Gregorij Kurillo:

MEASUREMENT AND EVALUATION OF GRASPING IN VIRTUAL REALITY

(Merjenje in ocenjevanje prijemanja v navideznem okolju)

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Contents

- Introduction
- Evaluation and Rehabilitation of Grasping
- Assessment of Grip Force Control
- Training of Grip Force Control
- VR System for Assessment and Rehabilitation
- Conclusion

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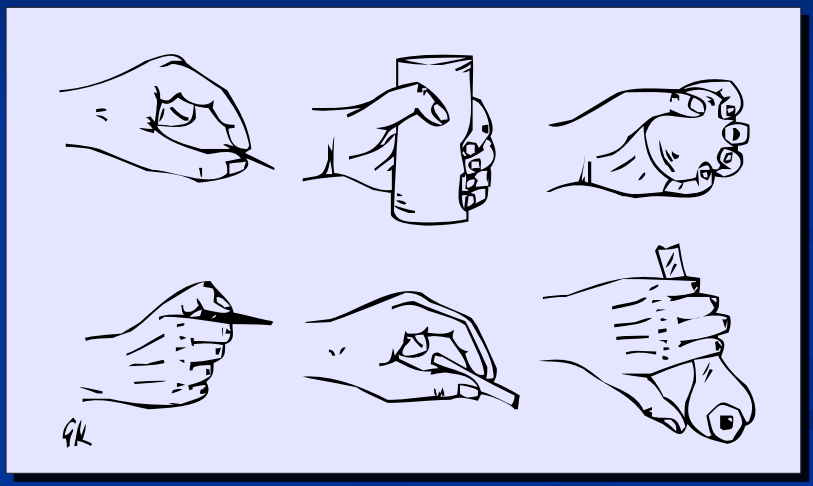
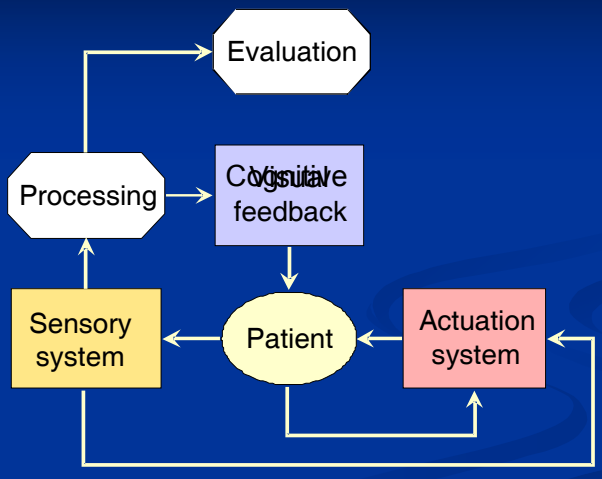
Hand Function



Assessment of Hand Function

- Why evaluate hand function?
  - Neural/neuromuscular diseases, CNS injury, trauma
  - Follow progress of therapy/disease
  - Find optimal treatment for a patient
- Assessment of hand function:
  - Hand function test: Jebsen, Fugl-Meyer, Smith, ADL
  - Manual Muscular Test (MMT)
  - Maximal voluntary grip force (MVGF)

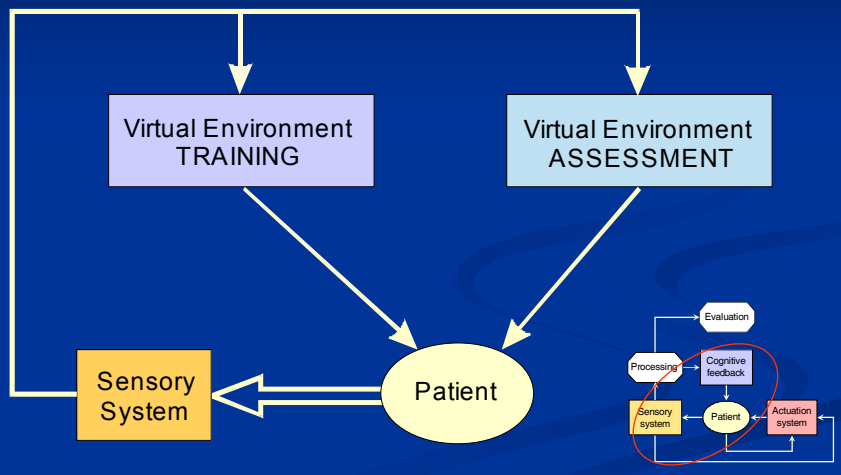
Computerized Assessment/Training System



Rehabilitation in Virtual Reality (VR)

- What is Virtual Reality?
- VR-augmented vs. VR-based rehabilitation
- VR rehabilitation of hand function:
  - Jack *et al. 2001*, VR-enhanced stroke rehabilitation
  - Chuang *et al. 2002*, A VR-based system for hand function analysis
  - Holden *et al. 2002*, Virtual environment training: a new tool for neurorehabilitation
  - Merians *et al. 2002*, VR-augmented rehabilitation of patients following stroke

VR Rehabilitation



Assessment of Grip Force Control

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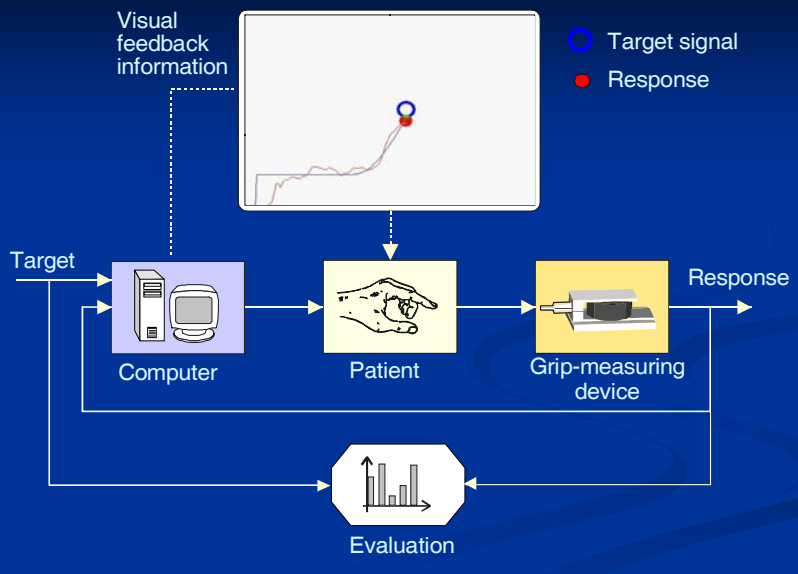
Tracking Task

- What is a tracking task?
- Previous studies:
  - Medicine, rehabilitation, pharmacology, (*Wetherell 1996. Jones 2000*)
  - Analysis of grip force control in children (*Blank et al. 2000*)
  - Patients with Parkinson's disease (*Vaillancourt et al. 2001. Kunesch et al. 1995*)
  - Training of sensory-motor functions (*Kriz et al. 1995*)



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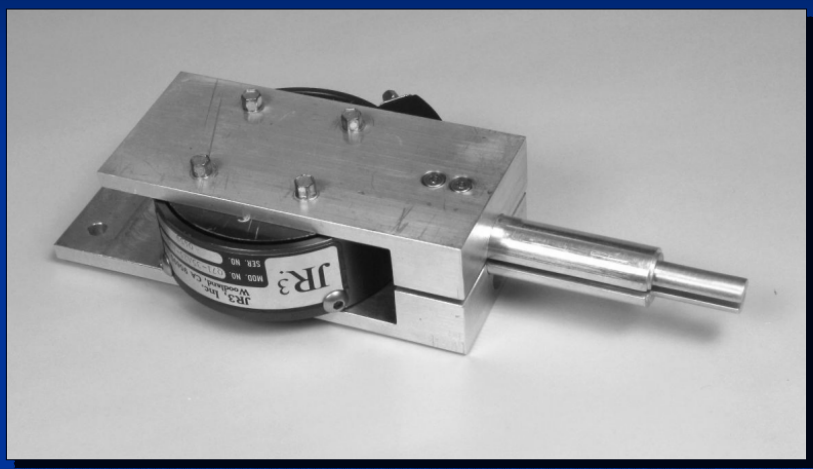
Grip Measuring Device



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Assessment of Grip Force Control in Healthy Subjects

- Effect of age on the grip force control: 12 children (10y), 10 younger adults (25-35y), 10 older adults (50-60y)
- Effect of hand dominancy on performance
- Obtain a control group for subsequent measurements

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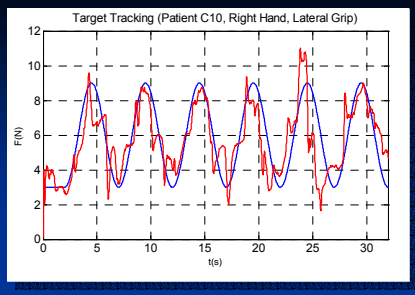
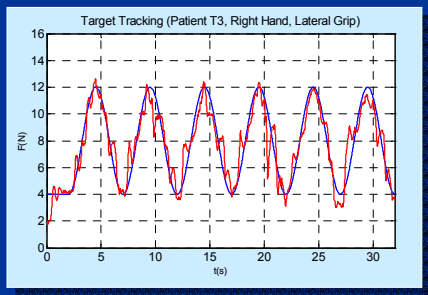


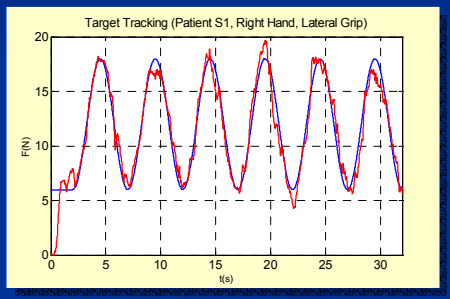
Child (10 years old)

Older Adult (54 years old)



Sinus Tracking

Young Adult (27 years old)



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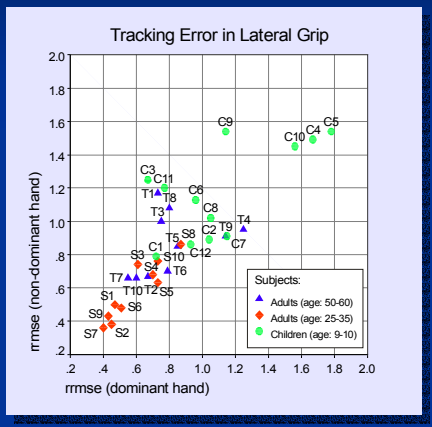
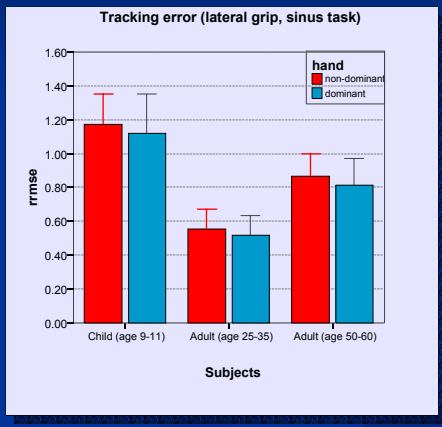
Results: Accuracy of Tracking in Different Age Groups





$$rrmse = \sqrt{\frac{1}{T}\sum_{t=0}^{T}\frac{(F_0(t)-F_T(t))^2}{max(F_T)^2}}$$

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Assessment of Grip Force Control in Patients with Neuromuscular Diseases

- Evaluate the effect of neuromuscular diseases on ability to control the grip force in different grips

Patient	*Gender*	*Age*	*Diagnosis*	*Patient*	*Gender*	*Age*	*Diagnosis*
P0	M	48	LGMD	P10	M	26	BMD
P1	F	28	FSHMD	P11	M	46	SMA3
P2	M	35	SMA3	P12	F	27	SMA2
P3	F	28	SMA2	P13	M	24	SMA2
P4	M	23	BMD	P14	M	45	SMA3
P5	F	28	SMA3	P15	M	49	FSHMD
P6	M	32	BMD	P16	F	51	FSHMD
P7	F	50	SMA3	P17	M	59	LGMD
P8	M	23	LGMD	P18	F	32	LGMD
P9	M	36	LGMD	P19	M	24	BMD

* control group: 9 healthy subjects

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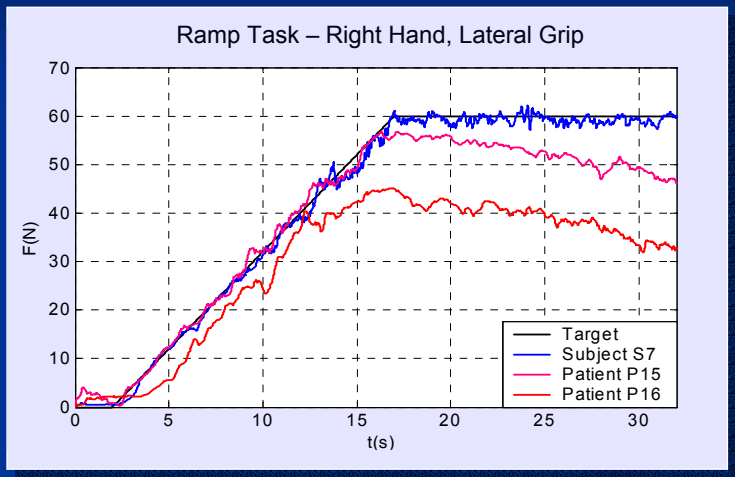
Ramp Target Tracking



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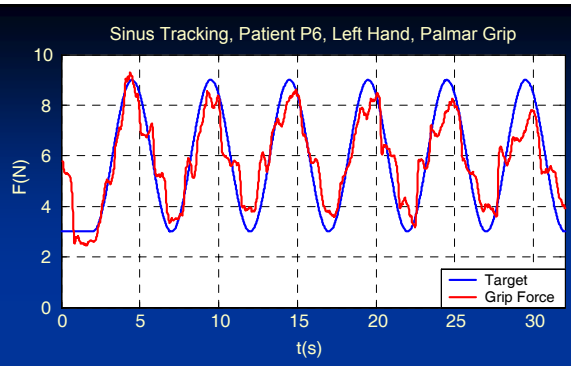
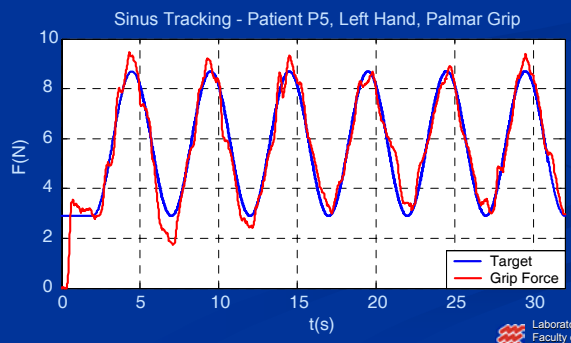
Patient #1:



Patient #2:



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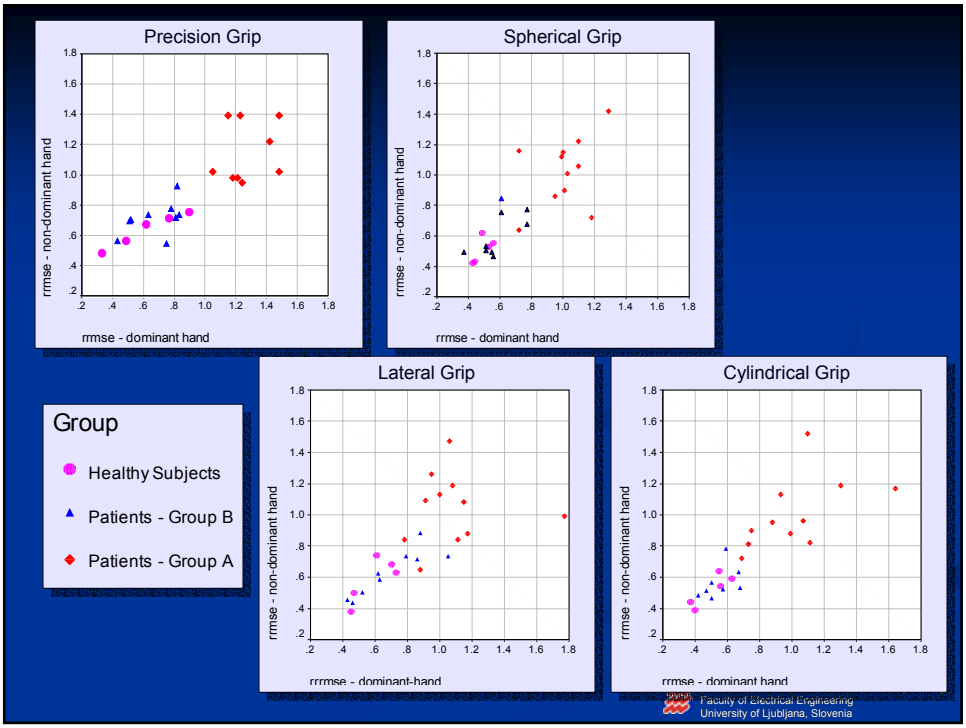
Precision Grip
Spherical Grip
Lateral Grip
Cylindrical Grip
rrmse - non-dominant hand
rrmse - dominant hand
Group
Healthy Subjects
Patients - Group B
Patients - Group A
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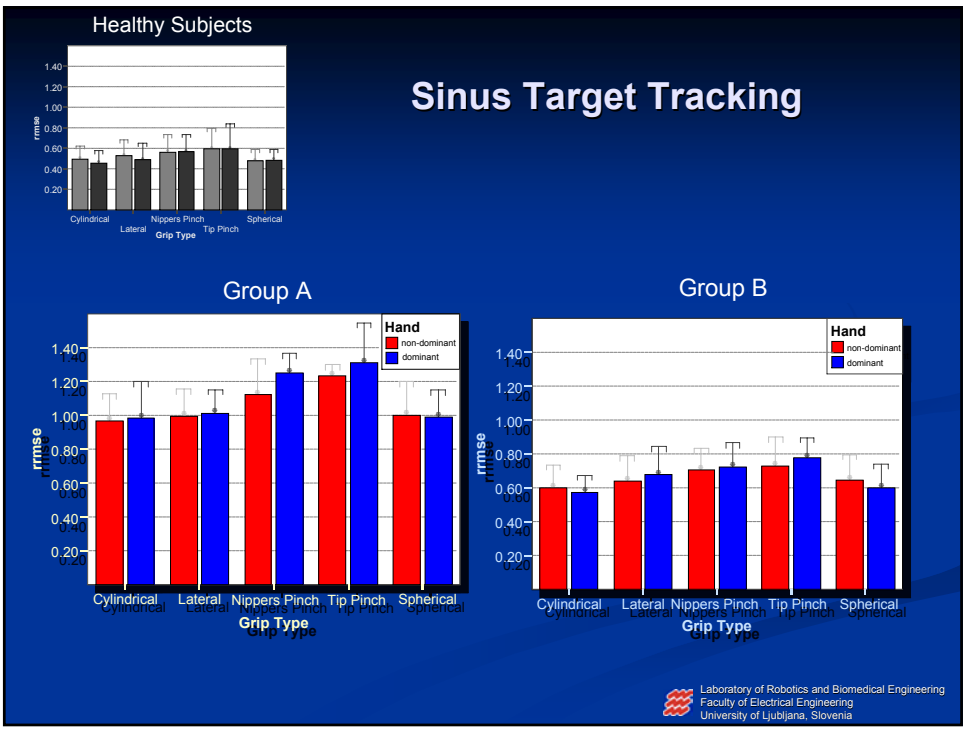
Healthy Subjects
Sinus Target Tracking
Group A
Group B
rrmse
Grip Type
Cylindrical
Lateral
Nippers Pinch
Tip Pinch
Spherical
Hand
non-dominant
dominant
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Assessment of Grip Force Control after Botulinum Toxin (BTX) Treatment

- Evaluate the effect of BTX treatment for spasticity on grip force control
- Follow BTX treatment in 38 year-old female patient (8 years post traumatic brain injury)

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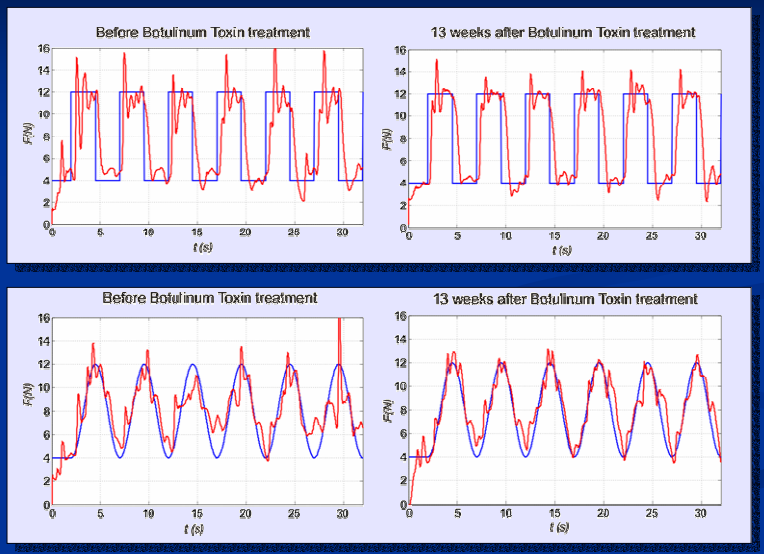
Results: BTX Treatment



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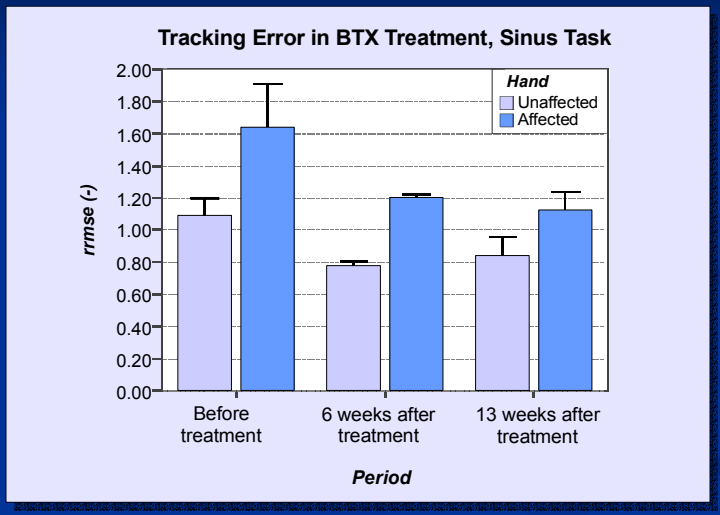
Results: Before and After BTX Treatment



Training of Grip Force Control

Training of Patients after Stroke

- Evaluation and training of grip force control in post-stroke patients

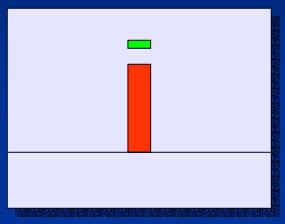
Patient	*Age*	*Gender*	*Hemiparesis*	*Time since onset*	*Grasp trained*	*Score at entering*	*Score at leaving*
P1	28	M	right	19 months	lateral	46	46
P2	20	M	left	6 months	cylindrical	31	35
P3	19	F	right	1 month	cylindrical	48	50
P4	44	M	right	1 month	lateral	10	12
P5	43	F	left	4.5 months	lateral	39	50
P6	49	M	right	3 months	lateral	12	21
P7	51	F	right	6 months	lateral	42	47
P8	36	F	right	6 years	cylindrical	22	22
P9	72	M	left	1 month	cylindrical	26	39
P10	79	M	left	4 months	cylindrical	25	30

* Modified Ross functional test (max score 50)

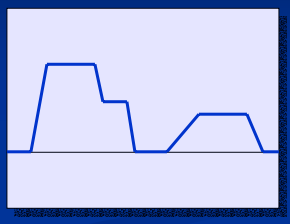
Force Measuring Unit

Training Tasks

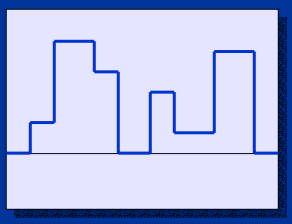
Maximal grip force:



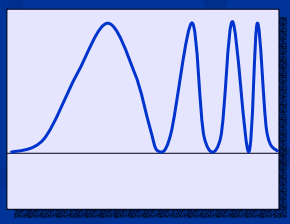
Randomized ramp target:



Randomized rectangular target:



Modulated sinus target:



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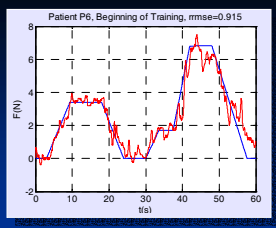

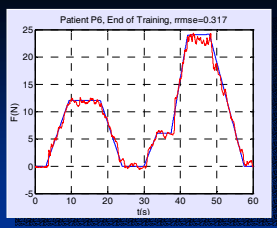

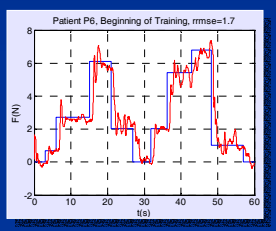

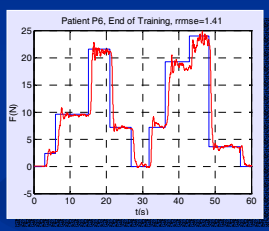

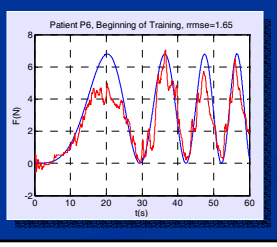

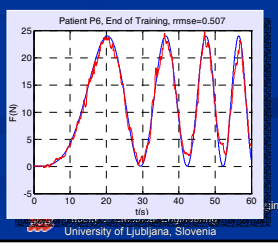

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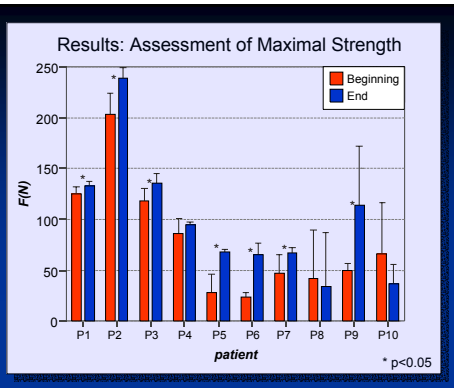

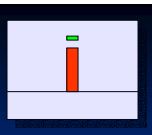

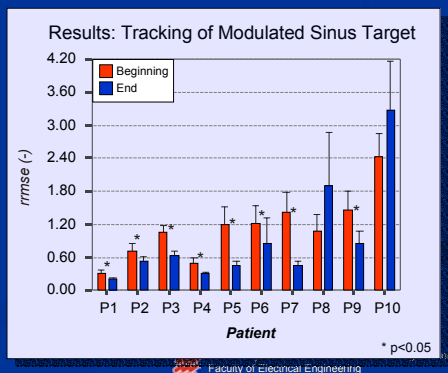

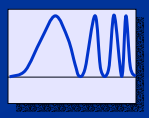

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Grip Force Tracking System

- … evaluation of grip strength, muscle fatigue and grip force control
- … to follow the progress of disease or influence of physical or medicamental therapy on patients
- … as a training method in rehabilitation after stroke or hand injury

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Multi-fingered VR Rehabilitation System

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Multi-fingered Grasping in VR

- ... design device to measure of fingertip forces and torques in three fingers
- … use of isometric input for VR manipulation
- … develop VR based assessment and rehabilitation system

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3By6 Finger Device

ALLADIN, 6th Framework European Project, http://alladin-ehealth.org, © 2005

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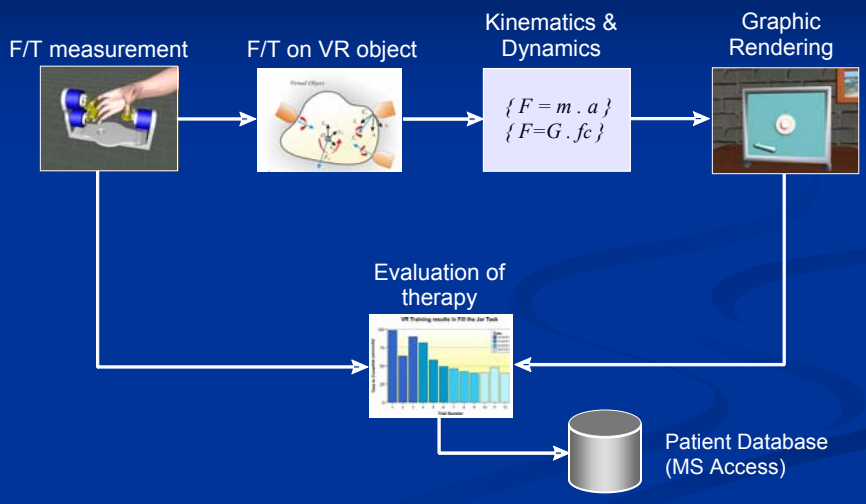

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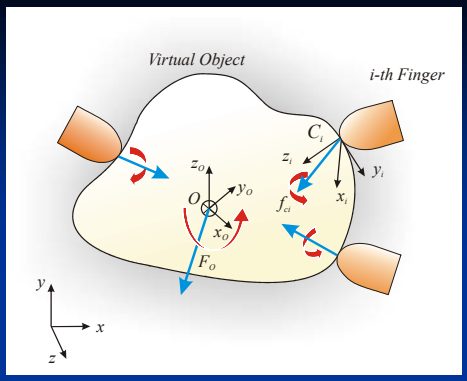

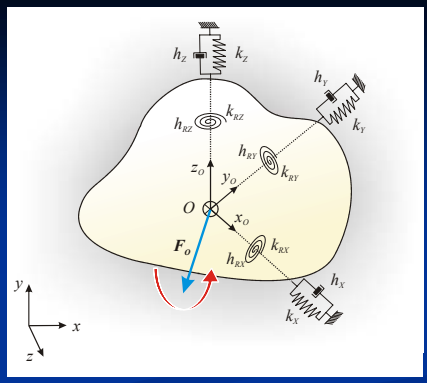

$$G_i = Ad_{Ci}^T \cdot B_{Ci} \quad \Rightarrow \quad \underline{Fo} = \left[\underline{\underline{G}}_1 \quad \ldots \quad \underline{\underline{G}}_k\right] \cdot \begin{bmatrix} \underline{fc}_1 \\ \ldots \\ \underline{fc}_k \end{bmatrix} \quad \Rightarrow \quad Fo = G \cdot fc$$

$$\Rightarrow \quad fc = \left(fc_1, fc_2, \ldots fc_m, \ldots, \dot{fc}_1, \dot{fc}_2, \ldots \dot{fc}_m\right) \in R \quad \Rightarrow \quad x = \iint \ddot{x} = \iint M^{-1}(Fo - C \cdot \dot{x} - N \cdot x)$$

$$Fo = \begin{bmatrix} F \\ T \end{bmatrix} \in R^6$$

References:
- Murray *et al. 1994,* A mathematical introduction to robotic manipulation
- Montana *1995,* The kinematics of multi-fingered manipulation

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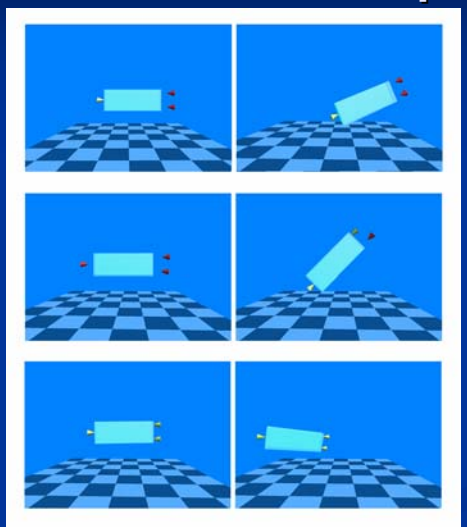
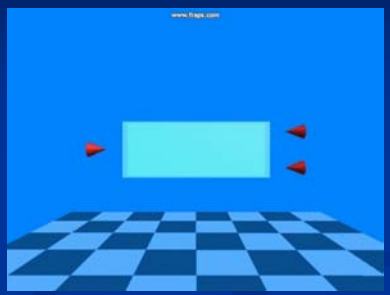
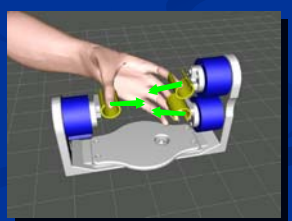
Multi-fingered grasping and manipulation







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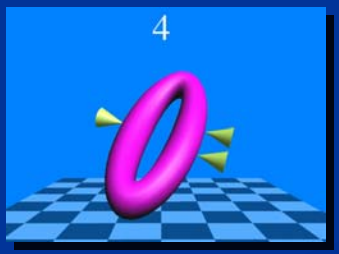
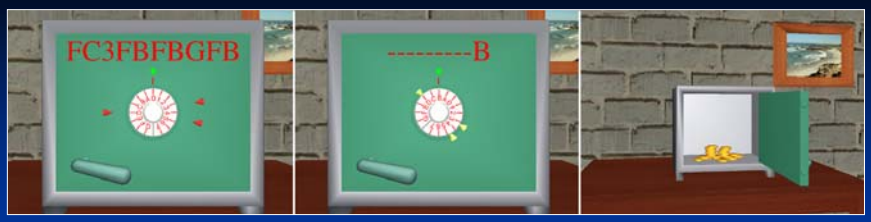
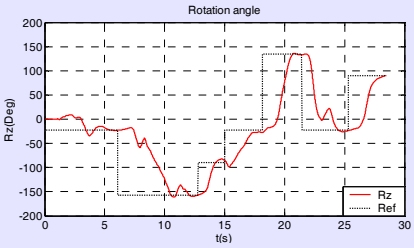
VR Tasks



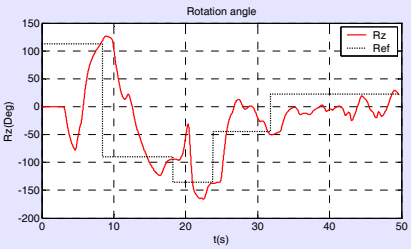
Task 1: Open the Safe



Healthy Subject



Chronic Post-Stroke Patient



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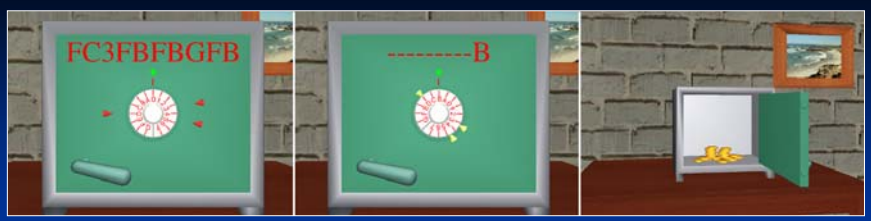

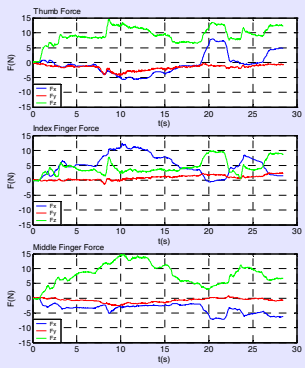

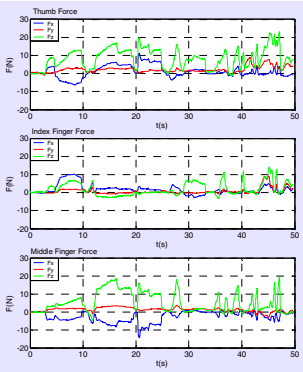

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Task 2: Fill the Jar

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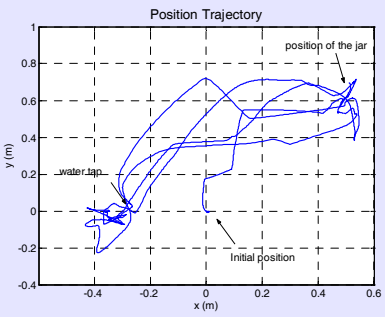
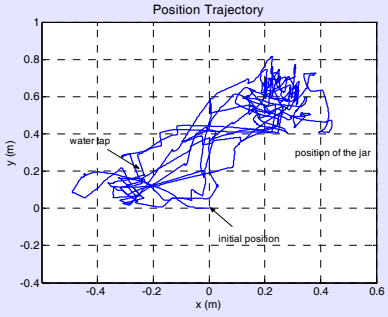
Healthy Subject



Chronic Post-Stroke Patient



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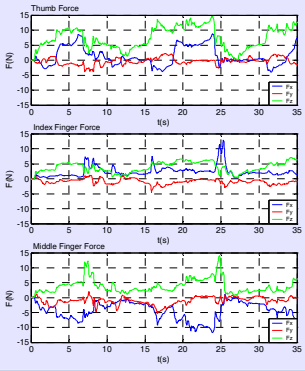

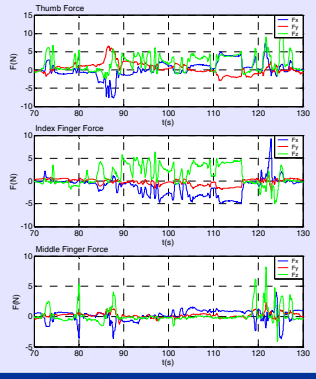

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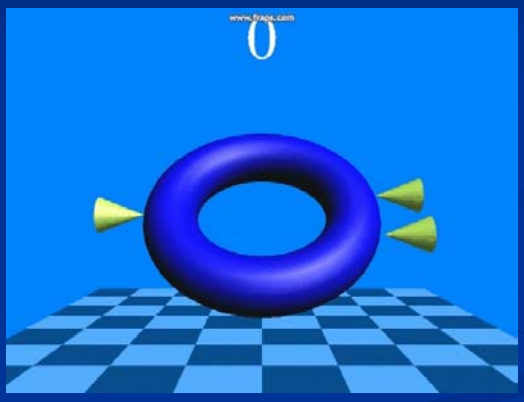
Task 3: Elastic Torus



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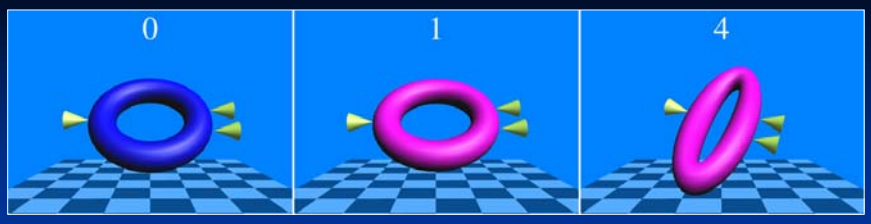
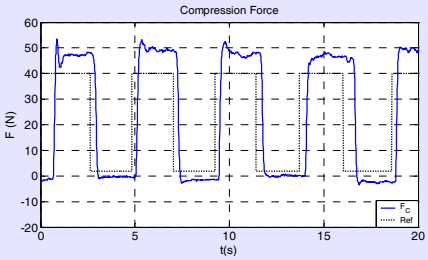
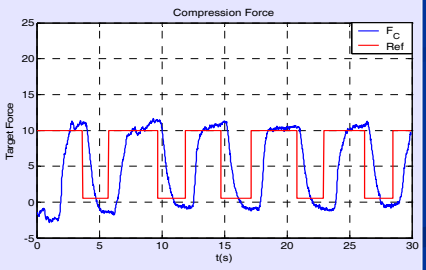


Healthy Subject



Chronic Post-Stroke Patient



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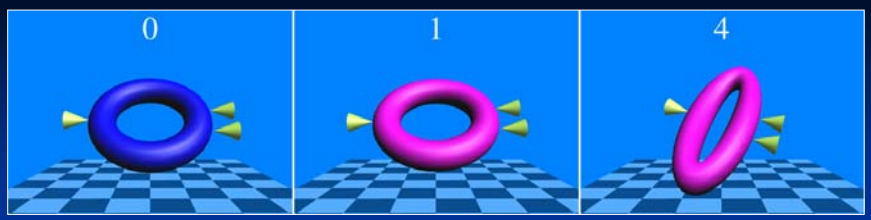

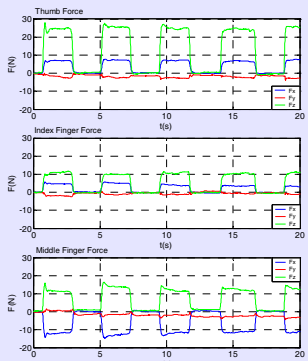

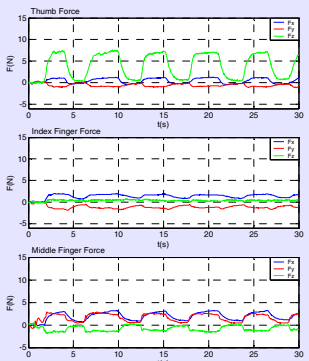

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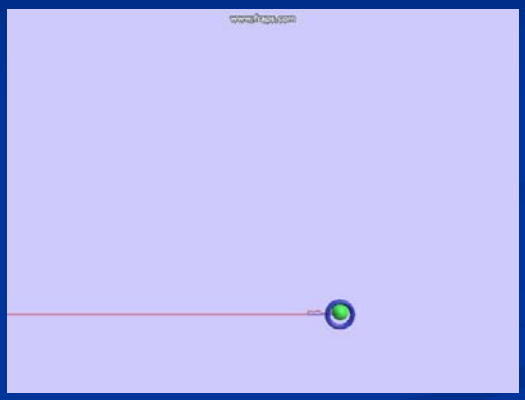
Task 4: Tracking Task



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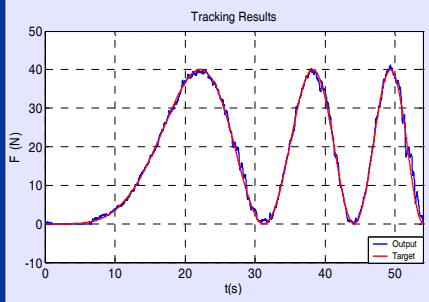
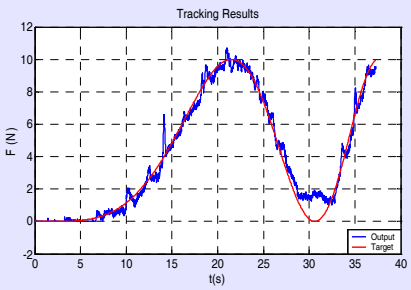
Healthy Subject



Chronic Post-Stroke Patient



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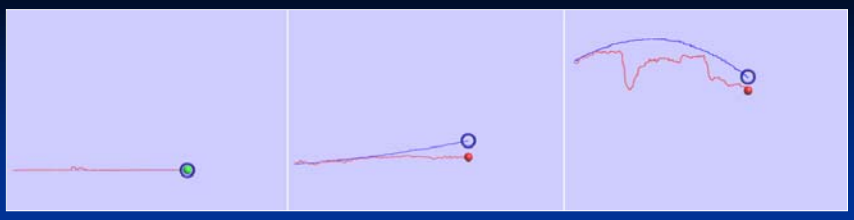

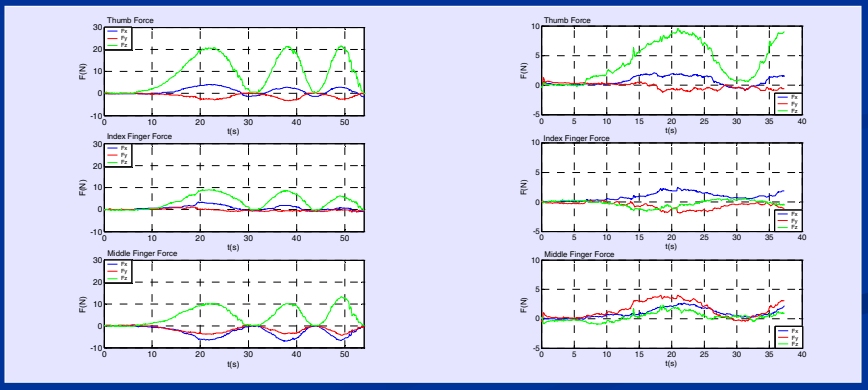

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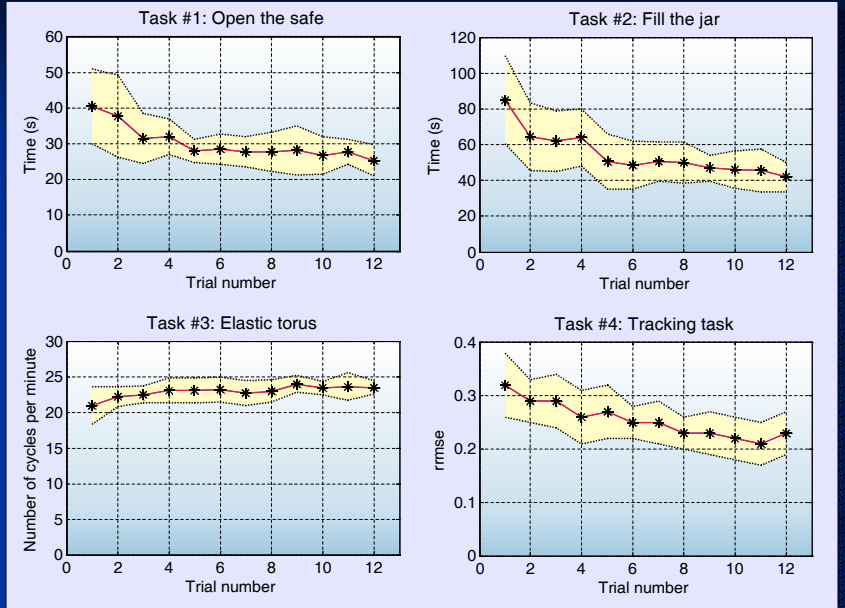
Performance of Healthy Subjects (N=10)



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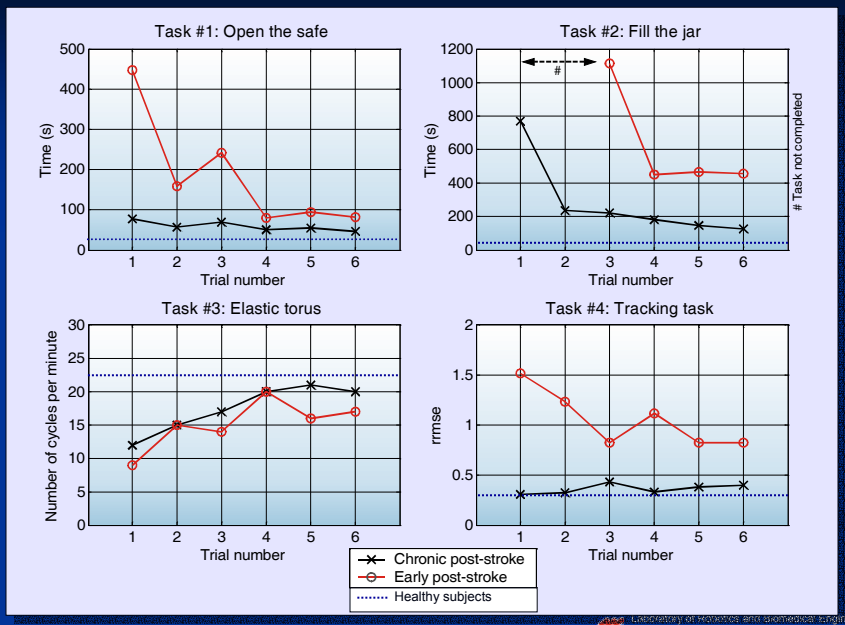
Performance of Two Post-Stroke Patients vs. Healthy Subjects



Conclusions

- Advantages of VR Rehabilitation:
  - Patient motivation (simple VR vs. complex VR)
  - Adaptability based on patient base-line
  - Automatic data storage
  - Safety
  - Cost efficiency – reduced medical costs
- Disadvantages:
  - Transfer of skills to functional tasks
  - Lack of computer skills of PT's
  - Expensive equipment
  - Infrastructure for telerehabilitation

Acknowledgment

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Republic of Slovenia

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Thank You!

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