General Schedule

Day 1: Thursday, November 10

9:00 Welcome and Opening Remarks
Lijie Grace Zhang, Local Chair, George Washington University
Tülay Adali, IEEE Brain Chair and General Chair, University of Maryland, BC
Ramana Vinjamuri, General Chair, University of Maryland, BC

Session 1: Emerging Neurotechnologies

9:10 **Keynote:** Tim Denison, Oxford, UK
10:00 Dean J. Krusienski, Virginia Commonwealth University, USA
10:20 Claire Rabut, Caltech, USA
10:40 *Coffee Break*
11:00 Alexander von Lühmann, Technische Universität Berlin, Germany
11:20 Mahsa Shoaran, EPFL, Switzerland
11:40 Emerging Neurotechnologies Panel Discussion
12:30 *Lunch Break*
2:00 Afternoon Remarks
John Lach, Dean School of Engineering and Applied Science, George Washington University

Session 2: Machine Learning for Brain Discovery

2:10 **Keynote:** Dani Smith Bassett, University of Pennsylvania, USA
3:00 Richard Betzel, Indiana University, USA
3:20 Dominique Duncan, University of Southern California, USA
3:40 *Coffee Break*
4:00 Archana Venkataraman, Boston University, USA
4:20 Behtash Babadi, University of Maryland, College Park, USA
4:40 Machine Learning for Brain Discovery Panel Discussion
5:30 *Light Reception, Exhibits*
5:45 **IEEE Brain Neuroethics Panel:** Guiding Responsible Neurotechnology Innovation – Anticipation and Responsiveness around BCIs (60 min)
Chair: Laura Y. Cabrera, Pennsylvania State University, IEEE Brain Neuroethics Chair
Jennifer French, Executive Director, Neurotech Network
Armani Porter, Senior Manager, Intellectual Property & Business Development, Magnus Medical
Martijn De Neeling MD, Amsterdam UMC, Chair IEEE SA WG P2794
Kim Thacker MD, MS, Neurologist and Bio/Neuroethicist
7:00 *Day 1 Workshop concludes*

Day 2: Friday, November 10

Session 1: Clinical Applications and Impact

9:00 **Keynote:** Lee Miller, Northwestern University, USA
10:00 Jennifer Collinger, University of Pittsburgh, USA
10:20 Nick Ramsey, UMC Utrecht, The Netherlands
10:40 *Coffee Break*
11:00 Aiko Thompson, Medical University of South Carolina, USA
11:20 Monica A. Perez, Northwestern University, USA
11:40 Clinical Applications and Impact Panel Discussion
12:30 *Lunch Break*
2:00 **Sponsoring Agencies Panel:** Opportunities and Challenges in Brain Research
Chairs: Vince Calhoun, Georgia State University and *Tülay Adali*, University of Maryland, BC, IEEE Brain Chair
Brooks Gross, NINDS
Chou Hung, Neurophysiology of Cognition, US DEVCOM Army Research Laboratory - ARO
Vani Pariyadath, NIH/NIDA
Abera Wouhib, NIH/NIMH
4:00 *Full Reception, Posters, Exhibits*
6:00 Awards
6:30 *Day 2 Workshop concludes*

Track A: Emerging Neurotechnologies

Keynote: Tim Denison, Oxford, UK
Bioelectronic Chronotherapy: Towards "Rhythm-aware" Neural Implants
Implantable neurostimulation devices are an effective precision medicine treatment for neurological conditions, targeting pathological dynamics in neural networks. Like the rest of our physiological functioning, neural activity is profoundly influenced by sleep and circadian rhythms, but current neurostimulation devices often do not take this into account. This is particularly important as biological rhythms interact with neurological disease, leading to predictable changes in disease symptoms and biomarkers, while sleep and circadian rhythm disruption is increasingly understood to be a causal factor in neurodegenerative as well as psychiatric disorders. Understanding the changes in pathological neuro dynamics over the diurnal cycle will therefore not only allow for optimization of therapy for different physiological states and different times of day, but also pave the way for bioelectronic therapy 'prescriptions' that directly target sleep and circadian rhythm disruption. We will motivate our work by providing a characterization of predictable neural biomarker fluctuations in neurodegenerative and psychiatric conditions during active deep brain stimulation and show that brain stimulation can influence patient sleep/wake rhythms. Next, we will describe the development and pilot application of the DyNeuMo system, a research platform technology that has the capacity to change its stimulation program according to time of day and behavioral state, which has now being applied in several first-in-human investigational trials.

Dean J. Krusienski, Virginia Commonwealth University, USA
Decoding of Speech from Intracranial Activity
Electrophysiological recordings obtained during clinical intracranial monitoring can uniquely provide sufficient spatial and temporal resolution for investigating the detailed spatiotemporal dynamics of speech. Recent studies have demonstrated the possibility of decoding various speech representations such as phonemes, words, and phrases directly from intracranial recordings. In pursuit of the ultimate objective of developing a natural speech neuroprosthetic for the severely disabled, this presentation will outline several recent results related to characterization and synthesis of speech directly from intracranial brain activity.

Claire Rabut, Caltech, USA
Fundamentals of Functional Ultrasound Neuroimaging
Functional ultrasound imaging (fUSI) is a portable method to image dynamic deep brain activity by directly measuring subtle cerebral blood volume changes induced by neurovascular coupling. The technology is characterized by high spatiotemporal resolution (2Hz, 100 μm) and sensitivity and is compatible with imaging in a large field of view allowing for extensive brain coverage. fUSI is non-radiative and is proven across multiple animal models (rodents, ferrets, birds, non-human primates, and humans) enabling a large range of new pre-clinical and clinical applications. For example, this technique has been applied to functional connectivity recording for diagnosis of neuropathology states, mapping of sensory cortical regions, tracking of spreading depression waves, and planning of movement. This talk will cover the fundamentals of functional ultrasound neuroimaging, including volumetric imaging and acoustic windows skull implant for clinical applications.

Alexander von Lühmann, Technische Universität Berlin, Germany
Diffuse Optical Tomography for Neuroscience in the Everyday World: Progress and Challenges
Recent advancements in system design and signal processing have established functional Near-Infrared Spectroscopy (fNIRS) as a practical and cost-efficient tool for routine, mobile, and increasingly unconstrained brain imaging. Succeeding wearable fNIRS, emerging wearable diffuse optical tomography (DOT) instruments leverage the advantages of fNIRS while further improving contrast and specificity through three-dimensional image reconstruction of functional brain activity. The shift towards experimental studies in dynamic, complex, and multisensory real-world environments presents both numerous interdisciplinary challenges and new avenues for research. In this talk, with an emphasis on instrumentation, we will explore the ongoing progress and hurdles in developing fNIRS and DOT infrastructure tailored for neuroscientific and neurotechnology applications in everyday settings.

Mahsa Shoaran, EPFL, Switzerland
Intelligent Neural Interfaces for Chronic Neurological and Psychiatric Disorders
Implantable neural interfaces hold the promise to offer new therapies for brain disorders that may no longer respond to conventional treatments. Despite significant advances in neural interface microsystems over the past decade, the small number of recording and stimulation channels and limited embedded processing in the existing clinical-grade technologies remain a barrier to their therapeutic potential. As a result, existing brain implants do not adequately meet the clinical needs for severe psychiatric illness and other disabling neurological conditions such as epilepsy and Parkinson's disease. In this talk, I will present an overview of our research on the integration of modern signal processing and machine learning techniques in neural interface System-on-Chips (SoCs) for epilepsy, movement, and mental disorders, and for the next-generation implantable brain-machine interfaces (BMIs). Our goal is to develop intelligent and highly integrated CMOS-based devices for a wide range of brain disorders in the future.

Track B: Machine Learning for Brain Discovery

Keynote: Dani Smith Bassett, University of Pennsylvania, USA
Quantifying Economy in Networks

Richard Betzel, Indiana University, USA
Edge-centric Connectomics
Network neuroscience has emphasized the connectional properties of neural elements – cells, populations, and regions. This has come at the expense of the anatomical and functional connections that link these elements to one another. A new perspective – namely one that emphasizes 'edges' – may prove fruitful in addressing outstanding questions in network neuroscience. In this talk, I highlight our recently proposed 'edge-centric' method and review its current applications, merits, and limitations.

Dominique Duncan, University of Southern California, USA
Machine Learning Techniques for Post-traumatic Epilepsy: Integrating Clinical and Preclinical Multimodal Data for Advanced Neurological Insights
The Epilepsy Bioinformatics Study for Antiepileptogenic Therapy (EpiBioS4Rx) is a multi-site, international collaboration including a parallel study of humans and an animal model, collecting MRI, EEG, and blood samples. The development of epilepsy after traumatic brain injury (TBI) is a multifactorial process and crosses multiple modalities. Without a full understanding of the underlying biological effects, there are currently no cures for epilepsy. This study aims to address both issues, calling upon data generated and collected at sites spread worldwide among different laboratories, clinical sites, in different formats, and across multicenter preclinical trials. Before these data can even be analyzed, a central platform is needed to standardize these data and provide tools for searching, viewing, annotating, and analyzing them. We have built a centralized data archive that will allow the broader research community to access these shared data as well as machine learning methods and other analytic tools to identify biomarkers of epileptogenesis in imaging, electrophysiology, molecular, serological, and tissue data.

Archana Venkataraman, Boston University, USA
Deep Imaging-Genetics to Parse Neuropsychiatric Disorders
Neuropsychiatric disorders, such as autism and schizophrenia, have two complementary viewpoints. On one hand, they are linked to cognitive and behavioral deficits via altered neural functionality. On the other hand, these disorders exhibit high heritability, meaning that deficits may have a genetic underpinning. Identifying the biological basis between the genetic variants and the heritable phenotypes remains an open challenge in the field. This talk will showcase a novel framework called GUIDE to integrate neuroimaging, genetic, and phenotypic data, while maintaining interpretability of the extracted biomarkers. Our framework uses a coupled autoencoder-classifier network to project the data modalities to a shared latent space that captures predictive differences between patients and controls. In conjunction, we have developed a biologically informed deep neural network for whole-genome analysis. This network uses hierarchical graph convolution and pooling operations that mimic the organization of a well-established gene ontology to track the convergence of genetic risk across biological pathways.

This ontology is coupled with an attention mechanism that automatically identifies the salient edges through the graph. We demonstrate that GUIDE achieves better predictive performance than other imaging-genetics methods and can identify complex biomarkers of the disorder.

Behtash Babadi, University of Maryland, College Park, USA
Advances in Granger Causality Inference with Case Studies from Auditory Neuroscience
In this talk, we will present new advances in inferring directional functional connectivity in the sense of Granger, and showcase their utility in the context of auditory processing. In particular, we show that integrating techniques from point process and state-space modeling, as well as high-dimensional inference, allows us to address several shortcomings of existing Granger causality inference. We will present applications to magnetoencephalography data from human participants under difficult listening conditions, to electrophysiology data from the ferret brain under attentive behavior, and to two-photon calcium imaging data from the mice brain under tone discrimination tasks.

Track C: Clinical Applications and Impact

Keynote: Lee Miller, Northwestern University, USA
In Pursuit of a Biomimetic iBCI for Dexterous Hand Use Following Spinal Cord Injury
My group pioneered the development of an intracortical brain computer interface (iBCI) that decodes muscle activity (EMG) from signals recorded in the motor cortex. We used these synthetic EMG signals to control Functional Electrical Stimulation (FES), causing the muscles to contract and thereby restore rudimentary control of a monkey's paralyzed hand. In the past few years, there has been much interest in the information carried by the "latent" signals within a low-dimensional neural manifold that can be computed from multi-electrode neural recordings. We have begun to examine the representation within this latent space, of a broad range of behaviors, including unconstrained, natural behaviors in the monkey's home cage, behaviors meant to better represent a person's daily activities. At the same time, we are working to develop EMG decoders for humans with spinal cord injury using these same latent signals. We hope to allow our human participants to control a prosthetic hand across a broad range of motor tasks using real-time EMG predictions input to a musculoskeletal model of the hand. Ultimately, these same decoders could be used to supply input to an FES system to allow persons with high-level spinal cord injury to control their own hands.

Jennifer Collinger, University of Pittsburgh, USA
Intracortical Brain-computer Interfaces for Computer Access at Home
Intracortical brain-computer interfaces (BCIs) have enabled impressive demonstrations showing that movement intention can be decoded to enable computer access for people with motor paralysis. However, most work to date has occurred in controlled settings using complicated laboratory-grade hardware and software. We will discuss progress towards independent operation of an intracortical BCI in the home by people with tetraplegia. This transition will enable the study of neural variability and learning in realistic environments. Our lab has expanded on previous work demonstrating BCI control of a computer mouse to investigate the potential to harness neural activity associated with individual finger movements for computer access.

Nick Ramsey, UMC Utrecht, The Netherlands
BCI Implants for Home Use

Aiko Thompson, Medical University of South Carolina, USA
Operant Conditioning of Motor Evoked Potentials to Enhance Neurorehabilitation after CNS Injuries
In this talk, we will discuss one of the emerging non-invasive neuromodulation and targeted neuroplasticity inducing methods, operant conditioning of motor evoked potentials (MEPs). Through operant conditioning of stimulus triggered muscle responses such as spinal reflexes and MEPs, a person learns and practices to produce a certain state and/or activity of a targeted neural pathway that is reflected in the size of the measured muscle response. Over time, through many repetitions, this leads to establishing a habitual behavior of the targeted neural pathway and improving its behaviors and functions. With MEP up-conditioning to increase the excitability of the targeted muscle's corticospinal pathway, plasticity can be targeted to the injury- (or disease-) weakened corticospinal drive to improve it, towards enabling more effective movement execution and inducing wider beneficial plasticity. Using several examples, we will consider what operant conditioning protocol may be applied to whom and why. In recent years, through multiple collaborations with multiple investigators, our lab has started applying various operant conditioning protocols to upper and lower extremities of people with spinal cord injury and other neurological disorders to improve sensorimotor function recovery. As we expand our translational research effort, the critical importance of rigorous scientific bases and inter-disciplinary collaborations in effective development and dissemination of new neurorehabilitation tools continues to become clearer.

Monica A. Perez, Northwestern University, USA
Are We Optimizing Our Rehabilitative Therapies Enough?
Translational research is an essential topic in rehabilitation and neuroscience. However, despite decades of research, new rehabilitation therapies and technologies have had limited impact on functional restoration from neurological disorders and

injury. I will discuss the need for work on optimizing our rehabilitative therapies and provide an example of how this effort can contribute to improving functional outcomes. Spinal cord injury (SCI) leads to damaged synaptic connections between corticospinal axons and motor neurons that innervate muscles, resulting in devastating paralysis. Injuries in humans are mostly anatomically incomplete with spared axons having malfunctioning synaptic connections. Throughout life, synapses can be modified by Hebbian plasticity (e.g., "neurons that fire together, wire together") suggesting that this principle could be used to strengthen residual connections. We have optimized a noninvasive Hebbian stimulation protocol over the years to target in parallel multiple upper- and lower- limb muscles to promote functional restoration of grasping and walking in humans with SCI. Moving from (a) proof of principle studies showing differences in how to target connections to upper- and lower-limb muscles, (b) randomized clinical trials highlighting the need for finding the optimal dose to reach the minimal clinically important difference, (3) the need to develop an animal model to continue to work on protocol optimization to improve functional restoration. Overall, our findings suggest that the optimization of Hebbian stimulation, informed by the physiology of the corticospinal system, represents an effective strategy to promote functional recovery following SCI.

IEEE Brain Neuroethics Panel

Guiding Responsible Neurotechnology Innovation – Anticipation and Responsiveness around BCIs

This 60-min session will feature engineers, neuroethicists, and end users of neurotechnologies who are contributing to different working groups of the IEEE Neuroethics Framework, and IEEE Standards Association. The session aims to foster an interdisciplinary conversation with the audience on key ethical, legal, social, and cultural considerations around the use and development of neurotechnology, using brain computer interfaces (BCIs) as a case example in three different application domains, and the importance of having technical and sociotechnical standards that are responsive to these considerations. Panelists will present a brief overview of the main ethical, legal, social, and cultural considerations identified in the use of BCIs in their respective domain of application and discuss the importance of integrating these considerations in standards. Then discussion will address two main questions: How are the identified issues overlap or are unique to a given domain of application? How can standards help towards stewardship, risk/harm vs. benefit assessment, and responsible innovation regarding BCIs for different applications? The session will conclude with identification of the ethical, legal, social, and cultural factors necessary for the design and reporting requirements of BCI research and development.

Chair: Laura Y. Cabrera, IEEE Brain Neuroethics Subcommittee Chair, Dorothy Foehr Huck and J. Lloyd Huck Chair in Neuroethics, Associate Professor of Neuroethics, Dept. Engineering Science and Mechanics, Penn State University

As a result of a snowboarding accident, ***Jennifer French*** *lives with tetraplegia due to a spinal cord injury. She is an early user of an experimental implanted neural prosthesis for paralysis and is the President and Founding member of the North American SCI Consortium, as well as the Founder and Executive Director of Neurotech Network, a nonprofit organization that focuses on education and advocacy of neurotechnologies. Jennifer has been featured in several media outlets and is an accomplished writer and speaker addressing organizations such as the National Academy of Sciences, the World Science Festival, and TEDx Talks. French has helped launch successful divisions is such organizations as Bombardier Capital and Connection, as well as several nonprofit organizations and patient/community engagement programs. French holds a B.S. in Aviation Science and an MBA. She serves on several advisory boards including the IEEE Neuroethics Initiative, Institute of Neuroethics, OpenMinds platform, BRAIN Initiative Multi-Council Working Group, and the American Bionics Project. She is the current Chair of the CDMRP Spinal Cord Injury Research Program programmatic committee. She is the author of On My Feet Again (Neurotech Press, 2013) and is co-author of Bionic Pioneers (Neurotech Press, 2014).*

Armani Porter *is the Senior Intellectual Property and Business Development Manager of Magnus Medical, a company that treats neuropsychiatric disorders using transcranial magnetic stimulation. Armani is an inventor on +10 US patents. He is also the co-founder and member of the board of DNA Bridge, a 501(c)3 organization that is focused on reuniting families that have been separated due to migration. He is responsible for starting the El Salvador family reunification program. Armani has received a BA in neuroscience and theology, an MA in Bioethics and Science Policy, and an MA in anthropology. Currently, Armani is working towards an LLM in corporate and constitutional law at the Pontifical Catholic University of Chile.*

Martijn de Neeling *is a medical doctor and Ph.D. candidate at the Amsterdam Medical Centre (AMC) in the field of adaptive deep brain stimulation (aDBS) and has been involved for several years in Brain-Computer Interfaces (BCI) research. He joined the IEEE Standards Working Group P2794 in search of improving transparency, homogeneity, and quality of neurotechnology research and is the current chair. He presented at several conferences on the topic of reporting standardization for neural interface research, including SfN, Neurotechnologies 2022, BCI Society meeting, INCF general assembly, Brain Initiative meeting, and NER. Currently, he is leading a joint effort with stakeholders from ISO/IEEE SA/INCF and the BCI society to improve and design standards for neural interface research. He aims to become a clinician-scientist (MD-PhD) involved in neurotechnology and clinical neuroscience research.*

Kim Thacker *MD, MS is a neurologist, executive, and bio/neuroethicist with more than twenty years of leadership experience in pharma and biotech. She is passionate about eldercare and neuroscience and strives to make a meaningful difference in healthcare. Dr. Thacker has expertise in medical affairs, clinical development, health economics and outcomes research, neuroethics, neurotechnology, and compliance. Dr. Thacker has authored multiple publications and successfully executed 12 drug launches. She has been working with IEEE Brain Neuroethics in the Military Working Group since its initiation. Dr. Thacker earned her medical degree at the State University of New York Health Science Center at Brooklyn. She did an internship in Internal Medicine at Danbury Hospital and residency in Adult Neurology at Long Island Jewish Medical Center, becoming Chief Resident, and a Fellowship in Epilepsy at NYU. She received her MS in Bioethics at Columbia University. Dr. Thacker is a Fellow of the New York Academy of Medicine.*

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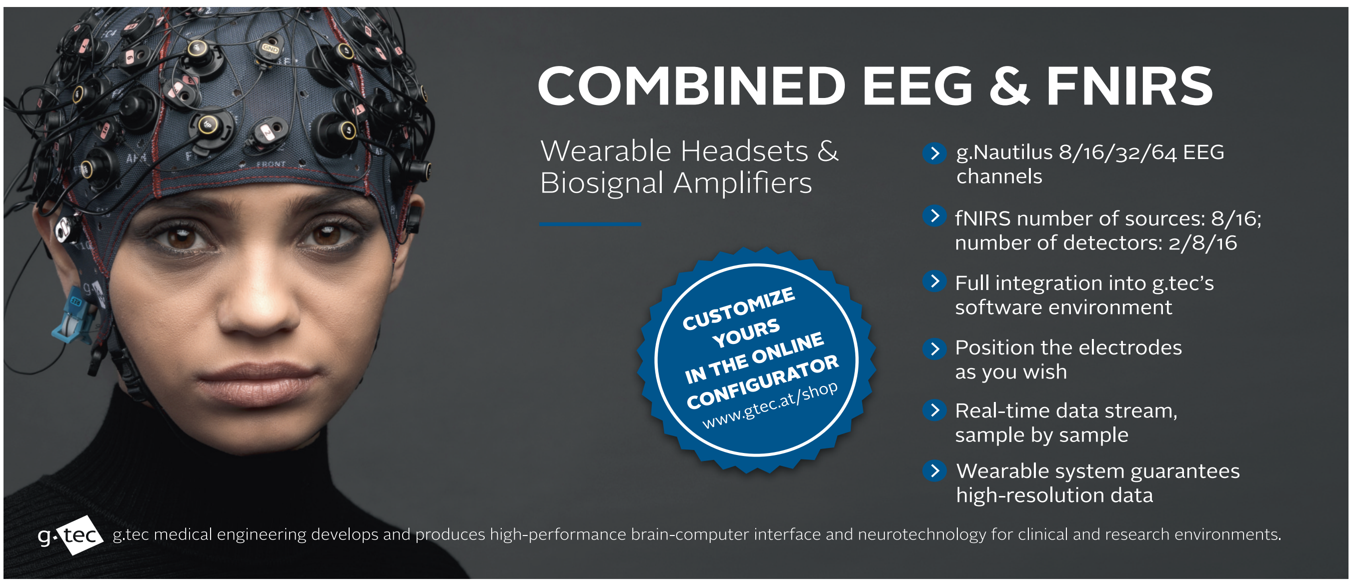

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