EPFL

Center for Neuroprosthetics

2018 annual report

© *EPFL Millán Lab*
Lightweight and portable hand exoskeleton that can be controlled with brainwaves: the device enhances
performance of brain-machine interfaces and can restore functional grasps for the physically impaired.

Credits

Innovation at the crossroad of neuroscience, engineering and medicine

Neurological disorders are common; they affect an individual's motor, sensory and cognitive functions, and result in limited activities and disabilities. Neuroprosthetics, by means of a non-invasive, wearable or implantable interface, offer opportunities to communicate with the nervous system to diagnose, prevent and treat neurological disorders and their consequences.

The mission of EPFL Center for Neuroprosthetics is to design, implement and validate innovative neurotechnologies to assess and treat neurological and psychiatric disorders. Research at the Centre is world-class, integrating knowledge and know-how in neuroscience, engineering and medicine.

The Centre currently hosts 8 labs from the EPFL School of Life Sciences and EPFL School of Engineering, gathering nearly 180 scientists, engineers and clinicians, driven by translational research. The Centre is homed at Campus Biotech and operates along the Lemanic coast from Geneva to Sion via Lausanne and Fribourg. The Centre is a vibrant research environment, with shared research space, state-of-the art experimental facilities, and longstanding partnerships with neighbouring health institutions. The scientific expertise of the Centre spans materials science, microfabrication, machine learning, neuroimaging, robotics, translational neuroengineering, cognitive neuroscience to clinical neuroprosthetic medicine. Interdisciplinarity projects focus on restoring vision and audition, enabling sensorimotor control after spinal cord injury, stroke or amputation, and alleviating cognitive and psychiatric maladies.

In 2018, breakthrough research from the Center include a Nerve-on-chip platform to design effective nerve implants, a foldable and photovoltaic retinal neuroprosthesis, biomimetic intraneural sensory feedback for natural restoration of tactile sensitivity in upper-limb amputes, a dual BCI-FES therapy for motor recovery after stroke, novel immersive digital therapies in amputees, neurofeedback based real-time fMRI, non-invasive brain stimulation for stroke recovery, and a targeted neurotechnology to restore walking in humans with spinal cord injury.
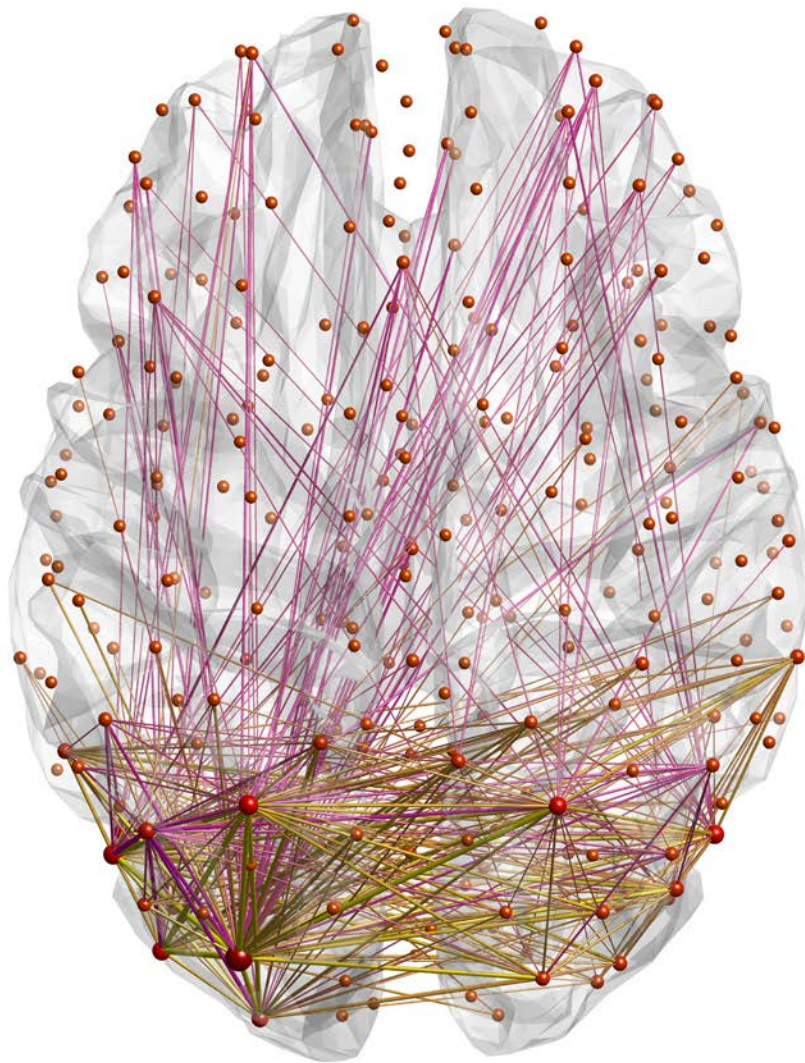
*Regional brain connections showing a significant increase (in yellow) or decrease
(in pink) in cross-subject synchrony upon watching a naturalistic movie segment,
respectively involving local occipital and occipito-frontal links.*

Principal Investigators

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Blanke Lab

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The Blanke Lab has two missions: the neuroscientific study of consciousness and the development of cognitive neuroprostheses. For the first part, we investigate the brain mechanisms of body awareness, combining psychophysical and cognitive paradigms with all major neuroimaging techniques. We have pioneered the use of engineering techniques such as robotics and haptics, virtual reality (VR) and augmented reality (AR) and their full integration with behavioral and physiological recordings (including MRI-compatible robotics), leading to the new research field of cognetics: the field of robotics and digital technologies dedicated to neuroscience research in cognition and consciousness studies.

Our clinical research projects focus on developing new diagnostic and therapeutic approaches along two main lines: Robotics in neurology and Digiceuticals. Robotics in neurology targets the design of wearable robotic devices for novel diagnostic and therapeutic solutions in Parkinson's disease suffering from hallucinations and dementia. In our digiceutical projects we develop novel immersive digital devices and therapies for chronic pain and related conditions by integrating digital technologies (VR, AR) with brain stimulation and latest research from the cognitive neurosciences. Our devices induce technology-mediated pain relief in patients suffering from complex regional pain syndrome, phantom limb pain, and neuropathic leg pain in spinal cord injury.

Results Obtained in 2018

This year we pursued our efforts to understand the behavioral and neural correlates of self-consciousness and related aspects including interoception (Park et al., Cerebral Cortex 2018; Salomon et al., Cortex, 2018), peripersonal space (Bernasconi et al., Cerebral Cortex, 2018; Pfeiffer et al., European Joural of Neuroscience, 2018), vestibular processing (Kaliuzhna et al., Neuropsychologia, 2018; Kaliuzhna et al., Experimental Brain Research, 2018; Nesti et al., PlosOne, 2018), and metacognition (Faivre et al., Journal of Neuroscience 2018). We also improved our MRI-compatible robotic device able to induce controlled mild hallucinations and investigated the neural underpinnings of such mental states with fMRI (Blondiaux et al., unpublished).

Major efforts in 2018 have been devoted to translate our research in basic neuroscience to the bedside. In digiceuticals, we developed a novel immersive digital therapy and validated it in several clinical studies. For example, in patients with limb amputation - through a new approach combining immersive VR and peripheral nerve stimulation (in collaboration with the Micera Lab: Rognini et al., Journal of Neurology, Psychiatry and Neurosurgery, 2018). By linking interceptive and exteroceptive signals in immersive VR we also induced strong analgesia and improved motor function in patients with complex regional pain syndrome (in collaboration with HUG and the SUVA: Solcà et al., Neurology, 2018). These studies pave the way for large-scale clinical trials and reveal the major impact digiceuticals, immersive VR, and automatized specific bodily stimulations will play in treating chronic pain and amputation in the near future.

Keywords

Multisensory and sensorimotor processing, consciousness, neuroscience, robotics, virtual and augmented reality, neuroimaging, fMRI, EEG, neurology, Parkinson's disease.

Bio

Olaf Blanke is founding director of the Center for Neuroprosthetics (2012-2018) and holds the Bertarelli Foundation Chair in Cognitive Neuroprosthetics at the Ecole Polytechnique Fédérale de Lausanne (EPFL). He directs the Laboratory of Cognitive Neuroscience at EPFL and is Professor of Neurology at the University Hospital of Geneva.

fb fondation bertarelli

Major efforts in 2018 were also directed at conducting and finalizing clinical projects that develop and test our neurorobotics approach in neurology and psychiatry. For this we established a large clinical network including the Hospitals of Geneva, Lausanne, and SUVA-Sion, and also, since 2018, in Barcelona (i.e. one of the most important European Clinics on cognitive deficits in Parkinson's disease) and completed a clinical study using our neurorobotics approach in patients with Parkinson's disease (Bernasconi et al., unpublished) and a clinical study in patients with schizophrenia (Serino et al., submitted).

Team

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In two upper limb amputees, neurotactile stimulation was coupled with automatized visual illumination of a circumscribed skin region on the patient's prosthetic hand that corresponded to the somatotopic location of circumscribed touch sensations experienced on the phantom hand. This multisensory stimulation induced prosthesis embodiment and reduced abnormal phantom limb perceptions. (Rognini et al., JNNP, 2018).

Selected Publications

Faivre N, Filevich E, Solovey G, Kühn S, Blanke O (2018). Behavioral, Modeling, and Electrophysiological Evidence for Supramodality in Human Metacognition. Journal of Neuroscience, 38(2), 263-277.

Bernasconi F, Noel JP, Park HD, Faivre N, Seeck M, Spinelli L, Schaller K, Blanke O, Serino A (2018) Audio-Tactile and Peripersonal Space Processing Around the Trunk in Human Parietal and Temporal Cortex: An Intracranial EEG Study. Cerebral Cortex. 28, 3385-3397.

Park HD, Bernasconi F, Salomon R, Tallon-Baudry C, Spinelli L, Seeck M, Schaller K, Blanke O (2018). Neural sources and underlying mechanisms of neural responses to heartbeats, and their role in bodily self-consciousness: An intracranial EEG study. Cerebral Cortex, Jul;28(7):2351-2364.

Rognini G, Petrini FM, Raspopovic S, Valle G, Granata G, Strauss I, Solcà M, Bello-Ruiz J, Herbelin B, Mange R, D'Anna E, Di Iorio R, Di Pino G, Andreu D, Guiraud D, Stieglitz T, Rossini PM, Serino A, Micera S, Blanke O (2018). Multisensory bionic limb to achieve prosthesis embodiment and reduce distorted phantom limb perceptions. Journal of Neurology, Neurosurgery & Psychiatry, jnnp-2018-318570.

Solcà M, Ronchi R, Bello-Ruiz J, Schmidlin T, Herbelin B, Luthi F, Konzelmann M, Beaulieu JY, Delaquaize F, Schnider A, Guggisberg AG, Serino A, Blanke O (2018). Heartbeat-enhanced immersive virtual reality to treat complex regional pain syndrome. Neurology, 91(5), e479-e489.

Nesti A, Rognini G, Herbelin B, Buelthoff HH, Chuang L, Blanke O (2018) Modulation of vection latencies in the full-body illusion; PLOS ONE 13(12): e0209189.

Courtine Lab

http://courtine-lab.epfl.ch

The mission of the laboratory is to develop neurotechnologies that improve functional recovery after neurological disorders such as spinal cord injury, stroke and Parkinson's disease. These developments are derived from a systematic investigation of the targeted neural mechanisms. This mechanism-based approach relies on synergies between multiple experimental models including *in silico* simulations (Human Brain Project) and long-lasting *in vivo* experiments in rodent (Campus Biotech) and nonhuman primate (University of Fribourg) models of neurological disorders—as well as clinical studies that are conducted at the Lausanne University Hospital (CHUV), in close collaboration with Prof. Jocelyne Bloch who leads the unit for functional neurosurgery.

Results Obtained in 2018

Neurotechnologies *(Nature Scientific Reports 2018, Nature Communication 2018)*: In collaboration with Prof. Micera, we showed the importance of controlling mediolateral trunk posture in real-time for facilitating locomotion during rehabilitation. We have also developed in rats a brain-controlled neuromodulation therapy during gait rehabilitation to augment the motor recovery from spinal cord injury.

Axonal Regeneration after complete spinal cord injury *(Nature 2018)*: We showed that efficient reversal of axon regenerative failure can be achieved via sequential activation of three mechanisms: i) neuronal growth capacity, ii) growth supportive substrates, and iii) axon-specific chemoattraction. This work provides a biological repair strategy with which to merge with neuroprosthetic rehabilitation paradigms to augment and improve functional recovery.

Mechanisms of recovery from spinal cord injury *(Nature Neuroscience 2018)*: We have identified the mechanisms through which electrochemical spinal cord stimulation and robot-assisted training restore volitional locomotion after spinal cord injury. We found that the motor cortex regained adaptive control over the paralyzed legs through relays in the brainstem, where residual projections below injury reside. Similar cortico–brainstem–spinal circuit reorganization may improve recovery in humans.

Clinical applications *(Nature 2018, Nature Neuroscience 2018, Nature Protocol 2018)*: We showed that targeted spinal cord stimulation enabled voluntary control of walking in non-ambulatory individuals. After rehabilitation, participants regained voluntary control over previously paralyzed muscles without stimulation and could walk or bike in ecological settings during spatiotemporal stimulation. Such neurological recovery had never been observed in previous clinical trials. These results establish the framework to develop a treatment that improve and accelerate neurological recovery and support activities of daily living after spinal cord injury.

Keywords

Spinal cord injury, neurorehabilitation, neuroprosthetics, neuroregeneration, brain-machine interface, robotics, EMG, kinematics, locomotion.

Bio

Grégoire Courtine was trained in Mathematics, Physics, and Neurosciences. After a Postdoc in Los Angeles (UCLA), he established his own laboratory in Zurich. He was appointed Associate Professor at the Center for Neuroprosthetics at EPFL in 2012, and integrated the department of Neurosurgery at the Lausanne University Hospital (CHUV) in 2015. He founded the startup GTX Medical in 2015.

Team

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** *jointly with Prof Micera*
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ºº *jointly with Prof Roullier*
& *jointly with Prof Lacour*

Selected Publications

Wagner FB*, Mignardot JB*, Le Goff-Mignardot CG*, Demesmaeker R, Komi S, Capogrosso M, Rowald A, Seáñez I, Caban M, Pirondini E, Vat M, McCracken LA, Heimgartner R, Fodor I, Watrin A, Seguin P, Paoles E, Van Den Keybus K, Eberle G, Schurch B, Pralong E, Becce F, Prior J, Buse N, Buschman R, Neufeld E, Kuster N, Carda S, von Zitzewitz J, Delattre V, Denison T, Lambert H, Minassian K*, Bloch J*, Courtine G* (2018). Targeted neurotechnology restores walking in humans with spinal cord injury. Nature, Nov;563(7729):65-71.

Formento E, Minassian K, Wagner F, Mignardot JB, Le Goff-Mignardot CG, Rowald A, Bloch J, Micera S*, Capogrosso M*, Courtine G* (2018). Electrical spinal cord stimulation must preserve proprioception to enable locomotion in humans with spinal cord injury. Nature Neuroscience, Dec;21(12):1728-1741.

Anderson MA*, O'Shea TM*, Burda JE, Ao Y, Barlatey SL, Bernstein AM, Kim JH, James ND, Rogers A, Kato B, Wollenberg AL, Kawaguchi R, Coppola G, Wang C, Deming TJ, He Z, Courtine G*, Sofroniew MV* (2018). Required growth facilitators propel axon regeneration across complete spinal cord injury. Nature, Sep;561(7723):396-400.

Asboth L*, Friedli L*, Beauparlant J*, Martinez-Gonzalez C, Anil S, Rey E, Baud L, Pidpruzhnykova G, Anderson MA, Shkorbatova P, Batti L, Pagès S, Kreider J, Schneider BL, Barraud Q, Courtine G (2018). Cortico-reticulo-spinal circuit reorganization enables functional recovery after severe spinal cord contusion. Nature Neuroscience, Apr;21(4):576-588.

Bonizzato M, Pidpruzhnykova G, DiGiovanna J, Shkorbatova P, Pavlova N, Micera S*, Courtine G* (2018). Brain-controlled modulation of spinal circuits improves recovery from spinal cord injury. Nature Communication, Aug 1;9(1):3015.

Capogrosso M*, Wagner FB*, Gandar J, Moraud EM, Wenger N, Milekovic T, Shkorbatova P, Pavlova N, Musienko P, Bezard E, Bloch J, Courtine G (2018). Configuration of electrical spinal cord stimulation through real-time processing of gait kinematics. Nature Protocols, Sep;13(9):2031-2061.

Moraud EM*, von Zitzewitz J*, Miehlbradt J, Wurth S, Formento E, DiGiovanna J, Capogrosso M, Courtine G*, Micera S* (2018). Closed-loop control of trunk posture improves locomotion through the regulation of leg proprioceptive feedback after spinal cord injury. Scientific Reports, Jan 8;8(1):76.

Capogrosso M*, Gandar J*, Greiner N, Moraud EM, Wenger N, Shkorbatova P, Musienko P, Minev I, Lacour S*, Courtine G* (2018). Advantages of soft subdural implants for the delivery of electrochemical neuromodulation therapies to the spinal cord. J Neural Eng, Apr;15(2):026024.

equal contribution

Infographics illustrating the delivery of targeted spinal cord stimulation to enable walking in people with spinal cord injury. Spatially-selective electrical bursts are delivered with a timing that coincides with the intended activation of the spinal cord, and thus desired leg movements.

Ghezzi Lab

http://lne.epfl.ch

Our laboratory is a multidisciplinary environment promoting cross-fertilization among various expertise. We bring materials science, engineering, life science, and medicine together by the convergence of physicists, engineers, neuroscientists, and ophthalmologists cooperating to accomplish innovative projects. Our mission is the development of application-driven solutions based on compliant, minimally invasive, and replaceable neuroprosthetic devices. Ultimately, we aim at translating our research findings into clinical practice.

Results Obtained in 2018

Worldwide about 32 million individuals are blind. In Europe, macular degeneration (16%) and glaucoma (12.2%) are considered the leading causes of blindness. Blindness is a widespread global public health issue, representing a significant personal and societal burden, limiting educational opportunities, affecting economic possibilities and reducing the quality of life. Retinal diseases, such as renitnis pigmentosa or macular degeneration, represent an important cause of blindness, for which there is still no established prevention, treatment or cure. The mission of the laboratory is focused on the implementation of novel technological approaches to fight blindness, providing a fundamental advancement towards sight restoration in patients affected by retinal dystrophies, and translating our research findings into clinical practice.

In 2018, we started the invivo validation of a photovoltaic, widefield, and injectable epiretinal prosthesis (POLYRETINA). Preliminary tests provided promising results for the translation of our device. Second, we validated the use of an optic nerve intraneural electrode (OpticSELINE) to restore sight.

Bio

Diego Ghezzi received his MSc in Biomedical Engineering (2004) and PhD in Bioengineering (2008) from Politecnico di Milano. He completed his postdoc at Istituto Italiano di Tecnologia (Neuroscience and Brain Technologies department), where he was promoted Researcher in 2013. In 2015, he was appointed Tenure Track Assistant Professor at the EPFL School of Engineering as member of the CNP and holds the Medtronic chair in neuroengineering.

Medtronic

Keywords

Neuroprosthetics; Visual prostheses; Organic neuroprosthetics; Fighting blindness; Neuro-optoelectronic interfaces; Optical stimulation.

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Selected Publications

Gribi S., du Bois de Dunilac S., Ghezzi D., Lacour S. P. (2018). A versatile nerve-on-a-chip platform for rapid and selective assessment of neural conduction in ex vivo peripheral nerve fibers. Nature Communications 9, 4403.

Airaghi Leccardi M.J.I., Vagni P., Ghezzi D. (2018). Multilayer 3D electrodes for neural implants. Journal of Neural Engineering. https://doi.org/10.1088/1741-2552/aae191

Ferlauto L., D'Angelo A.N., Vagni P., Airaghi Leccardi M.J.I., Mor F.M., Cuttaz E.A., Heuschkel M.O., Stoppini L., Ghezzi D. (2018). Development and characterisation of PEDOT:PSS/Alginate/PEG soft microelectrodes for application in neuroprosthetics. Frontiers in Neuroscience 12, 648.

Meng K., Fellner A., Rattay F., Ghezzi D., Meffin H., Ibbotson M., Kameneva T. (2018). Upper stimulation threshold for retinal ganglion cell activation. Journal of Neural Engineering 14(4):046012.

Ferlauto L., Airaghi Leccardi M.J.I., Chenais N.A.L., Gilliéron S.C.A., Vagni P., Bevilacqua M., Wolfensberger T.J., Sivula K., Ghezzi D. (2018). Design and validation of a foldable and photovoltaic wide-field epiretinal prosthesis. Nature Communications 9, 992.

Injectable, Foldable and Photovoltaic Wide-Field Epiretinal Prosthesiss

3 mm

Hummel Lab

http://hummel-lab.epfl.ch

Our research is focused on neurological disorders leading to long-term impairment, such as stroke, which are very frequent worldwide (e.g., in Europe 3.7 Mio people suffer from long-term deficits of stroke). Stroke is currently defined as the epidemic of the 21st century. Due to the aging society, it is expected that e.g., from 2010 to 2050 there will be a 1.5-2 fold increase of strokes/year with an expected augmentation in Europe up to 3 Mio new strokes/year. Despite recent efforts and advances in acute stroke treatment and rehabilitation, the recovery from stroke is still far from being satisfying, allowing only 15% of patients to get back to their normal professional and private life. This makes stroke the main causes of long-term disability with large socio-economic impact on the patients' and families' lives, health care systems and society. Thus, there is a mandatory need for cutting-edge research to enhance the understanding of the mechanisms of recovery from a brain lesion, to be able to develop innovative and effective treatment strategies based on neuro-technology, with the goal to be applied cost-effective in a home-based fashion by the patients themselves. It becomes more and more clear that not one treatment applied in the same way in all patients will be efficient ('one suits all strategy'), but that the treatments have to be personalized to the individual requirements and characteristics of the single patient (personalized, patient-tailored medicine approaches). To be able to stratify patients on an individual basis into personalized therapies, we need to develop biomarkers, stratifiers allowing us to predict which course of recovery a patient will take and from which treatment the patient will profit most in a certain period of the recovery process. To achieve this information, (biomarkers) longitudinal and multimodal evaluation of patients is mandatory, and such rich data will then have to be explored by modern computational analyses (e.g., machine learning).

Our general research goal is to develop novel, innovative, patient-tailored treatment strategies for neuro-rehabilitation based on neuro-technologies, especially neuromodulation techniques.

Results Obtained in 2018

Sleep-related learning effects and stroke *(Backhaus et al. 2018)*. We could determine the role of daytime sleep on motor learning as the basis of neurorehabilitative treatments in stroke patients. It is known that sleep has an important impact on the consolidation of learned skills. Here, we determined the ability of stroke patients to acquire novel motor skills with their impaired arm and whether daytime sleep could enhance these effects. We showed that stroke patients still have the ability to acquire novel motor skills, but daytime sleep did not differently impact on learning effects from healthy controls.

The role of structural connectivity for stroke recovery *(Schulz et al. 2019, Quandt et al. under revision, Park et al. under revision)*. In these projects, we determined the role of structural connectivity for stroke recovery, specifically we evaluated the role of the prefrontal connectivity (Schulz et al. 2019), of interactions of functional and structural connectivity and of BDNF-genotype structural connectivity interactions for motor recovery.

Keywords

Neuroimaging, Neurostimulation, Stroke Rehabilitation, Healthy aging, Motor control, Motor learning, psychophysics.

Bio

Friedhelm Hummel is a certified neurologist. After his post-doctoral appointment at the NIH (USA) and in Tübingen (Germany), he established 2006 the Brain Imaging and NeuroStimulation (BINS) Lab at the Hamburg University Medical Center (Germany) where he also held a clinical appointment as Vice-Director of the Department of Neurology. In September 2016, he was appointed Full Professor within the Defitech Foundation Chair in Clinical Neuroengineering and since leads the Hummel-Laboratory at the CNP. He also holds an Associate Professorship in the Department of Clinical Neuroscience, University Medical Center of Geneva.

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CANTON DU VALAIS
KANTON WALLIS

Personalized precision approaches to enhance the effects of innovative neurotechnology based rehabilitative treatments, e.g. non-invasive brain stimulation. We have identified the potential of using patient-tailored protocols based on systems neuroscience 'biomarkers' to individually maximize the neuroplasticity and functional improvement in patients with stroke (Raffin and Hummel 2018, Wessel & Hummel, 2018, Draaisma et al. 2018). These approaches are currently tested within a large-scale, longitudinal study (TiMeS study, PHRT-funded). To this end, we implemented a custom MRI protocol using two newly designed sequences. A multi-shell diffusion acquisition to measure unique properties of white and grey matter microstructure in collaboration with Prof. Thiran (EPFL). A multi-echo T2 sequence to generate quantitative maps of myelin, was defined in collaboration with Prof. Thiran and Dr. Tobias Kober (Siemens Healthineers, EPFL).

Gamified intervention towards home-based therapeutic use *(Guneysu Ozgur A., et al. 2018)*. Within a collaboration with Prof. Dillenbourg (EPFL), we developed and tested a simple rehabilitative intervention based on a hand-robot game to train the affected upper limb.

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Selected Publications

Backhaus W., Braass H., Gerloff C. and Hummel F.C. (2018). Can Daytime Napping Assist the Process of Skills Acquisition After Stroke? Frontiers in Neurology, 9, 1002.

Hummel F.C. (2018). Transkranielle elektrische Stimulation und ihre Bedeutung in der Neurorehabilitation. Neuroreha, 10, 167-173.

Guneysu Ozgur A., Wessel M.J., Johal W., Sharma K., Zgür A., Vuadens P., Mondada F., Hummel F.C., Dillenbourg P. (2018). Iterative Design of an Upper Limb Rehabilitation Game with Tangible Robots. ACM/IEEE International Conference on Human-Robot Interaction, 241-250.
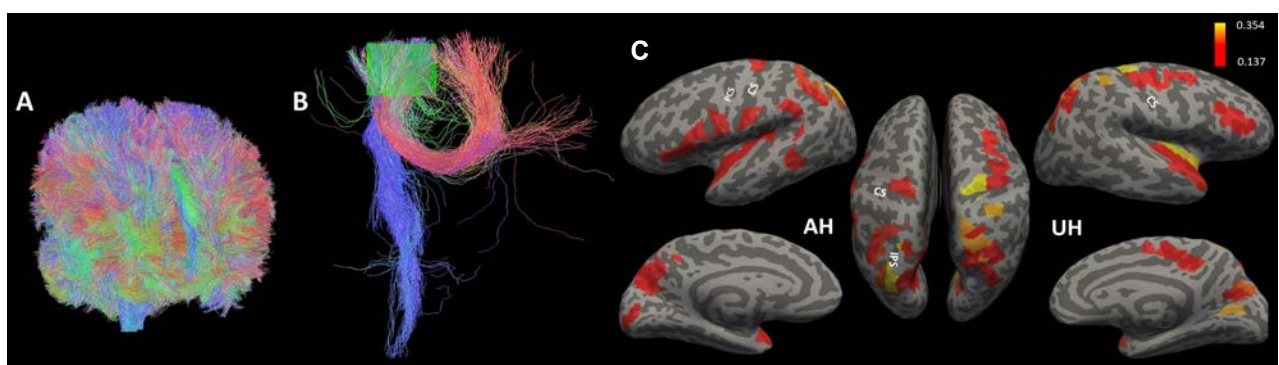
Draaisma L.R., Wessel M.J., Hummel F.C. (2018). Non-invasive brain stimulation to enhance cognitive rehabilitation after stroke. Neuroscience Letters, Jun 28pii: S0304-3940(18), 30450-6.

Bogdanov M., Timmermann J.E., Gläscher J., Hummel F.C., Schwabe L. (2018). Causal role of the inferolateral prefrontal cortex in balancing goal-directed and habitual control of behaviour. Scientific Reports, 20(8), 9382.

Raffin E., Hummel F.C. (2018). Restoring Motor Functions After Stroke: Multiple Approaches and Opportunities. Neuroscientist, 24(4), 400-416.

Wessel M.J. and Hummel F.C. (2018). Non-invasive Cerebellar Stimulation: a Promising Approach for Stroke Recovery? Cerebellum. 17(3), 359-371.

Diffusion Imaging, Tractography (A & B) and Structural Connectivity (C) to determine stroke recovery.

Lacour Lab

http://lsbi.epfl.ch

Bioelectronics integrate principles of materials science and electrical engineering to biology, medicine and ultimately health. The LSBI lab challenges and seeks to advance our fundamental concepts in man-made electronic systems destined to interface the human body and the nervous system. We design and manufacture transducers with mechanical properties close to those of the host biological tissue so that long-term reliability and minimal perturbation are induced in vivo and/or truly wearable systems become possible. We validate the soft bioelectronic interfaces in advanced multi-modal characterization tools and ultimately test them in vivo. Applications include epidural electrode implants for the spinal cord, soft electrocorticography arrays (ECoGs), optoelectronic implants for the peripheral nerves and wearable sensors for hand movement monitoring.

Results Obtained in 2018

The LSBI team is exploring novel device materials and their associated technologies to design and manufacture soft bioelectronic interfaces. They are broadly defined as microfabricated devices, distributed over large-areas, and with mechanical properties suited to comply the soft and dynamic biological tissues. In 2018, we proposed a nerve-on-chip platform to accelerate the design of peripheral nerve implants, and we optimized and conducted extensive characterization of the soft interfaces manufactured in the lab in view of their use in "real-life" applications. Interfacing the nervous system in a selective manner to study or alter neural function is a fundamental need in neuroscience and neural engineering. We proposed a nerve-on-chip platform to conduct rapid, high resolution and systematic recording of peripheral nerve activity (Nature Communication, 2018). The platform enables efficient probing of the heterogeneous fibers from peripheral nerves with a high selectivity and high (statistically relevant) throughputs.

Gallium and some gallium-based alloys offer a unique set of electromechanical properties for the design of soft, stretchable electronics and robotics (Acc. Chem. Res. 2019). We characterized the reliability of stretchable gallium-based biphasic films exposed to prolonged DC and AC current stressing. The films are locally thin (400 nm), resulting in high current densities locally when large currents flow within traces. We highlighted the effect of liquid electromigration in interconnects made of such from the films (APL Materials 2018). Next, we introduced a novel design, inspired by the effects of natural microstructures on wettability, to engineer liquid gallium films with precise control of the film thickness (in the micrometer range, over large surface area) and initial electrical resistance (Advanced Science 2018). The microstructured thin metal films display high and reversible elasticity, and lower resistance change upon stretching compared to previously reported Ga-based stretchable conductors.

We pursued our efforts in the evaluation of a range of tissue-matched implants including conformable auditory brainstem implants (ABI), soft electrocorticography (ECoG) and epidural spinal implants, and soft intracortical probes. Our research continues to build from synergic collaborations with colleagues in materials science, engineering and neuroscience, within EPFL, across Switzerland and the USA.

Bio

Stéphanie P. Lacour received her PhD in Electrical Engineering from INSA de Lyon, France, and completed postdoctoral research at Princeton University and the University of Cambridge. She is the recipient of the 2006 MIT TR35, European Research Council ERC Starting and POC Grants, a SNSF-ERC Consolidator Grant and was elected a 2015 Young Global Leader by the World Economic Forum. She holds the Bertarelli Foundation Chair in Neuroprosthetic Technology at the School of Engineering, and is Director of the Center for Neuroprosthetics.

Keywords

Thin film electronics; soft materials; neural implants; soft mechanical sensors.

fb fondation bertarelli

Team

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& jointly with Prof Courtine

Selected Publications

Hirsch A.E., Dejace L.M., Michaud H.O., Lacour S.P.(2019). Harnessing the Rheological Properties of Liquid Metals To Shape Soft Electronic Conductors for Wearable Applications; Accounts of Chemical Research, 52(3), 534-544.

Michaud H.O., Lacour S.P.(2019) Liquid electromigration in gallium-based biphasic thin films; APL Materials, 7, 031254.
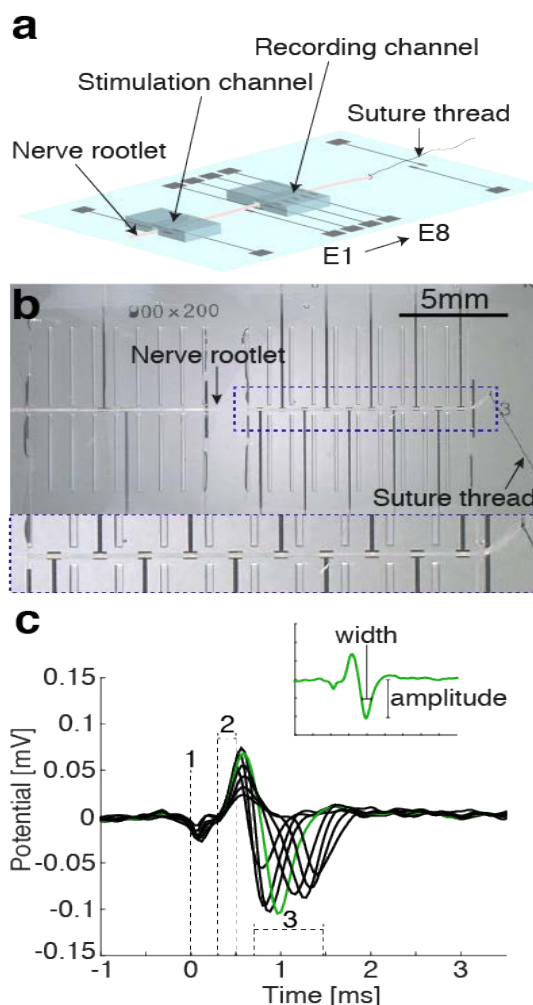
Schiavone G., Wagner F., Fallegger F., Kang X., Vachicouras N., Barra B., Capogrosso M., Bloch J., Courtine G., Lacour S.P. (2018). Long-term functionality of a soft electrode array for epidural spinal cord stimulation in a minipig model. 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Honolulu, HI, USA, 18-21 July 2018. 1432-1435.

Gribi S., du Bois de Dunilac S., Ghezzi D., Lacour S.P. (2018). A microfabricated nerve-on-a-chip platform for rapid assessment of neural conduction in explanted peripheral nerve fibers. Nature Communications, 9, 4403.

Hirsch A., Lacour S.P. (2018). A Method to Form Smooth Films of Liquid Metal Supported by Elastomeric Substrate. Advanced Science, 5, 1800256.

Michoud F., Sottas L., Browne L.E., Asboth L., Latremoliere A., Sakuma M., Courtine G., Woolf C.J., Lacour S.P. (2018). Optical cuff for optogenetic control of the peripheral nervous system. Journal of Neural Engineering, 15(1), 015002.

Buccarello A., Azzarito M., Michoud F., Lacour S.P., Kucera J.P. (2018). Uniaxial strain of cultured mouse and rat cardiomyocyte strands slows conduction more when its axis is parallel to impulse propagation than when it is perpendicular. Acta Physiologica, 223, e13026.

Nerve-on-chip for efficient probing of the heterogeneous fibers from peripheral nerves with a high selectivity and high throughputs.
(a) design
(b) top view photographs
(c) Single fiber action potential propagating in the microchannel.

Micera Lab

http://tne.epfl.ch

The main goal of the TNE laboratory is to develop implantable neural interfaces and robotic systems aimed at restoring sensorimotor function in people with different kind of disabilities (spinal cord injury, stroke, amputation, etc.), starting from basic scientific knowledge in the field of neuroscience, neurology and geriatrics, and investigating further to gain new information by using advanced technologies and protocols. For this reason, our activities combine (i) technological developments (robotics, implantable neural interfaces, algorithms for closed-loop control and signal processing), (ii) experiments to understand the basic neuroscientific principles of motor control; (iii) integration and test of different types of hybrid neuro-prosthetic systems to restore sensory and motor functions.

Starting from a background on signal processing and closed-loop control, we have been able to enlarge the focus of our scientific activities and now our team has the ability to investigate all the different issues related to the development and test of effective neural and rehabilitation systems. We are one of the few groups in the world able to study all these issues in an integrated and harmonized manner.

Results Obtained in 2018

Bionic limbs. Recently, we concluded a long-term study with three amputees, providing the first demonstration of long-term stability and functional exploitability of intraneural arrays. We also concluded several studies to improve sensory and control strategies.

Neuroprosthesis to restore locomotion. Electrical neuromodulation of the spinal cord has been shown to reverse leg paralysis in rodent and primate models of spinal cord injury. In 2018 we developed new approaches to develop stimulation protocols in patients exploiting several computational models.

Neuroprosthesis for grasping function restoration. Grasping is one of our most important motor function. It allows us to interact naturally and intuitively with our environment. Regaining the capacity to grasp and manipulate objects is thus crucial for people living with upper limb paralysis. During 2018, we gathered preliminary very promising results about the usability of intraneural electrodes to restore fine manipulation.

Robot-based neurorehabilitation. The goal of Neuroprobes is to develop personalized robot-based upper limb motor rehabilitation protocols using ALEx (upper limb exoskeleton), targeting the specific kinematic performance of each patient based on the model previously proposed. We are currently performing a clinical trial on 48 acute-subacute stroke patients to compare the personalized approach with other approaches, including the standard physiotherapy and a standard robotic therapy.

Ultrasound-based peripheral neuromodulation. Focused Ultrasound Stimulation (FUS) is a non-invasive therapeutic tool with great potential, widely used on humans for ablation therapies and diagnostic imaging. We are currently developing a modeling framework to predict how low-intensity ultrasonic waves can modulate the activity of different types of peripheral fibers.

Bio

Silvestro Micera is currently Professor of Biomedical Engineering at the EPFL where he is holding the Bertarelli Foundation Chair in Translational NeuroEngineering. He is also Professor of Biomedical Engineering at the Scuola Superiore Sant'Anna (Italy). In 2009 he was the recipient of the "Early Career Achievement Award" of the IEEE Engineering in Medicine and Biology Society.

fb fondation bertarelli

Keywords

Neuroprosthetics, Bionics, Artificial limbs, Bioelectronic Medicine.

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º visiting
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** jointly with Prof Van De Ville

Selected Publications

Petrini FM, Valle G, Strauss I, Granata G, Di Iorio R, D'Anna E, Čvančara P, Mueller M, Carpaneto J, Clemente F, Controzzi M, Bisoni L, Carboni C, Barbaro M, Iodice F, Andreu D, Hiairrassary A, Divoux JL, Cipriani C, Guiraud D, Raffo L, Fernandez E, Stieglitz T, Raspopovic S, Rossini PM, Micera S. (2019). Six-Month Assessment of a Hand Prosthesis with Intraneural Tactile Feedback. Annals of Neurology, Jan;85(1):137-154.

Rognini G, Petrini FM, Raspopovic S, Valle G, Granata G, Strauss I, Solcà M, Bello-Ruiz J, Herbelin B, Mange R, D'Anna E, Di Iorio R, Di Pino G, Andreu D, Guiraud D, Stieglitz T, Rossini PM, Serino A, Micera S, Blanke O (2018). Multisensory bionic limb to achieve prosthesis embodiment and reduce distorted phantom limb perceptions. Journal of Neurology, Neurosurgery & Psychiatry, jnnp-2018-318570.

Formento E, Minassian K, Wagner F, Mignardot JB, Le Goff-Mignardot CG, Rowald A, Bloch J, Micera S*, Capogrosso M*, Courtine G* (2018). Electrical spinal cord stimulation must preserve proprioception to enable locomotion in humans with spinal cord injury. Nature Neuroscience, Dec;21(12):1728-1741.

Valle G, Mazzoni A, Iberite F, D'Anna E, Strauss I, Granata G, Controzzi M, Clemente F, Rognini G, Cipriani C, Stieglitz T, Petrini FM, Rossini PM, Micera S. (2018). Biomimetic Intraneural Sensory Feedback Enhances Sensation Naturalness, Tactile Sensitivity, and Manual Dexterity in a Bidirectional Prosthesis. Neuron, Oct;100(1):37-45.

Bonizzato M, Pidpruzhnykova G, DiGiovanna J, Shkorbatova P, Pavlova N, Micera S*, Courtine G* (2018). Brain-controlled modulation of spinal circuits improves recovery from spinal cord injury. Nature Communication, Aug 1;9(1):3015.

Miehlbradt J, Cherpillod A, Mintchev S, Coscia M, Artoni F, Floreano D, Micera S (2018). Data-driven body-machine interface for the accurate control of drones. Proceedings of the National Academy of Sciences USA, Jul;115(31):7913-7918.

*equal contribution
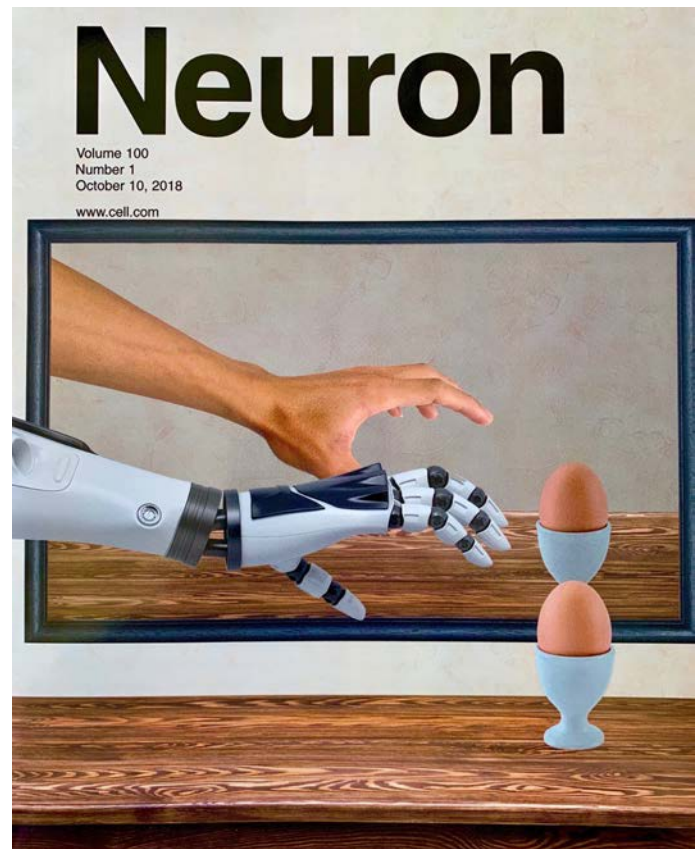
Restoration of touch sensation using biomimetic encoding strategies
(Neuron journal cover, see Valle et al. 2018)

Millán Lab

http://cnbi.epfl.ch

The Chair in Brain-Machine Interface laboratory (CNBI) carries out research on the direct use of human brain signals to control devices and interact with our environment. In this multidisciplinary research, we are bringing together our pioneering work on the two fields of brain-machine interfaces and adaptive intelligent robotics. Our approach to design intelligent neuroprostheses balances the development of prototypes, where robust real-time operation is critical, and the exploration of new interaction principles and their associated brain correlates. A key element at each stage is the design of efficient machine learning algorithms for real-time analysis of brain activity that allow users to convey their intents rapidly, on the order of hundred milliseconds. Our neuroprostheses are explored in cooperation with clinical partners and disabled volunteers for the purpose of motor restoration, communication, entertainment and rehabilitation.

Bio

Prof. José del R. Millán holds the Defitech Foundation Chair in Brain Machine Interface since 2009, where he designs neuroprostheses (brain-controlled devices like robots, exoskeletons and communication aids) for augmenting interaction experiences and restoring lost functions. His research on brain-machine interfaces has received a number of awards and recognitions.

Results Obtained in 2018

The art-science exhibit Mental Work continued its successful tour in San Francisco (May-July, 2018). Visitors employed our BMI technology to control artistic replicas of Industrial Revolution machines. Mental Work is the largest public science experiment to date in EEG/BMI technology –a unique dataset with almost 800 subjects, each providing 60-90 min of brain signals. First analysis reveals that average performance across all subjects was above chance level across the exhibit. Furthermore, subjects with poor initial performance could improve with experience.

At a more fundamental level, we have investigated principles to facilitate users' acquisition of BMI skills; in particular, mutual learning (Perdikis et al., 2018) and somatosensory feedback (Corbet et al., 2018). Mutual learning approaches make it possible that the human user and the BMI decoder adapt to each other. We have shown how mutual learning is a critical factor for successful BMI translational applications. Contrary to a popular trend of focusing almost exclusively on the machine learning aspects of BMI training, our results demonstrate that mutual learning is key for tetraplegic users to acquire BMI control of devices over long periods of time and in real-world conditions. Importantly, learning correlates could be derived at all levels of the interface –application, BMI output and EEG neuroimaging. In parallel, we have shown how a new form of somatosensory feedback increases both BMI stability over time and activation of target brain areas.

On the clinical front, our BMI approach to stroke motor rehabilitation has shown how it elicits significant, clinically relevant and lasting motor recovery of arm and hand function in chronic stroke survivors (Biasiucci et al., 2018). Such recovery, which remains 6-12 months after the end of therapy, was associated with quantitative signatures of functional neuroplasticity.
Publications also covered work on BMI control of robots and closed-loop brain stimulation.

Keywords

Brain-machine interfaces, Neuroprosthetics, Machine learning, Robotics, EEG.

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Mats Uytterhoeven

Guest researchers
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Marija Ušćumlić

Visiting Professor
Eun Ju Kimm

Research Engineers
Frédéric Giraud

Selected Publications

Biasiucci A., Leeb R., Iturrate I., Perdikis S., Al-Khodairy A., Corbet T., Schnider A., Schmidlin T., Zhang H., Bassolino M., Viceic D., Vuadens P., Guggisberg A.G., Millán J.d.R. (2018). Brain-actuated functional electrical stimulation elicits lasting arm motor recovery after stroke. Nature Communications, 9:2421.

Chavarriaga R., Ušćumlić M., Zhang H., Khaliliardali Z., Aydarkhanov R., Saeedi S., Gheorghe L.A., Millán J.d.R. (2018). Decoding neural correlates of cognitive states to enhance driving experience. IEEE Trans. Emerging Topics in Computational Intelligence, 2(4):288–297.

Corbet T., Iturrate I., Pereira M., Perdikis S., Millán J.d.R. (2018). Sensory threshold neuromuscular electrical stimulation fosters motor imagery performance. NeuroImage, 176:268–276.

Iturrate I., Pereira M., Millán J.d.R. (2018). Closed-loop electrical neurostimulation: Challenges and opportunities. Current Opinion in Biomedical Engineering, 8:28–37.

Martin S., Iturrate I., Chavarriaga R., Leeb R., Sobolewski A., Li A.M., Zaldivar J., Peciu-Florianud J., Pralong E., Castro-Jiménez M., Benninger D., Vingerhoets F., Knight R.T., Bloch J., Millán J.d.R. (2018). Differential contributions of subthalamic beta rhythms and 1/f broadband activity to motor symptoms in Parkinson's disease. NPJ Parkinson's Disease, 4:32.

Perdikis S., Tonin L., Saeedi S., Schneider C., Millán J.d.R. (2018). The Cybathlon BCI race: Successful longitudinal mutual learning with two tetraplegic users. PLoS Biology, 16(5):e2003787.

Two tetraplegic participants were trained with our mutual learning approach to control their avatar in a virtual BMI race game. The evolution of the training process, including competition outcomes (gold medal, tournament record), substantiates the effectiveness of this type of training.

Van De Ville Lab

http://miplab.epfl.ch

The Medical Image Processing Laboratory (MIP:lab) pursues the development and integration of innovative data-processing tools at various stages of the acquisition, analysis, and interpretation pipeline of neuroimaging data. We aim at obtaining new insights into brain function & dysfunction by approaches that are based on modeling the brain as a network and as a dynamical system. These new signatures of brain function are promising to interpret and predict cognitive and clinical conditions, and also to provide new avenues for neurofeedback based on real-time fMRI.

Results Obtained in 2018

We model brain networks at the systems level based on whole-brain magnetic resonance imaging (MRI), both in terms of anatomical structure and functional activity. By applying and extending graph theory, multiscale techniques and pattern recognition, we are able to identify and characterize brain networks in a meaningful way during cognitive tasks, as well as alterations by neurological conditions, which opens the potential for new imaging-based biomarkers that might for instance complement neuropsychological testing in prodromal stage of Alzheimer's Disease.

We also investigate temporal dynamics of these networks during spontaneous activity, for which we have pioneered subspace discovery methods and sparsity-driven deconvolution techniques that reveal meaningful, dynamic interactions between large-scale distributed networks. These techniques bring us closer to capturing the global brain state, which is essential for future development of invasive and non-invasive neuroprosthetics, such as neurofeedback based on real-time fMRI.

Bio

M.S. and Ph.D. in Computer Sciences from Ghent University, Belgium (1998, 2002), Post-doctoral Fellow at EPFL (2002-2005), Junior Group Leader of the CIBM Signal Processing Unit at University of Geneva (2005-2009), awarded SNSF professorship (2009), Associate Professor of Bioengineering since 2015 jointly affiliated with University of Geneva (Department of Radiology & Medical Informatics).

Keywords

Computational neuroimaging, network science, brain dynamics, signal processing, functional magnetic resonance imaging, electroencephalography.

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** jointly with Prof Micera
*** jointly with Prof Radenovic

Selected Publications

Bolton T. A. W., Tarun A., Sterpenich V., Schwartz S., Van De Ville D. (2018) Interactions Between Large-Scale Functional Brain Networks Are Captured by Sparse Coupled HMMs. IEEE Transactions on Medical Imaging, 37:230-240.

Huang W., Bolton T. A. W., Medaglia J. D., Bassett D. S., Ribeiro A., Van De Ville D. (2018). A Graph Signal Processing Perspective on Functional Brain Imaging. Proceedings of the IEEE, 106:868-885.

Bolton T. A. W., Jochaut D., Giraud A.-L., Van De Ville D. (2018). Brain Dynamics in ASD During Movie-watching Show Idiosyncratic Functional Integration and Segregation. Human Brain Mapping, 39:2391-2404.

Demesmaeker R., Preti M. G., Van De Ville D. (2018). Augmented Slepians: Bandlimited Functions that Counterbalance Energy in Selected Intervals. IEEE Transactions on Signal Processing, 66:4013-4024.

Tuleasca C., Regis J., Najdenovska E., Witjas T., Girard N., Thiran J.-P., Bach Cuadra M., Levivier M., Van De Ville D. (2018). Visually-sensitive Networks in Essential Tremor: Evidence from Structural and Functional Imaging. Brain, 141:e47

Zoeller D., Padula M. C., Sandini C., Schneider M., Scariati Jaussi E., Eliez S., Van De Ville D., Schaer M., Eliez S. (2018). Psychotic Symptoms Influence the Development of Anterior Cingulate BOLD Variability in 22q11.2 Deletion Syndrome. Schizophrenia Research, 193:319-328.

The brain's functional repertoire can be established from transient activity measured using functional magnetic resonance imaging (fMRI) during mere 10 minutes of resting state. Data-driven techniques let emerge known spatial configurations of activity (from task fMRI), ranging from "low level" sensory to "high level" cognitive ones. Computational temporal models can further learn us how essential features of brain function, such as learning, coordinated cognition, or stability in a changing environment, are supported.
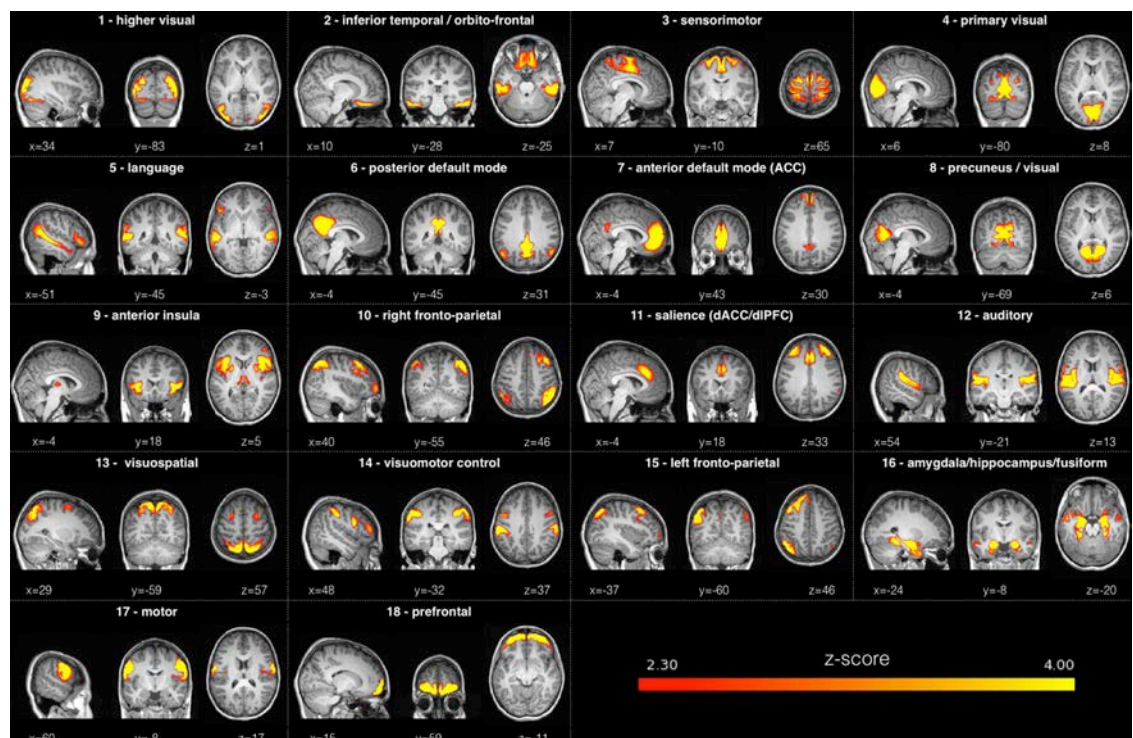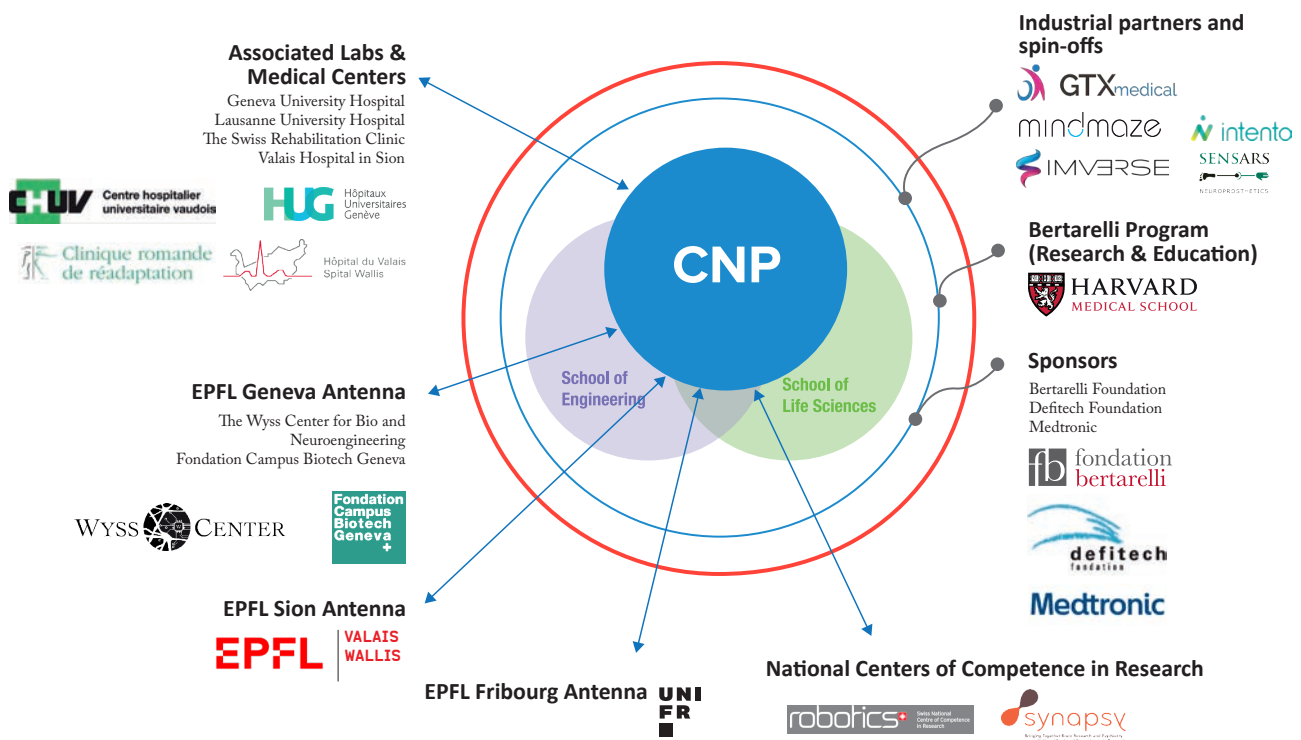
Research partners and activities

The Centre for Neuroprosthetics is connected to EPFL School of Life Sciences and EPFL School of Engineering, and associated institutes, e.g. the Brain and Mind Institute, the Institute of Bioengineering and the Institute of Microengineering. The Centre has established collaborations with the University of Geneva, University of Lausanne and University of Fribourg. At Campus Biotech, the Centre benefits from shared facilities and leads translational research projects with the Wyss Center for Bio and Neuroengineering and the Bertarelli Foundation (Catalyst funds).

Associated Labs & Medical Centers
Geneva University Hospital
Lausanne University Hospital
The Swiss Rehabilitation Clinic
Valais Hospital in Sion

EPFL Geneva Antenna
The Wyss Center for Bio and Neuroengineering
Fondation Campus Biotech Geneva

EPFL Sion Antenna

EPFL Fribourg Antenna

Industrial partners and spin-offs
GTXmedical
mindmaze
intento
IMVERSE
SENSARS

Bertarelli Program (Research & Education)
HARVARD MEDICAL SCHOOL

Sponsors
Bertarelli Foundation
Defitech Foundation
Medtronic

National Centers of Competence in Research

The Wyss Center

The Wyss Center for Bio & Neuroengineering and the CNP collaborate in research projects and supervise research platforms at Campus Biotech.

The Wyss Center is an independent, not for profit, research organization that aims to transform neurotechnology research ideas into clinical solutions. The Center advances technology to the marketplace to help people with nervous system disorders live independent lives. Established by a generous donation from the Swiss entrepreneur and philanthropist Hansjörg Wyss, and based at Campus Biotech in Geneva, the Wyss Center presents a new model in translational neurotechnology research. Over the course of the past year the Wyss Center has provided support and scientific, business and regulatory expertise to the CNP researchers.

Partners and associated medical centers

The Center has strategic partnerships with Geneva University Hospital (Hôpitaux Universitaires de Genève, HUG), Lausanne University Hospital (Centre Hospitalier Universitaire Vaudois, CHUV), and Valais Wallis Hospital (HVS), as well as with the Swiss Rehabilitation Clinic in Sion (Clinique Romande de Réadaptation, CRR) and the Berner Klinic Montana.
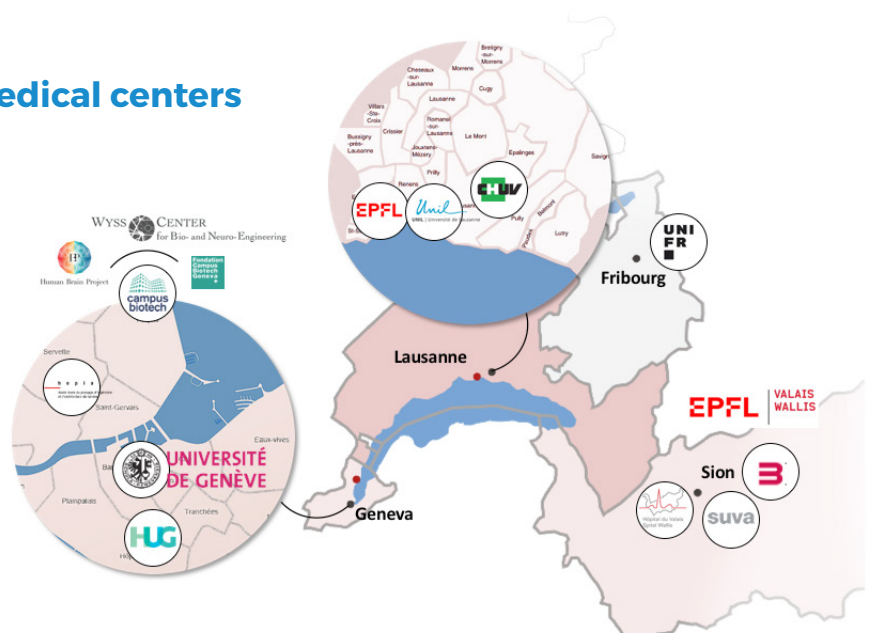
Close Collaborating laboratories

EPFL

AEBISCHER Patrick, SCHNEIDER Bernard, Neurodegenerative Disease Laboratory
BILLARD Aude, Learning Algorithms and Systems Laboratory
BLEULER Hannes, Robotic Systems Laboratory
BOULIC Ronan, Immersive Interaction Group
DILLENBOURG Pierre, Computer-Human Interaction Lab for Learning & Instruction
THIRAN Jean-Philippe, KOBER Tobias, Signal Processing Laboratory LTS5
VERSCHEURE Olivier, BOULLIER Eric, Swiss Data Science Center.

HVSW

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GHIKA Joseph, Neurology Department

SUVA CRR

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DISERENS Karin, Department of Clinical Neuroscience
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WOLFENSBERGER Thomas, Vitreoretinal Department, Jules-Gonin Eye Hospital, Lausanne.

UNIGE - HUG

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BURKHARD Pierre, Department of Clinical Neuroscience
HABRE Walid, Department of Anaesthetics, Pharmacology, Intensive Care and Emergencies
JANSSENS Jean-Paul, ADLER Dan, Department of Pneumology and Neurology
MONTET Xavier, Department of Radiology and Medical Informatics
SCHNIDER Armin, GUGGISBERG Adrian, Neurorehabilitation Clinic
SCHALLER Karl, MOMJIAN Shahan, Department of Neurosurgery
SEECK Margitta, VUILLEUMOZ Serge, ALLALI Gilles, Department of Neurology

Selected highlights 2018

January 2018

New Director of the Center for Neuroprosthetics

Professor Olaf Blanke has been at the helm of the Center for Neuroprosthetics (CNP) since 2012. He hands over the Direction of the Center to Professor Stéphanie Lacour on February 1st 2018. In six years as Director, Olaf Blanke launched and drove the CNP to become a major actor in research and clinical translation of EPFL excellence in neuroscience and neuroengineering. Professor Lacour brings cutting edge expertise in soft materials science and engineering to the CNP as well as innovative perspectives to help develop and deploy neuroprosthetic medicine. Her nomination at the CNP Directorship received unanimous support of the CNP faculties and EPFL Presidency.
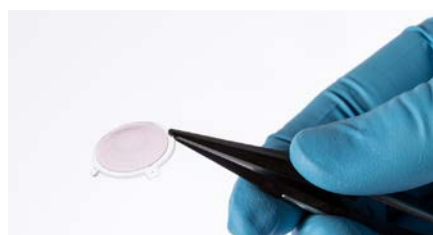
March 2018

A retinal implant that is more effective against blindness

CNP researchers have developed a new type of retinal implant for people who have become blind due to the loss of photoreceptor cells in their retinas. The implant partially restores their visual field and can significantly improve their quality of life. The laboratory of Prof. Diego Ghezzi have come up with a pioneering, wireless implant made of a highly flexible and pliable material and containing photovoltaic pixels. It is expected to provide wearers with a visual field of 46 degrees along with much better resolution.

April 2018

Bertarelli Symposium 2018

The 2018 Symposium of the Bertarelli Program in Translational Neuroscience and Neuroengineering took place at Harward Medical School, Boston, USA, on Wednesday, April 11th, 2018. The theme for this year was "Gene Therapy for Sensory Disorders" and the keynote Speakers were Kathy High (Spark Therapeutics in Philadelphia), David Liu (Harvard-MIT Broad Institute) and Botond Roska (Institute for Ophthalmology, Basel, Switzerland)..

Three CNP projects awarded Bertarelli Catalyst funding

Treating vision problems after a stroke - The project headed by Prof. Friedhelm Hummel and involving four colleagues from EPFL, HUG, Hôpital du Valais and the Clinique Romande de Réadaptation (Sion) will use a multimodal approach by functional magnetic resonance imaging (fMRI) and transcranial magnetic stimulation (TMS) simultaneously to map out activity in the visual system following a stroke to better understand the mechanisms of recovery.

Treating hallucinations in Parkinson's patients - The neurological processes at play have been studied in labs of Prof. Olaf Blanke and Dimitri Van De Ville and can now be triggered using robotic tools. By teaming up with Paul Krack (Geneva University Hospital), the researchers will be able to go further in exploring these processes in patients suffering from Parkinson's.

Controlling the paths of pain - Stéphanie Lacour (EPFL) and Isabelle Décosterd (Lausanne University Hospital – CHUV and FBM-University of Lausanne) focus on the hyperexcitability of pain nociceptive neurons and the ion channels that activate them. They are developing the tools needed to create a mechanistic model that could lead to innovative therapies – involving gene therapies, optogenetics and neurotechnologies.

June 2018

A dual-therapy approach to boost motor recovery after a stroke

Prof. José del R. Millán, Defitech Foundation Chair in Brain-Machine Interface, in association with other members of the CNP, the Clinique Romande de Réadaptation in Sion, and the Geneva University Hospitals, have shown that combining a brain-computer interface (BCI) with functional electrical stimulation (FES) can help stroke victims recover greater use of their paralyzed arm – even years after the stroke.

The scientists used a BCI system to link the patients' brains to computers using electrodes. That let the scientists pinpoint exactly where the electrical activity occurred in the brain tissue when the patients tried to reach out their hands. Every time that the electrical activity was identified, the system immediately stimulated the arm muscle controlling the corresponding wrist and finger movements.

July 2018

### Prof. Silvestro Micera promoted Full Professor

Combining engineering and neurosciences, Silvestro Micera enjoys worldwide recognition in the field of neuroprosthetics. He was named as Full Professor of Bioengineering at 50% in the School of Engineering (STI). Silvestro Micera, who works conjointly at EPFL and at Scuola Superiore Sant'Anna, holds the Bertarelli Foundation Chair in Translational Neuroengineering.

August 2018

Regenerating nerve fibers across spinal cord injury

In a collaboration led by Prof. Grégoire Courtine's Laboratory and UCLA (University of California at Los Angeles), scientists have designed a three-stepped recipe for regenerating electro-physiologically active nerve fibers across complete spinal cord lesions in rodents. Rehabilitation is still required to make these new nerve fibers functional for walking.
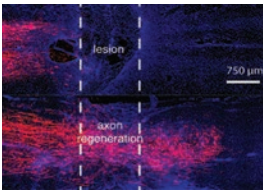
October 2018

Nerve-on-a-chip platform makes neuroprosthetics more effective

Scientists at the lab of Prof. Stéphanie Lacour have developed a miniaturized electronic platform for the stimulation and recording of peripheral nerve fibers on a chip. By modulating and rapidly recording nerve activity with a high signal-to-noise ratio, the platform paves the way to using chips to improve neuroprosthetic designs.

Three first patients of the STIMO study (Sebastian Tobler, Gert-Jan Oskam, and David Mzee).

November 2018

### Breakthrough neurotechnology for treating paralysis

Three patients with chronic paraplegia were able to walk over ground thanks to precise electrical stimulation of their spinal cords via a wireless implant. In a double study published in Nature and Nature Neuroscience, Prof. Grégoire Courtine and Prof. Jocelyne Bloch (CHUV/Unil) show that, after a few months of training, the patients were able to control previously paralyzed leg muscles even in the absence of electrical stimulation. This study, called STIMO (STImulation Movement Overground), establishes a new therapeutic framework to improve recovery from spinal cord injury. All patients involved in the study recovered voluntary control of leg muscles that had been paralyzed for many years.

Amputees feel as though their prosthetic limb belongs to their body

In a breakthrough approach that combines virtual reality and artificial tactile sensations, two amputees feel as though their prosthetic hand belongs to their own body. Moreover, the work of the Laboratory of Prof Olaf Blanke, in a collaboration with Prof. Silvestro Micera and Scuola Superiore Sant'Anna in Italy, shows that the perception of the phantom limb can extend so as to match with the prosthetic hand.
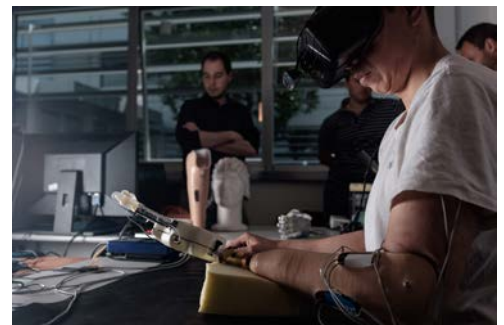
Distinguished Lectures in Neuroprosthetics
With the support of the Wyss Center

Brain-Computer Interfacing when all else fails, March 2018
By Prof. Nick F Ramsey, Brain Center Rudolf Magnus, NL.

From a "jolt to the head" to the gift of hearing: taking neural prostheses to the clinic, October 2018
By Prof. Robert K. Shepherd, University of Melbourne, AUS.

Rhythms for Cognition: Communication through Coherence, November 2018
By Prof. Pascal Fries, Ernst Strüngmann Institute, GE

Printed EEG and EMG electronic-tattoos for neurological applications, December 2018
By Prof. Yael Hanein, Tel Aviv University, IS.

http://cnp.epfl.ch/dln

Selected seminars in 2018

Automated neonatal diffusion MRI data processing to study white matter development, January 2018
By Dr. Matteo Bastiani, University of Oxford, UK.

Current and future applications of non-invasive and invasive BCIs, February 2018
By Dr. Christoph Guger, CEO g.tec, AU.

Functional recovery following paralysis facilitated by epidural and transcutaneous spinal stimulation, April 2018
By Prof. V. Reggie Edgerton, University of California Los Angeles, USA.

Reactivate, Rewire, Restore - Priming the nervous system to optimize function after spinal cord injury, June 2018
By Prof. Edelle Field-Fote, Emory University School of Medicine, USA.

Learning to Control Prosthetic Hands, September 2018
By Dr. Kianoush Nazarpour, Newcastle University, UK.

Tissue-engineering for implantable bionics, September 2018
By Dr. Rylie Green, Imperial College London, UK.

Toward a natural-resolution neural interface: artificial retina, September 2018
By Prof. E.J. Chichilnisky, Stanford University, USA.

Towards non-invasive BCI-controlled hand and arm function in high spinal cord injury, September 2018
By Prof. G. R. Müller-Putz, Graz University of Technology, AT.

Computational approaches to optimize spinal cord stimulation for chronic pain, October 2018
By Prof. Scott Lempka, University of Michigan, USA.

Towards Minimally-Supervised, Technology-Assisted Neurorehabilitation in the Clinic and at Home, October 2018
By Prof. Roger Gassert, ETH Zürich, CH.

November 23, 2018
Campus Biotech · Geneva
Auditorium H8 01 A

Neuroprosthetics
Annual
Research
Symposium

NEUROSCIENCE
ENGINEERING
MEDICINE

#EPFL_NARS
#BERTARELLINEURO

Free registration by November 21, 2018
https://cnp.epfl.ch/symposium

fb fondation bertarelli   campus biotech

First Neuroprosthetics Annual Research Symposium

With the support of the Bertarelli Foundation, the CNP is launching an Annual Research Symposium to involve the academic, industrial and clinical communities into interdisciplinary discussions on current and future trends in technologies and applications of neuroprosthetic research. The First Neuroprosthetics Annual Research Symposium took place on November 23, 2018, at Campus Biotech, Geneva, and saw over 270 attendees, including 40% from other institutions (UNIGE, WyssCenter, but also Fribourg, Paris, Milano, etc.)

http://cnp.epfl.ch/symposium

Minor in Neuroprosthetics

Students enrolled in a Master program at EPFL have the possibility to obtain an inter-faculty specialization in neuroprosthetics. This "Mineur" in neuroprosthetics covers the essential courses in neurosciences and neuroengineering in the field of neuroprosthetics, including medical applications. The programme is coordinated by Prof. José del R. Millán (School of Engineering, STI) and Prof. Olaf Blanke (School of Life Sciences, SV).

http://cnp.epfl.ch/teaching

International Bertarelli Fellowship HMS-EPFL

Since 2012, the Bertarelli Program in Translational Neuroscience and Neuroengineering funds Master students of EPFL to study at Harward Medical School for up to one year, and HMS medical students to study at EPFL and get immersed in a technology research laboratory.

http://ptnn.epfl.ch

Kirsty and Ernesto Bertarelli meet a group of EPFL awardees of Bertarelli Fellowships, on the occasion of the annual Bertarelli Symposium (Campus Biotech, April 7, 2017). Photo: Fondation Bertarelli ©
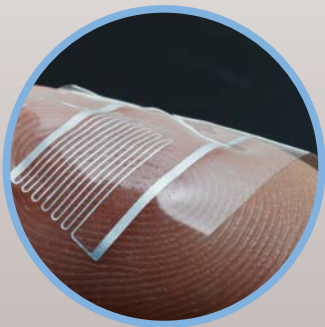
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