Proposal for PhD position

NEUROROBOTICS Working Group:

List of activities carried out by the Working Group and how they were communicated and promoted within the PNC from 27/2/2023 to today:

The "Neuroscience and Robotics" WG is composed of: A. Del Felice (head), P. Bisiacchi, M. Bertuccelli, E. Menegatti, L. Tonin, S. Tortora, S. Vassanelli.
The creation of a physical joint lab of "Neuroscience and Robotics" at DEI, where PhD students, postdocs, and visiting scientists (of PNC) from ReNet Lab (DNS), DSPS, and IAS-Lab (DEI) are daily working side-by-side. The lab is also sharing equipment, devices and knowledge on a daily basis.

Activities:

- Bimonthly working group meeting at IAS-Lab meeting room (Wednesday 14.30-16.00) - e-mail reminder to WG mailing list
- Seminar by John Jairo Villaiero Major, visiting researcher University College Dublin, "Physiological signals applied to assistive rehabilitation, physical activity and health", 19.02.2024, DEI – invitation sent to DNS and DEI members and circulated on WG mailing list
- European Project "PROGAIT - Physiological and Rehabilitation Outcomes Gains from Automated Interventions in Stroke Therapy" dissemination meeting 26.01.2024, Aula Nievo, Palazzo Bo, Padova – PNC news, invitation sent to DNS and DEI, UNIPD social media communication, and circulated on WG mailing list
- ANT Neuro Bootcamp 5-7.09.2024, DEI, UNIPD, organized by members of the Neurorobotics WG – will be sent on PNC news, invitation to DNS and DEI, UNIPD social media communication, and circulated on WG mailing list
- PNC Seminar by prof. Paolo Bonato, Harvard University and Spaulding Rehabilitation Hospital, MA, USA, "Precision rehabilitation interventions in neurological patients undergoing robot-assisted motor training", 02.11.2023 - PNC news and seminar list, invitation to DNS and DEI, and circulated on WG mailing list
- PNC Seminar by prof. Alessando Farnè, Lyon Neuroscience Center, FR, "Embodiment in exoskeleton gait and arm training", planned 23.05.2024 - PNC news and seminar list, invitation to DNS and DEI, and circulated on WG mailing list
- Visiting MSc student to Spaulding Rehabilitation Hospital & Harvard University, MA, USA on the project: "Lower limb exoskeleton to augment the ability of older adults to respond to balance perturbations." WG mailing list. Summer 2024

International Collaborations:

- Prof. P.Bonato, Harvard University and Spaulding Rehabilitation Hospital, MA, USA - Exoskeleton to augment the ability of older adults to respond to balance perturbations.
- Prof. G.Northoff, Ottawa University, CA – Intrinsic neural time scales entrained by assisted robotic gate.
- Prof. M. Sartori, Twente University, NL – development of soft lower limb exoskeleton
- Prof. S.Micera, EPFL, CH – HMI for prosthesis reaching and grasping.

Submitted grants:

- CARIPARO 2023 “SCI-Walk: EEG-based brain-spine interface for Walking restoration in Spinal Cord Injury patients”
- Doctoral Network, MSCA 2023: “Advanced Virtual Sensing for Smart Engineering Technologies” Lead UNICAL, IT, Neurorobotics WG partner with two PhD students

Active grants:

- PNRR-PE8 Age-It Challenge [9] Advanced Gerontechnologies for active and healthy aging: WP3 Robotic technologies for assistance and performance augmentation”
- PRIN 2022 “ReBalance: REinforcing BALANCE with a neurally-driven wearable assistive device”
- PON 2021 - Intelligent Exoskeleton for outdoor personal mobility in agriculture (AgriExo), PhD student, Neurorobotics WG

Past grants:

- ProGait “Physiological and Rehabilitation Outcomes Gains from Automated Interventions in Stroke Therapy” – MSCA RISE 2017
- SoftAct “Prevenzione delle cadute nella popolazione anziana: sviluppo di un esoscheletro morbido con integrazione di biosegnali muscolari e cerebrali per ridurre l'instabilita' della marcia” – MAECI Progetti di Grande Rilevanza 2018
- Progetti SEED “Brain-machine interfaces 2.0: A threefold symbiotic learning entity” - Dipartimento Ingegneria dell’Informazione, Università di Padova, 2020

Publications:

- **Tortora S, Tonin L**, Sieghartsleitner S, Ortner R, Guger C, Lennon O, Coyle D, **Menegatti E, Del Felice A**. Effect of Lower Limb Exoskeleton on the Modulation of Neural Activity and Gait Classification. IEEE Trans Neural Syst Rehabil Eng. 2023;31:2988-3003.
- Trombin E, **Tortora S**, Bettella F, **Del Felice A, Tonin L, Menegatti E**. Low Obstacle Avoidance for Lower Limb Exoskeletons. CEUR Workshop Proceedings. Volume 3417, 2023
- Tortora S, Beraldo G, Bettella F, Formaggio E, Rubega R, **Del Felice A**, Masiero S, Carli R, Petrone N, Menegatti E, Tonin L. Neural correlates of user learning during long-term BCI training for the Cybathlon competition. J NeuroEngineering Rehabil 19:69, 2022
- Rubega M, Lennon O, Formaggio E, Sutaj N, Dazzi G, Venturin C, Bonini I, Ortner R, Cerrel Bazo HA, Tonin L, **Tortora S**, Masiero S, **Del Felice A**, On Behalf Of The Pro Gait Consortium. Experimental Protocol to Assess Neuromuscular Plasticity Induced by an Exoskeleton Training Session. Methods Protoc. 2021 Jul 13;4(3):48
- Rubega M, Formaggio E, Di Marco R, Bertuccelli M, **Tortora S, Menegatti E**, Cattelan M, Bonato P, Masiero S, **Del Felice A**. Cortical correlates in upright dynamic and static balance in the elderly. Sci Rep. 2021 Jul 8;11(1):14132.
- Rubega M, Di Marco R, Zampini M, Formaggio E, **Menegatti E**, Bonato P, Masiero S, **Del Felice A.** Muscular and cortical activation during dynamic and static balance in the elderly: A scoping review. Aging Brain. 2021 Apr 7;1:100013.
- **Tortora S**, Rubega M, Formaggio E, Marco RD, Masiero S, **Menegatti E, Tonin L, Del Felice A**. Age-related differences in visual P300 ERP during dual-task postural balance. Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:6511-6514.

Proposal:

Title of the PhD project: **Neurophysiological markers of human-robot integration**

Abstract (max 500 words, space included):

Exoskeletons are increasingly adopted as rehabilitative and assistive devices. However, end-users report low acceptance of exoskeletons, limited control perception, and lack of sense of agency. Together, these elements reduce the effectiveness of robotic rehabilitation/assistance and are likely related to unsatisfactory human-robot interaction. The project aims at expanding the concept of embodiment, i.e. the integration of tools into the body schema, from prosthetics to exoskeletons and aims at improving user experience and functional outcomes. To ensure translatability and uptake of these findings in the robotics field, we need to implement an on-control of the exoskeleton, giving the user the control of the motion of the exoskeleton and to provide quantifiable measures of end-users responses to exoskeleton use with neurophysiological markers.

Toward this end, the project combines electroencephalography (i.e., event-related potentials analysis), Inertial-Movement-Units measurements, electromyography, and Artificial Intelligence with neurophysiology and neuropsychology to identify neurophysiological markers of human-robot integration in healthy and clinical populations. Different experimental set-ups will be based on devices already available at the Neurobotics WG lab: a lower limb commercial exoskeleton , a lightweight research device, a hip-exoskeleton, a soft exoskeleton will provide different degrees of assistance and different types of control (i.e., self-generated vs robot-generated) during a set of standardized everyday tasks. Individual responses will be measured with kinematic and neurophysiological parameters and compared with neuropsychological subjective measures.

These markers will i) pinpoint the different neurophysiological mechanisms underlying exoskeleton embodiment in neurological (e.g., stroke) and healthy populations; and ii) boost the processes of human-robot integration by offering a quantitative tool to increase acceptability, efficiency, and uptake in everyday life. This information may be integrated in future design and control of lower-limb exoskeletons.

Potential supervisor (1st name): Alessandra Del Felice

Potential supervisors (2nd name): Emanuele Menegatti

Description of the expected background of the PhD student (max 150 words, space included):

The ideal candidate will have a background in cognitive neuroscience or in bioengineering. Previous experience in EEG and EMG data collection, and/or signal analysis are required. Basic knowledge of human biomechanics and movement analysis will be a plus.

Strong English writing abilities, basic programming skills (e.g., MatLab, Python) and fundamental knowledge of statistics are preferred. We are looking for a student highly motivated to learn and interact in an interdisciplinary environment, with a strong academic commitment.

Description the multidisciplinary training path planned for the student's career (max 150 words, space included):

The "Neuroscience and Robotics"multidisciplinary group ensures a well-rounded training: the candidate will be exposed during 1st year to clinical/experimental settings to gain independence in set-up design and experiments conduction. Training in EEG/EMG/IMU data collection, basic analysis s and psychometric testing will be part of 1st-year foundations.

Basic clinical interpretation of neurophysiological data in clinical populations will be **provided by the clinical component of the group** to ensure proper interpretation of results.

Training in biosignal data processing/analysis will be **provided by the engineering component**, with increasing complexity over the last 2yrs, to ensure independence in data analysis/programming.

Soft skills training is provided with group working, bi-monthly lab meetings with results presentation and discussion, presentation of data at national/international congresses, and participation in grant writing. The participation in the joint activities of the "Neuroscience and Robotics" multidisciplinary group will give the PhD student a scientific language common to engineers, clinicians, and psychologists.