

First Name  
Last Name  
Identification Number

NEUROENGINEERING [2] – 27-Jan-2021

Available time: 60 min

Rehabilitation Robotics

1. Design one possible solution for the rehabilitation of a completely plegic upper limb (no volitional movement at all and no residual contraction of any muscle) in a stroke survivor during the post-acute phase. What is the type of control that should be used for the robot? Why facilitating user's involvement is anyway important also in this condition? How the user involvement can be promoted and how can it be checked?
2. Describe the goal of the use of robotics exoskeletons for antigravity support by a disabled person as an assistive technology for activities of daily life. Discuss the main characteristics of the user, accordingly In this context, what are the differences and the pros and cons between active and passive solutions?

Neuroprostheses and robotics in rehabilitation

3. What are the main limitations of using only standard linear feedback controllers for neuroprostheses?
4. Why Artificial Neural Networks (ANNs) can be successfully exploited to control a neuroprostheses, as used as an Inverse model of the neuromuscular system? and what are the assumptions (constraints/conditions) that you need to fulfil to make NN applicable in this case? What the limitations of using ANNs for inverse model neuroprostheses' control? How can you include also fatigue in the NN inverse model?

Computational Neuroscience.

5. What are the main elements for modelling a large biological inspired brain microcircuit?
6. Imagine you want to build a realistic bio-inspired neural network to model the cerebellum. Describe the cerebellum physiological features that make it a suitable benchmark of simulation.
7. How would you test your model? Describe one target experimnt.

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### **REHABILITATION ROBOTICS**

- 1.1 Describe the differences between exoskeletons and end-effector devices. Which are the pros and cons of each category?
- 1.2 Describe the assist-as-needed control strategy.
- 1.3 Describe one possible solution to implement the assist-as-needed control strategy on an exoskeleton device and on an end-effector one (you can choose between upper limb or lower limb devices).

### **DESIGN EXPERIMENTAL STUDIES IN REHABILITATION**

- 2.1 What is a meta-analysis? What are the steps to conduct a meta-analysis?
- 2.2 What are the main ingredients of a Randomized Controlled Trial?
- 2.3 What is a crossover design? What are the hypothesis of using a crossover design in a rehabilitation treatment? Do you think it is more appropriate for post-stroke survivors in the subacute phase or in chronic phase?

### **IN VITRO NEUROENGINEERING**

- 3.1 What are the characteristics of an experiment where you can use Multi-Electrode Arrays but you cannot use patch clamp.
- 3.2 What are the main advantages and drawbacks of using MEA?
- 3.3 Which solutions can be adopted to reduce the drawbacks of this experimental setup?

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#### Computational Neuroscience

1. Describe the main cerebellar circuit elements.
2. The cerebellum plays a central role in learning, what features embed learning capabilities in the cerebellar microcircuit?
3. how would you model these learning features in a SNN inspired to the cerebellar microcircuit?

#### In vitro neuroengineering

4. What are the main types of in-vitro preparations employed to study brain networks (specify also the goal of such in-vitro preparation)? What are their advantages and disadvantages?
5. Which are the technical specifications that must be considered for a technology that aims at conducting a proper analysis on the in vitro network activity.
6. Starting from the definition of these technical specifications choose one possible technique you know to acquire signals from neuronal cultures and evaluate it for each specification.

#### Neuroprosthesis

7. What are the hypothesized principles at the basis of neuroplasticity effect of FES?
8. Describe a possible solution to implement a control strategy for a myoelectrically controlled neuroprosthesis. Which are the pros and cons of the described solution?
9. Describe a situation (patients, diagnosis, and conditions) where the previously described NP is not applicable and a situation where it is for sure.

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## NEUROENGINEERING [2]

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### Motor Control

1. List and explain the elements of the human motor system that make it a complex one.
2. List the laws of voluntary movements in humans.
3. Define Efference copy, Forward and Inverse models in motor control.

### In vitro neuroengineering

4. What are the possible available solutions for applying stimulation of neurons in vitro?
5. Briefly describe the working principle of one solution.
6. Compare the selected solution with other possibilities (advantages and disadvantages).

### Rehabilitation Robotics

7. List the advantages and disadvantages of assistance-as-need robotics with respect to conventional therapy in a rehabilitation setting aiming at motor relearning.
8. Within the framework of assistance-as-need rehab robotics:
  - a. Describe a robot design features (degrees of freedom, actuated joints, embedded sensors, control strategy)
  - b. Design a clinical trial (study design, target population, goal, experimental setup, outcome measures) to test the efficacy of robotic neurorehabilitation with respect to conventional therapy.
9. At the end of your trial, you want to compare the results of the clinical trial described in the previous answer with the studies available in literature conducting a systematic review. Describe the appropriate clinical question to search for studies available in literature through the PICOS format (describe the keywords for each domain).

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### Neuroprostheses

1. Describe the working principle of Functional Electrical Stimulation (FES) and the main parameters that define the stimulation
2. Which are the main differences between natural and artificial muscular contraction?
3. Describe a possible solution to detect the human intention in an assistive neuroprosthesis.

### Rehabilitation Robotics

4. Define orthotics (or assistive or for restoration) and rehabilitation robotics
5. Describe one possible solution for rehabilitative device:
  - a. define the target users target user (pathology, level of disability, location of intervention)
  - b. the technical design (degree of freedom, actuated joints, embedded sensors),
  - c. the principle for the controller.

### Motor Control

6. Describe the specific role of the cerebellum in the motor control loop, and draw a scheme of the interconnections between the most important areas involved in motor control.
7. Describe a cerebellar model explaining how the elements in the cerebellar circuit are represented/simplified.