NATIONAL ACADEMIES Sciences Engineering Medicine

Brain-Machine and Related Neural Interface Technologies: Scientific, Technical, Ethical, and Regulatory Issues

A Virtual Workshop

September 22-23, 2022

Speaker Biographies

Abidemi Bolu Ajiboye,* Ph.D., is Associate Professor, Department of Biomedical Engineering, Case School of Engineering, at Case Western Reserve University. His main research interest is in the development and control of brain-computer-interface (BCI) neuroprosthetic technologies for restoring function to individuals who have experienced severely debilitating injuries to the nervous system, such as spinal cord injury and stroke. Currently, he is interested in understanding at a systems level the relationships between the firing patterns of multi-neuronal networks and the kinetic (muscle activity and force) and kinematic (limb position and velocity) outputs of these neural systems in the control of upper-limb movements. The end goal of his research is to develop BCI systems that allow for more natural interactions with one's surrounding environment, and more natural control of assistive technologies, such as artificial limbs and functional electrical stimulation (FES) based systems.

Ajiboye has received both a junior and senior level Career Development Award from the Department of Veteran's Affairs. He received his dual BS degree in Biomedical and Electrical Engineering, as well as a minor in Computer Science, from Duke University (Durham, NC) in 2000. He then received his Masters (2003) and Doctoral (2008) degrees from Northwestern University (Evanston, IL).

Sebastián Alvarado is an Assistant Professor at Queens College CUNY where he uses an African cichlid fish to understand molecular ecology, animal pigmentation, and behavioral neuroscience. Alvarado completed his Ph.D. at McGill University and was an A.P. Giannini Fellow at Stanford University. He is interested in how plastic molecular substrates can shape a genome to dynamic changes in the environment. Outside of his research program, Alvarado consults for the entertainment sector with Thwacke and writes books about science fiction.

Edward F. Chang,* M.D., is the Joan and Sanford Weill Chair and Jeanne Robertson Distinguished Professor of Neurological Surgery at the University of California, San Francisco.

Chang's clinical expertise is surgical therapies for epilepsy, pain, and brain tumors. He specializes in advanced neurophysiologic brain mapping methods, including awake speech and motor mapping, to safely perform neurosurgical procedures in eloquent areas of the brain.

Chang's research focuses on the discovery of cortical mechanisms of high-order neurological function in humans. His laboratory has demonstrated the detailed functional organization of the human speech

cortex and has translated those discoveries towards the development of a speech neuroprosthetic device to restore communication for people living with paralysis.

Chang is the 2015 Blavatnik National Laureate in Life Sciences and was elected to the National Academy of Medicine.

Dr. **Daniel Chao** is a neurotechnology entrepreneur, specializing in brain health and performance. Most saliently for this workshop, Chao was the founding Chief Executive Officer of Halo Neuroscience. Halo's first product, Halo Sport, is the first neurostimulation system built specifically to accelerate movement based training with applications in sports, military, musicianship, and stroke rehabilitation. Before Halo, Chao was the head of business development at NeuroPace, where he played a central role in the development of the world's first responsive neurostimulation system that was approved by the FDA for the treatment of epilepsy in a unanimous vote of 13-0. Prior to Neuropace, Chao was a management consultant at McKinsey & Company. He earned his M.D. and M.S. in neuroscience from Stanford University.

Cindy Chestek, Ph.D., is Associate Chair for Research in Biomedical Engineering (College of Engineering) and Associate Professor, Biomedical Engineering, at the University of Michigan.

Chestek's research focuses on brain machine interface (BMI) systems using 100 channel arrays implanted in motor and pre-motor cortex. The goal of this research is to eventually develop clinically viable systems to enable paralyzed individuals to control prosthetic limbs, as well as their own limbs using functional electrical stimulation and assistive exoskeletons. To move towards arm control, she is particularly interested in algorithms that better model the non-linear relationship between neural activity and the complex biomechanics of the arm. Other research areas include developing mitigation strategies for non-stationarities in neural recordings over time, and implantable wireless systems. Such systems can eliminate the transcutaneous infection risk associated with current BMIs, as well as expand the number of independent channels in the neural interface.

Jennifer Collinger, Ph.D., is an associate professor in the Department of Physical Medicine and Rehabilitation at the University of Pittsburgh with secondary appointments in the Department of Bioengineering at the University of Pittsburgh and the Department of Biomedical Engineering at Carnegie Mellon University.

Collinger's research interests are related to the use of neuroprosthetics to restore function for individuals with upper limb paralysis or loss. She has more than 10 years of experience in developing implanted brain-computer interface technology and leads the scientific efforts related to restoration of motor functions at the University of Pittsburgh. Much of this work has been conducted under an FDA Investigational Device Exemption with funding from the Defense Advanced Research Projects Agency (DARPA) and the National Institutes of Health. Her team has demonstrated high degree-of-freedom control of a robotic arm that enabled natural reaching and grasping function in people with tetraplegia. The team went on to demonstrate that tactile feedback provided by intracortical microstimulation significantly improved functional performance with a brain-controlled robotic arm. Collinger's team has also collaborated with industry partners to develop a portable intracortical brain-computer interface that enables independent computer access in the home.

Collinger is currently the President of the International Brain-Computer Interface Society. She has published on ethical guidelines for neuroscientific research using implanted neural interfaces as part of her role on the NIH BRAIN Initiative Research Opportunities in Humans Consortium and actively engages with stakeholders through her role on the NeuroAbilities Advisory Council, which is facilitated by the Global Initiative for Inclusive Information Communication Technologies (G3ict).

Tim Denison is Royal Academy of Engineering Chair in Emerging Technologies and MRC Investigator at the University of Oxford. Professor Denison holds a joint appointment in Engineering Science and Clinical Neurosciences at Oxford, where he explores the fundamentals of physiologic closed-loop systems. Prior to that, Denison was a Technical Fellow at Medtronic PLC and Vice President of Research & Core Technology for the Restorative Therapies Group, where he helped oversee the design of next generation neural interface and algorithm technologies for the treatment of chronic neurological disease.

In 2012, Denison was awarded membership to the Bakken Society, Medtronic's highest technical and scientific honor, and in 2014 he was awarded the Wallin leadership award, becoming only the second person in Medtronic history to receive both awards. In 2015, he was elected to the College of Fellows for the American Institute of Medical and Biological Engineering (AIMBE).

Denison received an A.B. in Physics from The University of Chicago, and an M.S. and Ph.D. in Electrical Engineering from MIT. He recently completed his MBA and was named a Wallman Scholar at The University of Chicago.

John P. Donoghue,** Ph.D., is the Wriston Professor of Neuroscience and Engineering at Brown University. He is known for translational research in human brain computer interfaces to restore movement for people with paralysis (known as 'BrainGate'), as well as for fundamental research on brain function. At Brown, he was the founding Chair of the Department of Neuroscience, the founder and director of the Brown Carney Brain Institute and the Department of Veterans Affairs Center for Neurorestoration and Neurotechnology. He also served as the founding Director Donoghue of the Wyss Center for Neurotechnology (Geneva) and co-founded Cyberkinetics, an early Neurotechnology start-up that developed brain computer interfaces and demonstrated their initial use in humans. Donoghue was a member of the US B.R.A.I.N. initiative's first NIH Working Group. He is a fellow of the National Academy of Medicine, American Academy of Arts and Sciences, and AIMBE. He received his PhD in Neuroscience from Brown University, MS in Anatomy from the University of Vermont, and Bachelor of Arts in Biology from Boston University; he was also a Staff Fellow in the National Institute of Mental Health of the NIH. His awards include the International Prize for Translational Neuroscience (Max Plank/Reemtsma Foundation Germany, the Roche-Nature Medicine Prize, the Schrödinger Prize (Germany), and the first Israeli Brain Technology Prize.

Veljko Dubljević, Ph.D., D.Phil. is a University Faculty Scholar and Associate Professor of Philosophy and Science, Technology & Society at NC State University. Dubljević leads the NeuroComputational Ethics Research Group at NC State, serves as a co-editor for the Springer Book Series "Advances in Neuroethics" and a member of the Board of Directors for the International Neuroethics Society. He has published over 70 peer-reviewed articles and conducted studies with conceptual and empirical (qualitative and quantitative) methods, including interviews, survey development, Delphi panels, and consensus workshops. Dubljević is the author of *Neuroethics and Justice: Public Reason in the Cognitive Enhancement Debate,* (a monograph published in the Springer Book Series **"**The International Library of Ethics, Law and Technology"). He is currently co-editing a volume titled "*Policy, Identity, and Neurotechnology: The Neuroethics of Brain-Computer Interfaces.*"

Dubljević is Principal Investigator of a current National Science Foundation CAREER grant. Before joining NC State, Dubljević spent three years as a postdoctoral fellow at the Neuroethics Research Unit at IRCM and McGill University in Montreal, Canada, where he was funded by a Banting Postdoctoral Fellowship. He initially studied philosophy and economics, and obtained a Ph.D. in Political Science (University of Belgrade). After that, he joined the research Training Group 'Bioethics' (funded by the German Research Foundation) at University of Tuebingen, and after studying philosophy, bioethics, and neuroscience there, obtained a doctorate in philosophy (University of Stuttgart).

Brandy Ellis is a Neuromodulation Patient Advocate. She participated in a Deep Brain Stimulation for Treatment Resistant Depression clinical trial with Dr. Helen Mayberg at Emory University.

Nita A. Farahany,** J.D., Ph.D. is the Robinson O. Everett Distinguished Professor of Law & Philosophy and Founding Director of the Duke Initiative for Science & Society. She is a widely published scholar on the ethics of emerging technologies, including the forthcoming book *The Battle for Your Brain: Defending Your Right to Think Freely in the Age of Neurotechnology* (St. Martin's Press 2023). Farahany is a frequent commentator for national media and radio and keynote speaker at events including TED, the Aspen Ideas Festival, the World Economic Forum, and judicial conferences worldwide. From 2010-2017, she served as a Commissioner on the U.S. Presidential Commission for the Study of Bioethical Issues. She currently serves on the National Advisory Council for the National Institute for Neurological Disease and Stroke, as an elected member of the American Law Institute, Fellow of the American Association for the Advancement of Science, immediate past President of the International Neuroethics Society, ELSI advisor to the NIH Brain Initiative and to the Defense Advanced Research Projects Agency, member of the Forum on Neuroscience and Nervous System Disorders and the Standing Committee on Biotechnology Capabilities and National Security Needs for the National Academies of Sciences, Engineering, and Medicine, the Global Future Council on Frontier Risks for the World Economic Forum. She is the Reporter for the Drafting Committee on updating the Uniform Determination of Death Committee for the Uniform Law Commission (ULC), as well as a ULC Commissioner. Farahany is a co-editor-in-chief of the Journal of Law and the Biosciences and on the Board of Advisors for Scientific American. She also serves on scientific and ethics advisory boards for corporations. Farahany holds an AB (Genetics) from Dartmouth College, an ALM (Biology) from Harvard University, and a J.D., M.A., and Ph.D. (Philosophy) from Duke University.

Andreas Forsland is the Founder and Chief Executive Officer of Cognixion, the Assisted Reality company based in Santa Barbara, California and Toronto, Ontario. Cognixion ONE is a brain-computer interface that is integrated with an augmented reality display. It has wide ranging implications as foundational technology for a future metaverse where our mind and body are immersed into the user experience. Their primary focus is ensuring that the future of AR is universally accessible with the help of biological sensors and intuitive user interfaces and designed to assist millions of people with complex disabilities using their face, eyes and now brain as a direct control interface for mobile and AR, and is addressing the needs of a half billion people worldwide with physical and communication challenges. Cognixion is recognized as a top 21 neurotech startup to watch, recently won the Red Dot Best of the Best Award for AR/VR and nominated for the Red Dot Luminary Award, the Edison Award and Singularity Global Grand Challenge, and are led by luminaries including the creator Siri, and signal processing sensor fusion for the Tricorder Xprize winner, plus multiple patents in the areas of natural user interfaces and brain computer interface for augmented reality.

Talma Hendler, M.D., Ph.D, is a professor of Psychiatry and Neuroscience at Tel Aviv University, and the founding director of the Sagol Brain Institute Tel-Aviv. She holds an M.D. from Tel Aviv University, a Ph.D. from SUNY at Stony Brook, NY, and is a licensed psychiatrist in Israel.

Hendler leads the #Neuropsychiatry & Neuromodulation research team and an associated investigator of all the other 6 research teams at the Sagol Brain Institute. She has mentored over 50 post-doctoral, doctoral and masters students, published over 130 articles and lectured at more than 75 domestic and international meetings and conferences over the past 15 years.

Throughout her scientific career, Hendler has been applying advanced brain imaging techniques, including functional magnetic resonance imaging (fMRI), Diffusion Tensor imaging (DTI) intracranial and scalp electroencephalography (EEG) and magnetic encephalography (MEG) to study processing in the healthy and diseased human brain.

Hendler's research has focused on the extensive debate over predisposing vs acquired factors in vulnerability to psychopathological conditions, mostly with respect to the effects of stress - using a prospective multi-level and multi-scale approach. More recently, her lab has pioneered the development of a new real-time imaging approach for the non-invasive identification of "neural finger-prints", that can reliably depict deep limbic areas through trans-modality learning computation (e.g. from fMRI to EEG). This novel method enables accessible bedside Brain Computer Interface procedures aimed to alleviate and/or prevent stress related psychopathologies. Hendler's accumulative work in affective neuroscience over the last two decades has paved the way for the promising utilization of imaging technologies for developing therapeutics for mental suffering.

Leigh R. Hochberg, M.D., Ph.D., is the *L. Herbert Ballou University Professor of Engineering and Professor of Brain Science* in the School of Engineering and Carney Institute for Brain Science at Brown University; *Director,* Dept. of Veterans Affairs RR&D Center for Neurorestoration and Neurotechnology (CfNN) in Providence, Rhode Island; and a Neurointensivist and Vascular Neurologist at Massachusetts General Hospital and *Senior Lecturer on Neurology* at Harvard Medical School. He also directs the MGH Center for Neurotechnology and Neurorecovery (CNTR), and is the *IDE Sponsor-Investigator* of the BrainGate clinical trials, conducted by a consortium of scientists and clinicians at Brown, Emory University, MGH, Providence VA, Stanford, and University of California, Davis. Hochberg's research focuses on the development and testing of novel neurotechnologies to help people with paralysis and other neurologic disorders.

Hochberg is a Fellow of the American Academy of Neurology and the American Neurological Association. His research with the collaborative BrainGate team has been honored with the Joseph Martin Prize in Basic Research, the Herbert Pardes Prize for Excellence in Clinical Research, the first Israel Brain Technologies international B.R.A.I.N. Prize, presented by President Shimon Peres, the Derek Denny-Brown Young Neurological Scholar Award, the CERF Prize in Medical Engineering, and the Paul B. Magnuson Award. Hochberg's BrainGate research, which has been published *Nature, Lancet, Science Translational Medicine, eLife, the Journal of Neuroscience, the Journal of Neural Engineering,* and others, is supported by the Rehabilitation R&D Service of the U.S. Department of Veterans Affairs, the National Institutes of Health including the BRAIN Initiative/NINDS and NIDCD, and philanthropies including the ALS Association, the American Heart Association, and the Cerebral Palsy Alliance Research Foundation.

Marcello Ienca,* Ph.D., is a Principal Investigator at the College of Humanities at the Swiss Federal Institute of Technology in Lausanne (EPFL), where he leads the Intelligent Systems Ethics group. He is also a member of the Competence Center for Rehabilitation Engineering & Science at ETH Zurich. His scholarship focuses on the ethical, legal, social and policy implications of emerging technologies. Ienca is an appointed member of the Organisation for Economic Co-operation and Development's (OECD) Steering Committee on Neurotechnology, an expert advisor to the Council of Europe's Bioethics Committee and a Board Member of the Italian Neuroethics Society. He has received awards for social responsibility in science and technology such as the Vontobel Award for Ageing Research, the Prize Pato de Carvalho, the Sonia Lupien Award, the Paul Schotsmans Prize from the European Association of Centres of Medical Ethics and the Data Privacy Plaque of Honour. He has authored one monograph, several edited volumes, 60 scientific articles in peer-review journals, and is a contributor to *Scientific American*. His research was featured in journals such as *Neuron, Nature Biotechnology, Nature Machine Intelligence, Nature Medicine* and media outlets including *Nature, The New Yorker, The Guardian, The Times, Die Welt,* and *The Financial Times.*

Michael Kahana is Edmund J. and Louise W. Kahn Term Professor of Psychology at the University of Pennsylvania. Kahana received a B.A. from Case Western Reserve University and a Ph.D. in psychology from the University of Toronto.

Kahana researches human memory and its neural mechanisms. He is interested in human episodic memory for verbal, visual and spatial information. To study this general problem, he conduct experiments that measure behavioral and electrophysiological responses during memory tasks, and develop computational models to explain the resulting data. Kahana's lab is one of several in the world studying the electrophysiological responses of neurons through direct intracranial electroencephalographic (iEEG) recording from the living human brain. Such recordings can be obtained from epilepsy patients who have had electrodes surgically implanted on the cortical surface of the brain or through the medial temporal lobes (including hippocampus) as part of the clinical process of localizing seizure foci. By analyzing how brain activity, including the responses of individual neurons, correlates with task variables, the lab is able to study the neurophysiological basis of memory with a high degree of spatial and temporal resolution. Current projects include studies of spatial navigation using a virtual taxi driver game, and computational modeling of the role of temporal context in visual and verbal memory.

Andrew Krystal is the Ray and Dagmar Dolby Distinguished Professor in the Departments of Psychiatry and Neurology, Vice-Chair for Research in the Department of Psychiatry, Director of the Dolby Family Center for Mood Disorders, Director of the University of California, San Francisco Interventional Psychiatry Program and Co-Director of the TMS [transcranial magnetic stimulation] & Neuromodulation Clinic. Dr. Krystal is Board Certified in Clinical Neurophysiology by the American Board of Clinical Neurophysiology and the American Board of Psychiatry and Neurology and Board Certified in Psychiatry by the American Board of Psychiatry and Neurology. He is a pioneer in the application of computational modeling to the study of biomarker development using electroencephalogram (EEG) in patients with depression and sleep disorders and application of biomarkers in treatment development clinical trials. He also has extensive experience in clinical and research personalization of therapies for the treatment of patients with mood disorders. He has been the principal investigator of more than 50 single-site and multi-site clinical trials

Dr. **Paul Larkin** trained as a neuroscientist, studying neurodegenerative disease at the University of California, San Francisco and Stanford University. After completing post-doctoral studies, he spent several years working in commercialization of life science innovations. Most recently, Larkin joined the ALS Association as Director of Research where he oversees grant-making activities for a diverse portfolio of amyotrophic lateral sclerosis (ALS) research projects.

Geoffrey Ling is a pharmacologist and physician and co-founder and Chief Executive Officer of On Demand Pharmaceuticals. Clinically, Dr. Ling is a professor of neurology, neurosurgery, and anesthesiology at Johns Hopkins University and the Uniformed Services University of the Health Sciences, and an attending neuro critical care physician at Johns Hopkins Hospital. He was previously the Founding Director of the Biological Technologies Office (BTO) at the Defense Advanced Research Projects Agency (DARPA), where he was also a program manager. He was also an Assistant Director in President Obama's White House Office of Science and Technology Policy. Ling is a retired U.S. Army colonel after 21 years on active duty. He served as a neuro-intensive care physician with the 452nd CSH (combat support hospital) in OEF-Afghanistan (2003) and 86th CSH and 10th CSH in OIF-Iraq (2005) as well as on all 4 Gray Team missions (2009, 2011) to evaluate TBI and PTSD clinical care in the war theaters.

Justin Lowery is a BrainGate clinical trial participant. BrainGate is an investigational system that utilizes an array of micro-electrodes implanted into the brain to allow neural signals associated with the intent to move a limb to be "decoded" by a computer in real-time and used to operate external devices.

Ana Maiques is the Chief Executive Officer of Neuroelectrics, a company aiming to change the way we interact with the brain, developing innovative technologies to monitor and stimulate the brain to help many patients in need. She was nominated by IESE Business School as one of the most influential entrepreneurs under 40 in Spain in 2010. Maiques received the EU Prize for Women Innovators from

the European Commission EC in 2014. In 2015 and 2016, she was named one of the most inspiring women on the Inspiring Fifty list in Europe.

In 2022, together with eight other Spanish scale-ups, Maiques co-founded EsTech, an organization of high-growth companies that want to make more visible the impact of a new productive model. She recently joined the European Innovation Council Advisory Board, the pan-European organism that aims to scale up European companies. Maiques continues breaking the barriers of science and technology in an impactful way with business ethics.

Helen S. Mayberg,* M.D., is Professor of Neurology, Neurosurgery, Psychiatry and Neuroscience and the Mount Sinai Professor in Neurotherapeutics at the Icahn School of Medicine where she serves as founding Director of the Nash Family Center for Advanced Circuit Therapeutics. A neurologist, Mayberg is recognized for her neuroimaging studies of brain circuits in depression and their translation to the development of deep brain stimulation as a novel therapeutic for treatment resistant patients. She now leads a patient-focused transdisciplinary research team with the shared mission to advance precision surgical treatments for complex neuropsychiatric disorders. She is a member of the National Academy of Sciences, the National Academy of Medicine, the National Academy of Inventors, the American Academy of Arts and Sciences, the Johns Hopkins University Society of Scholars, fellow of the AAAS and President Elect of the American College of Neuropsychopharmacology. Mayberg received a B.A. in Psychobiology from the University of California, Los Angeles and an M.D. from the University of Southern California, trained in Neurology at the Neurological Institute at Columbia and did a research fellowship in nuclear medicine at Johns Hopkins.

Vivian Mushahwar is a Professor in the Division of Physical Medicine and Rehabilitation at the University of Alberta. An engineer by training (electrical), Dr. Mushahwar obtained her Ph.D. in biomedical engineering from the University of Utah. Research in the Mushahwar lab focuses on many aspects such as the restoration of standing and walking after spinal cord injury and the detection and prevention of deep tissue pressure sores using functional electrical stimulation (FES) techniques. The Mushahwar lab is working with other groups of the Project SMART team to develop implantable devices that utilize intraspinal microstimulation (ISMS) to stimulate the "control centre" for standing and stepping in the spinal cord and thereby restore this ability after spinal cord injury. In addition, in collaboration with researchers in the Stein, Chan, and Dukelow research groups, Mushahwar's lab is developing a garment to detect and prevent the onset of pressure sores in wheelchair and bed ridden patients.

Dr. **Carlos Peña** is Chief Regulatory Officer and Chief Quality Officer, leading the newly-established Offices of Regulatory Services and Office of Quality Services at the Jacobs Institute (JI), in Buffalo, New York. Prior to the JI, Peña served 20+ years as a public servant in federal government, including his most recent appointment as Director of the Office of Neurological and Physical Medicine Devices, at the Center for Devices and Radiological Health (CDRH), U.S. Food and Drug Administration (FDA). While at the FDA, he also served on detail as Assistant Director of Emerging Technologies in the White House Office of Science & Technology Policy, within the Executive Office of the President of the United States.

Dr. **Vivek Pinto** is Director for the Division of Neuromodulation and Physical Medicine Devices in the Office of Neurological and Physical Medicine Devices at the U.S. Food and Drug Administration. Pinto has been with the agency for the past decade reviewing premarket and postmarket submissions for medical devices. He has experience making regulatory decisions on array of device types including deep brain stimulation, brain computer interface devices, vagal nerve stimulator, digital therapeutics, assistive devices, and non-invasive rehabilitation devices, among others. Prior to joining the FDA, Pinto received his B.S. degree in Mechanical Engineering from the University of Pittsburgh along with design and manufacturing experience at Mine Safety Appliances. In addition, into received his M.S. and Ph.D. degrees from New York University (NYU) in Ergonomics and Biomechanics while conducting clinical trials

research for the NYU Hospital for Joint Diseases. He is currently enrolled in an Executive MBA program at New York University with an expected graduation in 2024.

Gina Poe,* Ph.D., is Professor, Department of Integrative Biology and Physiology, University of California, Los Angeles (UCLA). Poe has been working since 1995 on the mechanisms through which sleep serves memory consolidation and restructuring. Poe is a southern California native who graduated from Stanford University then worked for two post-baccalaureate years at the VA researching Air Force Test Pilots' brainwave signatures under high-G maneuvers. She then earned her Ph.D. in Basic Sleep in the Neuroscience Interdepartmental Program at UCLA under the guidance of Ronald Harper then moved to the University of Arizona for her postdoctoral studies with Carol Barnes and Bruce McNaughtons looking at graceful degradation of hippocampal function in aged rats as well as hippocampal coding in a 3-D maze navigated in the 1998 space shuttle mission. Poe brought these multiunit teachings to answer a burning question of whether REM sleep were for remembering or forgetting and found that activity of neurons during REM sleep is consistent both with the consolidation of novel memories and the elimination of already consolidated memories from the hippocampus, readying the associative memory network for new learning the next day. Moving first to Washington State University then to the University of Michigan before joining UCLA in 2016, Poe has over 80 undergraduates, 6 graduate students, and 6 postdoctoral scholars, and has served in university faculty governance as well as leading 5 different programs designed to diversify the neuroscience workforce and increase representation of people of the global majority in the STEM fields. At UCLA, she continues research and teaching and Directs the COMPASS-Life Sciences and BRI-SURE programs and co-Directs the MARC-U*STAR program. Nationally she is course director of the Marine Biological Lab's SPINES course and co-Directs the Society for Neuroscience's NSP program which earned the nation's highest mentoring honor in 2018. These programs have served over 600 PhD level trainees over the years.

Rajesh P. N. Rao is the CJ and Elizabeth Hwang Professor in the Paul G. Allen School of Computer Science and Engineering and Department of Electrical and Computer Engineering at the University of Washington (UW), Seattle. He is the co-Director of the Center for Neurotechnology (CNT), Adjunct Professor in the Bioengineering department, and faculty member in the Neuroscience Graduate Program at UW. He directs the Neural Systems Laboratory in the Paul G. Allen Center for Computer Science and Engineering and is an IEEE Senior Member. His awards include a Guggenheim Fellowship, a Fulbright Scholar award, an NSF CAREER award, an ONR Young Investigator Award, a Sloan Faculty Fellowship, and a David and Lucile Packard Fellowship. His primary research interests are in computational neuroscience, brain-computer interfaces, and artificial intelligence, with secondary interests in the Indus script and classical Indian paintings.

Kate Rosenbluth,* Ph.D., is the Chief Scientific Officer and Founder of Cala Health, a company she spun out from Stanford University that merges cutting-edge neuroscience to neurotechnology to advance novel bioelectronic therapies. She is an Adjunct Faculty member of the Department of Medicine at Stanford University, where she lectures on innovation, science, technology, ethics, regulatory and reimbursement. She has authored more than 60 patents and peer-reviewed publications, and developed cutting-edge neurotherapies with Brainlab, Autonomic Technologies, and Genentech. She completed postdoctoral fellowships in University of California, San Francisco (UCSF) neurosurgery and Stanford Biodesign and a Ph.D. in Bioengineering at the University of California, Berkeley and UCSF. She currently serves on the Board of Directors of Cala Health and CloudCath, and serves on the Strategy Group of the Center for Healthcare Innovation and the Stanford Digital Health Working Group.

Gaurav Sharma, Ph.D., is the Chief Scientist at the 711th Human Performance Wing at Air Force Research Laboratory. He is the primary science and technology advisor to the Wing commander and provides technical vision and strategy for the Wing's science and technology plans, and coordinates with other Department of Defense organizations, academic institutions, and industrial partners. Prior to joining AFRL, Sharma was at Battelle Memorial Institute where he co-created and led the NeuroLife

program to develop groundbreaking neural bridging technologies that helped a paralyzed individual regain control of his hand using an implanted Brain Computer Interface (BCI). He was also the PI on DARPA's Next-generation Non-surgical Neurotechnologies (N3) program where he led a multidisciplinary team to develop novel, minutely invasive, injectable BCIs to improve Airmen performance.
Sharma attended Rutgers University and Northeastern University where his research was foundational in the field of bionanotechnology. His work has been widely covered in the media and published in high impact journals including *Nature, Nature Medicine* and *Cell*. He has more than 10 patents (granted and filed) and has won three R&D 100 Awards, BCI Best Technology Award and Battelle's President's Achievement Award.

The Honorable **David S. Tatel** was appointed to the United States Court of Appeals for the District of Columbia Circuit in October 1994. Judge Tatel earned his undergraduate degree from the University of Michigan and his J.D. from the University of Chicago. Among other things, he has served as Director of the National Lawyers' Committee for Civil Rights Under Law and Director of the Office for Civil Rights of the U.S. Department of Health, Education and Welfare during the Carter Administration. Returning to private practice in 1979, Tatel joined Hogan & Hartson, where he founded and headed the firm's education practice until his appointment by President Clinton to the D.C. Circuit. Tatel currently co-chairs the National Academy of Sciences, Engineering, and Medicine's Committee on Science, Technology, and Law and serves on the board of Associated Universities, Inc. He is a member of the American Philosophical Society and the American Academy of Arts and Sciences.

Krishnan Thyagarajan is a physicist leading teams to help deliver solutions to technically hard problems in the domains of Healthcare and Neurotechnologies, among many other pressing needs of society. His recent work has revolved around electromagnetic and acoustic solutions for invasive and non-invasive brain stimulation. He was a Principal Investigator for the Defense Advanced Research Project Agency's (DARPA) Next-generation Non-surgical Neurotechnologies (N3) program where he led a multidisciplinary team across industry and academia, to develop high-precision magneto-acoustic non-invasive deep-brain BCIs. He was also a technical PI on NIH's BRAIN Initiative program to develop implants for localized magnetic stimulation of the visual and motor cortices. As the research area manager of the Sensors, Devices, and Systems group at the Palo Alto Research Center (PARC), a Xerox company, he also works with a group of other curious scientists to tackle problems spanning climate change, food security, and secure communication, and keenly engages as a thought leader in policy and ethics-relevant discussions in these domains. His projects have been funded by diverse agencies across the globe, including Federal governments (Asia, North America, Europe) and Fortune 100 companies, and his scientific work has been featured in the *MIT Technology Review*, *Science*, *IEEE Spectrum*, *Popular Mechanics*, and *GeekWire*.

Dr. Thyagarajan obtained his B.S. in Physics from the University of Delhi (India) and his M.S. and Ph.D. degrees in Physics from the École polytechnique fédérale de Lausanne (EPFL, Switzerland), before spending a few years as the Swiss National Science Foundation Fellow at the Thomas J. Watson Labs of Applied Physics and Materials Science at the California Institute of Technology (Caltech), Pasadena.

Douglas Weber is Akhtar and Bhutta Professor, Mechanical Engineering, Neuroscience Institute, Carnegie Mellon University.

Weber is broadly interested in understanding the role of sensory feedback in supporting and regulating a wide range of perceptual, motor, cognitive, and autonomic functions. His research combines fundamental neuroscience and engineering research to understand physiological mechanisms underlying sensory perception, feedback control of movement, and neuroplasticity in sensorimotor systems. Knowledge gained from these studies is being applied to invent new technologies and therapies for enhancing sensory and motor functions after stroke, spinal cord injury, or limb loss. These principles are also being applied to develop wearable devices for enhancing sensory, motor, and cognitive functions in healthy humans. He is committed to transitioning outputs of his academic

research into practical technologies that support real-world applications, and he works actively with industrial partners to bridge the gap from bench to market.

A founding member of the Defense Advanced Research Agency's (DARPA) Biological Technologies Office, Weber created and managed a portfolio of neurotechnology research programs to support the White House BRAIN initiative, launched by President Obama in 2013. He created DARPA's HAPTIX, ElectRx, and TNT programs, which are developing implantable, injectable, and wearable neurotechnologies that restore natural motor and sensory functions for amputees, enable novel and drug-free therapies for treating inflammatory disease and mental health disorders, and promote plasticity in the brain to enhance learning of complex cognitive skills.

Weber completed post-doctoral training in the Centre for Neuroscience at the University of Alberta. He holds eight issued United States patents and has published extensively on a wide range of topics spanning sensorimotor neurophysiology, biomechanics, neural engineering, and physical medicine. He has mentored over 100 undergraduate, graduate and medical students and several post-doctoral fellows.

Dr. **Cristin Welle** is an Associate Professor and Vice-Chair for Research in Neurosurgery at the University of Colorado School of Medicine. She runs the BIOElectrics Lab, which investigates circuit-level structure and function in the context of translational neurotechnology. They explore how neurotechnology can be used to drive neuroplasticity in the healthy and injured nervous system, by using in vivo imaging, electrophysiology and optogenetics in animals models. Before moving to the University of Colorado, Welle led a research group at the Center for Devices and Radiological Health, U.S. Food and Drug Administration (FDA), with a focus on safety and performance of novel Brain Computer Interface technology. While at the FDA, Welle also led public workshops to engage the scientific and regulatory neural interface communities, and participated in regulatory reviews of over 100 neurological submissions.

***Member of Workshop Planning Committee**
****Co-chair of Workshop Planning Committee**