Methods: Twenty-four community-dwelling persons with chronic stroke met inclusion criteria and volunteered to participate. Upper limb robotic therapy was administered to patients. Performance indices on patient motor performance were computed from kinematic and dynamic data recorded with a magneto-inertial sensor and the InMotion2 robotic machine. Cognitive issues were investigated by means of techniques of motion decomposition into submovements. A linear regression analysis was carried out to study correlation with clinical scales.
Results: Robotic outcome measures showed a significant improvement of kinematic motor performance; the improvement of dynamic components was significant only in resistive motion and highly correlated with Motor Power. The analysis of motion decomposition into submovements showed a significant change of the submovement number, frequency and amplitude with recovery, tending to patterns measured in healthy subjects.
Conclusions: Preliminary results showed that arm motor function and strength of the paretic arm can be objectively measured by means of the proposed bunch of performance indices. Correlation with MP is high, while correlation with FM is moderate. Further, cognitive features related to motion planning strategies can be extracted from submovement analysis.

P13.8
Functional brain networks during motor imagery after stroke

F. Pichiorri[1], F. De Vico Fallani[2], C. Di Lanzo[1], I. Pisotta[3], F. Cincotti[1], M. Molinari[3], F. Babiloni[2], D. Mattia[1]
[1]Neuroelectrical Imaging and BCI Lab, Fondazione Santa Lucia IRCCS, Rome, Italy, [2]Dipartimento di Fisiologia Umana, Università "Sapienza", Rome, Italy, [3]Laboratorio di Neuroriabilitazione Sperimentale, Fondazione Santa Lucia, IRCCS, Rome, Italy

Introduction: Graph theory has been introduced as a novel method to study the functional brain networks in a wide range of neurological disorders.
Objectives: We propose a methodological approach to assess the functional brain network organization underlying motor imagery (MI) after stroke and to evaluate the effects of MI-based brain computer interfaces (BCIs) as adjunctive rehabilitation strategy.
Methods: High-density EEG data were collected from 15 stroke patients (band-pass 0.1–70 Hz; frequency sample 200 Hz), who were asked to imagine grasping with unaffected (UH) and affected hand (AH). Functional brain networks were estimated by computing the imaginary coherence; the values obtained were stored in a channel-channel matrix, in which only those links that were significantly different between rest and task were considered. The EEG functional connectivity matrices were characterized by means of a graph theoretical approach by computing node degree, global (Eg) and local efficiency (El).
Results: The EEG network patterns estimated for the Beta band (14–29 Hz) showed that MI of the UH was associated with an unbalance of the overall connectivity in favor of the unaffected hemisphere. This asymmetry was absent during MI of the AH. The Eg values were similar during the UH and AH MI, while El was smaller during MI of AH, suggesting that information transfer is more clustered in the UH condition.
Discussion: Our findings indicate that MI after stroke is associated with abnormalities of the functional brain network in the Beta band, which is known to be involved in motor acts. We propose this methodology as valuable to assess functional reorganization of the motor cortical system after stroke promoted via a MI-based BCI training.
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P13.9
A design methodology for neurorehabilitative and assistive wearable robots incorporating embodied intelligence

D. Accoto[1], F. Sergi[1], G. Carpino[1], N.L. Tagliamonte[1], E. Guglielmelli[1]
[1]Laboratory of Biomedical Robotics and Biomicrosystems, CIR, Università Campus Bio-Medico di Roma, Rome, Italy

Introduction: Wearable Robots (WRs), often proposed for assistive and rehabilitative purposes, have to cope with human body dynamics, which is influenced by a number of concurrent biomechanical and neurophysiological factors. Embodied Intelligence (EI), i.e. the emerging of intelligent behaviours from the combination of low level sensorimotor activity, (bio)mechanical properties, and learning processes, is a recent paradigm in robotics, holding promise for enabling the design of robots with a smoother functioning, lighter structures and higher energy efficiency.
Objectives: We are developing a WR for lower limbs, which will give rise to bipedal walking as an emerging behavior. Such WR aims at harvesting the potentialities of EI, establishing a strict interaction with the user not only at a cognitive level (motion intention) but also at a biomechanical one (emerging dynamic behaviours).
Methodology: Computational methods are used for co-optimizing robot's morphology and control. Central Pattern Generators (CPGs) tune both robot joints torques and impedance. The emerging behaviours are sought for in simulations, where both the robot and the human body are taken into account.
Results: The proposed methodology aims at a smooth adaptation of the WR bahaviours to users' capabilities and intentions, with minimal computational effort. On the one hand, such adaptation assures *assistance as needed*, on the other one it highlights the adaptation process of the user to the use of the WR.
Discussion: Compared to existing WRs for lower limbs, the WR under development will allow the emerging of a proper walking pattern only while dynamically interacting with the user. This will help unveiling the interplay between neuromotor control and biomechanics in human walking for both neurorehabilitation purposes and neurophysiological investigations.
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P13.10
A new method for in vivo measurement of the dynamic impedance of multi-joint leg movements

B. Koopman[1], H. van der Kooij[2]
[1]Institute for Biomedical Technology and Technical Medicine (MIRA), University of Twente, Enschede, Netherlands, [2]Institute for Biomedical Technology and Technical Medicine (MIRA), University of Twente, Enschede, Netherlands

Introduction: Wearable Robots (WRs) have to cope with the human body dynamics, which is influenced by biomechanical and neurophysiologic factors. The goal is to assure a safe physical human-robot interaction by identifying the optimal dynamical properties of WRs. Hence, it is necessary to model the human component and to allow the tunability of robot mechanical properties (enabled by variable impedance actuators and joints) so to react to human joints impedance variation.
Objectives: The objective is to develop a method to simultaneously quantify hip and knee impedance and evaluate the potential cross coupling between hip and knee joint movement. These measures are needed as input for the development of a novel biomechanical model taking into account impedance variations of human joints subsequent to specific motions.
Methodology: LOPES (Lower Extremity Powered ExoSkeleton) is used to apply multisine torque perturbations to the hip and knee joint simultaneously and measure the resulting joint angles. Two different conditions were tested; one where the subjects were asked to relax and one where they were asked to keep the deviation as small as possible. On the recorded data two different leg models were fitted: one with and one without the effect of cross coupling between joints.
Results: Hip impedance was found to be higher in all subjects compared to the knee impedance. Impedance levels during the active tests were approximately 4 and 14 times higher than during the passive tests for the hip and knee joint respectively. Recent results also indicate that passive impedance increases in elderly people while active impedance decreases.
Discussion: Preliminary results show that LOPES can successfully be used to estimate the hip and knee impedance. We can conclude that the effect of cross coupling needs to be incorporated in the human model to explain the experimental results. The selected experimental platform (assistive exoskeleton for lower limbs) may have an enormous impact on the field of assistive and neurorehabilitation technologies.
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