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RECENT ADVANCES IN NEUROSCIENCE RESEARCH

HIGHLIGHTS FROM THE 8TH INTERNATIONAL BRAIN RESEARCH ORGANIZATION MEETING, HELD JULY 14-18, 2011, FLORENCE, ITALY

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SUMMARY

The 8th International Brain Research Organization (IBRO) meeting focused on recent advances in neuroscience research in different fields from genetic, molecular, cellular, anatomical, neurophysiological system, comparative, evolutionary, computational and behavioral evidence, raising new hopes for the treatment of disorders and diseases of the nervous system. The IBRO meeting continued for 4 days of scientific meetings, poster presentations and other opportunities to discover "better scientific knowledge of the brain while promoting rationality and a committed search for truth among neuroscientists from all countries in the world." In conclusion, the IBRO meeting was specifically aimed at findings on treatment strategies, as well as encouraging information transfer from the clinic back to the basic research arena, and contributing to the breadth of the field of neuroscience and its creative use of all the tools of modern biology to understand neural function in health and disease in the 21st century. The 9th IBRO meeting will be held at Rio de Janeiro, Brazil, in 2015 and will be an excellent platform to discuss new strategies and tools that can connect and engage scientific and public conversation to advance knowledge, learning and engagement about the brain.

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INTRODUCTION

The International Brain Research Organization (IBRO) was founded in 1961 in response to the growing demand from neuroscientists in many countries for the creation of a central organization that would cut across world boundaries and improve communication and collaboration among brain researchers. The origin of IBRO can be traced back to a meeting of electroencephalographers in London in 1947, which led to the establishment of an International Federation of EEG and clinical neurophysiology. At a conference of this group and others in Moscow in 1958, there was unanimous support for a resolution proposing the creation of an international organization representing brain research worldwide. This plan was welcomed by UNESCO, and in 1960, IBRO was established as an independent, non-governmental organization.

The IBRO World Congress of Neuroscience is a seminal, worldwide event reflecting IBRO's core mission of promoting international collaboration and exchange of scientific information. As compared with other scientific events in the neuroscience field, the IBRO meeting is characterized by the strong participation of researchers and scientists from emerging countries in Asia and Africa, in addition to those coming from the European Union and the Americas, and in the strong encouragement in the participation of young people from all over the world. The 8th IBRO meeting took place in Florence and coincided with a very special event, the 50th anniversary of IBRO. The meeting attracted 4,200 attendees, among whom 1,500 were from economically disadvantaged countries, underlining how effective IBRO is as a worldwide organization in neuroscience. An exciting parenthesis was the Young Investigator Program (YIP) that allowed

83 young researchers from economically disadvantaged countries to spend 1 month in European laboratories before participating at the IBRO meeting. The regions of origin of the students were: Latin America (29), Africa (19), Asia (31) and Eastern Europe (4). The YIP provided PhD students and postdocs an excellent opportunity to establish collaborations and learn new techniques, and offered a wonderful opportunity for Western European researchers to expand their view on neuroscience research in the world. This meeting, by offering the opportunity of exchanging scientific information to researchers from 86 different countries throughout the world, paved the way for a more efficient exchange of information and growth of scientific knowledge, opening up new avenues of research in genetic, molecular, cellular, anatomical, neurophysiological system, computational and behavioral neuroscience, and raising new hopes for the treatment of disorders and diseases of the nervous system. Topics discussed at the meeting included neurogenetics, neural plasticity, neurodegeneration and aging, neuroimaging, neuroinformatics, computational neuroscience, neuroelectronics, neurorobotic interfaces and neuroethics.

NEUROIMAGING: VISUALIZING BRAIN STRUCTURE AND FUNCTION

Techniques such as near infrared spectroscopy, positron emission tomography, computerized axial tomography and functional magnetic resonance imaging are used to diagnose brain disorders and levels of consciousness. Neuroimaging falls into two broad categories: 1) structural imaging, which deals with the structure of the brain and the diagnosis of gross (large-scale) intracranial disease (such as tumors) and injury; and 2) functional imaging, which is used to diagnose metabolic diseases and lesions on a finer scale (such as Alzheimer's disease), and also for neurological and cognitive psychology research and building brain–computer interfaces. Because of its high-resolution imaging and the ability to provide real-time visualization, it is easy to visualize the development of early brain structures and spinal cord in utero and guide pulled-glass needles for injections of cells, drugs, genetic material or metabolic agents into developing small animals. Besides many neurobiological applications, including the study of embryonic and neonatal brain development, cell lineage and progressive neural degenerative diseases associated with small animal models, cerebral blood flow can also be visualized and quantified for better assessment of disorders and angiogenesis studies. Furthermore, the noninvasive nature of the system allows for longitudinal study of the same animal. Research is progressing to see if and how these technologies can be used to analyze behavior or identify an individual.

NEUROETHICS

Neuroethics was defined as "the study of the ethical, legal, and social questions that arise when scientific findings about the brain are carried into medical practice, legal interpretations, and health and social policy." In other words neuroethics is "the examination of what is right and wrong, good and bad about the treatment of, perfection of, and welcome invasion or worrisome manipulation of the human brain." Neuroethics encompasses the myriad ways in which developments in basic and clinical neuroscience intersect with social and ethical issues. The field is so young that any attempt to define its scope and limits will now undoubtedly be proven wrong in the future as neuroscience develops and its implications continue to be revealed. At present, however, we can discern two general categories of neuroethical issues: those emerging from what we can do and those emerging from what we know. In the first category are the ethical problems raised by advances in functional neuroimaging, psychopharmacology, brain implants and brain–machine interfaces. In the second category are the ethical problems raised by our growing understanding of the neural bases of behavior, personality, consciousness and states of spiritual transcendence. Keeping this in mind, the Neuroethics Research Unit located at the Institut de Recherches Cliniques de Montréal was the first Canadian unit dedicated to neuroethics research and constitutes an active international center for the development of applied interdisciplinary neuroethics research. Their main focus is on the progress and success in developing novel interdisciplinary initiatives to deal with ethical issues related to: 1) innovative research areas in neuroscience (e.g., functional neuroimaging, deep brain stimulation); 2) the ethical integration of neuroscience to clinical care (e.g., disorders of consciousness, cerebral palsy); and 3) intercultural and public neuroethics (e.g., public understanding).

Future challenges for the development of neuroethics nationally and worldwide include developing international partnerships and sustaining capacity building efforts to generate wide and high-level expertise in education, research and policy.

NEUROGENETICS

Genetic methodologies are having a rapidly increasingly impact on studies of the normal and diseased nervous system. To date, more than 200 genes have been identified that cause or contribute to neurological disorders. It is essential that neuroscientists exploit the power of modern molecular genetics and use sequencing information of the human genome. The past three decades, we have witnessed remarkable advances in our understanding of the molecular etiologies of hereditary neurodegenerative diseases, which have been accomplished by "positional cloning" strategies. The discoveries of the causative genes for hereditary neurodegenerative diseases accelerated not only the studies on the molecular mechanisms of diseases, but also studies for the development of disease-modifying therapies. Genome-wide association studies (GWAS) based on the "common disease–common variants hypothesis" are currently undertaken to elucidate the disease-relevant alleles. Although GWAS have successfully revealed susceptibility genes for neurodegenerative diseases, the rapidly improving technologies of next-generation sequencing enable researchers to identify all the variants in an individual's personal genome, in particular, clinically relevant alleles. To accomplish the aim of personal genome analysis, interdisciplinary research activities integrating comprehensive genome analysis, informatics and clinical information and resources will be essential.

NEUROINFORMATICS

The mammalian brain is a large network of neurons (approx. 108 in rodents and up to 1,011 in humans), sparsely interconnected by synapses (approx. 104 per neuron). Most synapses are directional contacts between extensive tree-like structures, namely the axon of the sending (output) neuron and the dendrite of the receiving (input) neuron. The ongoing assembly of complete maps of such circuits ("connectomes") is crucial to understanding the brain structure–function relationship. Yet analyzing and interpreting the forthcoming connectomic data remains an unsolved challenge, particularly in light of the huge number of neural connections expected in a single brain map. Although the exact connectivity pattern of each neuron is unique, the common working assumption posits the existence of distinct "neuronal classes", where neurons in the same class share similar connectivity patterns compared to neurons in different classes. Nonetheless, a rigorous definition of a neuronal class is still lacking, and even the order of magnitude of the number of neuronal classes is a source of wide disagreement. Scientists introduce a probabilistic model that formalizes the concept of neuronal class based on network connectivity. Given a complete list of all neurons and their connections in a network, a technique is used to estimate the number of neuronal classes and an assignment of each neuron to a class. A connectome was modeled using a random dot product model. The connection probability is determined by the dot product of latent vectors associated with the pre- and postsynaptic neurons. The model was fitted using sparse singular value decomposition, and cluster the latent vectors into groups, which define the proposed neuronal classes. Using neurobiologically realistic surrogate data, we demonstrate that this approach is robust and computationally tractable. This model provides both a practical and theoretical foundation to bridge neuronal- and system-level neuroanatomy.

NEUROELECTRONICS AND NEUROROBOTIC INTERFACE

Neuron types are in general operationally described based on their properties, e.g., electrophysiological, morphological, molecular, developmental, functional and connectivity. Such descriptions are usually expressed in natural language, optimizing intuitive understanding and human communication. For a computational consumption, this knowledge must be expressed into a machine-readable form. The conversion should be sufficiently flexible to enable wide applicability, balancing rigorous logic, algorithm efficiency and accessibility to neuroscience experts. This poses a challenge in neuroscience and its application fields, such as brain–machine interfacing and robotics to establish bidirectional communication (recording and stimulation) with the brain at high spatial resolution through innovative neuronal probes. Attempts so far have been based on microscale processing of metals, inorganic semiconductors as electrodes or photoactive layers in biased devices, and more recently, nanomaterials have been investigated. However, despite extensive research, the communication between biological tissues and artificial sensors is still a challenge. Constraints exist in the complexity of the fabrication processes (that is, metal and semiconductor lithography) and the mechanical properties of the implanted sensing/recording elements (poor flexibility and biocompatibility) that could elicit deleterious tissue reactions such as inflammation and gliosis. In addition, electrodes have fixed geometries that limit the location in space of the stimulus, and electrical currents are often detrimental to the overall system. Recently, organic soft matter showed the potential in terms of flexibility, favorable mechanical properties and biological affinity. The use of semiconducting polymers has been reported in mechanical actuators for precise delivery of neurotransmitters, and in biosensors, such as pH and glucose sensors, in which their ability to support mixed ionic/electronic charge transport was fully exploited. Conversely, organic polymers have been tested as coatings of conventional electrodes in direct neuronal interfaces for recording and stimulating neuronal activity, whereas the exploitation of their appealing optoelectronic features has never been considered for neuronal communication and photo manipulation devices.

CONCLUSIONS

In the last two decades, neuroscience research has made a giant leap forward. The emergence of sophisticated genetic and molecular tools, with the advancement in neuroelectronics and neurorobotics, combined with imaging techniques of unprecedented spatial and temporal resolution, and their application to in vivo models of major brain diseases, has allowed spectacular progress in our understanding of the structure and function of the brain in health and disease. The 9th IBRO meeting will be held in Rio de Janeiro, Brazil, in 2015 and will be an excellent platform to discuss new strategies and tools that can connect and engage scientific and public conversation to advance knowledge, learning, and engagement about the brain.

For further information see References.

DISCLOSURES

The authors state no conflicts of interest.

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