The human connectome in light of evolution

Stephanie Forkel Co Organizer
King's College London
London, Greater London
United Kingdom

Katherine Bryant, PhD Organizer
University of Oxford
Wellcome Centre for Integrative Neuroimaging
Oxford
United Kingdom

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Symposium
In recent years, the number of researchers involved in evolutionary-informed analysis of human and primate brains has grown, as evidenced by the 2015 and 2018 Cortical Evolution Conferences, the 2019 Brain and Behavioural Evolution in Primates conference in Erice, Italy, and the 2019 Comparative Neuroimaging Workshop in Dusseldorf, Germany and the PRIME-DE Global Collaboration Workshop in London (Neuron in press). The development of sophisticated techniques for imaging nonhuman brains, including postmortem brains, combined with the open data movement, is creating an opportunity for neuroimagers interested in human brain specializations (language, tool use, social behavior) to probe the anatomical substrates as well as the phylogeny of these abilities with novel comparative datasets.

Objective

After attending this symposium, attendees should know more about evolutionary-informed approaches to connectomics, become familiar with some of the basics of evolutionary analyses, and get perspective on the breadth of species which are being studied with comparative neuroimaging techniques and what new research questions these datasets will facilitate. Specifically, the learning objectives are:

1. Learn basic principles of evolutionary analyses of neuroimaging data
2. Understand some of the recent methodological developments in comparative connectomics
3. Learn where they can access comparative neuroimaging datasets for their own use in research

Target Audience

The target audience will be researchers who are interested in seeing how evolutionary approaches can inform and enrich their research questions, and researchers who wish to learn about methods and analyses for evolutionary neuroscience research. This symposium will be of special interest to those who study structural and functional connectivity.

Presentations

Plasticity and learning in ontogeny and phylogeny

Humans are characterized by exceptional behavioral flexibility. Our species' archetypal adaptation is, arguably, our surprising lack of innate physical adaptations to the environmental niches we have colonized: instead, we rely on individual problem solving, social learning, and cumulative cultural transmission of increasingly-complex learned adaptive solutions to environmental problems. How has this "anti-trait" evolved, and on what neural mechanisms does it rely? How have our brains acquired innate predispositions toward certain domains of learned skills, and what features unite the skill domains for which humans show an innate predisposition to learn? In this talk, I will examine these questions can be examined via a combination of comparative neuroscience research and neuroarchaeological research, which uses modern humans as model organisms for our recent hominid ancestors. In one line of studies, we have measured experience-dependent plasticity in the white matter and gray matter of modern humans as they undergo in-depth, hands-on, real-world training for Paleolithic stone toolmaking skills. Results indicate that some pre-training neural phenotypes are associated with increased skill acquisition and neural plasticity during and after training. Furthermore, the implicated circuits show evidence of progressive evolved change from the monkey-ape last common ancestor, to the ape-human LCA, to humans. This suggests that recently evolved human neural traits exist in order to support skill learning, including socially learned technological skills.

Presenter

Erin Hecht, PhD, Harvard University Cambridge, MA
United States

Imaging brain evolution: the next frontier

The past decade has seen tremendous progress in terms of magnetic resonance imaging applied to several species. We are now able to compare anatomical features across species and, by doing so, infer evolutionary principles. Thanks to open data initiatives, this endeavor is within everybody's reach, but requires sophisticated analyses plus good theoretical knowledge. This lecture will be dedicated to the description of some of the leading evolutionary theories and has the purpose to boost curiosity as well as motivate the neuroimaging community to develop tools and run analyses to build the first brain evolutionary tree.

Presenter

Michel Thiebaut de Schotten, BCBlab Bordeaux, Aquitaine
France

Variability of structural connections within and between the species

A large amount of variability exists across human brains; revealed initially on a small scale by postmortem studies and, more recently, on a larger scale with the advent of neuroimaging. MRI-based diffusion-weighted imaging tractography has been used to segment whole brain tractograms and study the subdivisions of the living human brain based on its anatomical connectivity. In recent years, this method has evolved as a comparative anatomy tool allowing us to study the in vivo anatomy on a large scale and across species. Tractography studies revealed some shared and unique patterns of structural connectivity within and across species. During this lecture, I will present some recent MRI-based diffusion imaging applications to study the variability within and across species with a special focus on the frontal and parietal white matter pathways.

Presenter

Stephanie Forkel, King's College London London, Greater London
United Kingdom

Neurophylogenetic approaches to human brain mapping

Humans possess uniquely complex cognitive skills, including language, tool manufacture and use, and large-scale cooperation. Rather than studying the human brain in isolation, examining the human brain in context with our closest relatives, primates, as well as members of other mammalian taxa, can help us pinpoint the structural specializations that facilitated the evolution of these abilities. Of particular interest for comparative neuroanatomists are species who have convergently evolved large brains and complex cognitive abilities (e.g., members of the mammalian orders Carnivora, Cetacea, and Proboscidea). Comparative neuroanatomical studies must go beyond absolute and relative brain size to examine white matter connectivity, the expansion and differentiation of cortical areas, and the relationship between size and sulcal patterning. Combining data from neuroimaging, morphometry, and paleoneurology with evolutionary phylogenetic approaches will elucidate the relationship between structure, function, and evolution. In this talk, I will discuss my research on the organization of major white matter tracts in humans, chimpanzees, macaques, and other primates in relation to cortical areas, methods for comparative analysis, and propose future directions for studying human brains using phylogenetic approaches.

Presenter

Katherine Bryant, PhD, University of Oxford
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Oxford
United Kingdom