Neural and Cognitive Engineering

Eduardo Rocon, PhD.

Centro de Automática y Robótica
CSIC

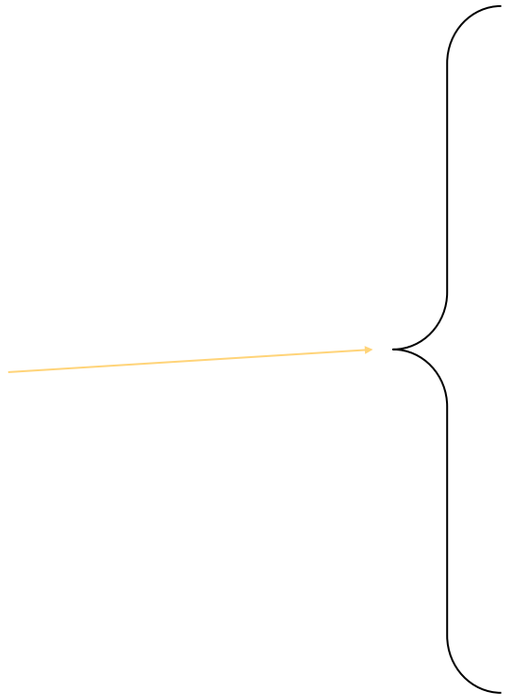
Consejo Superior de Investigaciones Científicas

- Consejo Superior de Investigaciones Científicas, CSIC:

  Public research organisation: over 130 Institutes, about 10,000 people

  Research activity organised according to scientific areas:

Biology
Natural Resources
…
Physical Technologies
Materials
…
Chemistry



Acoustics
Microelectronics
…
Robotics
…
Optics

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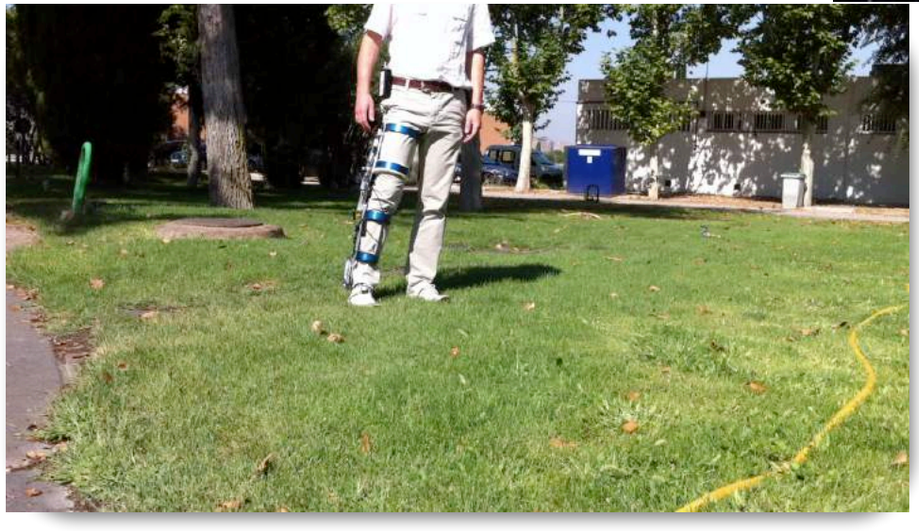
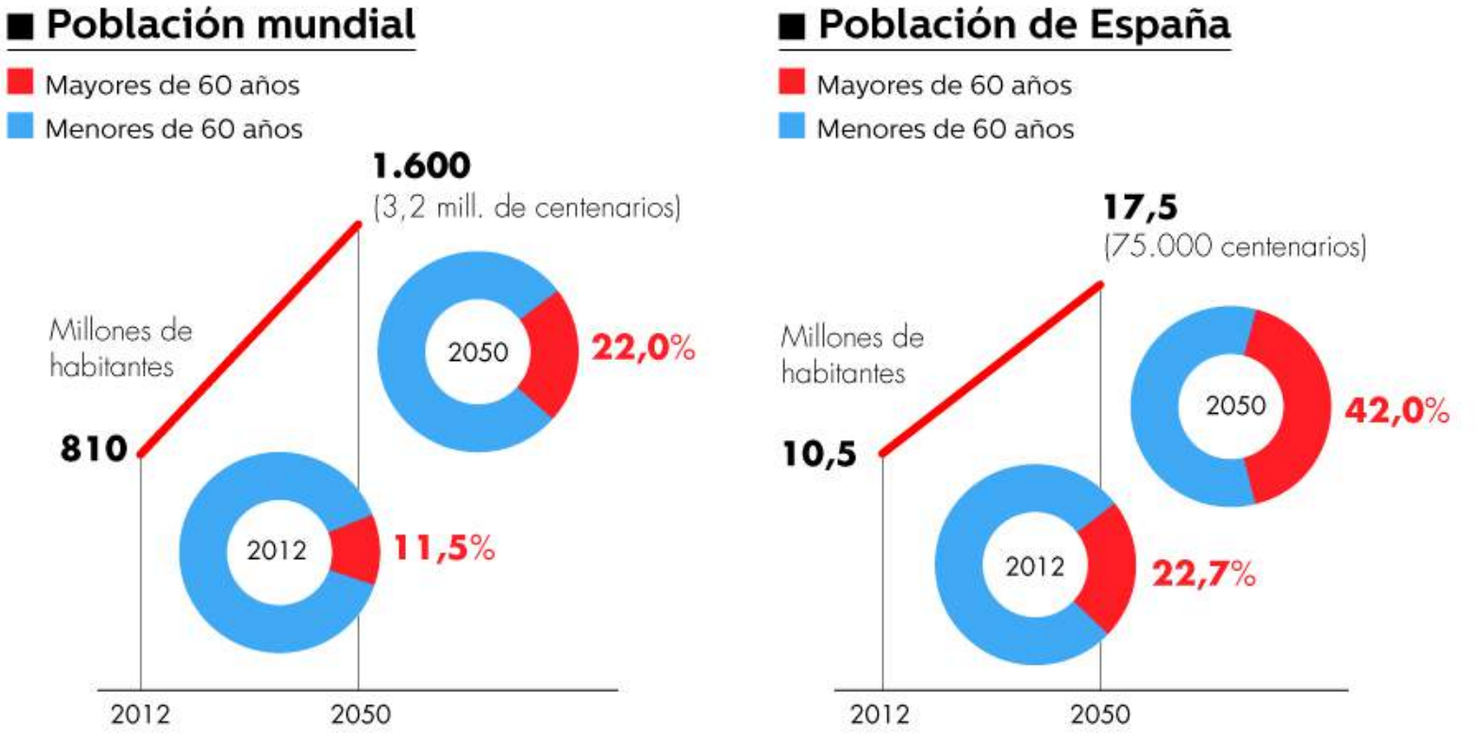
Neural and Cognitive Engineering group



Motivation

- Stroke, 5,5 % of world population (770k new cases every year)
- Tremor (6% of people older than 60 years)
- Spinal Cord Injury (800 per million of habitants)
- Cerebral Palsy (2,8 per 1000 habitnts. Spain: 120.000)

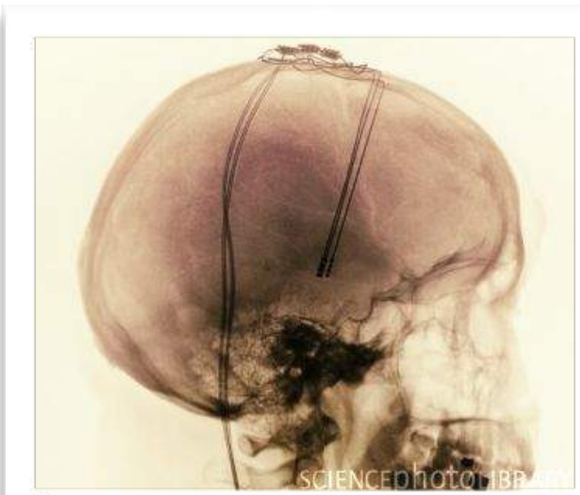
"We're launching a campaign to get people to take up smoking again!"



Neurorehabilitation

- Multidisciplinary research field that combines methodologies of engineering and medicine in the rehabilitation of patients.

- High socio-economic impact.



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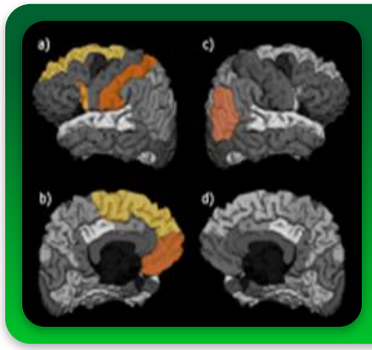
Rehabilitation technologies



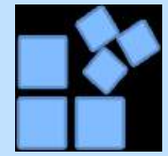
Neurophysiology, Cognition and movement

Man-machine interfaces

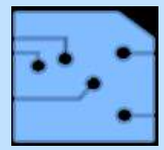
Biosignals

Neurological Diseases

Data mining



Robotics



Control–Función

Neural and Cognitive Engineering group

Research Lines

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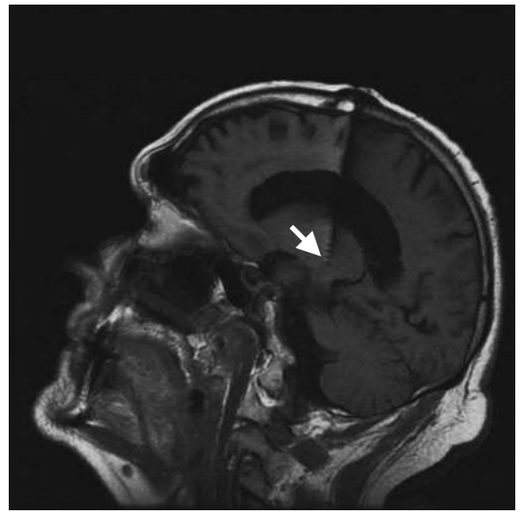
Motivation

- *Most common movement disorder* (~6% people >50 years[1]). Prevalence will double by 2050[2]

- Caused by *10 different "syndromes"*

  - ✦ Essential tremor (ET) y Parkinson disease (PD)

  - ✦ Main treatments: drugs, in some patients neurosurgery (Deep Brain Stimulation [DBS])



Shneyder et al *TOHD* 2012

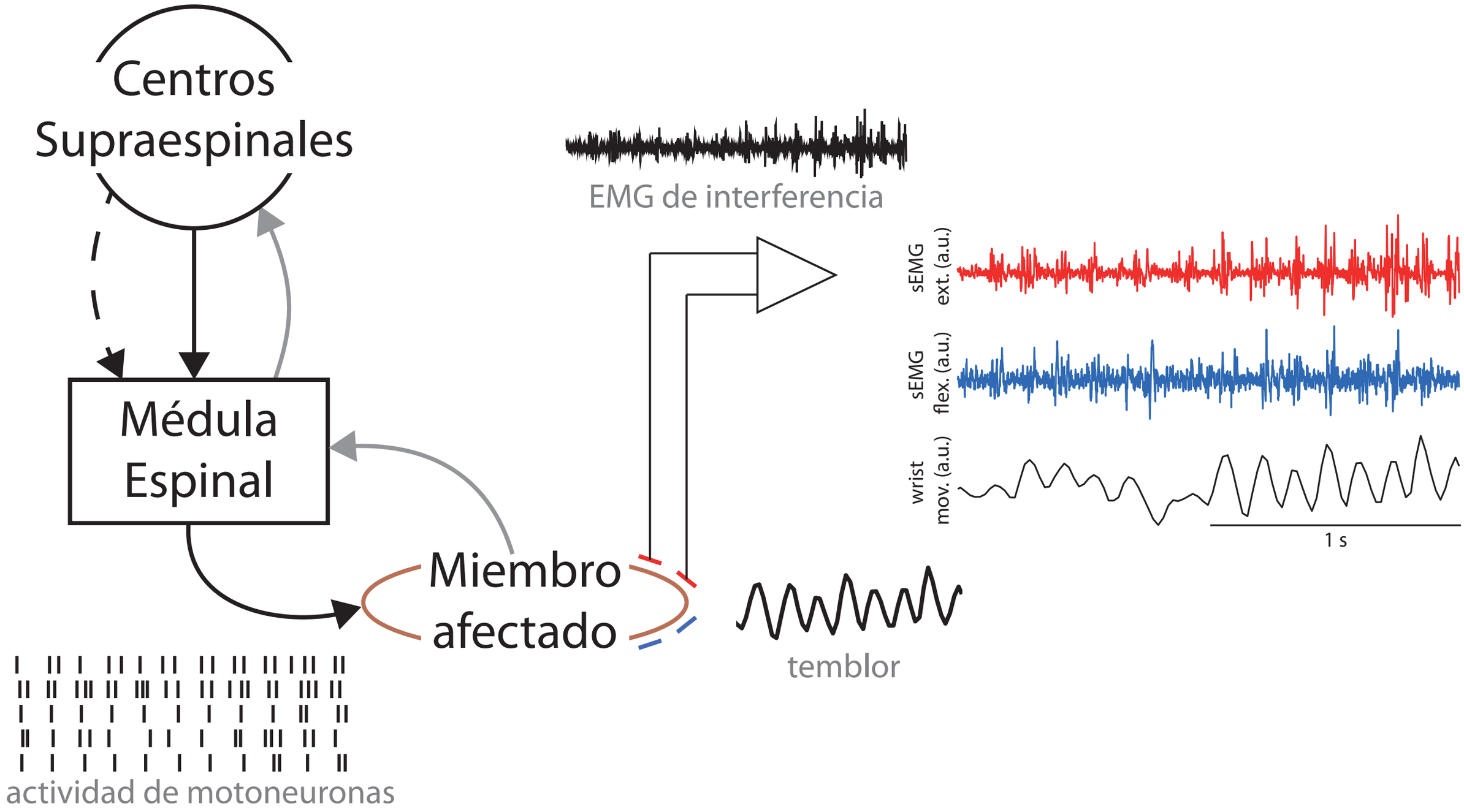
- Big proportion of patients (~25%[3]) do not benefit from any treatment

  - *High impact in the quality of life, independence*

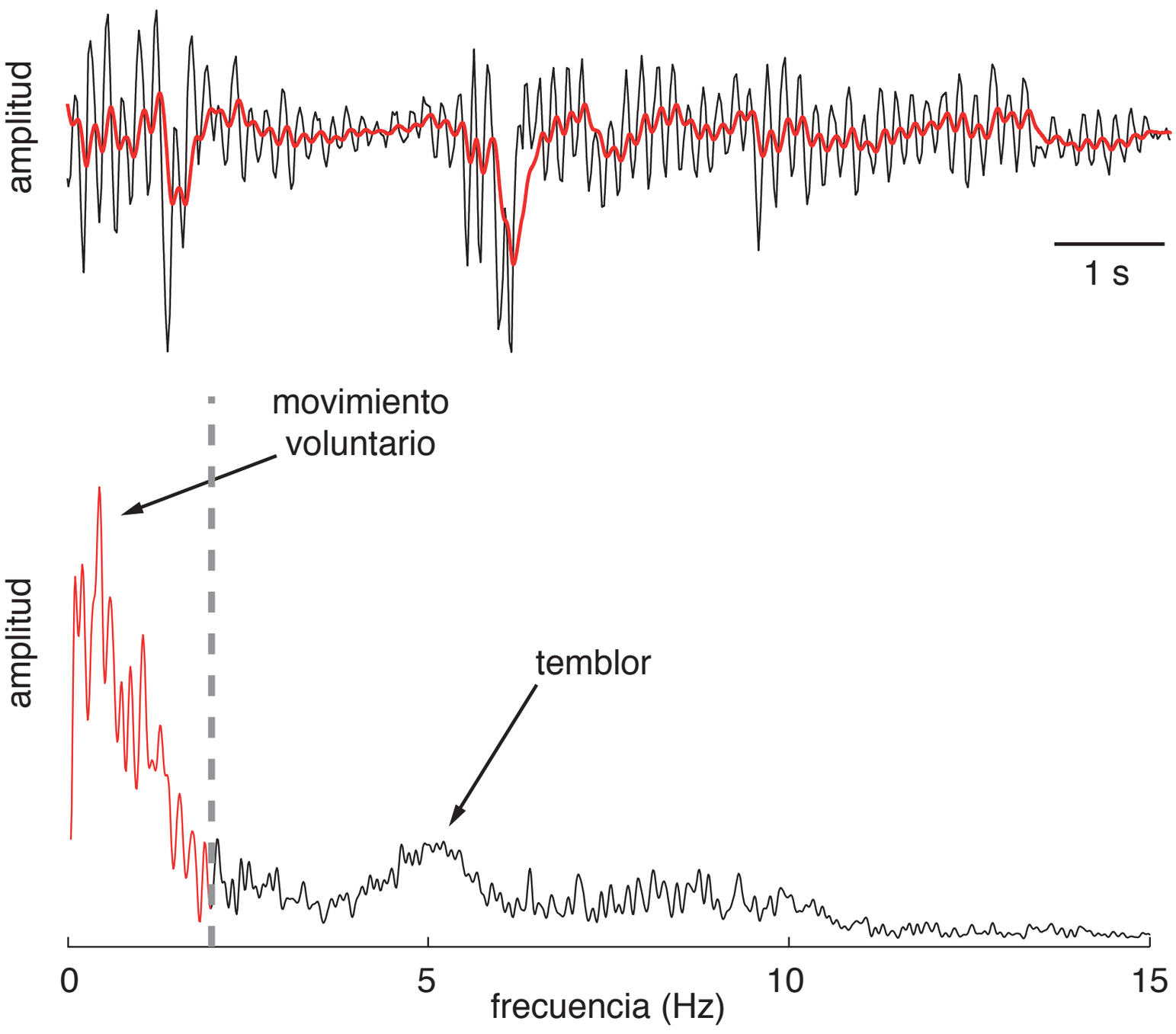
  - Social and psychological problems.

1. Wenning GK, Kiechl S, et al. *Lancet Neurol* 2005
2. Bach JP, Ziegler U, et al. *Mov Disord* 2011
3. Elble R, Koller J. "Tremor" 1990

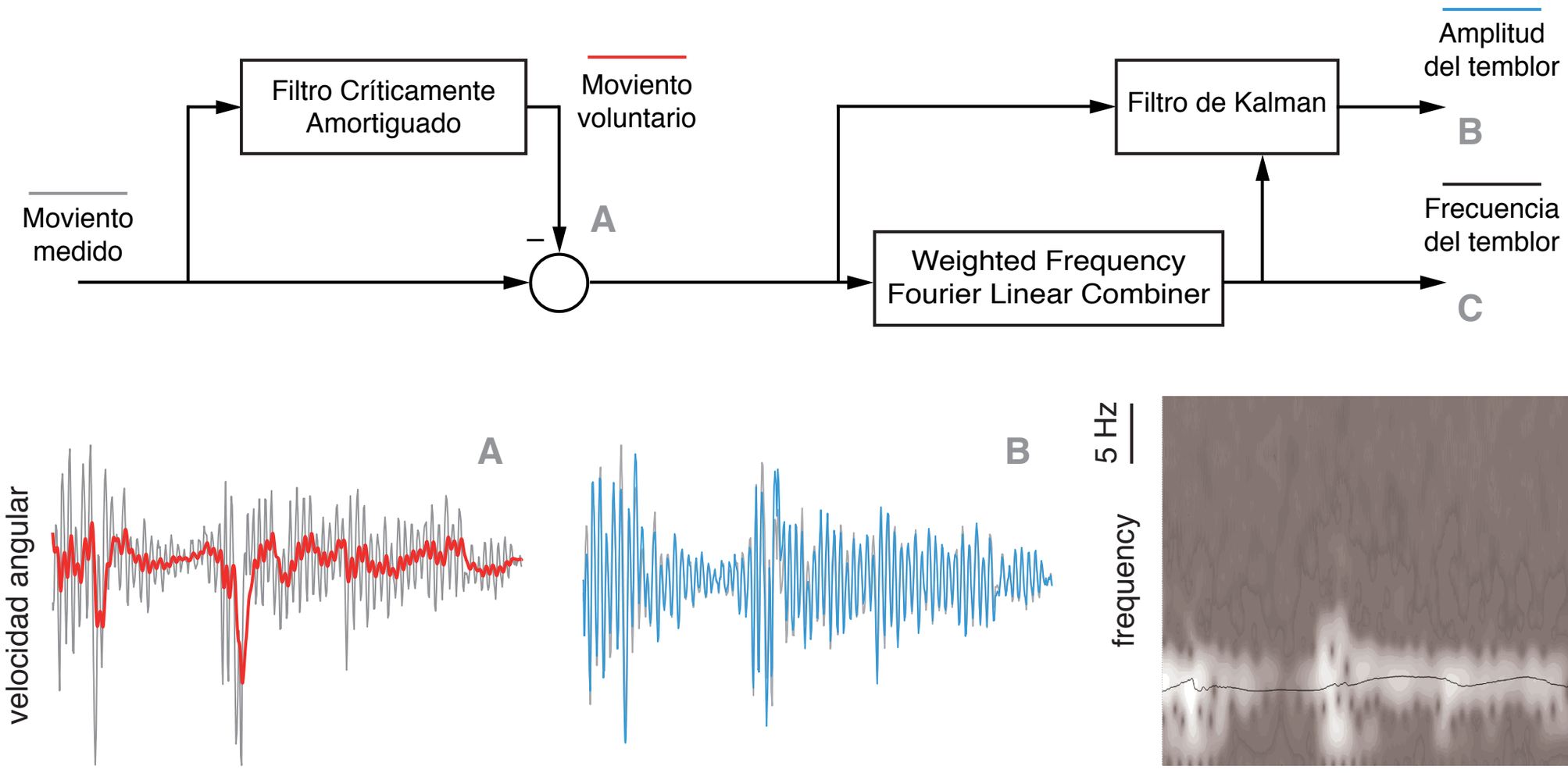
How an engineer “see" tremor?



Voluntary and tremorous movement



How to use this information?



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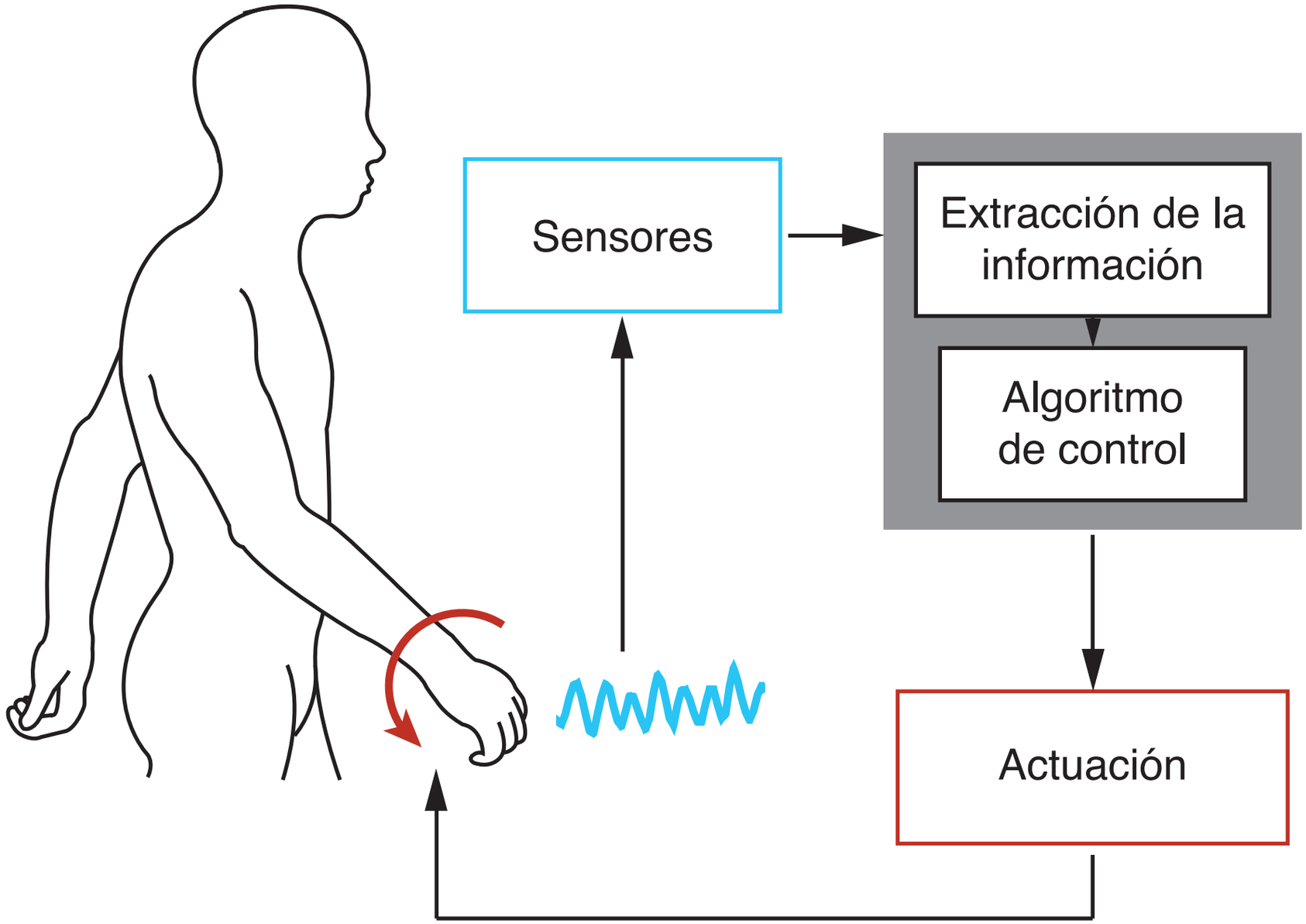
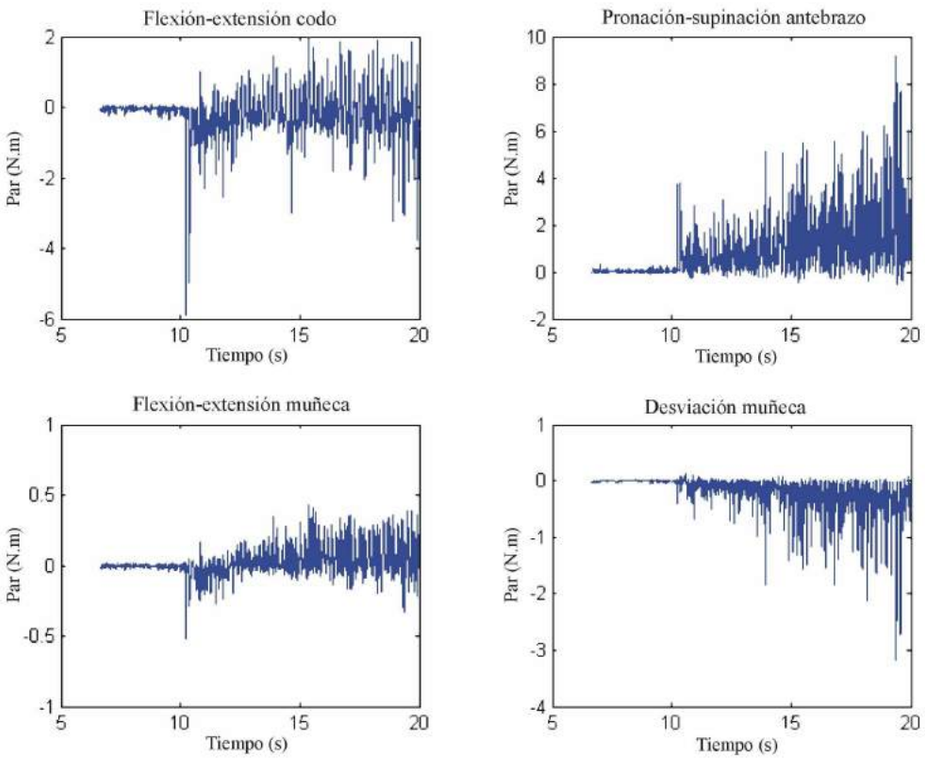
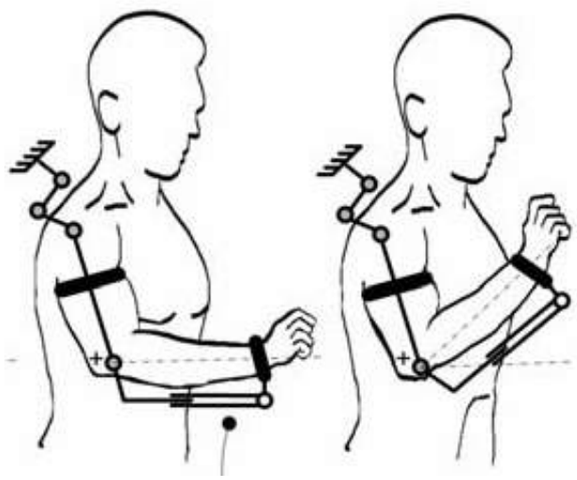


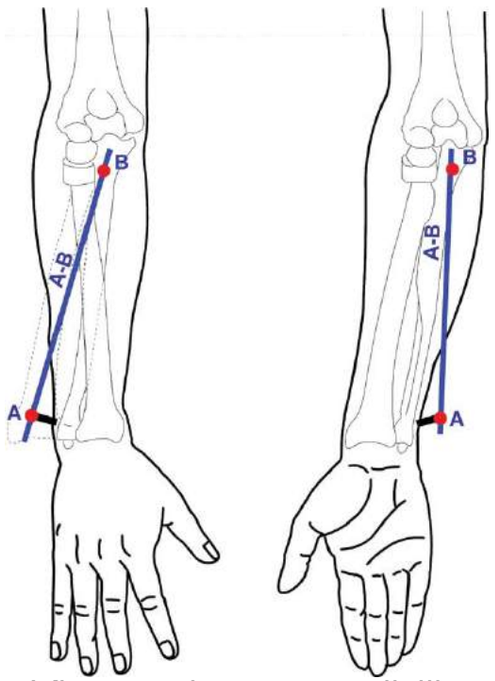
Exoskeleton: Biomechanics



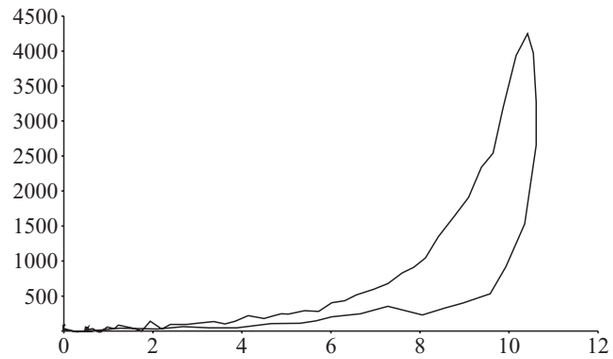
Joint torque



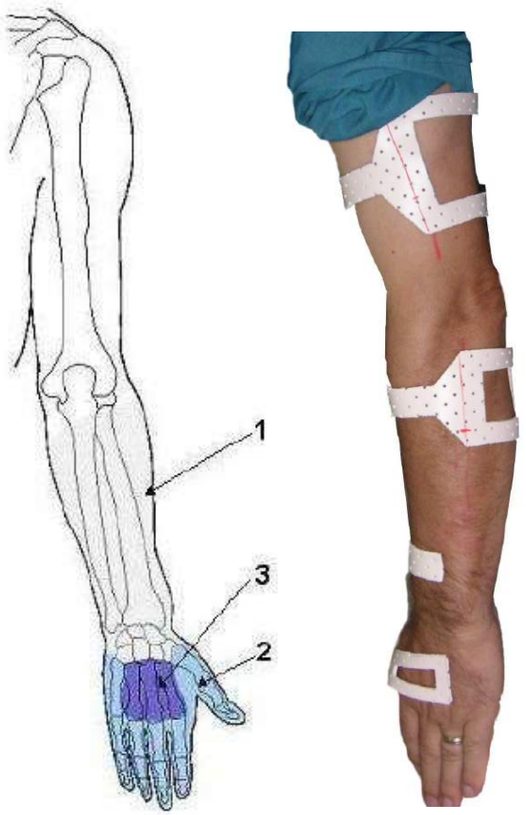
kinematics compatibility



Kinematic compatibility



Force x tissue deformation

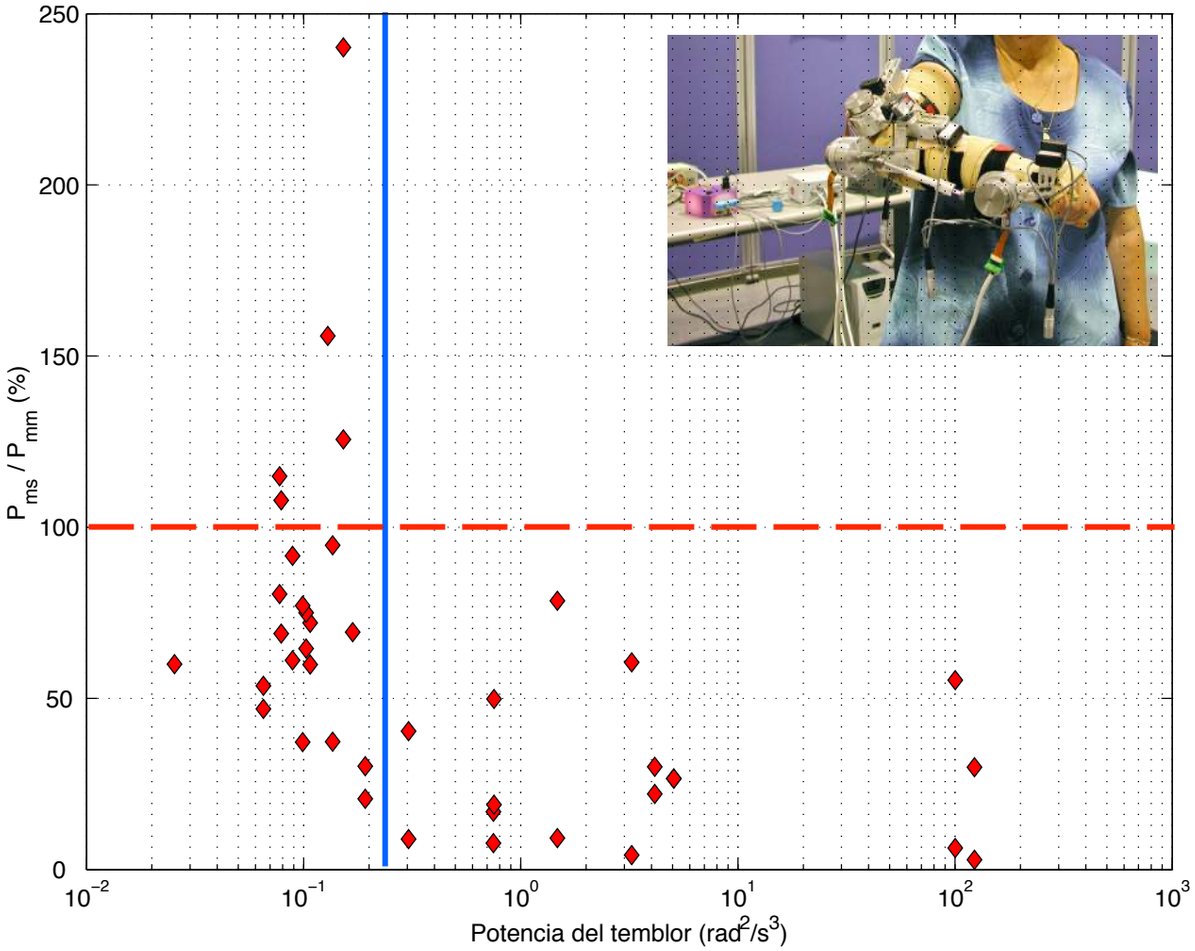


Force application

The Exoskeleton WOTAS

- Duraluminium structure (850 g)
- Joints: wrist (flexion-extension , prono-supination) y elbow (flexion-extension)
- Sensors: Force sensors (strain gauges) and movement (gyroscopes)
- Actuation: DC motor and harmonic drive (max torque 3 Nm)

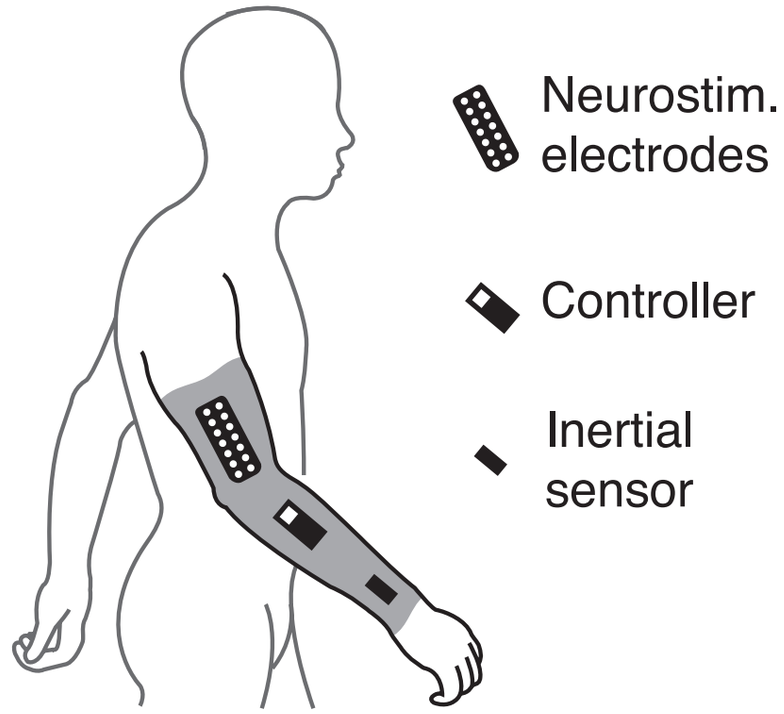
Evaluation



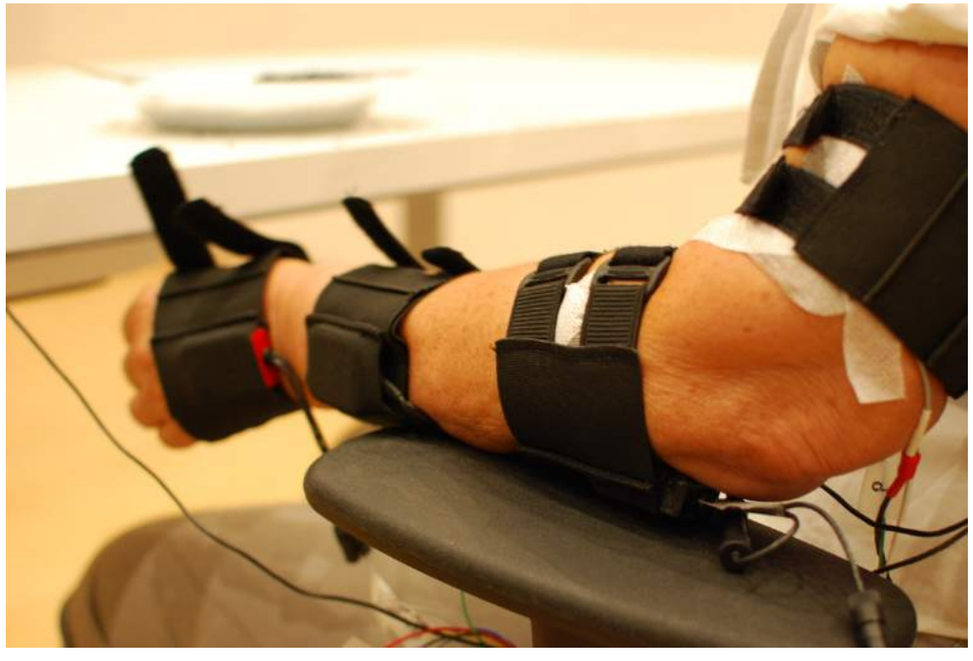
- Tremor attenuation up to 90% in severe patients
- Limitations:
  - Bulky solution
  - Inefficient to suppress small tremors
  - Actuation
- Do not accomplish the aesthetical requirements for a practical solution

The development of a neuroprosthesis

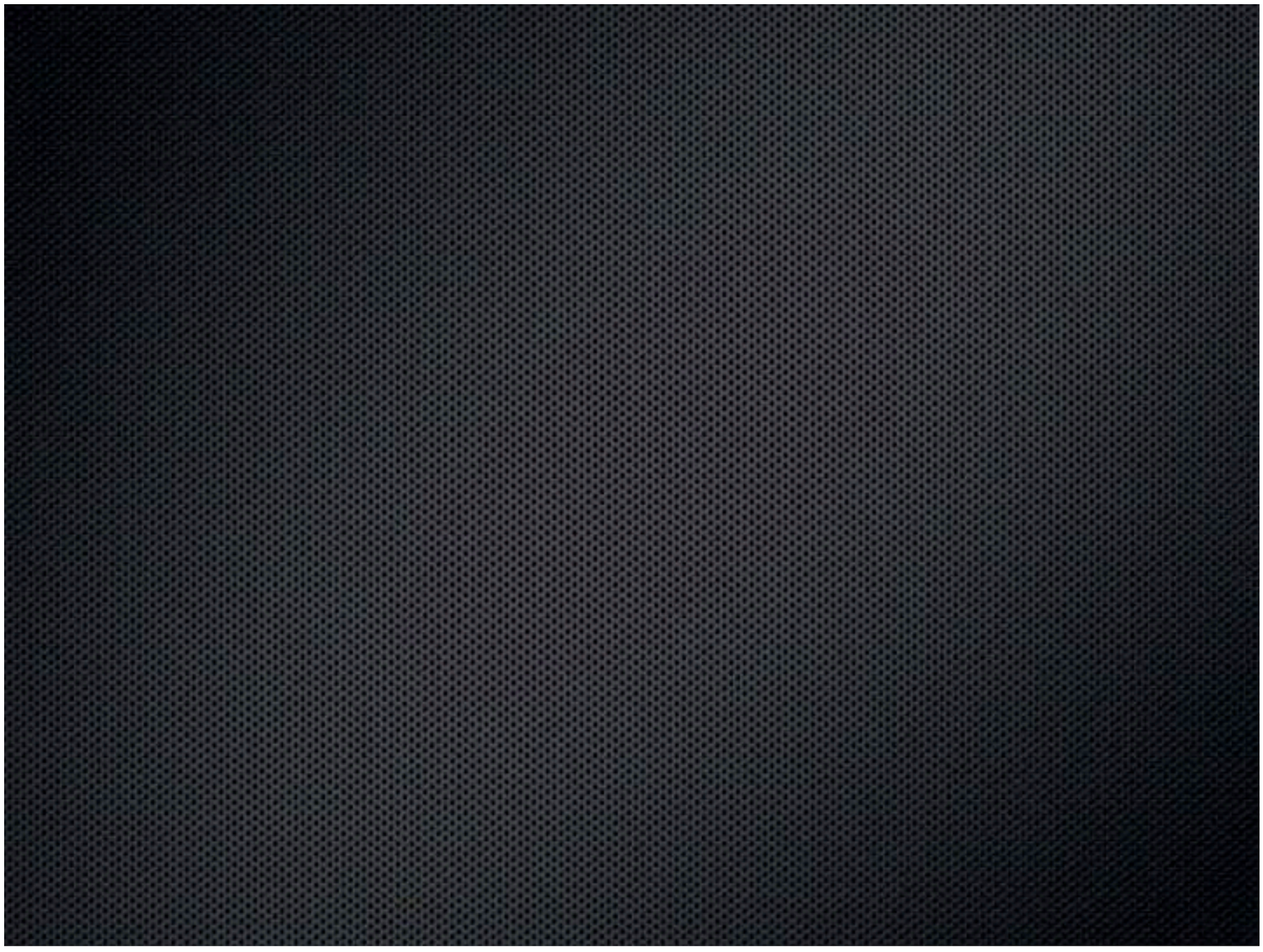
- Textile solution
  - Modular solution (customization)
- Able to suppress tremor at wrist and elbow joint
- Sensors: gyroscopes
- Actuation: Functional electrical Stimulation



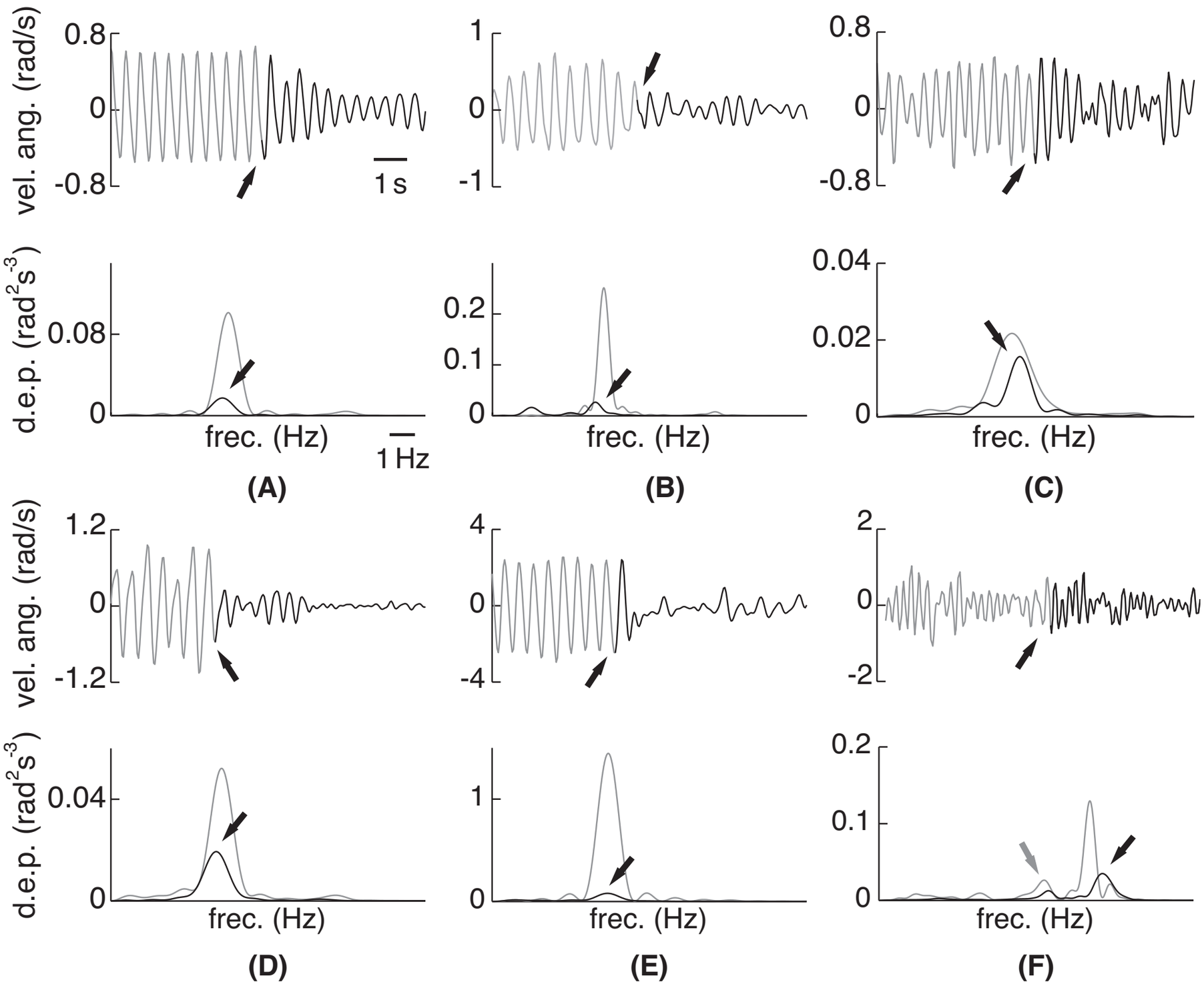
- Strategy: co-contraction of muscles
  - Control strategies very similar to the exoskeleton



Results

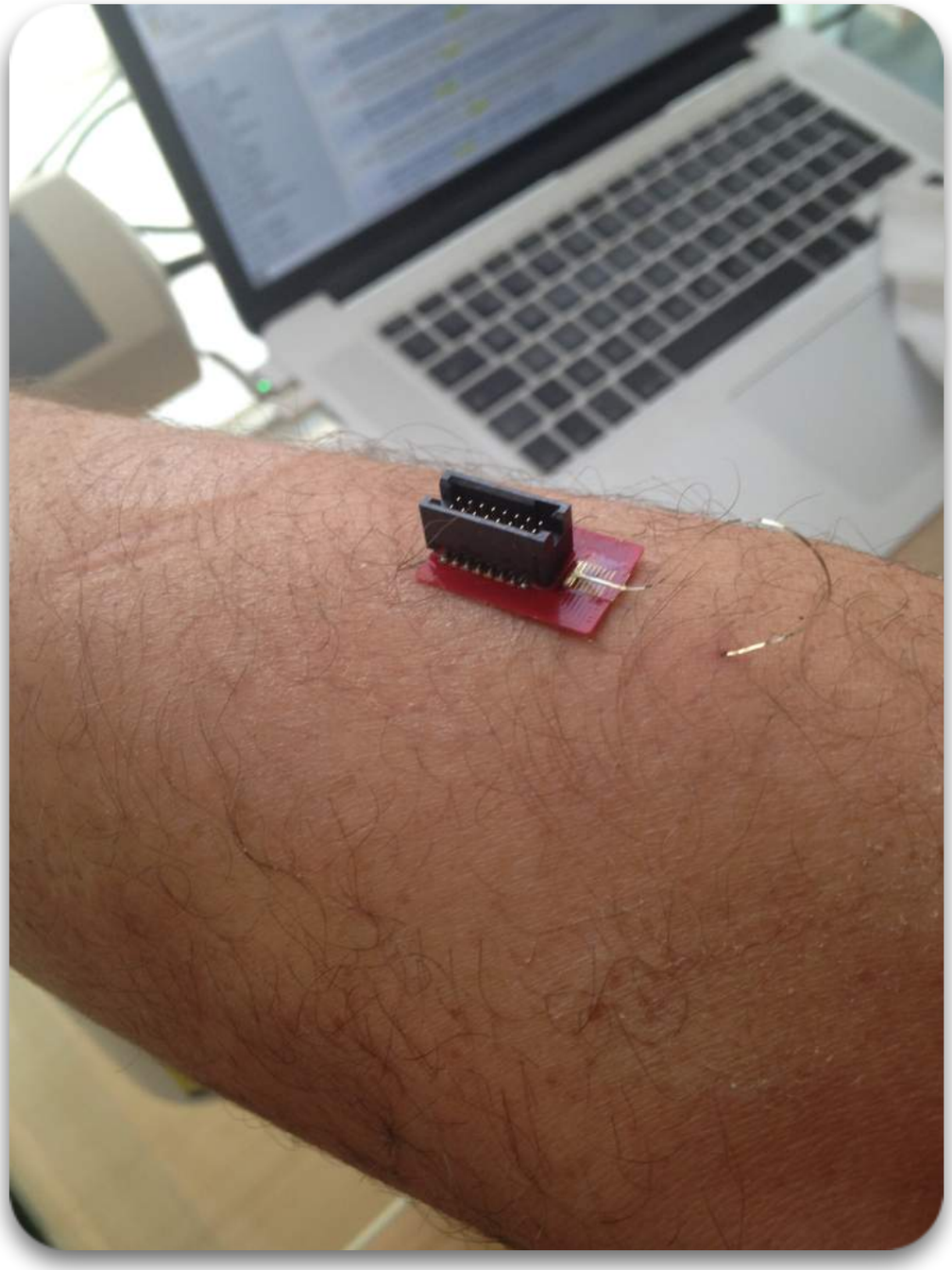


Results

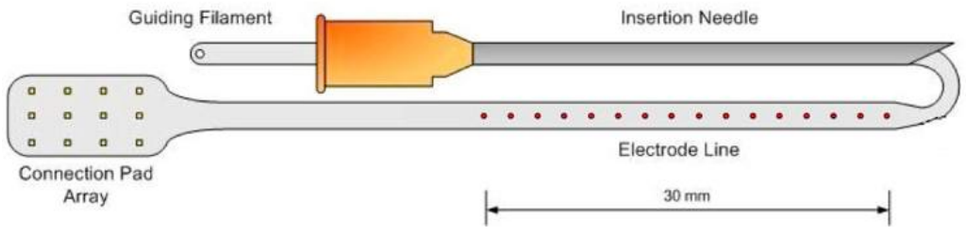

vel. ang. (rad/s)
0.8
0
-0.8
1 s
d.e.p. (rad²s⁻³)
0.08
0
frec. (Hz)
1 Hz
(A)
1
0
-1
0.2
0.1
0
frec. (Hz)
(B)
0.8
0
-0.8
0.04
0.02
0
frec. (Hz)
(C)
vel. ang. (rad/s)
1.2
0
-1.2
d.e.p. (rad²s⁻³)
0.04
0
frec. (Hz)
(D)
4
0
-4
1
0
frec. (Hz)
(E)
2
0
-2
0.2
0.1
0
frec. (Hz)
(F)

Functional evaluation

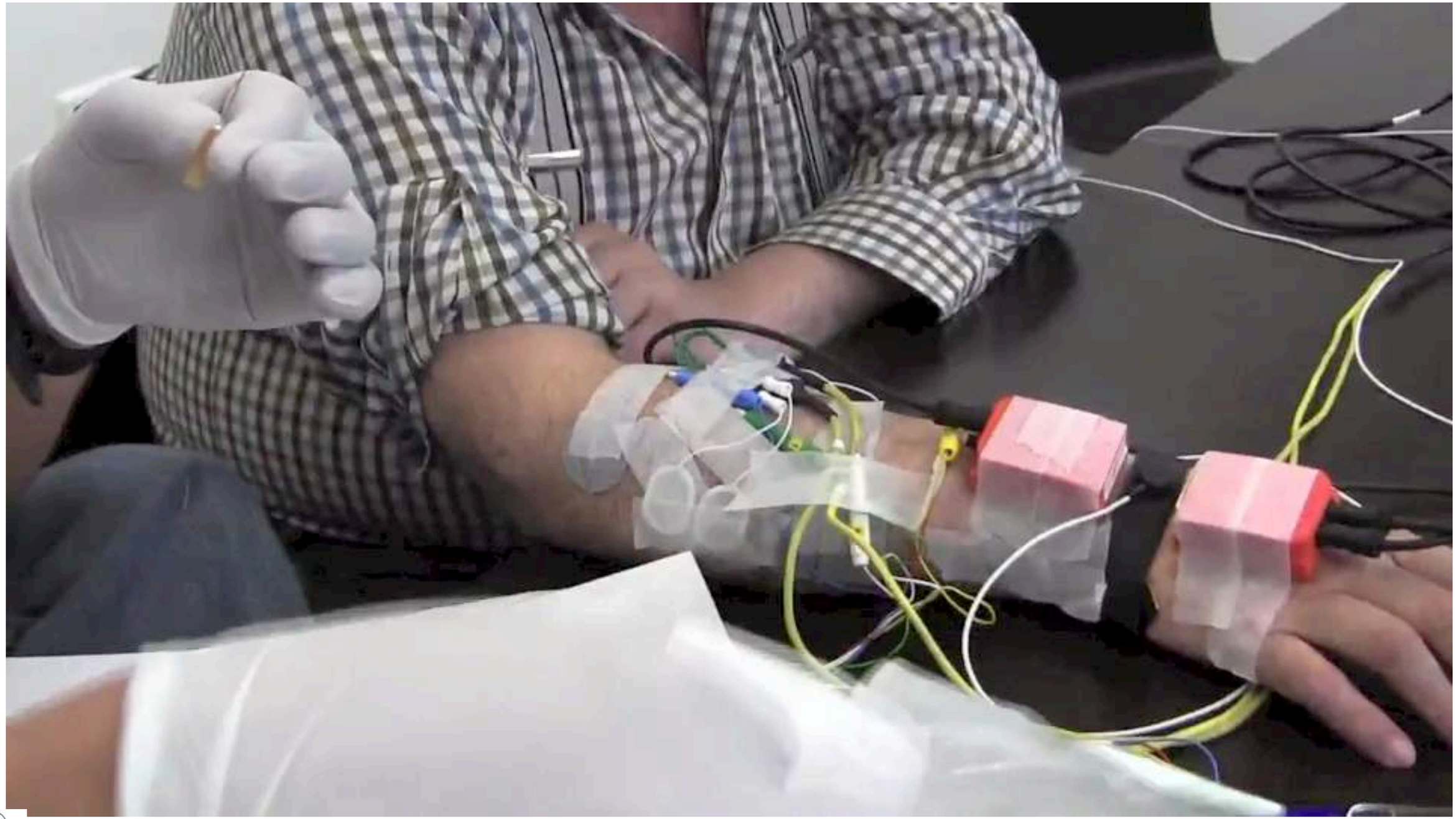
Tremor suppression by afferent stimulation



Fraunhofer
IBMT



Tremor suppression by afferent stimulation

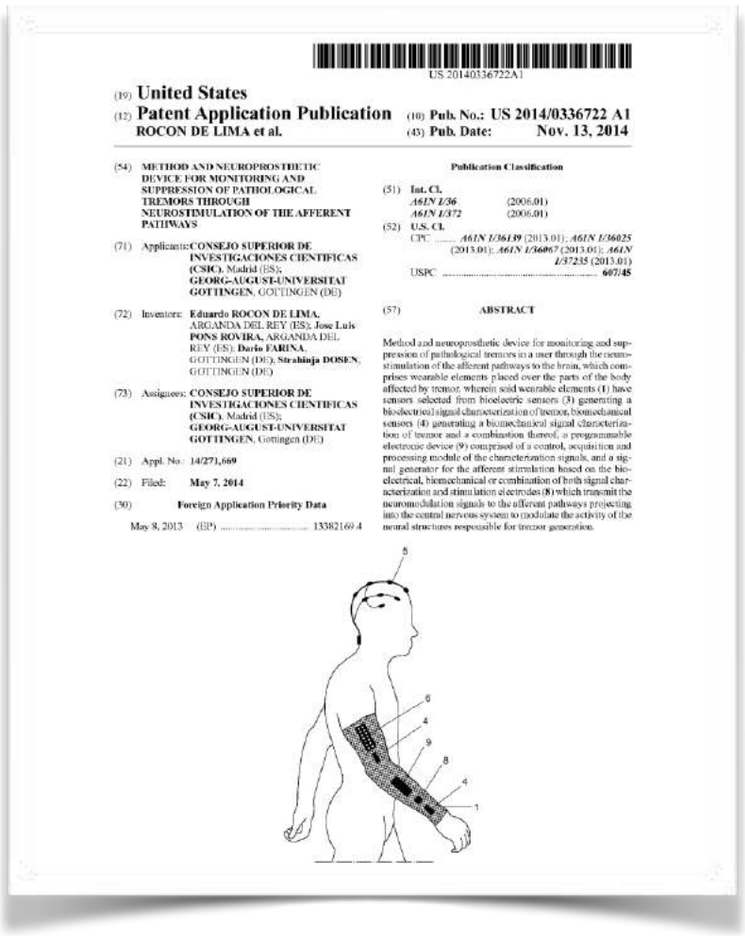


Evolution towards bionic devices: Tremor Suppression

ICHR → BNCI

IFHR → EEF

Desarrollo Tecnológico → NP



(19) **United States**

(12) **Patent Application Publication**
ROCON DE LIMA et al.

(10) **Pub. No.: US 2014/0336722 A1**
(43) **Pub. Date: Nov. 13, 2014**

(54) METHOD AND NEUROPROSTHETIC DEVICE FOR MONITORING AND SUPPRESSION OF PATHOLOGICAL TREMORS THROUGH NEUROSTIMULATION OF THE AFFERENT PATHWAYS

Publication Classification

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A61N 1/372 (2006.01)

(52) U.S. Cl.
CPC *A61N 1/36139* (2013.01); *A61N 1/36025* (2013.01); *A61N 1/36067* (2013.01); *A61N 1/37235* (2013.01)
USPC 607/45

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(21) Appl. No.: **14/271,669**

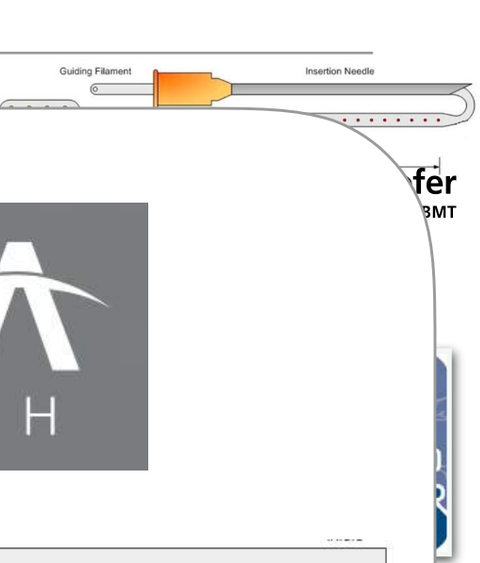
(22) Filed: **May 7, 2014**

(30) **Foreign Application Priority Data**

May 8, 2013 (EP) 13382169.4

(57) **ABSTRACT**

Method and neuroprosthetic device for monitoring and suppression of pathological tremors in a user through the neurostimulation of the afferent pathways to the brain, which comprises wearable elements placed over the parts of the body affected by tremor, wherein said wearable elements (1) have sensors selected from bioelectric sensors (3) generating a bioelectrical signal characterization of tremor, biomechanical sensors (4) generating a biomechanical signal characterization of tremor and a combination thereof, a programmable electronic device (9) comprised of a control, acquisition and processing module of the characterization signals, and a signal generator for the afferent stimulation based on the bioelectrical, biomechanical or combination of both signal characterization and stimulation electrodes (8) which transmit the neuromodulation signals to the afferent pathways projecting into the central nervous system to modulate the activity of the neural structures responsible for tremor generation.



CALA HEALTH

Detalles del Contrato

Título del Contrato	CONTRATO DE LICENCIA EXCLUSIVA EP 13382169.4"METHOD AND NEUROPROSTHETIC DEVICE FOR MONITORING AND SUPPRESSION OF PATHOLOGICAL TREMORS THROUGH NEUROSTIMULATION OF THE AFFERENT PATHWAYS"	**Actividad**	LICENCIA
Código	050601160021	**Centro**	010564
Actividad y Forma Jurídica	CONTRATO	**Código OTT**	20163907
Fecha Comienzo	05 00:00:00.0/07/2016	**Fecha Fin**	07 00:00:00.0/05/2033
Total Ingresado			

PARTICIPANTES DEL CONTRATO

Investigador	Función	Cuerpo	NIF
ROCON DE LIMA, EDUARDO	RESPONSABLE	E.CIENTIFICOS TITULARES DE ORGANISMOS PUBLICOS DE INVESTIGAC	51557600H

EMPRESAS DEL CONTRATO

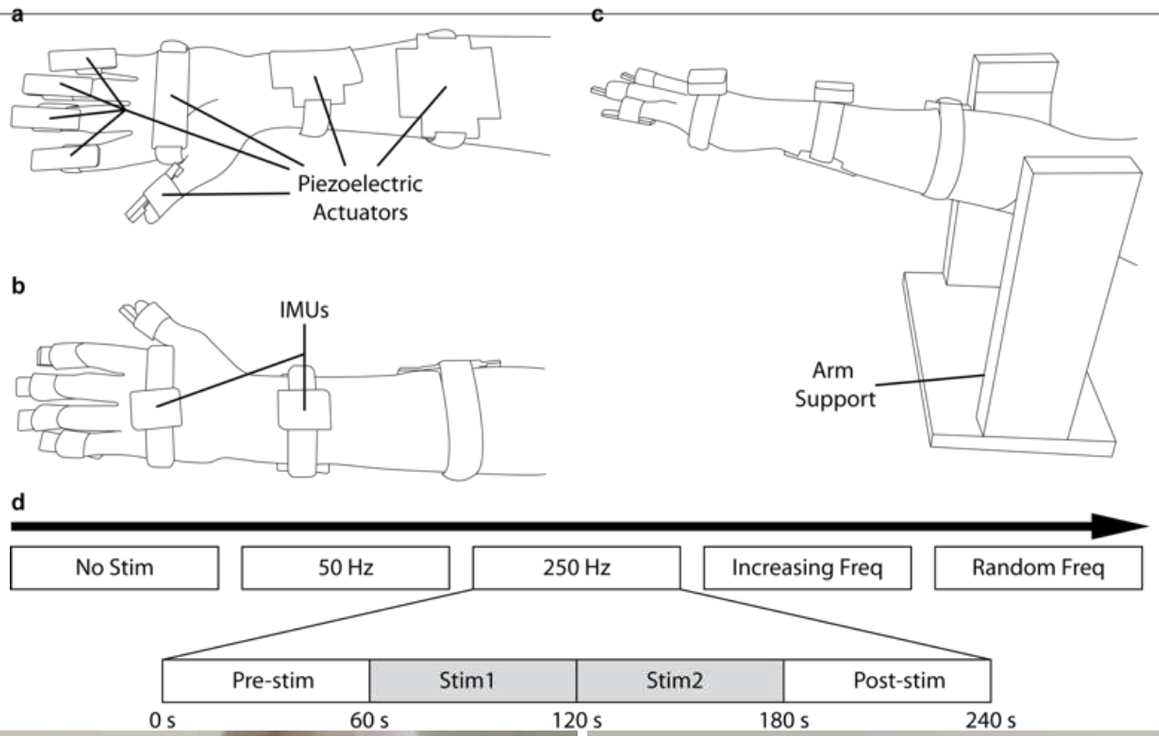
Código del Contrato	Centro	Empresa
050601160021	010564	CALA HEALTH, INC
050601160021	010564	Universitätsmedizin Göttingen

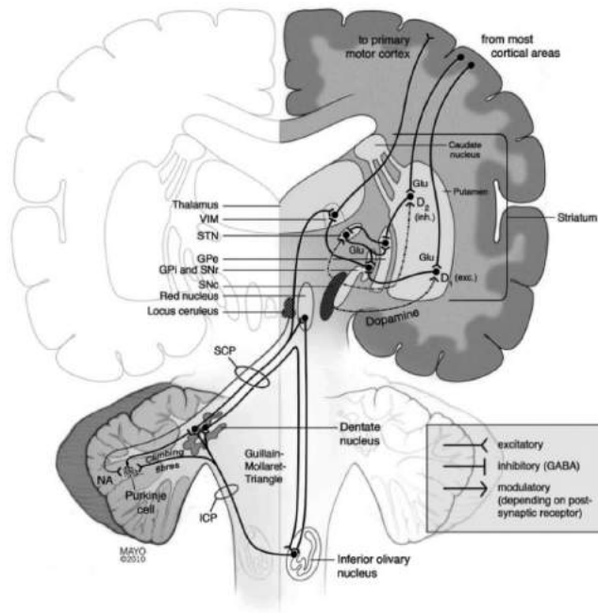
off medication

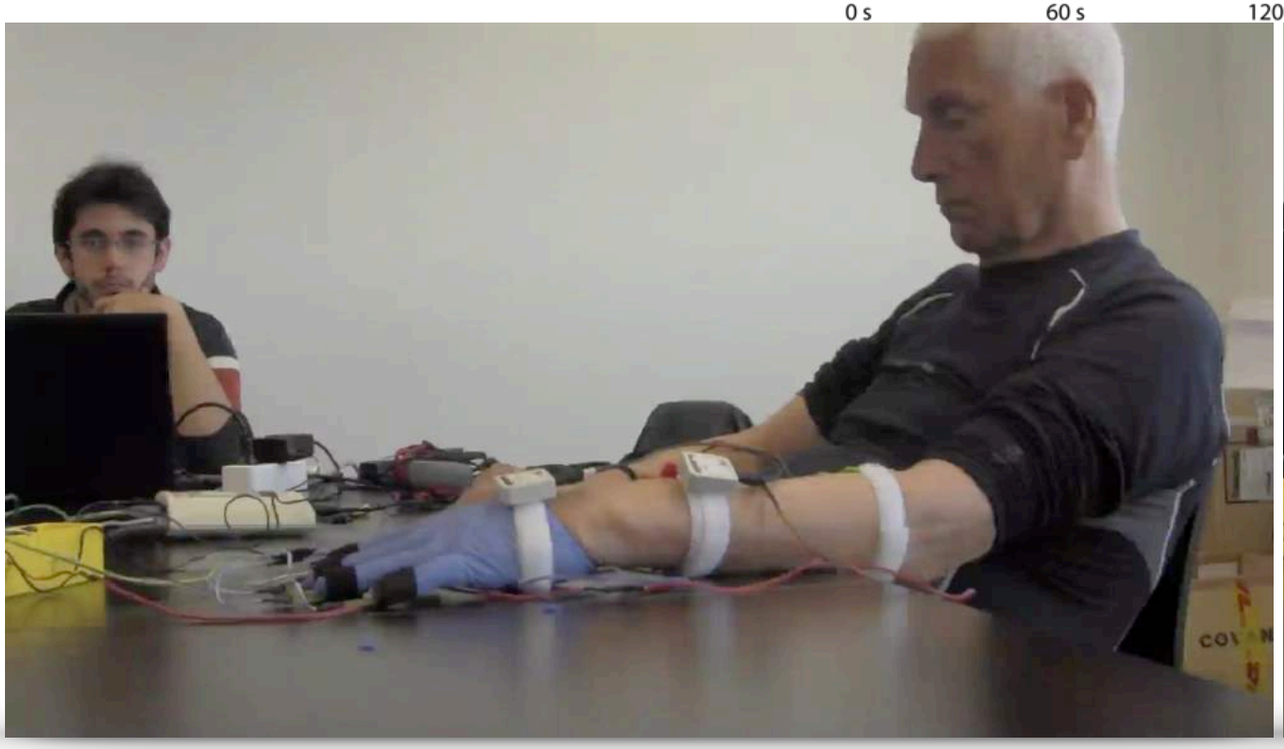
on stimulation (130 Hz)

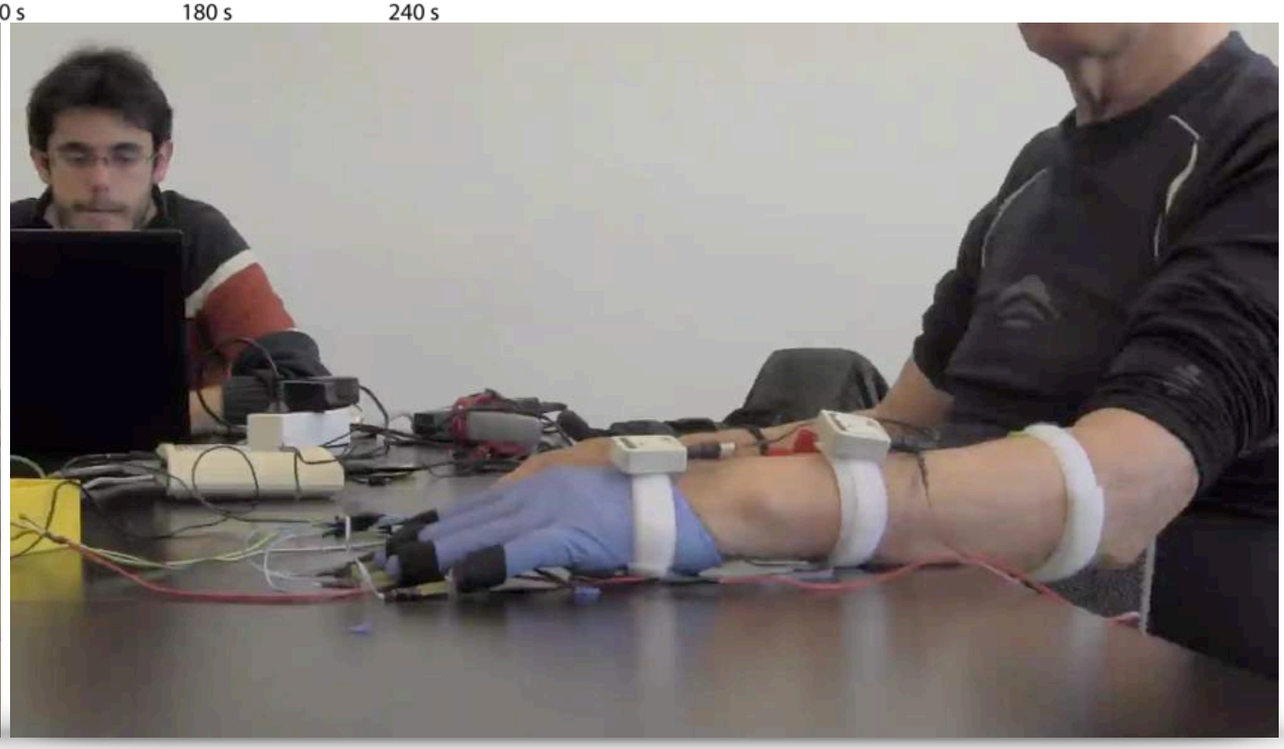
Neuromodulation in tremor suppression

Explora Tecnología - > FET









Neuromodulation in tremor suppression

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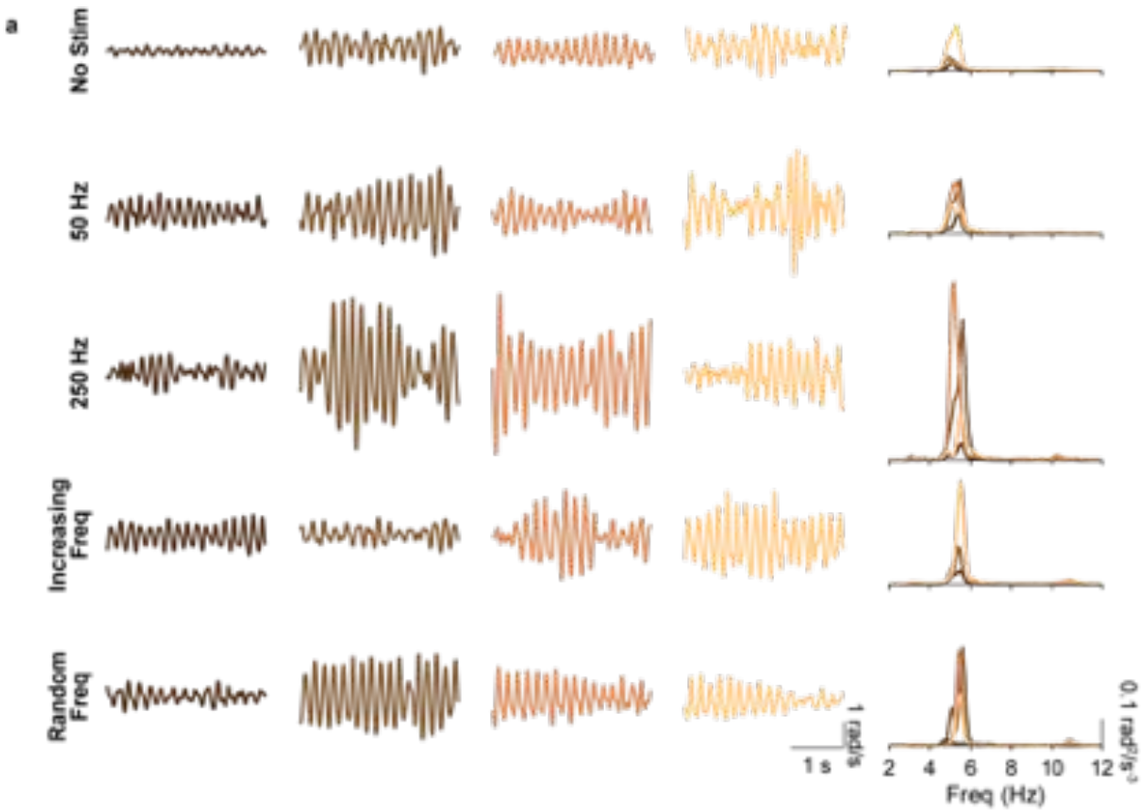
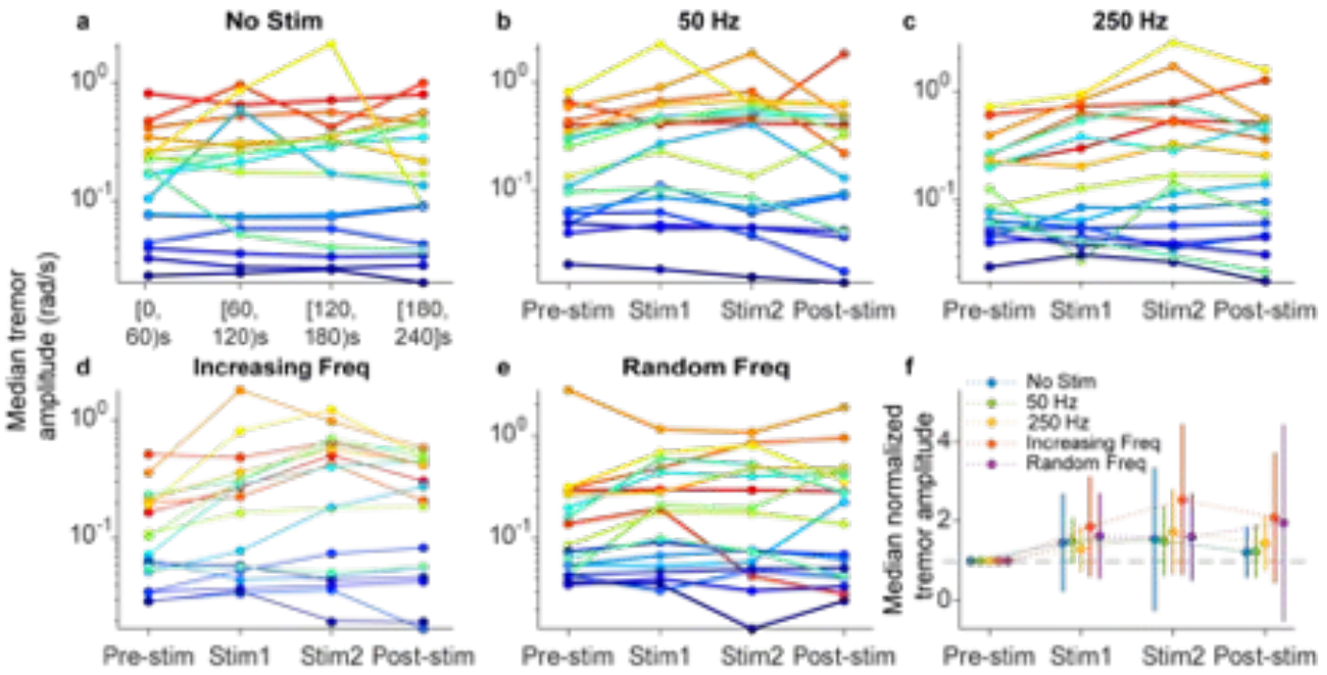
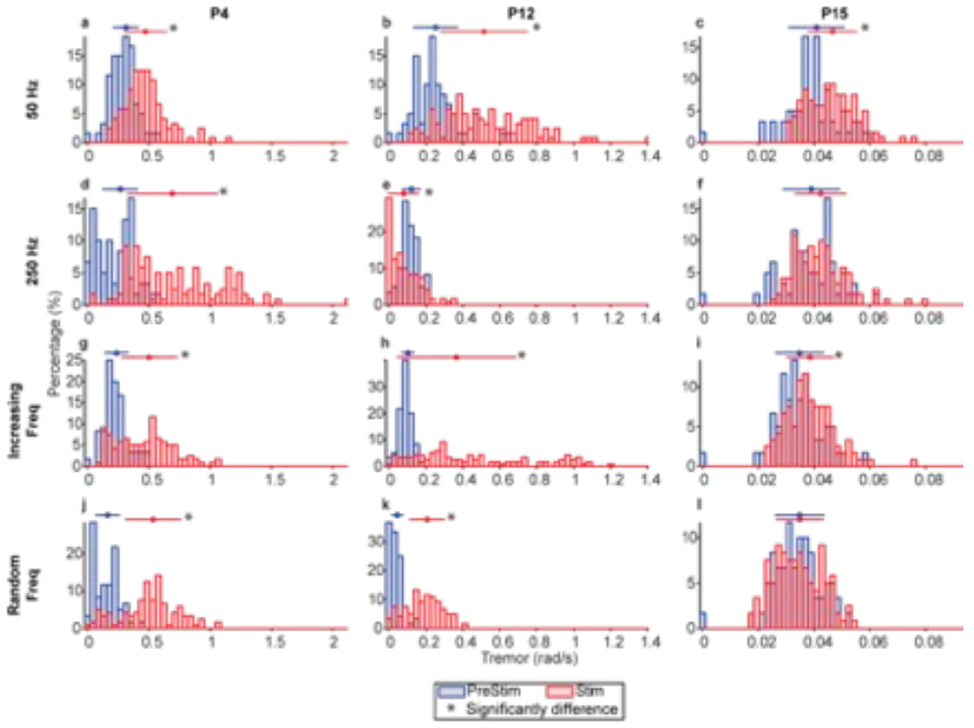
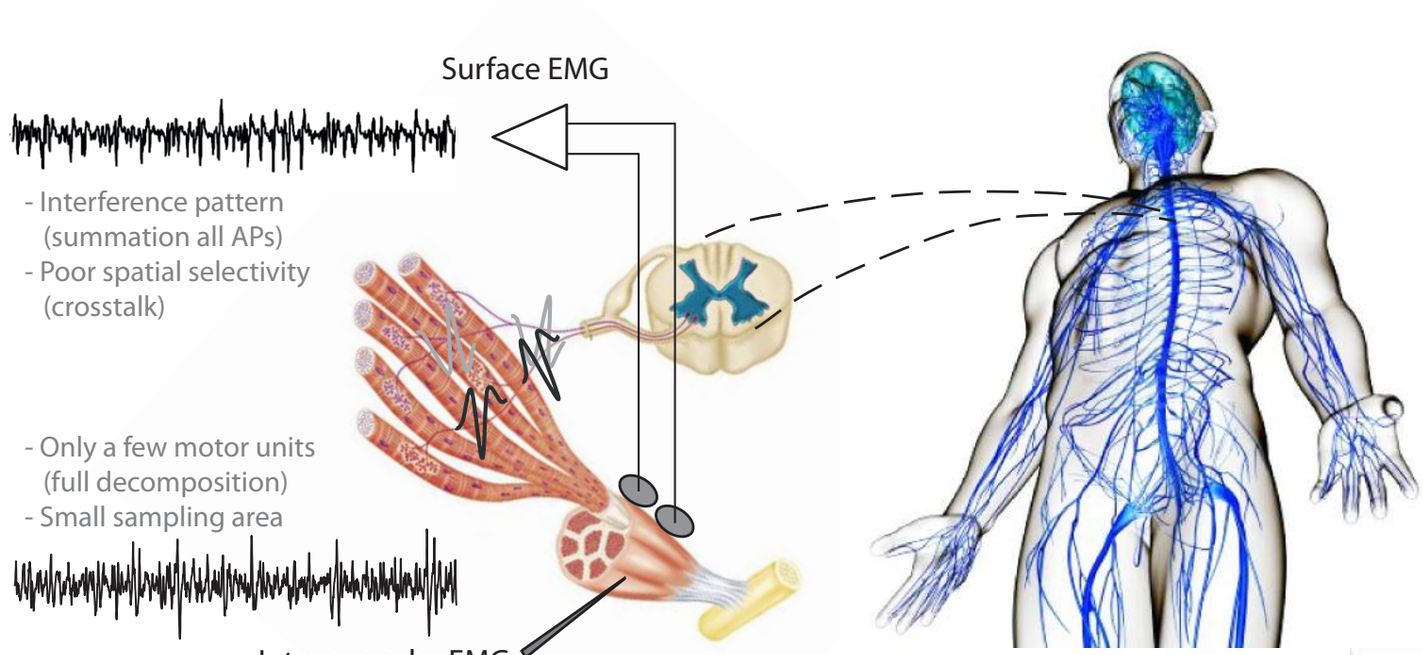
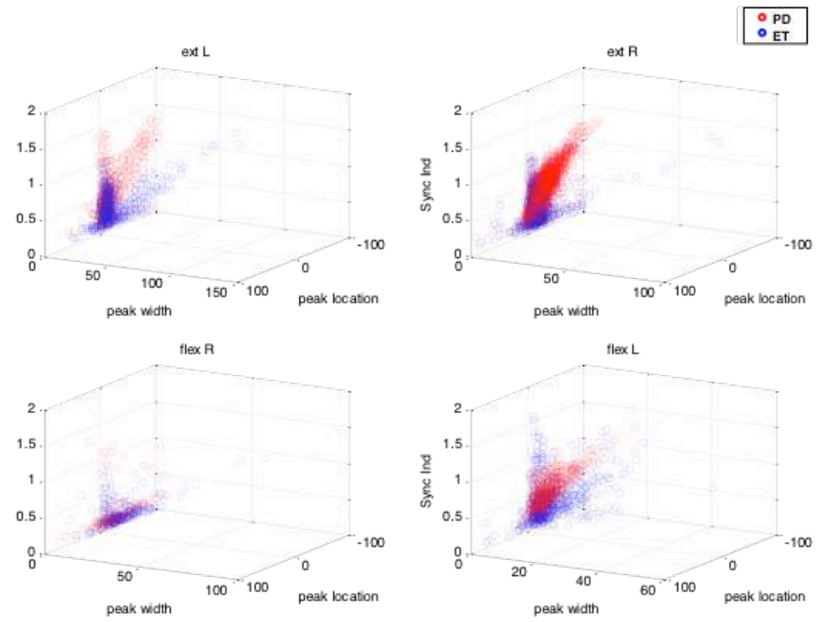


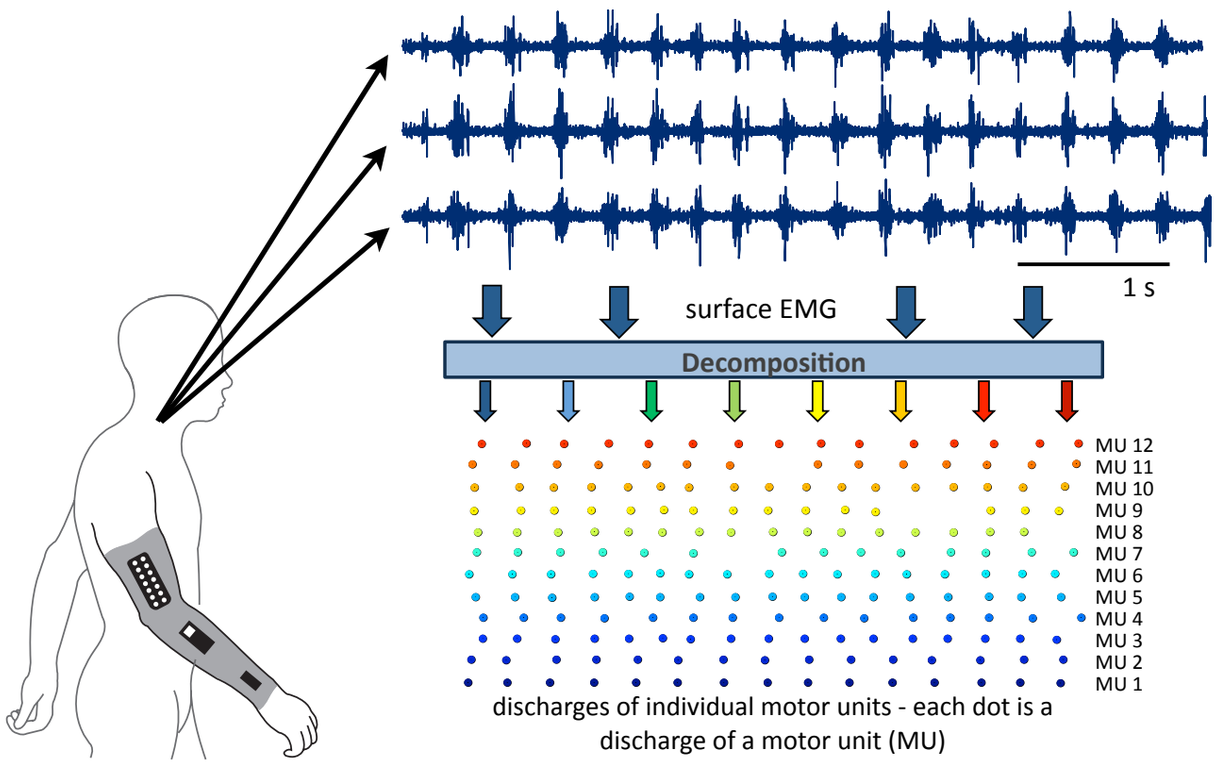


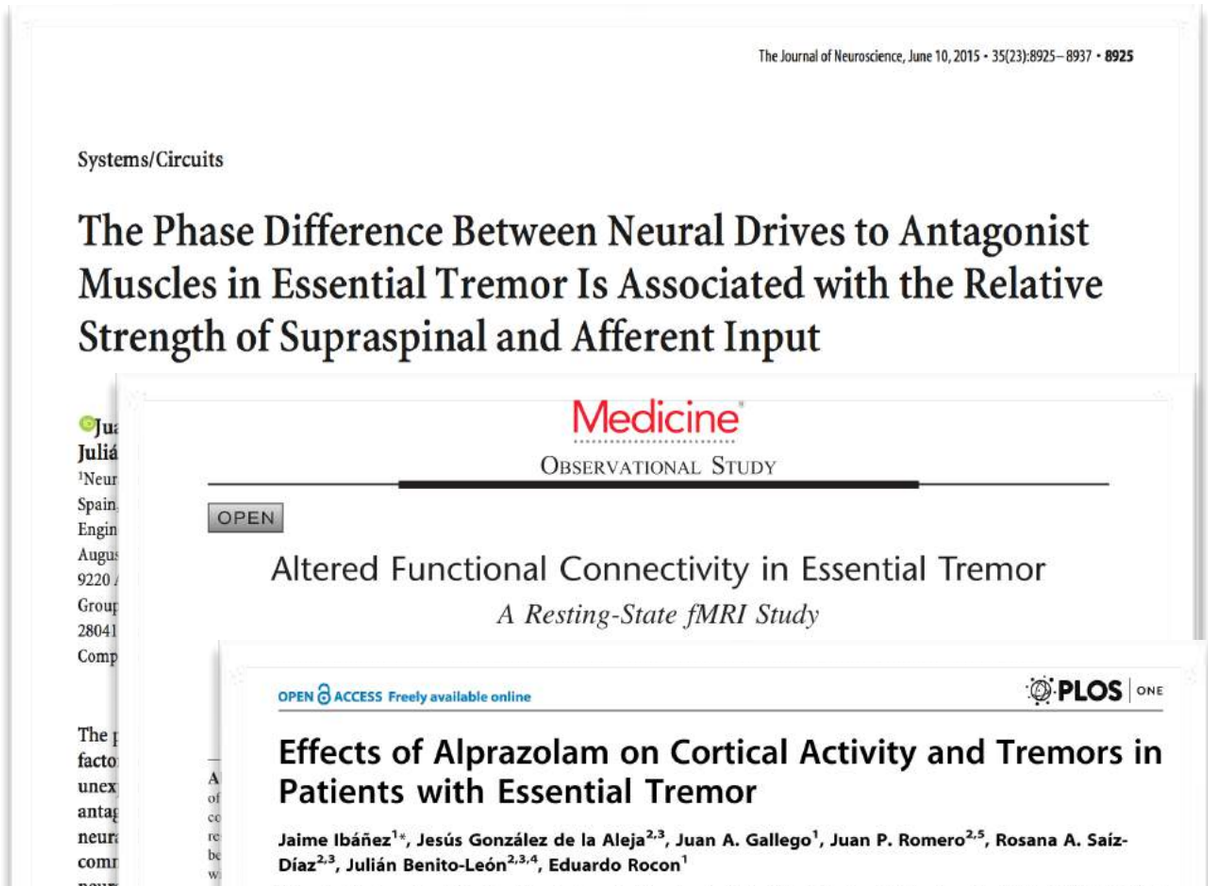


Neurophysiology: understanding pathologies









The Journal of Neuroscience, June 10, 2015 • 35(23):8925–8937 • 8925

Systems/Circuits

The Phase Difference Between Neural Drives to Antagonist Muscles in Essential Tremor Is Associated with the Relative Strength of Supraspinal and Afferent Input

Medicine
OBSERVATIONAL STUDY

OPEN

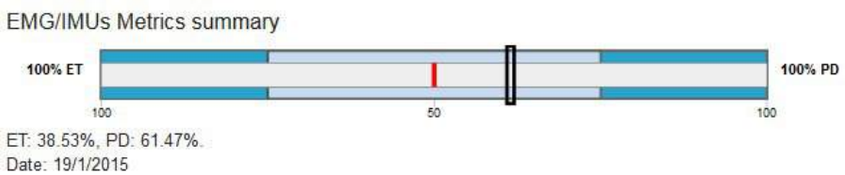
Altered Functional Connectivity in Essential Tremor
A Resting-State fMRI Study

OPEN ACCESS Freely available online
PLOS ONE

Effects of Alprazolam on Cortical Activity and Tremors in Patients with Essential Tremor

Jaime Ibáñez[1]*, Jesús González de la Aleja[2,3], Juan A. Gallego[1], Juan P. Romero[2,5], Rosana A. Saíz-Díaz[2,3], Julián Benito-León[2,3,4], Eduardo Rocon[1]

Neurophysiology: understanding pathologies



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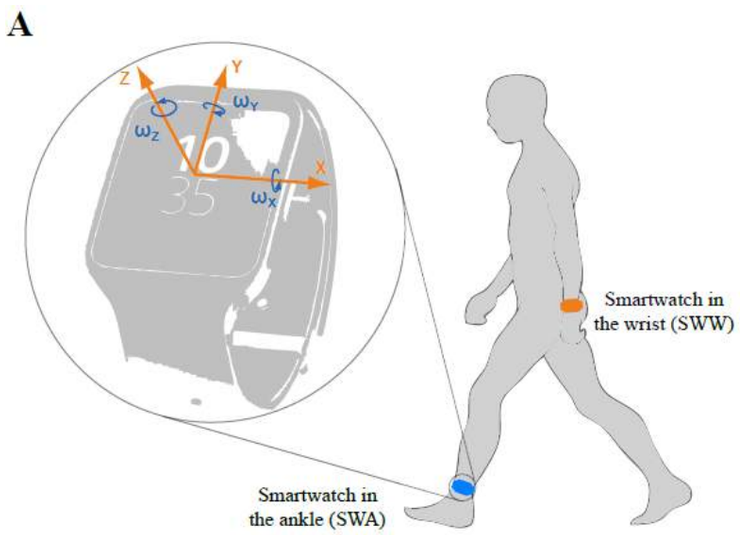
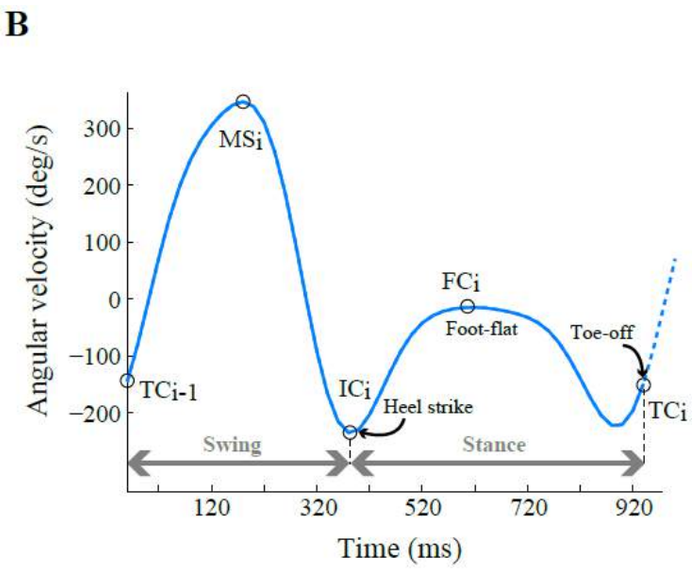
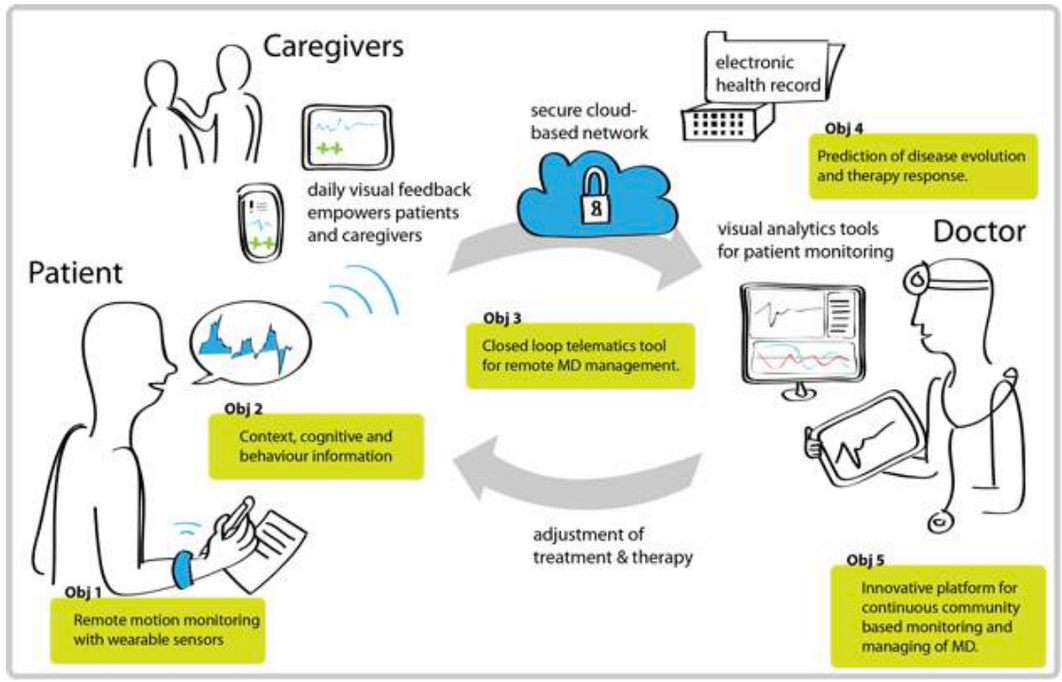
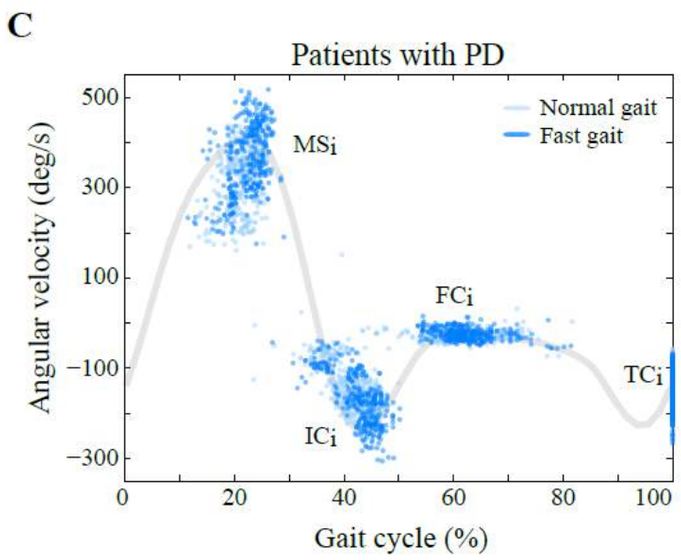
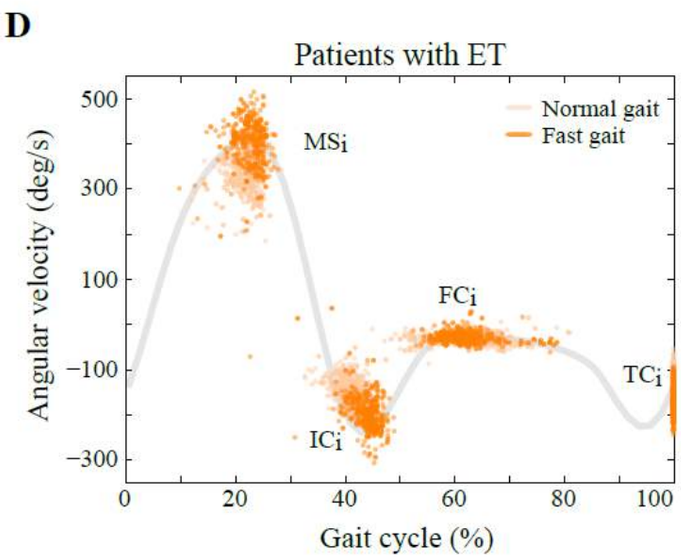
Neurophysiology: understanding pathologies

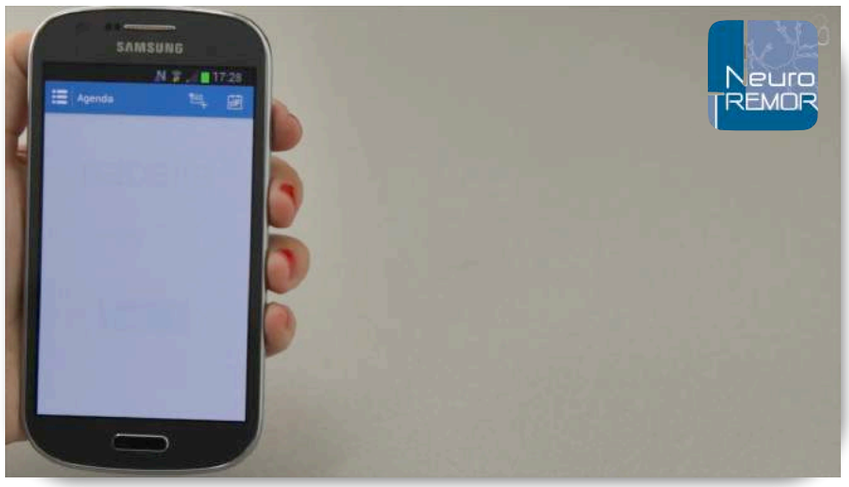












Motivation: Robotic-based rehabilitation of CP

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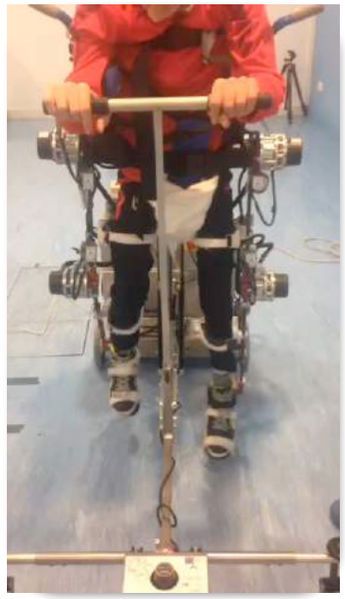
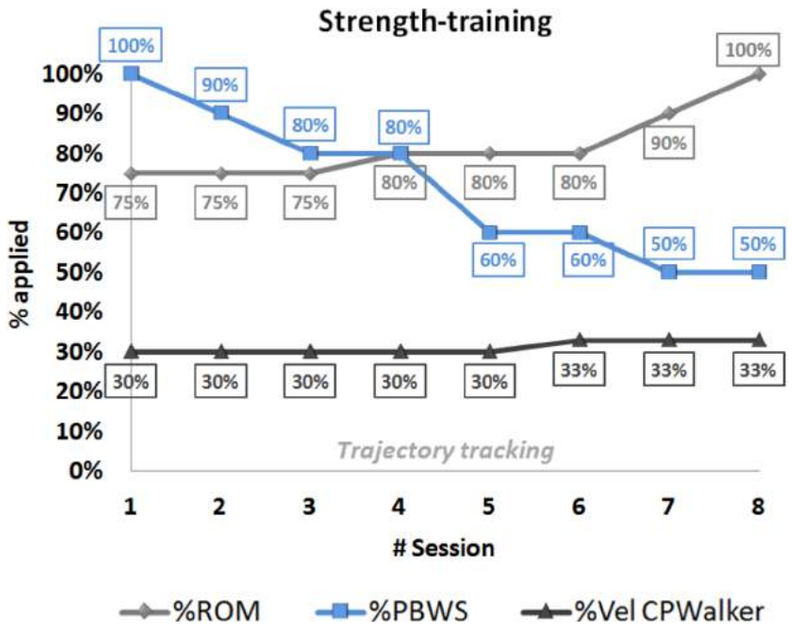
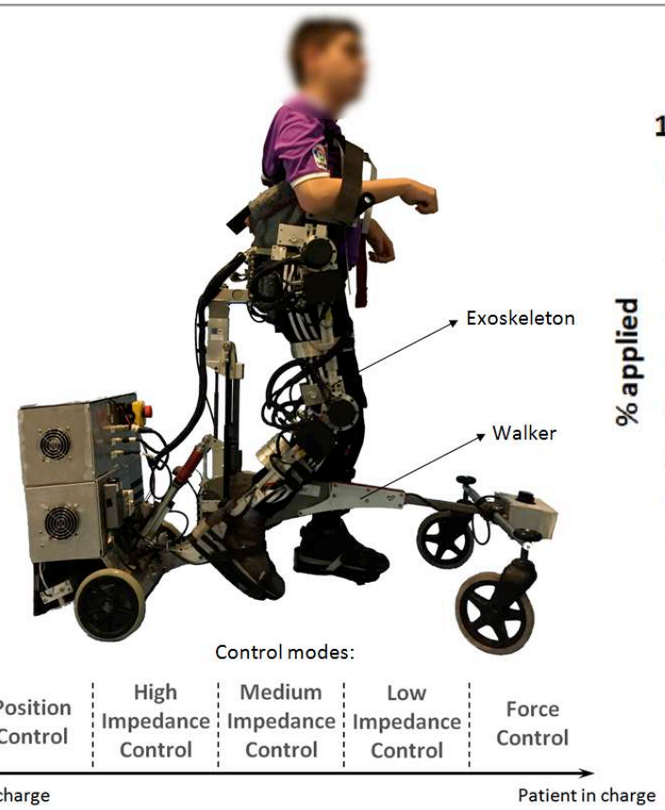
IkerWaCP

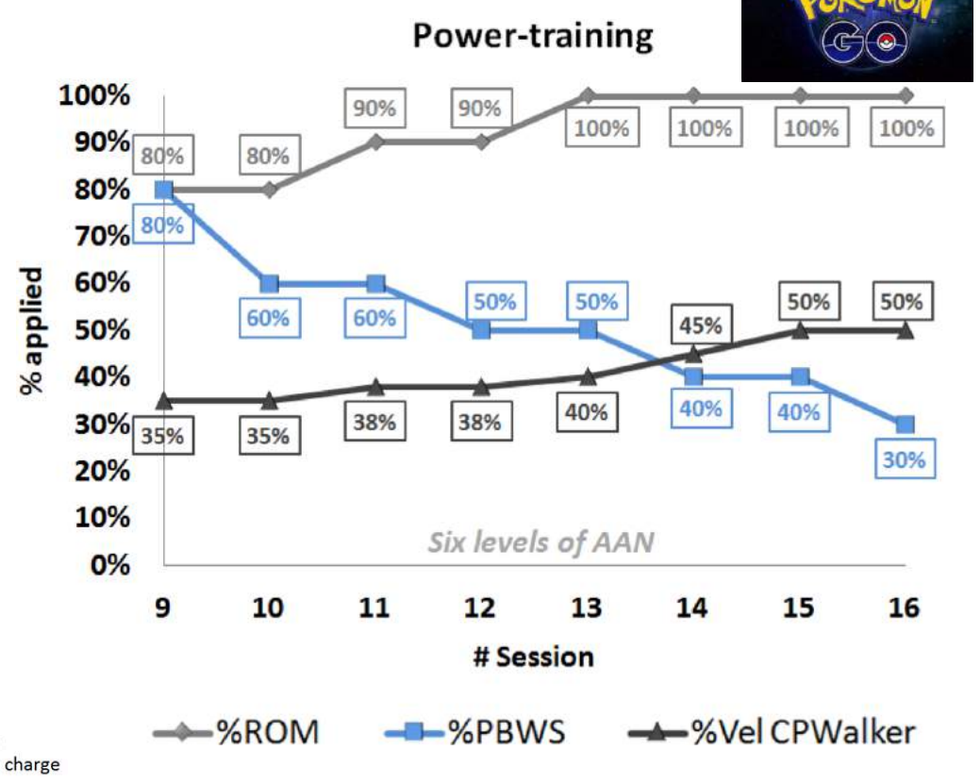


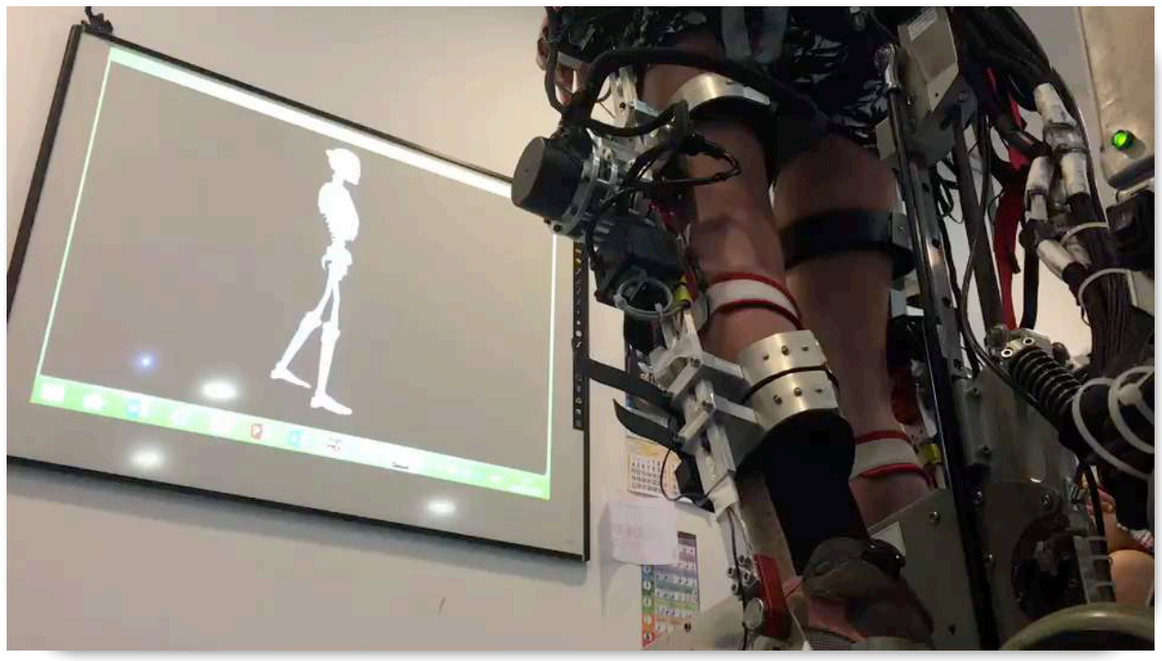
Technologies for rehabilitation: CPWalker

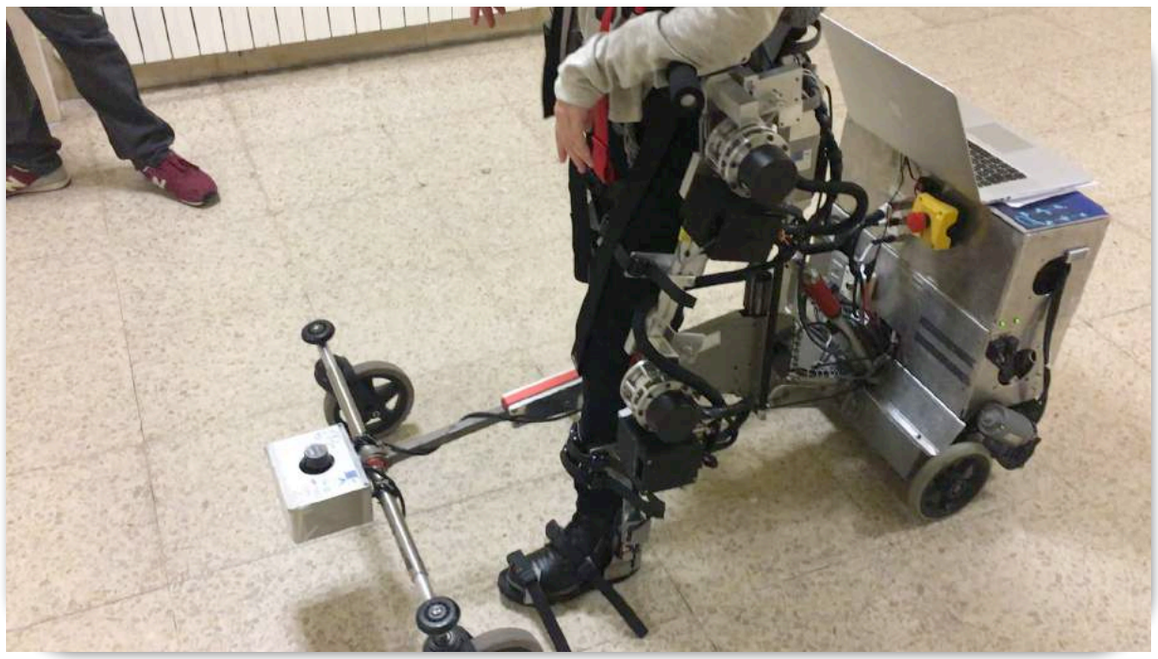
Rehabilitation program: CPWalker











Rehabilitation program: CPWalker

Rehabilitation program: CPWalker

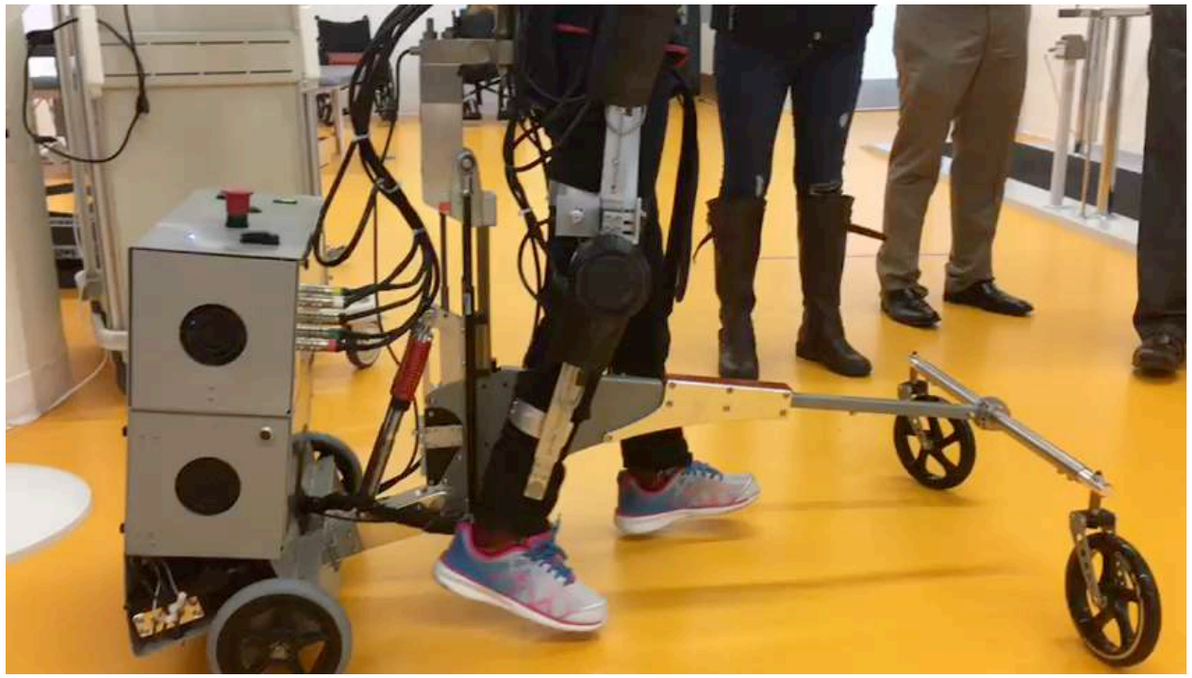
Rehabilitation program: CPWalker

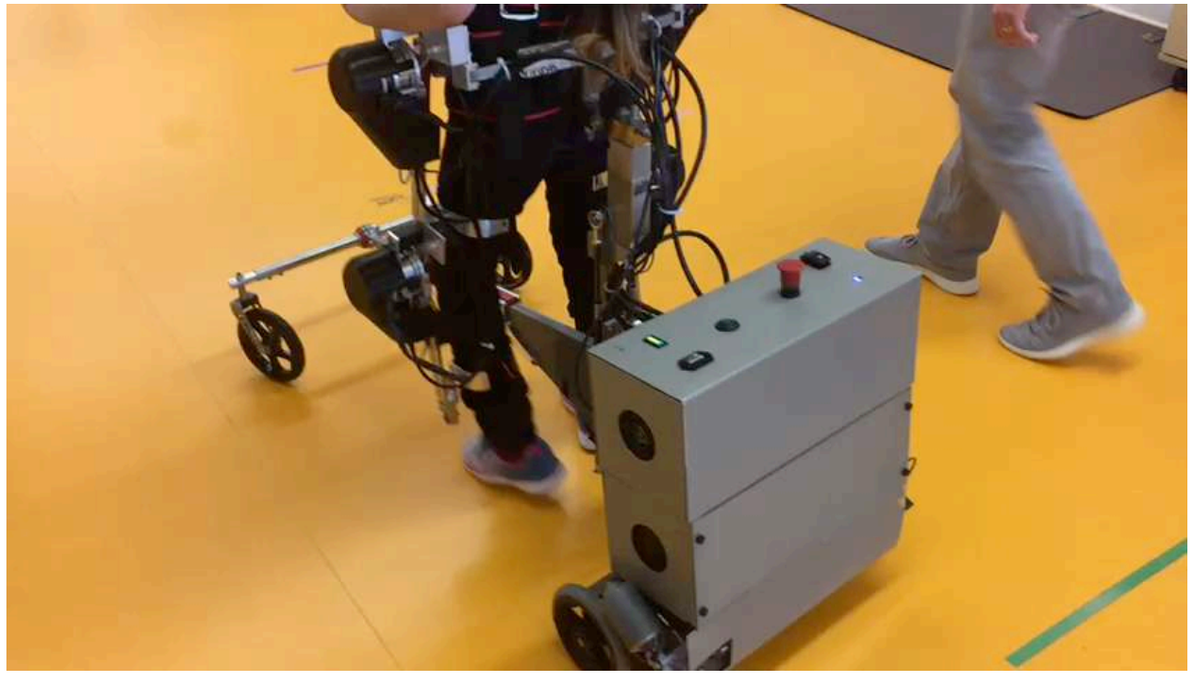
Rehabilitation program: CPWalker

Rehabilitation program: CPWalker

Clinical Validation @USA

Shirley Ryan Abilitylab | THE FUTURE OF THE REHABILITATION INSTITUTE OF CHICAGO





- #1 Rehabilitation Hospital in USA
- 70 children with CP will participate in the trials
- US grant to support the development

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Future work: Neuromodulation

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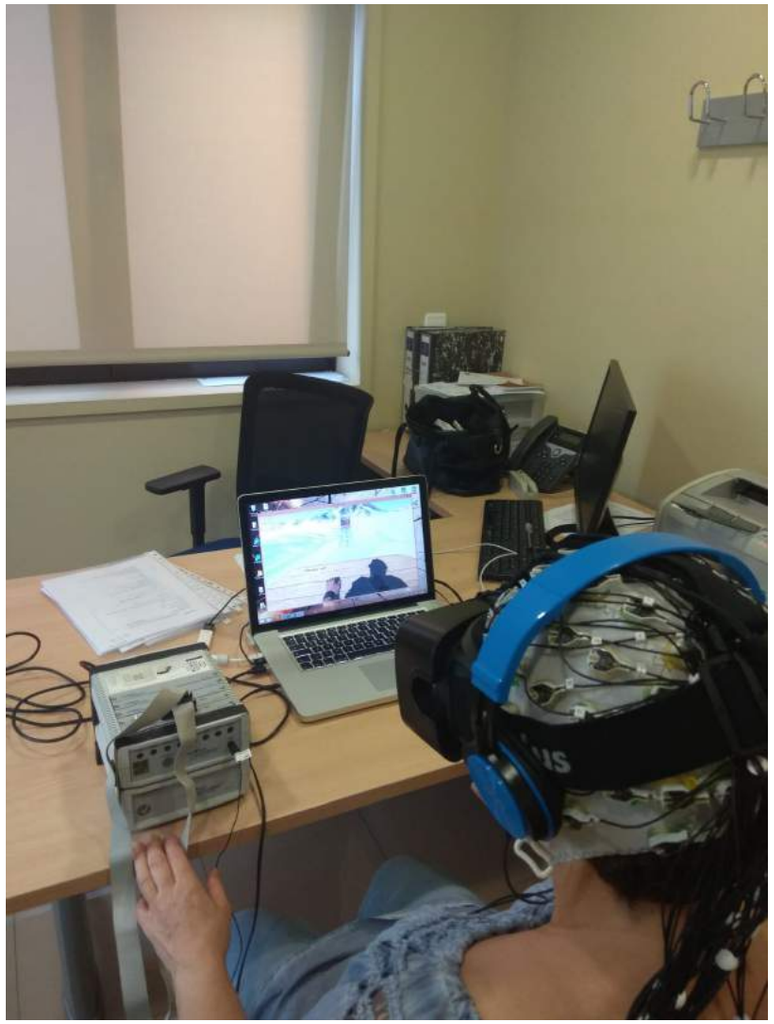
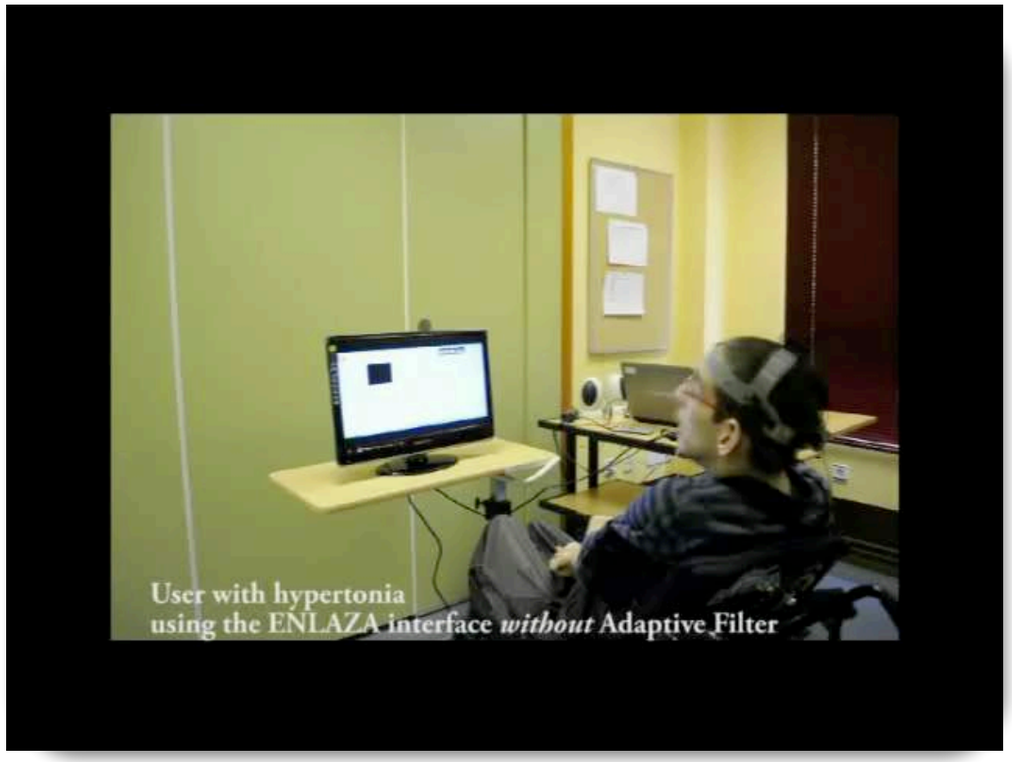
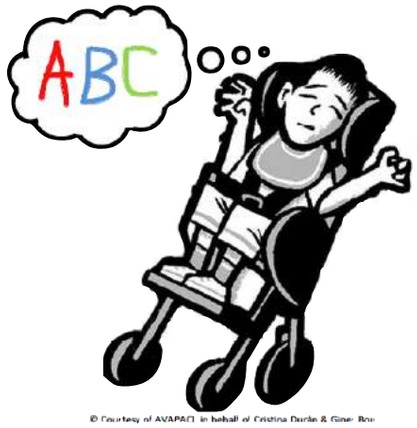
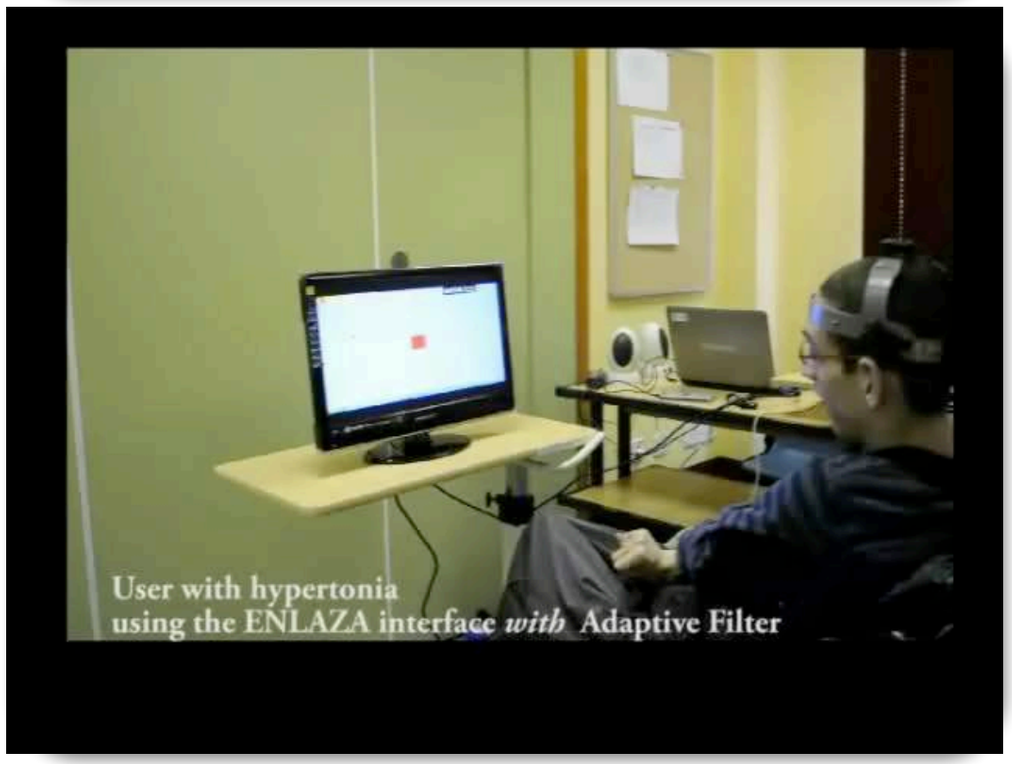


Future work: Neuromodulation

Human Computer Interface

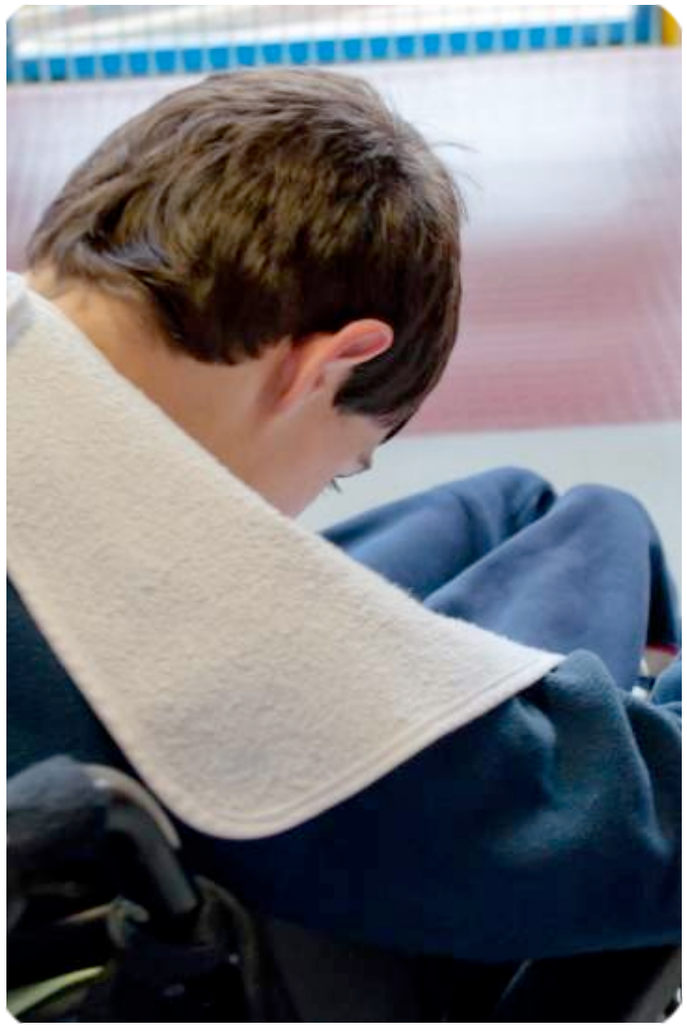






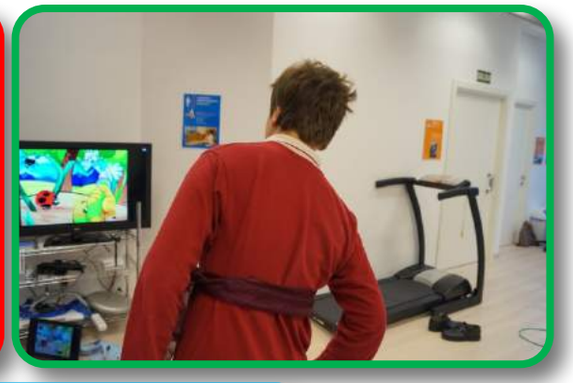
Human Computer Interface

Interfaces and Serious Games



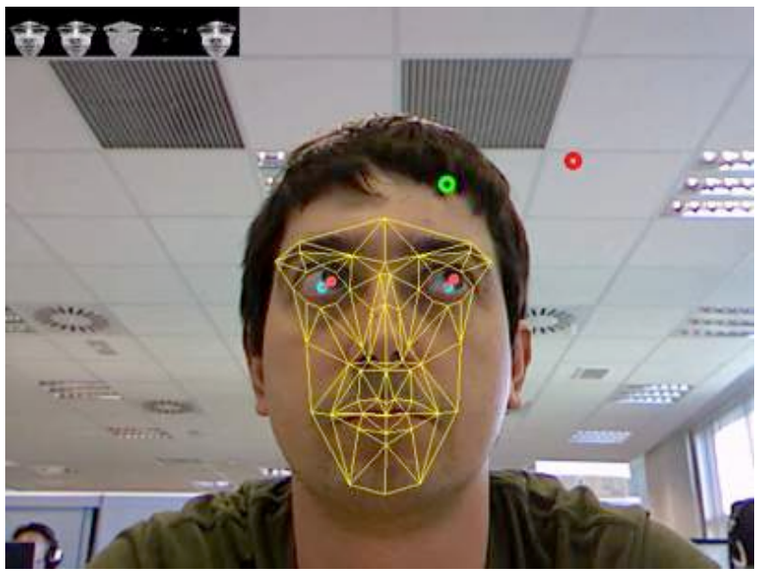
Interfaces and Serious Games

- Characteristics:
  - The relationship between player's interactions and system responses must be consistent.
  - The game must be challenging, maintain an optimal difficulty and include motivational elements to prevent the apparition of fatigue and boredom.
  - Monitoring mechanisms: Their inclusion simplifies the therapist's work.
- Design requirements
  - The platform must be friendly and easy to use
  - The platforms must be adaptable to the particular condition of the user
  - The platform must assess the performance of its activity



Interfaces and Serious Games

- Protocol defined
- Clinical validation - *120 children with CP*
- Multi-center study:
  - FSL (Italy)
  - AVAPACE (Spain)
  - Hospital Niño Jesús (Spain)
  - Hospital 12 de Octubre (Spain)
  - Spaulding Rehabilitation Hospital (USA)
  - Centro Cruz del Sur (Chile)



Historic note

"This amazing feat shall revolutionize the way in which paraplegic Scientists continue their honorable work in the advancement of Science! Even in this modern day and age, some injuries cannot be healed. Even with all the Science at our command, some of our learned brethren today are without the use of their legs. This Device will change all that. From an ordinary-appearing wheelchair, the Pneumatic Bodyframe will transform into a light exoskeleton which will allow the Scientist to walk about normally. Even running and jumping are not beyond its capabilities, all controlled by the power of the user's mind. The user simply seats himself in the chair, fits the restraining belts around his chest, waist, thighs and calves, fastens the Neuro-Impulse Recognition Electrodes (N.I.R.E.) to his temples, and is ready to go!"

Prof. H Wangestein, 1883

Thanks for your attention!

Contact info: e.rocon@csic.es

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