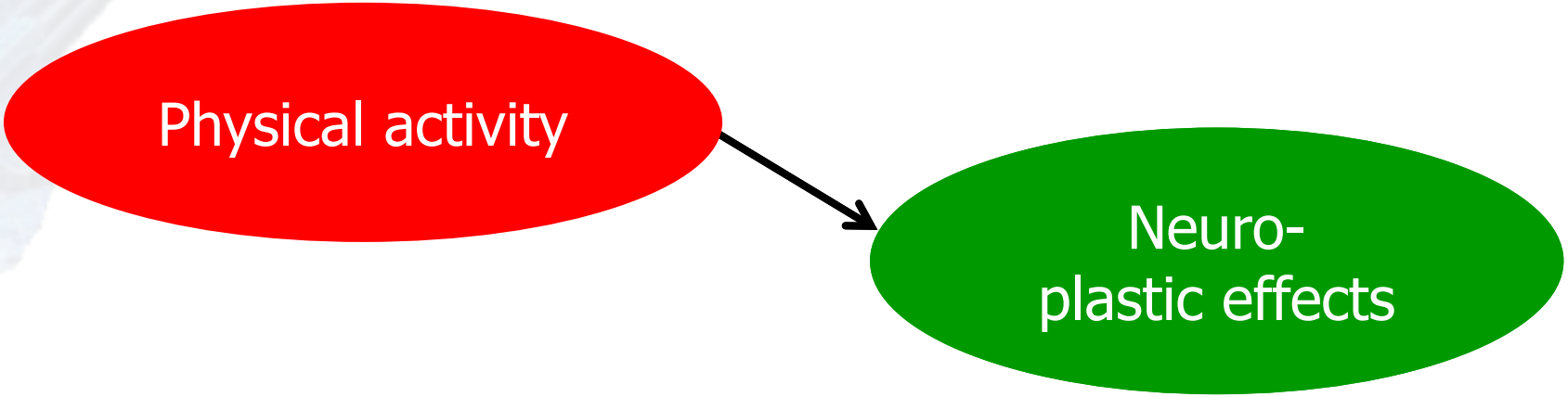
Conventional Training



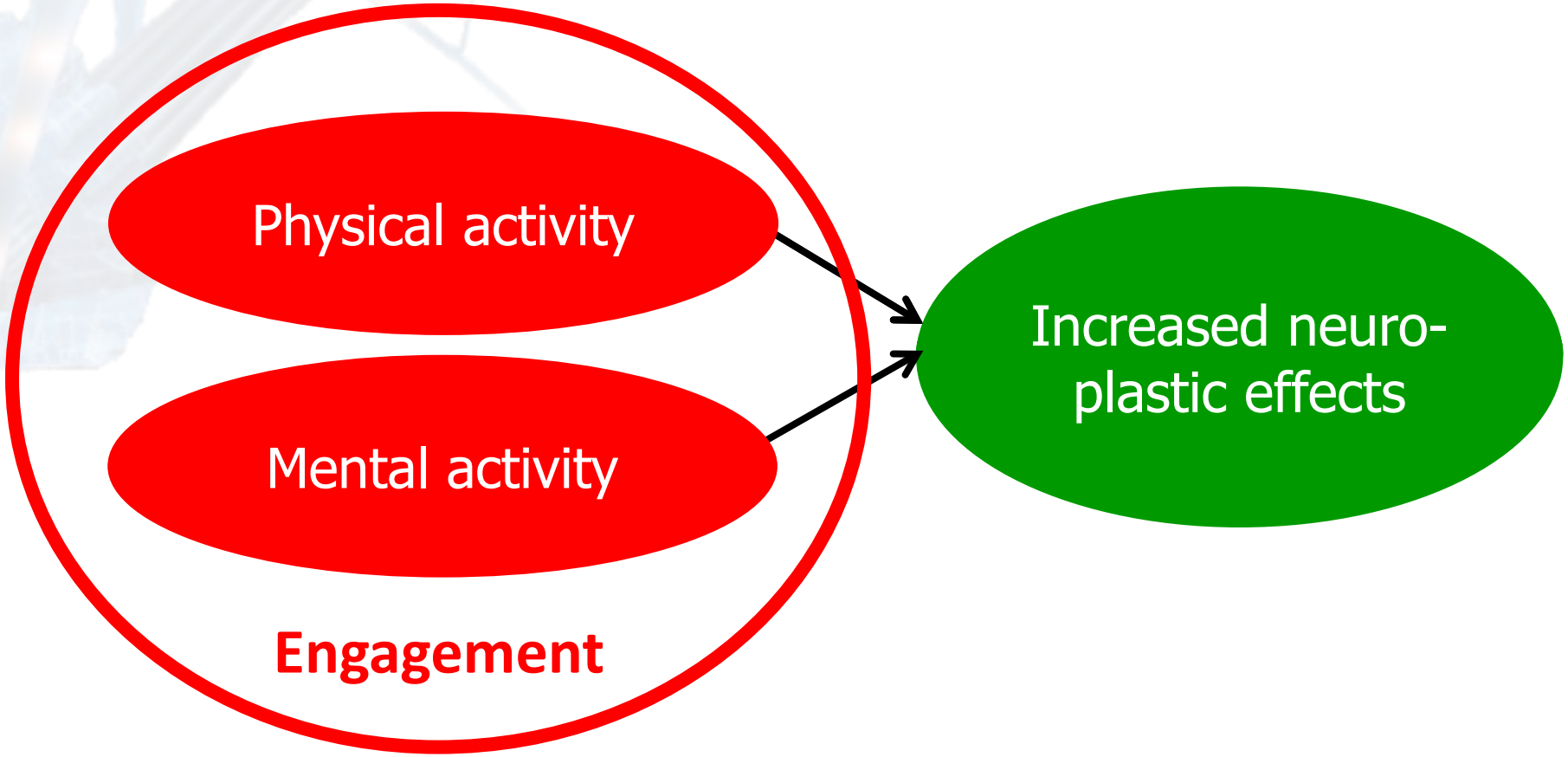
Can be monotonous and boring

Gait Training & Virtual Reality

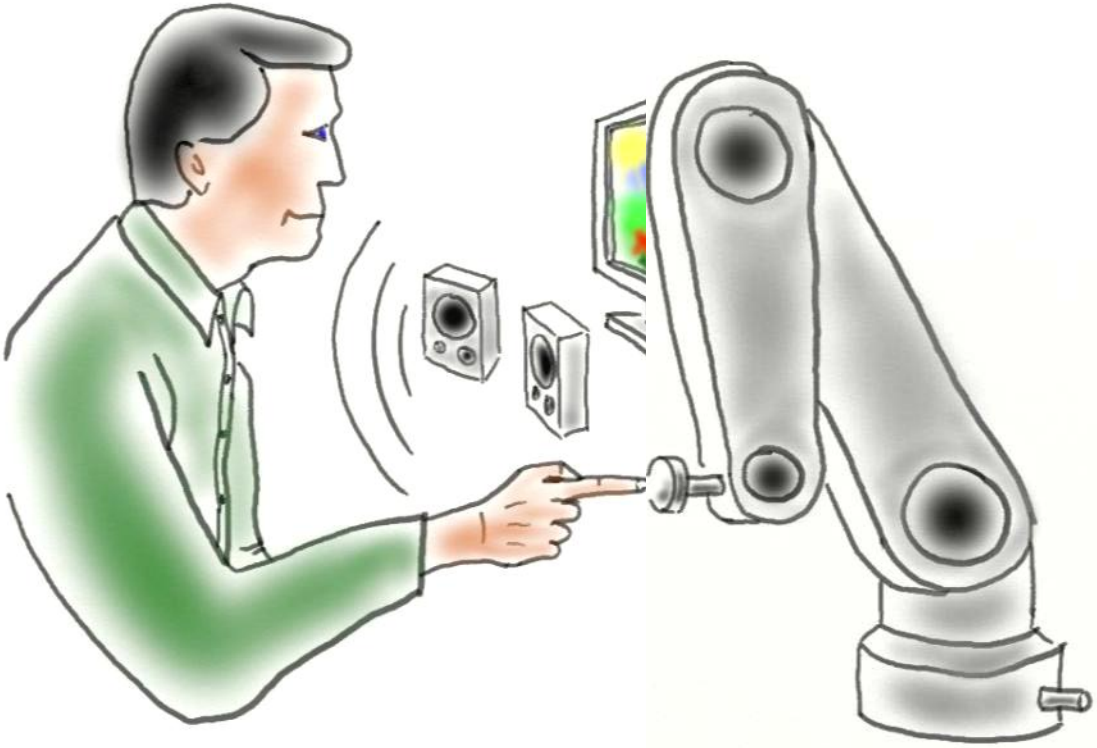
Engagement Increases Neuroplasticity



Engagement Increases Neuroplasticity



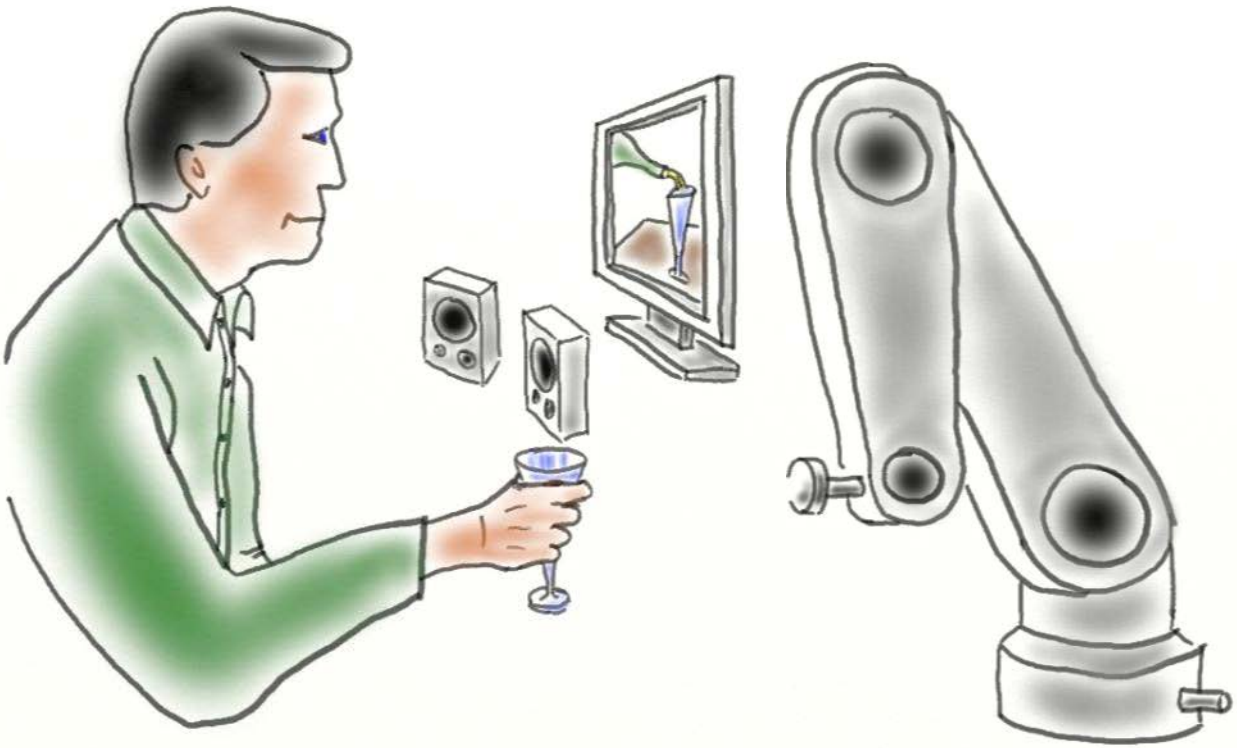
Human-Robot Cooperation



Key Features

- Intensive
- Cooperative
- Transparent
- Engaging
- Rewarding

Human-Robot Cooperation

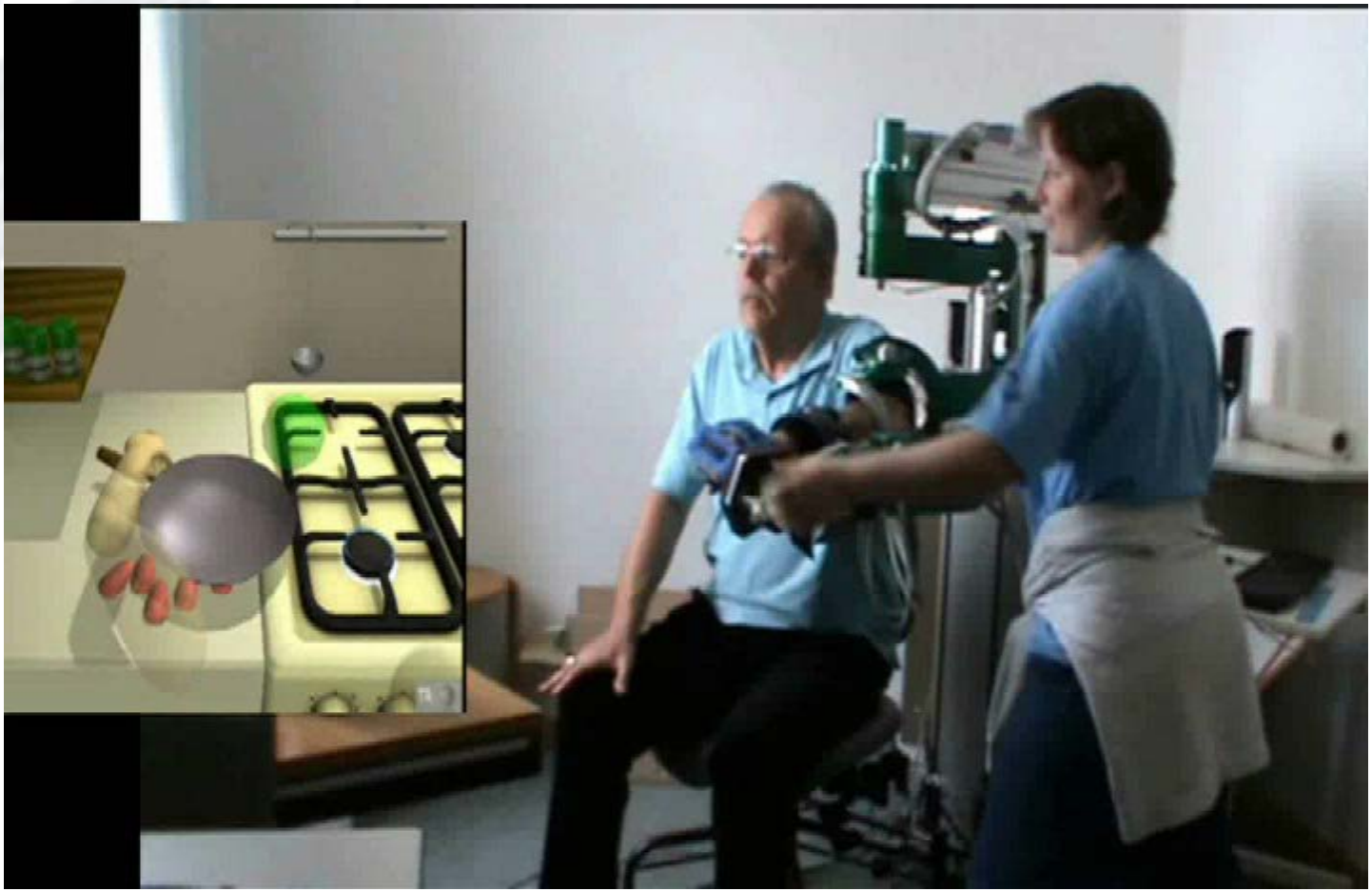


Key Features

- Intensive
- Cooperative
- Transparent
- Engaging
- Rewarding
- Task-specific

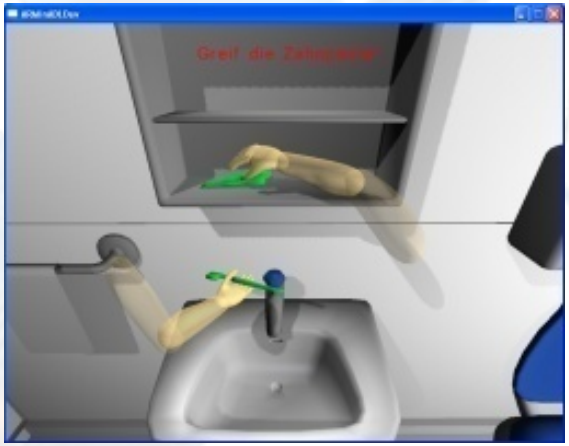
Activities of Daily Living Training

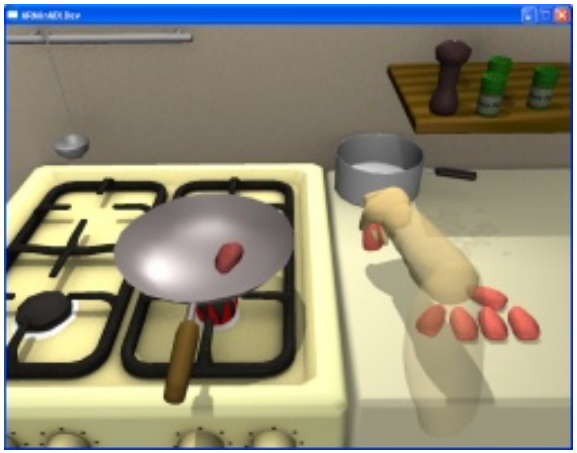
Chronic Stroke Patient (FMA=26)

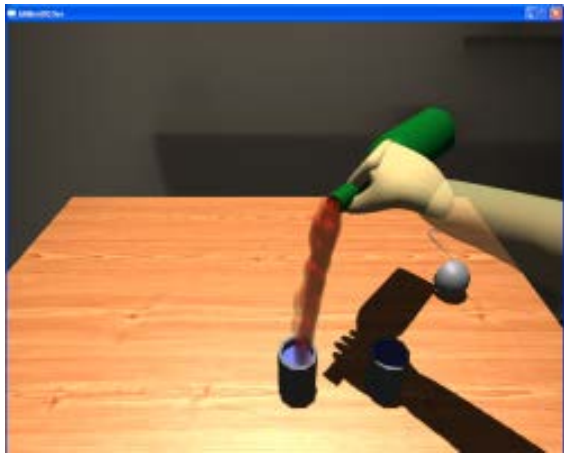


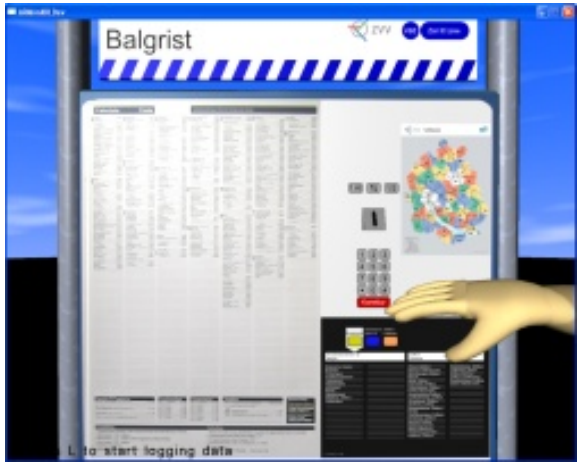
Guidali, Riener et al., MBEC 2011

Activities of Daily Living Training





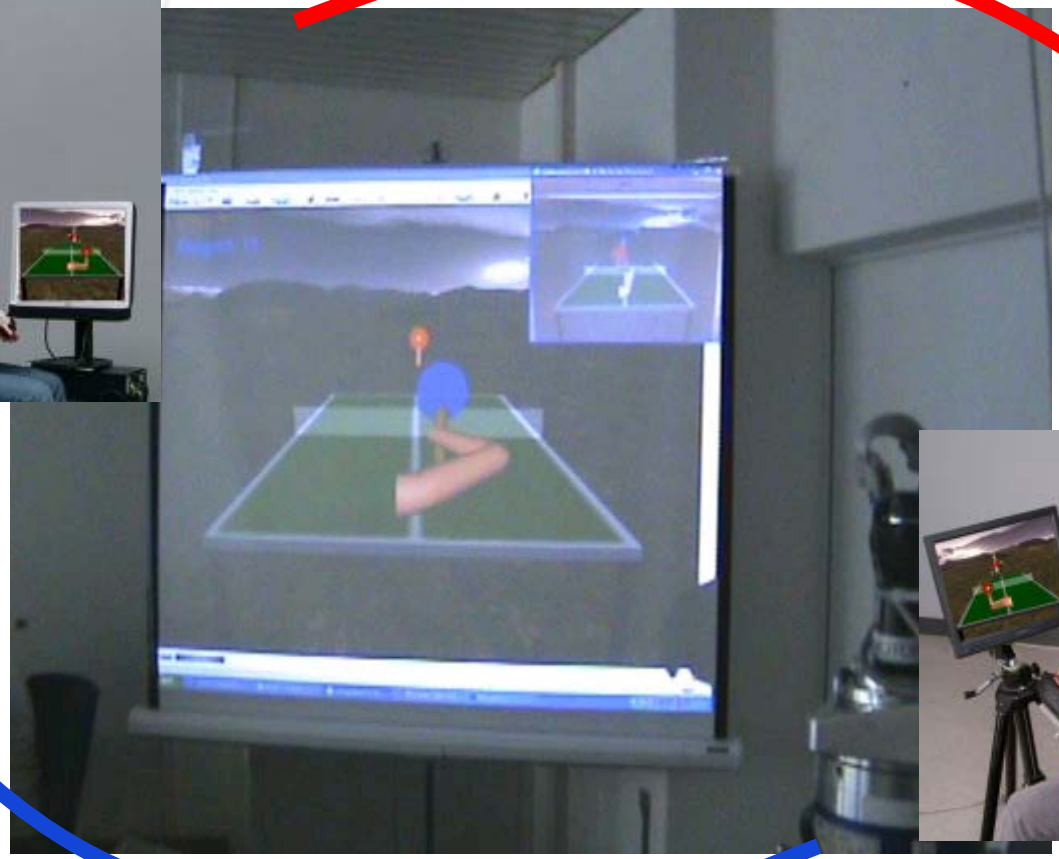




Guidali, Riener et al., MBEC 2011

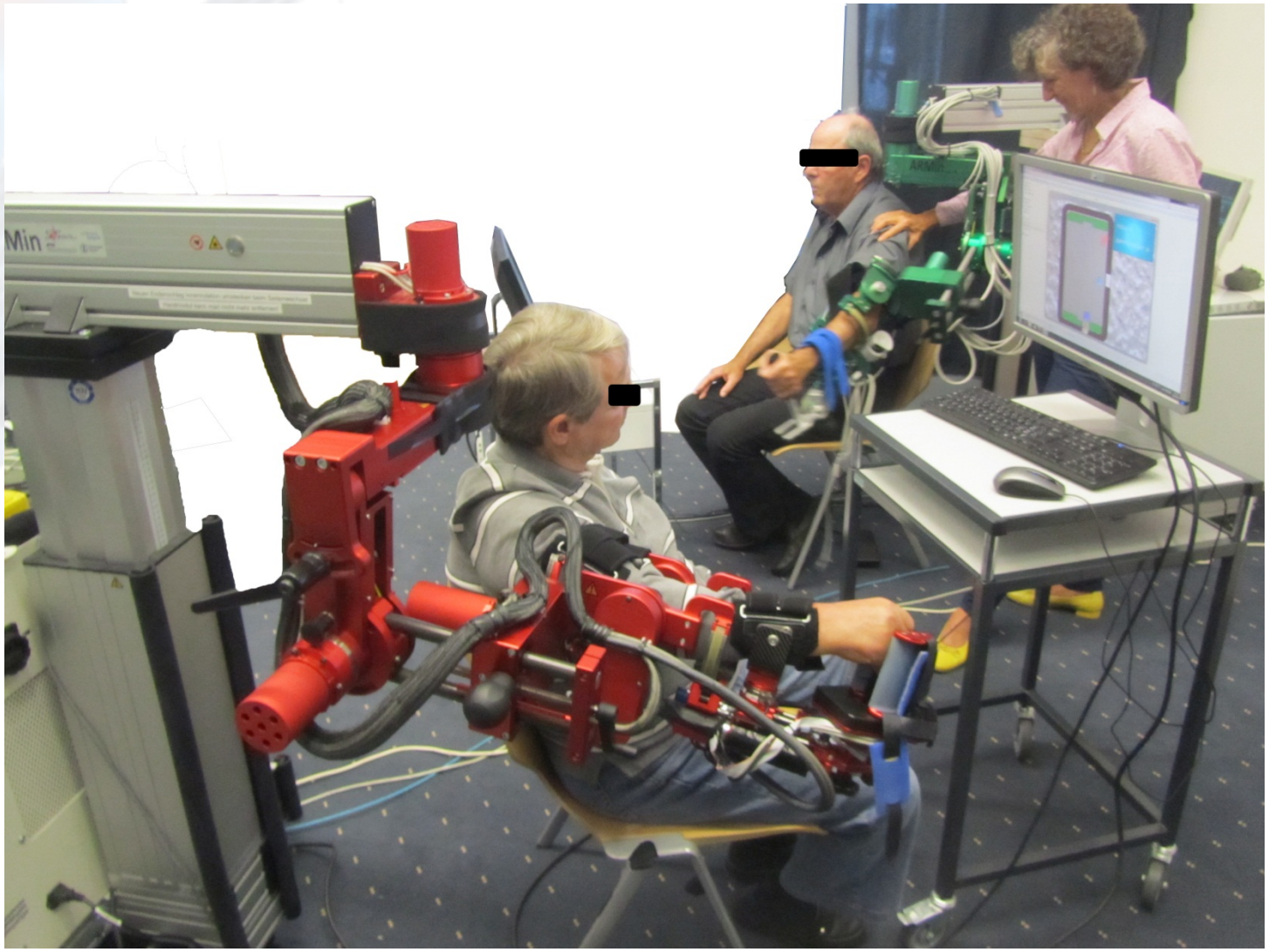
Social Reward: Tele-Rehabilitation

Player RED
Uniklinik Balgrist



Player BLUE
ETH Zurich

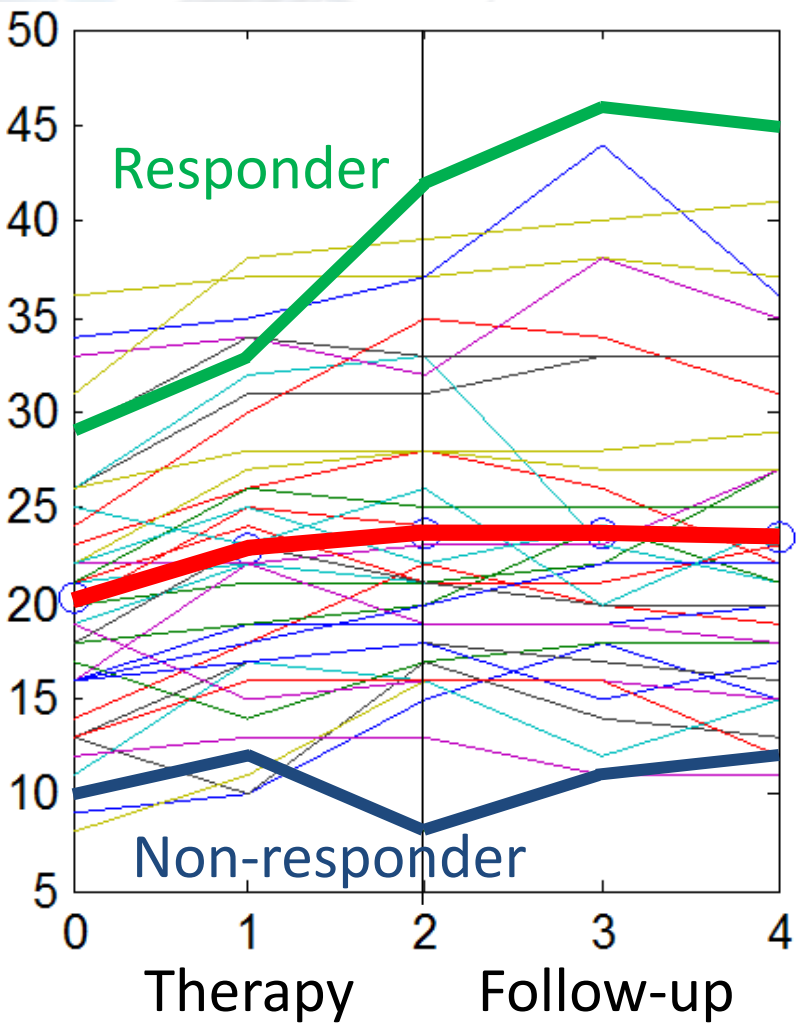
Social Reward: Collaborative Gaming



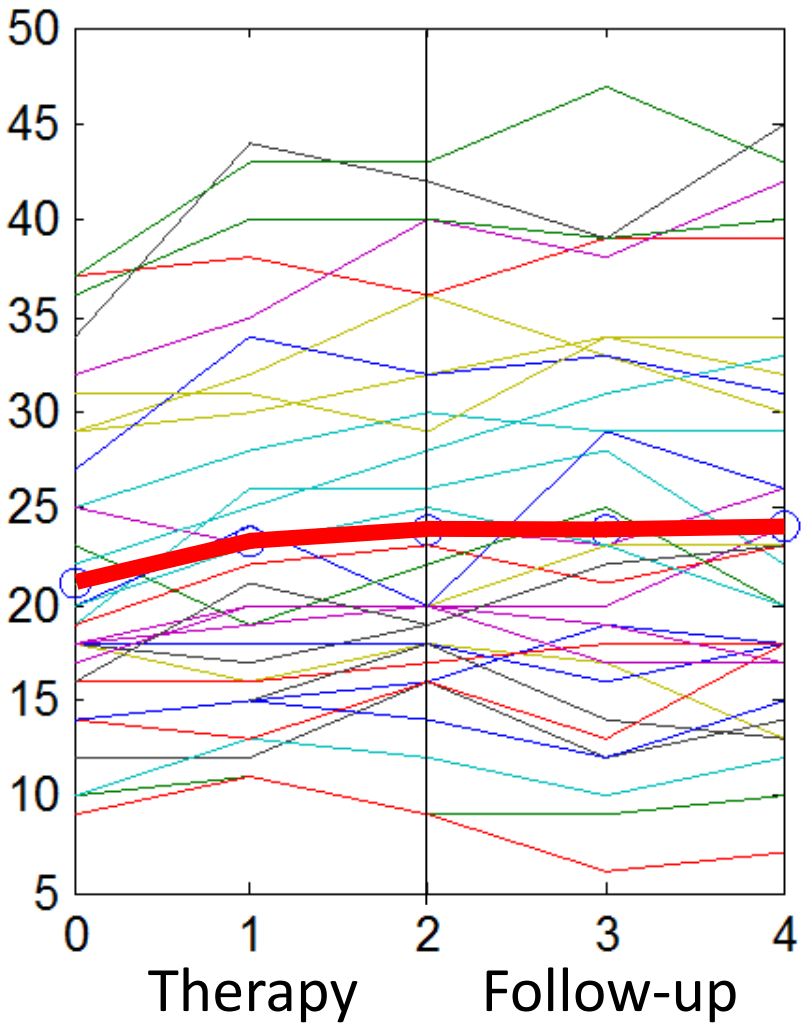
Outlook & Vision

Problem: Averaging

FMA ARMin Group



FMA Control Group

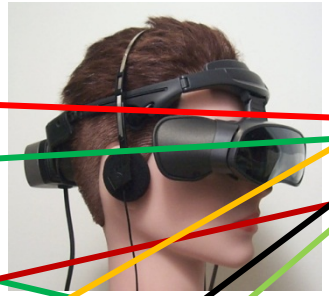


Challenge: Find the Responders

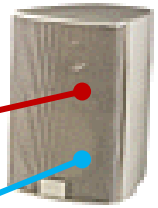
Human Subjects

Subject A
Subject B
Subject C
Subject D
Subject E
Subject F
Subject G
Subject H
Subject J
Subject K

Technical Features



Visual feedback 2D/3D, VR

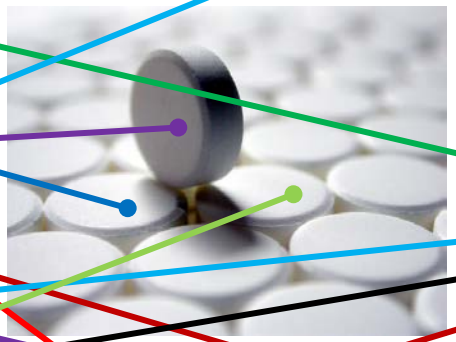


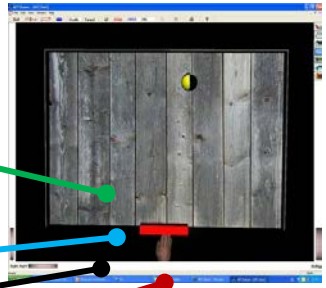
Auditory feedback

Dose (intensity)

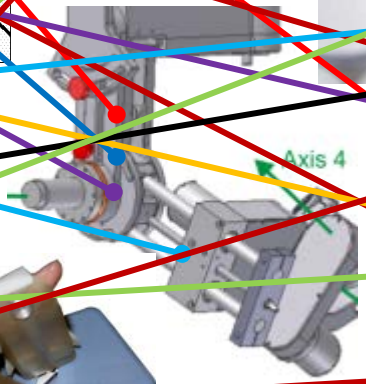
Game, control

Further displays

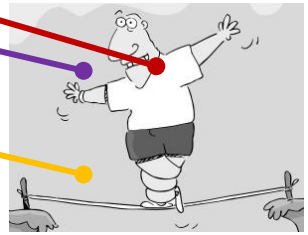


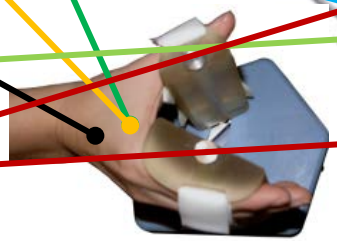


Task difficulty



ROM





Distal/ proximal

Conclusion

Conclusion

Robots should Cooperate and Motivate

- Current robotic approaches often ignore patient activity
- Therapeutic outcome can be increased, when patient is active
- Therefore, future robots should be “patient-cooperative” enhancing patient activity and engagement/reward

Outlook

- Implement **novel technical features** (e.g. provide high intensity treatment, reward-driven therapy)
- Adjust the technology and therapy to **find the reponders**
- Prove effectiveness in **clinical studies**

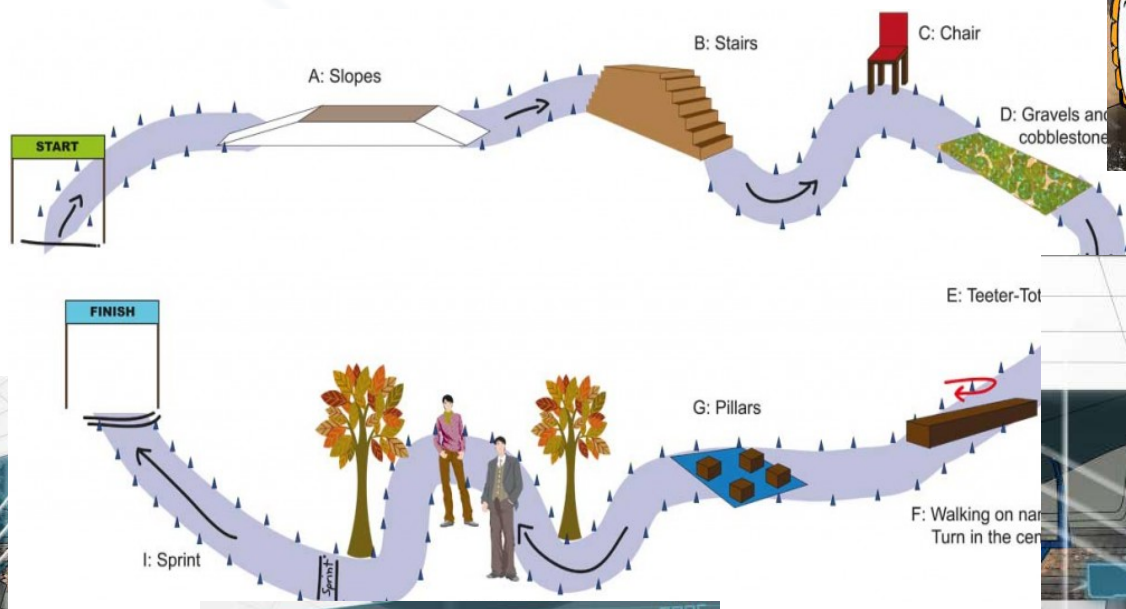
CYBATHLON

CHAMPIONSHIP FOR
ROBOT-ASSISTED PARATHLETES

Six Different Disciplines

General Criteria

- Challenge requires actuated devices
- Course contains tasks of daily life



Objectives of the Cybathlon

The Cybathlon will promote the development of assistive systems for people with disabilities to be suitable for daily use. This should remove barriers between general public, the users and the developers.