



HAL
open science

Brainhack: Developing a culture of open, inclusive, community-driven neuroscience

Rémi Gau, Stephanie Noble, Katja Heuer, Katherine Bottenhorn, Isil Bilgin,
Yu-Fang Yang, Julia Huntenburg, Johanna M.M. Bayer, Richard A.I.
Bethlehem, Shawn Rhoads, et al.

► **To cite this version:**

Rémi Gau, Stephanie Noble, Katja Heuer, Katherine Bottenhorn, Isil Bilgin, et al.. Brainhack: Developing a culture of open, inclusive, community-driven neuroscience. *Neuron*, 2021, 109 (11), pp.1769-1775. 10.1016/j.neuron.2021.04.001 . inserm-03221248

HAL Id: inserm-03221248

<https://inserm.hal.science/inserm-03221248v1>

Submitted on 17 Jun 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Brainhack: developing a culture of open, inclusive, community-driven neuroscience

Rémi Gau^{*1}, Stephanie Noble^{*2}, Katja Heuer^{*3,4}, Katherine L. Bottenhorn^{*5}, Isil P. Bilgin^{*6,7}, Yu-Fang Yang^{*8}, Julia M. Huntenburg^{*9}, Johanna Bayer^{*10,11}, Richard A.I. Bethlehem^{*12,13}, Shawn A. Rhoads¹⁴, Christoph Vogelbacher¹⁵, Valentina Borghesani¹⁶, Elizabeth Levitis^{17,18}, Hao-Ting Wang^{19,20,21}, Sofie Van Den Bossche²², Xenia Kobeleva^{23,24}, Jon Hartz Legarreta²⁵, Samuel Guay²⁶, Selim Melvin Atay²⁷, Gael P. Varoquaux^{28,29}, Dorien C. Huijser^{30,31}, Malin S. Sandström³², Peer Herholz³³, Samuel A. Nastase³⁴, AmanPreet Badhwar^{35,16,36}, Guillaume Dumas^{37,38}, Simon Schwab³⁹, Stefano Moia^{40,41}, Michael Dayan⁴², Yasmine Bassil⁴³, Paula P. Brooks³⁴, Matteo Mancini^{20,44,45}, James M. Shine⁴⁶, David O'Connor⁴⁷, Xihe Xie⁴⁸, Davide Poggiali⁴⁹, Patrick Friedrich⁵⁰, Anibal S. Heinsfeld^{54,55}, Lydia Riedl⁵¹, Roberto Toro^{52,53}, César Caballero-Gaudes⁴⁰, Anders Eklund^{56,57,58}, Kelly G. Garner^{59,60,61}, Christopher R. Nolan⁶², Damion V. Demeter⁶³, Fernando A. Barrios⁶⁴, Junaid S. Merchant^{65,66}, Elizabeth A. McDevitt³⁴, Robert Oostenveld^{67,68}, R. Cameron Craddock⁶⁹, Ariel Rokem⁷⁰, Andrew Doyle⁷¹, Satrajit S. Ghosh^{72,73}, Aki Nikolaidis⁷⁴, Olivia W. Stanley^{75,76}, Eneko Uruñuela^{40,41}, [The Brainhack Community](#)

The Brainhack Community:

Nasim Anousheh⁷⁷, Aurina Arnatkeviciute⁷⁸, Guillaume Auzias⁷⁹, Dipankar Bachar⁸⁰, Elise Bannier⁸¹, Ruggero Basanisi⁸², Arshitha Basavaraj⁸³, Marco Bedini⁸⁴, Pierre Bellec^{85,16}, R. Austin Benn⁸⁶, Kathryn Berluti¹⁴, Steffen Bollmann^{87,88}, Saskia Bollmann⁸⁸, Claire Bradley⁵⁹, Jesse Brown⁸⁹, Augusto Buchweitz⁹⁰, Patrick Callahan⁹¹, Micaela Y. Chan⁹², Bramsh Q. Chandio⁹³, Theresa Cheng⁹⁴, Sidhant Chopra⁹⁵, Ai Wern Chung⁹⁶, Thomas G. Close^{97,98}, Etienne Combrisson⁹⁹, Giorgia Cona¹⁰⁰, R. Todd Constable^{101,102}, Claire Cury¹⁰³, Kamalaker Dadi¹⁰⁴, Pablo F. Damasceno¹⁰⁵, Samir Das¹⁰⁶, Fabrizio De Vico Fallani^{107,108}, Krista DeStasio¹⁰⁹, Erin W. Dickie^{110,111}, Lena Dorfschmidt¹³, Eugene P. Duff¹¹², Elizabeth DuPre¹¹³, Sarah Dziura¹¹⁴, Nathalia B. Esper¹¹⁵, Oscar Esteban¹¹⁶, Shreyas Fadnavis¹¹⁷, Guillaume Flandin¹¹⁸, Jessica E. Flannery¹¹⁹, John Flournoy¹²⁰, Stephanie J. Forkel^{121,122}, Alexandre R. Franco^{123,74,124}, Saampras Ganesan^{125,126}, Siyuan Gao¹²⁷, José C. García Alanis¹²⁸, Eleftherios Garyfallidis⁷⁷, Tristan Glatard¹²⁹, Enrico Glerean^{130,131}, Javier Gonzalez-Castillo¹³², Cassandra D Gould van Praag^{133,134}, Abigail S. Greene¹³⁵, Geetika Gupta^{136,137}, Catherine Alice Hahn¹³⁸, Yaroslav O. Halchenko³⁹, Daniel Handwerker¹⁴⁰, Thomas S. Hartmann¹⁴¹, Valérie Hayot-Sasson¹²⁹, Stephan Heunis¹⁴², Felix Hoffstaedter^{50,143}, Daniela M Hohmann⁵¹, Corey Horien¹⁴⁴, Horea-Ioan Ioanas^{145,146}, Alexandru Iordan¹⁴⁷, Chao Jiang¹⁴⁸, Michael Joseph¹⁴⁹, Jason Kai⁷⁶, Agah Karakuzu^{150,151}, David N. Kennedy¹⁵², Anisha Keshavan^{153,154,155}, Ali R. Khan¹⁵⁶, Gregory Kiar²⁹, P. Christiaan Klink¹⁵⁷, Vincent Koppelmans¹⁵⁸, Serge Koudoro¹¹⁷, Angela R. Laird¹⁵⁹, Georg Langs^{160,161}, Marissa Laws¹⁶², Roxane Licandro^{163,164}, Sook-Lei Liew¹⁶⁵, Tomislav Lipic¹⁶⁶, Krisanne Litinas¹⁶⁷, Daniel J Lurie¹⁶⁸, Désirée Lussier¹⁶⁹, Christopher R. Madan¹⁷⁰, Lea-Theresa Mais¹⁷¹, Sina Mansour L.¹²⁶, J.P. Manzano-Patron¹⁷², Dimitra Maoutsa¹⁷³, Matheus Marcon¹⁷⁴, Daniel S. Margulies^{175,176}, Giorgio Marinato¹⁷⁷, Daniele Marinazzo¹⁷⁸, Christopher J. Markiewicz¹⁷⁹, Camille Maumet¹⁸⁰, Felipe Meneguzzi¹⁷⁴, David Meunier⁸⁰, Michael P. Milham¹⁸¹, Kathryn L. Mills^{182,183}, Davide Momi¹⁸⁴, Clara A. Moreau^{185,26}, Aysha

Motala¹⁸⁶, Iska Moxon-Emre¹⁸⁷, Thomas E. Nichols^{188,189}, Dylan M. Nielson¹⁹⁰, Gustav Nilsson^{191,192}, Lisa Novello¹⁹³, Caroline O'Brien¹⁹⁴, Emily Olafson⁴⁸, Lindsay D. Oliver¹⁹⁵, John A. Onofrey¹⁹⁶, Edwina R. Orchard⁹⁵, Kendra Oudyk¹⁹⁷, Patrick J. Park¹⁹⁸, Mahboobeh Parsapoor^{199,200,201}, Lorenzo Pasquini²⁰², Scott Peltier¹⁶⁷, Cyril R. Pernet²⁰³, Rudolph Pienaar^{204,205}, Pedro Pinheiro-Chagas²⁰⁶, Jean-Baptiste Poline^{207,208}, Anqi Qiu²⁰⁹, Tiago Quendera²¹⁰, Laura C. Rice^{211,212}, Joscelyn Rocha-Hidalgo¹⁴, Saige Rutherford²¹³, Mathias Scharinger²¹⁴, Dustin Scheinost²¹⁵, Deena Shariq²¹⁶, Thomas B. Shaw⁹⁸, Viviana Siless²¹⁷, Molly Simmonite²¹⁸, Nikoloz Sirmipilatze²¹⁹, Hayli Spence²²⁰, Julia Sprenger⁸⁰, Andrija Stajduhar^{221,222}, Martin Szinte⁸⁰, Sylvain Takerkart⁸⁰, Angela Tam²²³, Link Tejavibulya²²⁴, Michel Thiebaut de Schotten^{225,226}, Ina Thome⁵¹, Laura Tomaz da Silva¹⁷⁴, Nicolas Traut^{227,3}, Lucina Q. Uddin²²⁸, Antonino Vallesi^{229,230}, John W. VanMeter^{231,232}, Nandita Vijayakumar²³³, Matteo Visconti di Oleggio Castello²⁰⁸, Jakub Vohryzek¹³⁴, Jakša Vukojević²³⁴, Kirstie Jane Whitaker²³⁵, Lucy Whitmore²³⁶, Steve Wideman^{237,238}, Suzanne T. Witt²³⁹, Hua Xie⁶⁶, Ting Xu²⁴⁰, Chao-Gan Yan^{241,242}, Fang-Cheng Yeh²⁴³, B.T. Thomas Yeo²⁴⁴, Xi-Nian Zuo^{245,246,247}

Affiliations are listed at the end of this document.

Author Contributions:

The contributions of the different authors are detailed [here](#), and our crediting system is described [here](#).

* denotes equal contributions.

Corresponding Author and Lead Contact: +

Abstract / In brief

Brainhack is an innovative meeting format that promotes scientific collaboration and education in an open inclusive environment. The authors describe the myriad benefits for participants and the research community, and how Brainhacks complement conventional formats to augment scientific progress.

Keywords: best practices, Brainhack, collaboration, community building, hackathon, inclusivity, neuroscience, open science, reproducibility, training

Discipline: Life-science, Meta-science, Neuroscience (Cognitive Neuroscience, Computational Neuroscience, Systems Neuroscience, Other Neuroscience and Neurobiology)

Introduction

Social factors play a crucial role in the advancement of science. New findings are discussed and theories emerge through social interactions, which usually take place within local research groups, and at academic events such as conferences, seminars or workshops. This system tends to amplify the voices of a select subset of the community—especially more established researchers—thus limiting opportunities for the larger community to contribute and connect. [Brainhack](#) events (or Brainhacks for short) complement these formats in neuroscience with decentralized two-to-five day gatherings, in which participants from diverse backgrounds and career stages collaborate and learn from each other in an informal setting. The Brainhack format was introduced in a previous publication (Craddock et al., 2016; Fig. 1A&B). It is inspired by the **hackathon** model (see Glossary), which originated in software development and has gained traction in science as a way to bring people together for collaborative work and educational courses. Unlike many hackathons, Brainhacks welcome participants from all disciplines and with any level of experience—from those who have never written a line of code to software developers and expert neuroscientists. Brainhacks additionally replace the sometimes competitive context of traditional hackathons with a purely collaborative one, and also feature informal dissemination of ongoing research through **unconferences**.

In the following, we aim to address two key questions about the merits of a Brainhack. First, how do participants benefit from attending a Brainhack event? Second, what is the relevance and importance of Brainhacks for neuroscience more broadly? To answer these questions, we discuss the five defining Brainhack features: 1) a *Project-Oriented Approach* that fosters active participation and community-driven problem-solving; 2) *Learning By Doing*, which enables participants to gain more intensive training, particularly in computational methods; 3) training in *Open Science & Collaborative Coding*, which helps participants become more effective collaborators; 4) *Focus on Reproducibility*, which leads to more robust scientific research; and 5) accelerated *Building and Bridging of Communities*, which encourages inclusivity and seamless collaboration between researchers at different career stages. Altogether, Brainhacks and similar formats are increasingly recognized as a new way of providing academic training and conducting research that extends traditional settings. These events foster a new research culture that celebrates **open science**, collaboration and diversity, unlocking opportunities for scientific progress.

A Project-Oriented Approach

Brainhacks are fundamentally centered around attendee-led projects. At the beginning of each Brainhack, participants pitch project ideas and form teams to realize some of these ideas during the “**hacking**” sessions (Fig. 1B). The teams are dynamic, and their composition can change throughout the course of a project. As participants group themselves based on their common interest in a question, method, goal or idea, interdisciplinary teams naturally emerge. Each participant can hone diverse skills by playing an active part in multiple projects. This format avoids the scientific silos that often arise when scientists connect over a specific methodological or

conceptual approach. Brainhack projects promote the flow of information between specialized domains within the multidisciplinary field of neuroscience.

The project-oriented structure of Brainhack enables everyone to be an active participant at the event, with contributions taking a variety of forms. Importantly, the term “hacking” is not used to refer to coding in particular, but to describe an intensive form of work, eschewing strict conventions, and often targeted at prototyping an idea within a short period of time. Participants are therefore not required to have coding skills in order to make meaningful contributions. An example of an impactful project that did not focus on coding is [Open Brain Consent](#) (Open Brain Consent working group, 2021). This project developed consent form templates for the collection and sharing of human neuroimaging data, incorporating data protection standards such as the General Data Protection Regulation (GDPR) of the European Union. The consent forms can be used in ethics approval procedures to ensure that the collected data is shareable, while the participants’ privacy is protected.

Unlike some traditional hackathons, there is no competitive element to Brainhacks. The focus is on collective and community-driven work, making the events more welcoming for inexperienced participants. Neither the level of completeness nor the publication potential determine the success of a project. Instead, Brainhacks emphasize the value of collaborating, exploring unconventional ideas, group thinking and building tools that benefit the community. Exemplary of these values is a project that originated at the first Brainhack in 2012: The [Brain Catalogue](#) provides magnetic resonance (MR) brain images of a range of different species and allows multiple users to view and segment them on the web simultaneously. Its successor, [BrainBox](#), has evolved to enable real-time collaborative segmentation of any MR image accessible online (Heuer et al., 2016). BrainBox has been used in many subsequent Brainhack projects, research collaborations, and science outreach events. Similarly, [braindr](#) fosters citizen science while solving visual quality control for massive datasets (Keshavan et al., 2019). This app enables anyone to contribute to scientific progress by swiping left or right on brain images to classify them as clean or corrupted. The project originated from a hackathon in 2017, was extended in a Brainhack project in 2018, and recently led to the development of the extensible [SwipesforScience](#) citizen science template.

Many Brainhack projects take on a life of their own and grow beyond a single event. The open science approach embraced by the Brainhack community makes it easier for anyone to contribute to, or take the lead in pushing projects forward beyond their initial creation. For example, the [Autism Gradients](#) project, exploring the cortical hierarchy in individuals with autism, was conceptualised at Brainhack Global 2016. It was subsequently picked up by another group who expanded the original idea and invited the initial Brainhack team to collaborate. This resulted in a peer-reviewed publication (Hong et al., 2019), multiple follow-up projects, two exchange [grants](#), and international workshops ([Autism workshop at INSAR](#) and [gradient workshop at OHBM](#)) on the same topic. Another example is the development of [Nighres](#), a Python package for processing high-resolution neuroimaging data. The initial project spanned two Brainhacks in 2016, and resulted in a [toolbox](#) that made algorithms for layer-specific analysis of the cortex easier to install and use. This sparked the development of the full Nighres package, with a broader range of functions and various contributors across several Brainhacks. Nighres has been presented in a peer-reviewed publication ([Huntenburg et al., 2018](#)), is actively maintained, and has been used

and cited in multiple studies. Some projects transcend the domain of brain sciences; for example, [DueCredit](#) is a project promoting citable code that emerged at Brainhack OHBM 2015 and is now used in molecular dynamics, geophysics, and other sciences. Many more projects have been part of Brainhacks over the years, attracting users and developers and evolving together with the community. An expanding list lives in the accompanying [Jupyter Book](#).

All these examples highlight how the project-oriented approach of Brainhacks encourages active participation and interdisciplinary collaboration that can reach beyond a single event. The projects directly benefit participants, who can explore new ideas in a stimulating setting, leverage their projects for career advancement, and gain new skills by collaborating with experienced researchers and developers. Brainhack projects also contribute to the progress of the wider neuroscience community by fostering exchange across scientific silos, resulting in multi-disciplinary tools, community-driven guidelines and reference data, as well as traditional publication output.

Learning by Doing

Alongside projects, educational activities lie at the heart of Brainhacks. Such activities include informal teaching between project teammates, theoretical discussions in self-organized groups, unconference presentations, and structured workshops on a particular tool or topic. A recent format for major Brainhack events is the **TrainTrack**, entirely education-focused sessions that run in parallel with project work (Fig. 1A-B). This format lowers the entry barrier for new participants, enabling them to build relevant skills and familiarize themselves with the structure and environment of a Brainhack before diving into their first project. The variety of educational approaches supports different ways of learning. Furthermore, the informal nature of these activities empowers participants to be proactive about learning and asking for help.

Brainhack instructors strive to share their materials with the scientific community, including recorded presentations, slide decks, or interactive tutorials. For example, all the materials developed for the [TrainTrack of OHBM Brainhack 2020](#) have been made publicly available under a permissive license so as to encourage reuse, redistribution, and reproduction of the content. Educational content developed for Brainhacks covers a range of topics including analytical and statistical methods (e.g., machine learning, data preprocessing), reproducible workflows (e.g., automated pipelines, automated data standardization, version control, software containers), and other relevant concepts (e.g., preregistration, p-hacking). Brainhacks represent an ideal place to showcase neuroscientific tools in the form of presentations or training sessions. These sessions are designed to be hands-on and interactive as they typically feature small groups having active discussions. Participants are explicitly encouraged to adopt what they learned at a Brainhack event to their own context and to improve the teaching material with their own ideas.

Skills learned at Brainhacks are not constrained to those of a technical nature; the event format provides a unique opportunity for early career researchers to develop transferable skills such as teamwork and leadership. Project teams are often interdisciplinary, allowing participants to practice communicating beyond their own field. Everyone is encouraged to propose and lead their

own projects, and the informal structure of the events often empowers more junior participants to also take on a leadership role. The growing pool of training materials provides a ready route to extend teaching opportunities to any member of the community, including trainees. Such experiences are rare for early career researchers, but crucial for their advancement given that they can potentially mold future interests, boost the quality of their research, and widen their scientific horizons. Altogether, the broad range of scientific and professional training opportunities equips participants with a skill set that can be applicable across many domains and career stages and may therefore open up a greater range of career opportunities.

Open Science & Collaborative Coding

Despite the increasingly central role of programming in neuroscience research, formal training in coding is not common in the neuroscience curriculum. In addition, code is seldom shared across more than a few labs, and too often read and executed by only a single individual. As a result, many scripts and workflows are hard to reuse and share and may contain undiscovered errors (Merali et al., 2010).

By putting cross-disciplinary collaboration at its heart, Brainhacks have brought awareness to the need for usability, reusability, and long-term maintenance of tools. This comes with a shift of efforts, from individuals creating tools for their own needs to a community actively contributing to an existing resource, solving the aforementioned issues. Practices such as writing good code and documentation, improving code readability, performing basic version control, working collaboratively on a codebase on [GitHub](#), [GitLab](#), or [BitBucket](#), and using appropriate open licenses have become essential within the community. These open practices and tools facilitate community-driven development and ensure that tools are available to all researchers, fostering global inclusivity. Brainhacks have highlighted the utility of producing a variety of research deliverables other than scientific papers (such as software, tutorials, workflows, and datasets), a concept that is increasingly endorsed by publishing venues such as [F1000](#), [RIO](#), [eLife](#), [Aperture](#), and others over the years.

Mastering collaborative programming skills enables Brainhack participants to contribute to open research objects which impact the wider scientific community. It can also make them more efficient at conducting their own research; for example, skills such as version control can be transferred to their own research group and foster more seamless collaboration amongst lab members. The wider neuroscience community benefits from the creation of transparent, reproducible tools, and from researchers equipped with the skills to maintain and extend them.

A Focus on Reproducibility

In line with their open, transparent, and collaborative nature, Brainhacks promote increased awareness of the importance of reproducible practices that integrate easily into research workflows. In addition to the coding practices mentioned above, an important aspect of reproducibility is data sharing. Public datasets are featured extensively in Brainhack projects and training sessions, since they are ideal for testing out new ideas or learning how to use a new tool.

First-time users thus experiment with these datasets and related tools under the guidance of expert users, which lowers the barrier to working with public data in the future. This approach establishes open data sharing as a standard practice and teaches participants how to curate their own data and metadata to make them accessible and reusable by others.

Resources that help researchers handle their data in a reproducible fashion are integral to Brainhacks; many of these have been introduced to the Brainhack community through structured efforts from the Center for Reproducible Neuroimaging Computation (Kennedy et al., 2019). For example, many projects and trainings use [DataLad](#), a tool that not only lets participants version-control their own data, but also helps them find, access, share, and work with increasingly large publicly available datasets. Similarly, a growing number of projects build on the [Brain Imaging Data Structure](#) (BIDS, Gorgolewski et al., 2016), a community standard for the organization of brain imaging data and metadata founded with the International Neuroinformatics Coordinating Facility ([INCF](#)). Introducing participants to data standards, such as BIDS, in the environment of a Brainhack allows them to experience the benefits of a unified data organization and provides them with the skillset to use these formats in their own research. Additionally, past Brainhacks have highlighted best practices in neuroimaging data analysis as defined by the Committee on Best Practice in Data Analysis and Sharing (COBIDAS guidelines [for MRI](#) as well as [for EEG and MEG](#)). By creating a scientific culture around open and standardized data, metadata, and methods, as well as detailed documentation and reporting, Brainhacks promote fundamental building blocks of a more efficient and reliable scientific research process.

Building and Bridging Communities

All aspects of Brainhacks discussed above build upon an active commitment to a diverse, inclusive, and non-hierarchically organized community. This commitment has been formalized in a [Code of Conduct](#) that aims to ensure a safe and welcoming environment for participants from all backgrounds. The Code of Conduct is discussed at the beginning of a Brainhack and adherence is monitored throughout the event. There have also been dedicated efforts to raise awareness about equity, diversity and inclusivity, such as a recent [panel discussion](#) at Brainhack Ontario 2020. While far from perfect or bias-free, we feel that the Brainhack community itself is continuously growing more diverse in terms of race, ethnicity, gender identity and expression, sexual orientation, career stage, and other aspects of personal background and identity. The enthusiastically inclusive culture helps members hold each other to a standard of mutual respect that empowers individuals from typically underrepresented groups to claim their space and take on central roles in the community.

Brainhacks are designed to promote intensive networking. The project-oriented and decentralized setting puts participants on an equal footing regardless of backgrounds and career stage. Unconferences provide a unique opportunity for people interested in the same topic to meet and discuss, sometimes sparking new collaborations. Working in small groups during projects, workshops, and unconferences over the course of several days encourages frequent interactions that often go deeper than relatively short encounters at traditional conferences. These interactions contribute to building lasting collaborations that bridge across disciplines, research contexts,

career stages, and geographical borders. Sometimes they lead to job opportunities, grant proposals, new ideas, and new projects. Often they turn into friendships. We firmly believe that growing this diverse community and insisting on a culture of collaboration and inclusivity has untold benefits for the retention and well-being of all scientists doing brain research.

In addition to year-round locally organized Brainhacks, Brainhack Global has emerged as a major yearly initiative that has sparked numerous simultaneous events around the world (Fig. 1C-D). The focus on open collaboration through virtual spaces throughout the years meant that the community had the infrastructure, knowledge and motivation to go fully virtual in 2020, accommodating restrictions due to the COVID-19 pandemic, budget constraints, and increased awareness of the climate cost of travel. The general format of project-oriented, community-building events has gained traction in the field of neuroscience and beyond. Large initiatives such as the [Human Brain Project](#), [Neurodata Without Borders](#), and the [Society for the Improvement of Psychological Science](#) have also chosen hackathons as a primary work format. Summer schools like the [ABCD-ReproNim](#) course, [NeuroHackademy](#), the [ABCD Workshop](#) and the [Brainhack School](#) are based on the same principles as the original Brainhack events. Brainhacks have been organized with other communities such as [Network Neuroscience](#), thereby forming a bridge with those communities. Many brainhack community members also play active roles in like-minded initiatives such as the [Open Science Special Interest Group](#) of [OHBM](#) or [Neuromatch Academy](#), amongst others. Thus, a community of individuals and practices has emerged that transports the benefits and values of the brainhack format far beyond any individual event or organization. Brainhacks are spreading to an increasingly wide community, as their non-hierarchical, self-organising structure enables individuals to organize a Brainhack anywhere in the world (Fig. 1C), while events are kept financially accessible. An online community with over 4000 members and 500 channels uses the [Mattermost](#) messaging platform to provide continuity across time and space. Posts range from questions about a specific resource, to job openings and discussions about research ethics; and anyone can join regardless of having attended a Brainhack. The community evolves with every new member and their ideas, and many members become local advocates for the principles of open and collaborative science in their home institutions.

Conclusion & Future Directions

Brainhacks complement traditional academic settings and offer additional opportunities for participants to achieve their scientific and professional goals. The focus on building a community that promotes open science and inclusivity has naturally led to better coding practices, more reproducible methods, accelerated knowledge dissemination and ample opportunities for collaboration. Brainhacks differ from many scientific meetings, as they are more project-oriented, less formal, and have broadened the notion of what constitutes successful outputs in science. Within neuroscience, Brainhacks have the potential to evolve beyond their initial focus on neuroimaging data and include more projects on theory, hardware, and different types of neural data. With a growing global community, and an iteratively improving format (Fig. 1D), Brainhacks provide a successful template that can be extended to other scientific fields. Nearly a decade of successful Brainhacks have already brought about positive change for individual researchers and

the field as a whole, in the form of improved skills, reusable resources, new collaborations, and a diverse and inclusive community.

Figure Legends

Figure 1. Brainhack in time and space. (A) Anatomy of a Brainhack shows how the components of Brainhack events relate to overarching topics that lead to scientific and professional opportunities in neuroscience. (B) Timeline of a Single Event describes the typical daily schedule throughout a brainhack. Project work and educational activities occur simultaneously interspersed with unconferences. (C) Brainhack Cartography displays cities across the world that have hosted a Brainhack. Marker color indicates the year in which each city hosted its first Brainhack, and marker size indicates the number of events hosted in each city. (D) The Brainhack Timeline displays the number of events per month since the inaugural Brainhack in September 2012, along with notable happenings throughout the years. Months are only denoted in the first year with a single letter; this ordering is repeated for all subsequent years. See the latest version of this figure [here](#).

Acknowledgments

The present manuscript is part of a growing community effort to collate BrainHack related insights and expertise into a [Jupyter Book](#) that will serve as a centralized set of resources for the community; we acknowledge all the individuals who contributed and will make ongoing contributions to these resources. A pre-print version of the present manuscript is available as part of the Jupyter Book [here](#). Moreover, we would like to acknowledge all Brainhack organizers, supporters, presenters, and participants for their contribution to growing and maintaining this community. The benefits described in this manuscript would not be possible without them. We also thank all institutions, labs, and organizations who have helped this community grow, meet in stimulating environments and add an excellent educational resource pool and agenda. With an expanding community, Brainhack's support network keeps growing and we thank all labs and individual researchers for their dedication and expertise offered to this community (see Supplementary Materials for a full list of individual acknowledgments; an updated list will be maintained in the Jupyter Book [here](#)).

Declaration of Interests

Anisha Keshavan is an employee of Octave Bioscience

References

Bannier, E., Barker, G., Borghesani, V., Broeckx, N., Clement, P., de la Iglesia Vaya, M., Emblem, K. E., Ghosh, S. S., Glerean, E., Gorgolewski, K. J., Havu, M., Halchenko, Y. O., Herholz, P., Hespel, A., Heunis, S., Hu, Y., Chuan-Peng, H., Huijser, D., Jancalek, R., ... Zhu, H. (2021). The

Open Brain Consent: Informing research participants and obtaining consent to share brain imaging data. *Human Brain Mapping*; 1-10. <https://doi.org/10.1002/hbm.25351>

Craddock, R. C., Margulies, D. S., Bellec, P., Nichols, B. N., Alcauter, S., Barrios, F. A., Burnod, Y., Cannistraci, C. J., Cohen-Adad, J., De Leener, B., Dery, S., Downar, J., Dunlop, K., Franco, A. R., Froehlich, C. S., Gerber, A. J., Ghosh, S. S., Grabowski, T. J., Hill, S., ... Xu, T. (2016). Brainhack: a collaborative workshop for the open neuroscience community. *GigaScience*, 5(1). <https://doi.org/10.1186/s13742-016-0121-x>.

Gorgolewski, K. J., Auer, T., Calhoun, V. D., Craddock, R. C., Das, S., Duff, E. P., Flandin, G., Ghosh, S. S., Glatard, T., Halchenko, Y. O., Handwerker, D. A., Hanke, M., Keator, D., Li, X., Michael, Z., Maumet, C., Nichols, B. N., Nichols, T. E., Pellman, J., ... Poldrack, R. A. (2016). The brain imaging data structure, a format for organizing and describing outputs of neuroimaging experiments. *Scientific Data*, 3(1). <https://doi.org/10.1038/sdata.2016.44>.

Heuer, K., Ghosh, S., Robinson Sterling, A., & Toro, R. (2016). Open Neuroimaging Laboratory. Research Ideas and Outcomes 2: e9113. <https://doi.org/10.3897/rio.2.e9113>

Hong, S.-J., Vos de Wael, R., Bethlehem, R. A. I., Lariviere, S., Paquola, C., Valk, S. L., Milham, M. P., Di Martino, A., Margulies, D. S., Smallwood, J., & Bernhardt, B. C. (2019). Atypical functional connectome hierarchy in autism. *Nature Communications*, 10(1). <https://doi.org/10.1038/s41467-019-08944-1>

Huntenburg, J., Steele, C.J. & Bazin P-L (2018). Nighres: processing tools for high-resolution neuroimaging. *GigaScience*, 7(7), <https://doi.org/10.1093/gigascience/giy082>

Kennedy, D. N., Abraham, S. A., Bates, J. F., Crowley, A., Ghosh, S., Gillespie, T., Goncalves, M., Grethe, J. S., Halchenko, Y. O., Hanke, M., Haselgrove, C., Hodge, S. M., Jarecka, D., Kaczmarzyk, J., Keator, D. B., Meyer, K., Martone, M. E., Padhy, S., Poline, J.-B., ... Travers, M. (2019). Everything Matters: The ReproNim Perspective on Reproducible Neuroimaging. *Frontiers in Neuroinformatics*, 13. <https://doi.org/10.3389/fninf.2019.00001>

Keshavan, A., Yeatman, J. D., & Rokem, A. (2019). Combining Citizen Science and Deep Learning to Amplify Expertise in Neuroimaging. *Frontiers in Neuroinformatics*, 13. <https://doi.org/10.3389/fninf.2019.00029>

Merali, Z. (2010). Computational science: ...Error. *Nature* 467, 775-777 <https://doi.org/10.1038/467775a>

Affiliations

¹Institute of psychology, Université catholique de Louvain, Louvain la Neuve, Belgium, ²Radiology & Biomedical Imaging, Yale University, New Haven CT, USA, ³Center for Research and Interdisciplinarity, Université Paris Descartes, Paris, France, ⁴Department of Neuropsychology,

Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, ⁵Department of Psychology, Florida International University, Miami FL, USA, ⁶Biomedical Engineering, Cybernetics, University of Reading, Reading, UK, ⁷Allied Health Professions, University of the West of England, Bristol, UK, ⁸Department of Psychology, Würzburg University, Würzburg, Germany, ⁹Systems Neuroscience Lab, Champalimaud Research, Lisbon, Portugal, ¹⁰Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne, Melbourne, Australia, ¹¹Orygen Youth Health, Melbourne, Australia, ¹²Autism Research Centre, Department of Psychiatry, University of Cambridge, Cambridge, UK, ¹³Brain Mapping Unit, Department of Psychiatry, University of Cambridge, Cambridge, UK, ¹⁴Department of Psychology, Georgetown University, Washington D.C., USA, ¹⁵Laboratory for Multimodal Neuroimaging, Department of Psychiatry and Psychotherapy, University of Marburg, Marburg, Germany, ¹⁶Centre de Recherche de l'Institut Universitaire de Gériatrie de Montréal, University of Montréal, Montréal, Québec, Canada, ¹⁷National Institute of Mental Health, Bethesda MD, USA, ¹⁸Centre for Medical Image Computing, Department of Computer Science, University College London, London, UK, ¹⁹Sackler Centre for Consciousness Science, University of Sussex, Brighton, UK, ²⁰Department of Neuroscience, Brighton and Sussex Medical School, University of Sussex, Brighton, UK, ²¹Sussex Neuroscience, University of Sussex, Brighton, UK, ²²Department of Data Analysis, Faculty of Psychology and Educational Sciences, Ghent University, Ghent, Belgium, ²³Department of Neurology, University of Bonn, Bonn, Germany, ²⁴German Center for Neurodegenerative Diseases (DZNE), Bonn, Germany, ²⁵Computer Science, Université de Sherbrooke, Sherbrooke, Canada, ²⁶University of Montréal, Montréal, Québec, Canada, ²⁷Neuroscience and Neurotechnology, Middle East Technical University, Ankara, Turkey, ²⁸Parietal, Inria, Saclay, France, ²⁹Montréal Neurological Institute, McGill University, Montréal, Québec, Canada, ³⁰Erasmus School of Social and Behavioural Sciences, Erasmus University Rotterdam, Rotterdam, The Netherlands, ³¹Developmental and Educational Psychology, Leiden University, Leiden, The Netherlands, ³²INCF, Karolinska Institute, Stockholm, Sweden, ³³McConnell Brain Imaging Centre, The Neuro (Montreal Neurological Institute-Hospital), McGill University, Montréal, Québec, Canada, ³⁴Princeton Neuroscience Institute, Princeton University, Princeton NJ, USA, ³⁵Multimomics Investigation of Neurodegenerative Diseases (MIND) Lab, University of Montréal, Montréal, Québec, Canada, ³⁶Département de pharmacologie et physiologie, University of Montréal, Montréal, Québec, Canada, ³⁷Department of Psychiatry, University of Montréal, Montréal, Québec, Canada, ³⁸Mila, University of Montréal, Montréal, Québec, Canada, ³⁹University of Zurich, Zurich, Switzerland, ⁴⁰Basque Center on Cognition, Brain and Language, San Sebastián-Donostia, Spain, ⁴¹University of the Basque Country (EHU UPV), San Sebastián-Donostia, Spain, ⁴²Human Neuroscience Platform, Fondation Campus Biotech Geneva, Geneva, Switzerland, ⁴³Graduate Division of Biological & Biomedical Sciences, Emory University, Atlanta, USA, ⁴⁴Cardiff University, Cardiff, UK, ⁴⁵Polytechnique Montreal, Montréal, Québec, Canada, ⁴⁶Faculty of Medicine and Health, The University of Sydney, Sydney, Australia, ⁴⁷Department of Biomedical Engineering, Yale University, New Haven CT, USA, ⁴⁸Department of Neuroscience, Weill Cornell Medicine, New York City, USA, ⁴⁹Padova Neuroscience Center, University of Padova, Padova, Italy, ⁵⁰Institute of Neuroscience and Medicine, Brain & Behaviour (INM-7), Research Centre Jülich, Jülich, Germany, ⁵¹Department of Psychiatry and Psychotherapy, Philipps Universität, Marburg, Germany, ⁵²Neuroscience department, Institut Pasteur, Paris, France, ⁵³Center for Research and Interdisciplinarity (CRI), Université Paris Descartes, Paris, France, ⁵⁴Computational Neuroimaging

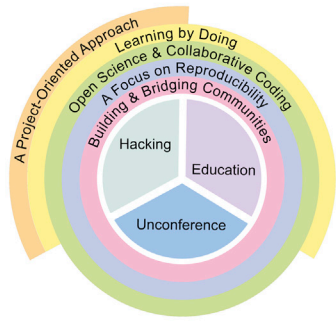
Lab, University of Texas at Austin, Austin TX, USA, ⁵⁵Department of Computer Science, University of Texas at Austin, Austin TX, USA, ⁵⁶Department of Biomedical Engineering, Linköping University, Linköping, Sweden, ⁵⁷Department of Computer and Information Science, Linköping University, Linköping, Sweden, ⁵⁸Center for Medical Image Science and Visualization (CMIV), Linköping University, Linköping, Sweden, ⁵⁹Queensland Brain Institute, The University of Queensland, St Lucia, Australia, ⁶⁰School of Psychology, University of Birmingham, Birmingham, UK, ⁶¹School of Psychology, The University of Queensland, St Lucia, Australia, ⁶²Department of Psychology, University of New South Wales, Sydney, Australia, ⁶³Psychology Department, The University of Texas at Austin, Austin TX, USA, ⁶⁴Instituto de Neurobiología, Universidad Nacional Autónoma de México, Querétaro, México, ⁶⁵Neuroscience and Cognitive Science Program, University of Maryland, College Park MD, USA, ⁶⁶Department of Psychology, University of Maryland, College Park MD, USA, ⁶⁷Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, The Netherlands, ⁶⁸NatMEG, Karolinska Institutet, Stockholm, Sweden, ⁶⁹Department of Diagnostic Medicine, The University of Texas at Austin Dell Medical School, Austin TX, USA, ⁷⁰Psychology and eScience Institute, University of Washington, Seattle WA, USA, ⁷¹McGill Centre for Integrative Neuroscience, McGill University, Montréal, Québec, Canada, ⁷²McGovern Institute for Brain Research, MIT, Cambridge, USA, ⁷³Department of Otolaryngology - Head and Neck Surgery, Harvard Medical School, Boston, USA, ⁷⁴Center for the Developing Brain, Child Mind Institute, New York City, USA, ⁷⁵Centre for Functional and Metabolic Mapping, University of Western Ontario, London ON, Canada, ⁷⁶Department of Medical Biophysics, University of Western Ontario, London ON, Canada, ⁷⁷Intelligent Systems Engineering, Indiana University, Bloomington IN, USA, ⁷⁸The Turner Institute for Brain and Mental Health, School of Psychological Sciences, Monash University, Victoria, Australia, ⁷⁹Institut de Neurosciences de la Timone UMR 7289, Aix-Marseille Université, CNRS,, ⁸⁰Institut de Neurosciences de la Timone, CNRS - Aix-Marseille University, Marseille, France, ⁸¹CHU Rennes, Radiology Department, Univ Rennes, CNRS, Inria, Inserm, IRISA UMR 6074, Empenn - ERL U 1228, F-35000 Rennes, France,, ⁸²Institut de Neurosciences de la Timone UMR 7289, Aix Marseille Université, CNRS, Marseille, France,, ⁸³National Institute of Mental Health,, ⁸⁴Center for Mind/Brain Sciences, University of Trento,, ⁸⁵Psychology Department, University of Montréal, Montréal, Québec, Canada, ⁸⁶Centro Nacional de Investigaciones Cardiovasculares (CNIC), Madrid, Spain, ⁸⁷School of Information Technology and Electrical Engineering, The University of Queensland, Brisbane, Australia, ⁸⁸Centre for Advanced Imaging, The University of Queensland, Brisbane, Australia, ⁸⁹Department of Neurology, University of California San Francisco, San Francisco, USA, ⁹⁰Brain Institute of Rio Grande do Sul, Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Brazil, ⁹¹Memory and Aging Center, UCSF,, ⁹²Center for Vital Longevity, School of Behavioral and Brain Sciences, University of Texas at Dallas, Dallas TX, USA, ⁹³Department of Intelligent Systems Engineering, Indiana University, Bloomington IN, USA, ⁹⁴Department of Psychology, University of Oregon, USA,, ⁹⁵Turner Institute for Brain and Mental Health, Monash University, Melbourne, Australia, ⁹⁶Fetal-Neonatal Neuroimaging and Developmental Science Center, Boston Children's Hospital, Harvard Medical School, Boston, USA, ⁹⁷School of Biomedical Engineering, The University of Sydney, Sydney, Australia, ⁹⁸National Imaging Facility, Sydney, Australia, ⁹⁹Aix-Marseille University, Institut de Neurosciences de la Timone,, ¹⁰⁰Department of General Psychology, University of Padova, Padova, Italy, ¹⁰¹Yale MRRRC, Yale University, New Haven CT, USA, ¹⁰²School of Medicine, Yale University, New Haven CT, USA, ¹⁰³Empenn ERL U 1228 IRISA UMR 6074,

Univ Rennes, Inria, CNRS, Inserm, Rennes, France,, ¹⁰⁴INRIA,, ¹⁰⁵Center for Intelligent Imaging, University of California, San Francisco, USA, ¹⁰⁶McGill University,, ¹⁰⁷ARAMIS team, Inria, Paris, France, ¹⁰⁸Paris Brain Institute, Sorbonne Universites, Paris, France, ¹⁰⁹University of Oregon,, ¹¹⁰Krembil Centre from Neuroinformatics, Centre for Addiction and Mental Health, Toronto, Canada, ¹¹¹Department of Psychiatry, University of Toronto, Toronto, Canada, ¹¹²University of Oxford, Oxford, UK, ¹¹³NeuroDataScience - ORIGAMI laboratory, McGill University, Montréal, Québec, Canada, ¹¹⁴Department of Psychology, University of Maryland, College Park, MD, USA,, ¹¹⁵Neuroimaging of Human Cognition, Brain Institute of Rio Grande do Sul, Porto Alegre, Brazil, ¹¹⁶Department of Radiology, Lausanne University Hospital, University of Lausanne, Lausanne, Switzerland, ¹¹⁷Indiana University, Bloomington IN, USA, ¹¹⁸Wellcome Centre for Human Neuroimaging, University College London, London, UK, ¹¹⁹University of North Carolina, Chapel Hill,, ¹²⁰Department of Psychology, Harvard University, Cambridge, MA, USA,, ¹²¹CNRS UMR 5293 Institut des Maladies Neurodégénératives, Bordeaux, France, ¹²²Department Neuroimaging, Institute of Psychiatry, Psychology and Neurosciences, King's College London, London, UK, ¹²³Center for Biomedical Imaging and Neuromodulation, Nathan Kline Institute, Orangeburg NY, USA, ¹²⁴Department of Psychiatry, NYU Grossman School of Medicine, New York City, USA, ¹²⁵Systems Neuroscience, Melbourne Neuropsychiatry Centre, Melbourne, Australia, ¹²⁶Department of Biomedical Engineering, The University of Melbourne, Melbourne, Australia, ¹²⁷Yale University,, ¹²⁸Department of Psychology, Philipps Universität, Marburg, Germany, ¹²⁹Department of Computer Science and Software Engineering, Concordia University, Montréal, Québec, Canada, ¹³⁰Department of Neuroscience and Biomedical Engineering, Aalto University, Espoo, Finland,, ¹³¹International Laboratory of Social Neurobiology, Institute of Cognitive Neuroscience, National Research University Higher School of Economics, Moscow, Russia, ¹³²NIH,, ¹³³Wellcome Centre for Integrative Neuroimaging, University of Oxford, Oxford, UK, ¹³⁴Department of Psychiatry, University of Oxford, Oxford, UK, ¹³⁵Interdepartmental Neuroscience Program and MD/PhD program, Yale School of Medicine, New Haven, CT, USA,, ¹³⁶Department of Psychology, Western University, London ON, Canada, ¹³⁷Brain and Mind Institute, Western University, London ON, Canada, ¹³⁸Department of Radiology and Biomedical Imaging, Yale School of Medicine,, ¹³⁹Center for Open Neuroscience, Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA,, ¹⁴⁰Section on Functional Imaging Methods, National Institute of Mental Health, Bethesda, MD, USA,, ¹⁴¹Philipps Universität, Marburg, Germany, ¹⁴²Department of Electrical Engineering, Eindhoven University of Technology, Eindhoven, The Netherlands, ¹⁴³Institute of Systems Neuroscience, Medical Faculty, Heinrich-Heine University Duesseldorf, Duesseldorf, Germany, ¹⁴⁴Interdepartmental Neuroscience Program, Yale School of Medicine, New Haven, CT, USA,, ¹⁴⁵Biological Engineering, MIT, Cambridge, USA, ¹⁴⁶D-ITET, ETH Zurich, Zurich, Switzerland, ¹⁴⁷Department of Psychology, University of Michigan, Ann Arbor, MI, USA,, ¹⁴⁸Key Laboratory of Behavioral Sciences, Institute of Psychology, Chinese Academy of Sciences, Beijing, China,, ¹⁴⁹Campbell Family Mental Health Research Institute, The Centre for Addiction and Mental Health, Toronto, Canada, ¹⁵⁰NeuroPoly Lab, Institute of Biomedical Engineering, Montréal, Québec, Canada, ¹⁵¹Montreal Heart Institute, University of Montréal, Montréal, Québec, Canada, ¹⁵²University of Massachusetts Medical School,, ¹⁵³Octave Bioscience, USA, ¹⁵⁴eScience Institute, University of Washington, Seattle WA, USA, ¹⁵⁵Institute for Learning and Brain Science, University of Washington, Seattle WA, USA, ¹⁵⁶Robarts Research Institute, Western University, London, Canada, ¹⁵⁷Department of Vision & Cognition, Netherlands Institute for Neuroscience, Amsterdam,

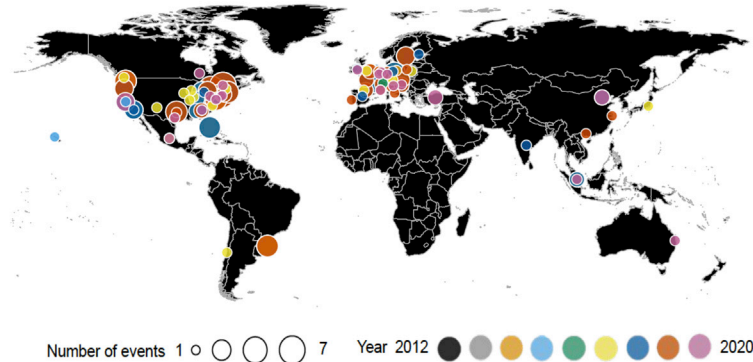
The Netherlands, ¹⁵⁸Department of Psychiatry, University of Utah, Salt Lake City, UT, USA,,
¹⁵⁹Department of Physics, Florida International University, Miami FL, USA, ¹⁶⁰CIR Department of
Biomedical Imaging and Image-guided Therapy, Medical University of Vienna, Vienna, Austria,
¹⁶¹CSAIL, MIT, Cambridge, USA, ¹⁶²Center for the Study of Learning, Georgetown University
Medical Center, Washington DC, USA, ¹⁶³Medical University of Vienna, Vienna, Austria, ¹⁶⁴TU Wien,
Vienna, Austria, ¹⁶⁵Stevens Neuroimaging and Informatics Institute, University of Southern
California, Los Angeles CA, USA, ¹⁶⁶Laboratory for Machine Learning and Knowledge
Representation, Ruder Boskovic Institute, Zagreb, Croatia, ¹⁶⁷Functional MRI Laboratory,
University of Michigan, Ann Arbor, USA, ¹⁶⁸Department of Psychology, University of California,
Berkeley, Berkeley, USA, ¹⁶⁹Centre de recherche de l'Institut universitaire de gériatrie de Montréal,,
¹⁷⁰Psychology, University of Nottingham, Nottingham, UK, ¹⁷¹University of Marburg, Marburg,
Germany, ¹⁷²Radiological Sciences & Sir Peter Mansfield Imaging Centre, University of
Nottingham, Nottingham, UK, ¹⁷³Institute of Software Engineering and Theoretical Computer
Science, Technical University of Berlin, Berlin, Germany, ¹⁷⁴School of Technology, Pontifical
Catholic University of Rio Grande do Sul, Porto Alegre, Brazil, ¹⁷⁵Centre National de la Recherche
Scientifique (CNRS), France, ¹⁷⁶INCC UMR 8002, Université de Paris, Paris, France, ¹⁷⁷CIMeC,
University of Trento, Trento, Italy, ¹⁷⁸Department of Data Analysis, Ghent University, Belgium,,
¹⁷⁹Department of Psychology, Stanford University, Stanford, CA, USA,, ¹⁸⁰Empenn ERL U 1228
IRISA UMR 6074, Univ Rennes, Inria, CNRS, Inserm, Rennes, France, ¹⁸¹Center for the
Developing Brain, Child Mind Institute, New York, NY USA, ¹⁸²Department of Psychology,
University of Oregon, Eugene, USA, ¹⁸³PROMENTA Research Center, Department of Psychology,
University of Oslo, Oslo, Norway, ¹⁸⁴Department of Neuroscience, Imaging and Clinical Sciences
University "G. d'Annunzio" of Chieti Chieti Italy, ¹⁸⁵Pasteur Institute, Paris, France, ¹⁸⁶Department of
Psychology, University of Western Ontario, London ON, Canada, ¹⁸⁷Child, Youth and Family
Service, Centre for Addiction and Mental Health, Toronto, Canada, ¹⁸⁸Big Data Institute, University
of Oxford, Oxford, UK, ¹⁸⁹WIN-FMRIB, University of Oxford, Oxford, UK, ¹⁹⁰Section on Clinical and
Computational Psychiatry (Comp Ψ), National Institute of Mental Health, National Institutes of
Health, Bethesda, Maryland,, ¹⁹¹Department of Clinical Neuroscience, Karolinska Institutet,
Stockholm, Sweden, ¹⁹²Department of Psychology, Stockholm University, Stockholm, Sweden,
¹⁹³Center for Mind/Brain Sciences (CIMeC), University of Trento, Rovereto (Trento), Italy,
¹⁹⁴Department of Neuroscience, Georgetown University, Washington, DC, United States,, ¹⁹⁵Centre
for Addiction and Mental Health, Toronto, Canada, ¹⁹⁶Departments of Radiology & Biomedical
Imaging and of Urology, Yale School of Medicine, New Haven, USA, ¹⁹⁷Montreal Neurological
Institute, McGill University, Montreal, Canada, ¹⁹⁸Engineering, University of Western Ontario,
London ON, Canada, ¹⁹⁹Computer Science Department, University of Toronto, Toronto, Canada,
²⁰⁰Vector Institute for Artificial Intelligence,, ²⁰¹Women in Artificial Intelligence & Machine Learning
(WinAIML),, ²⁰²Neurology Department, Memory and Aging Center, University of California San
Francisco,, ²⁰³Centre for Clinical Brain Sciences, University of Edinburgh, Edinburgh, UK,
²⁰⁴Radiology, Boston Children's Hospital, Harvard Medical School, Boston, USA, ²⁰⁵Radiology,
Harvard Medical School, Boston, USA, ²⁰⁶Stanford University,, ²⁰⁷Neurology and Neurosurgery,
McGill University, Montréal, Québec, Canada, ²⁰⁸Helen Wills Neuroscience Institute, University of
California, Berkley, Berkeley, USA, ²⁰⁹Department of Biomedical Engineering, National University
of Singapore, Singapore, Singapore, ²¹⁰Champalimaud Research, Lisbon, Portugal,
²¹¹Neuroscience, American University, Washington D.C., USA, ²¹²Neurology, Johns Hopkins

University, Baltimore MD, USA, ²¹³Department of Psychiatry, University of Michigan,, ²¹⁴German Linguistics & Fine Arts Science, Institute of German Linguistics, University of Marburg, Marburg, Germany, ²¹⁵Department of Radiology & Biomedical Imaging, Yale School of Medicine,, ²¹⁶University of Maryland, College Park,, ²¹⁷Athinoula A. Martinos Center for Biomedical Imaging - Harvard Medical School - MGH,, ²¹⁸Department of Psychology, University of Michigan, Ann Arbor, USA, ²¹⁹Functional Imaging Laboratory, German Primate Center - Leibniz Institute for Primate Research, Göttingen, Germany, ²²⁰Section on Molecular Neurobiology, National Institute of Child and Human Development, Bethesda, MD, ²²¹Croatian Institute for Brain Research, School of Medicine, University of Zagreb, Zagreb, Croatia, ²²²Andrija Stampar School of Public Health, School of Medicine, University of Zagreb, Zagreb, Croatia, ²²³Perceiv Research Inc., Montréal, Québec, Canada, ²²⁴Interdepartmental Neuroscience Program, Yale University, New Haven CT, USA, ²²⁵Brain Connectivity and Behaviour Laboratory, Sorbonne Universities, Paris, France, ²²⁶Groupe d'Imagerie Neurofonctionnelle, Institut des Maladies Neurodégénératives- UMR 5293, CNRS, CEA University of Bordeaux, Bordeaux, France, ²²⁷Human Genetics and Cognitive Functions, Institut Pasteur, Paris, France, ²²⁸Department of Psychology, University of Miami, Florida, USA, ²²⁹Department of Neuroscience & Padova Neuroscience Center, University of Padova, Padova, Italy, ²³⁰Brain Imaging and Neural Dynamics Research Group, IRCCS San Camillo Hospital, Venice, Italy, ²³¹Department of Neurology, Georgetown University, Washington D.C., USA, ²³²Center for Functional and Molecular Imaging, Georgetown University Medical Center, Washington D.C., USA, ²³³School of Psychology, Deakin University, Melbourne, Australia, ²³⁴University psychiatric hospital Vrače, Zagreb, Croatia, ²³⁵Tools, Practices and Systems Research Programme, Alan Turing Institute, London, UK, ²³⁶Department of Psychology, University of Oregon, Eugene OR,, ²³⁷NBL, University of Alabama at Birmingham, Birmingham AL, USA, ²³⁸CNC, University of Alabama at Birmingham, Birmingham AL, USA, ²³⁹BrainsCAN, University of Western Ontario, London ON, Canada, ²⁴⁰Center for the Developing Brain, Child Mind Institute, New York, USA, ²⁴¹CAS Key Laboratory of Behavioral Science, Institute of Psychology, Beijing, China, ²⁴²International Big-Data Center for Depression Research, Chinese Academy of Sciences, Beijing, China, ²⁴³University of Pittsburgh,, ²⁴⁴Department of Electrical and Computer Engineering, Centre for Sleep & Cognition & Centre for Translational MR Research, National University of Singapore, Singapore, Singapore,, ²⁴⁵State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China, ²⁴⁶National Basic Public Science Data Center, Chinese Academy of Sciences, Beijing, China, ²⁴⁷School of Education Sciences, Nanning Normal University, Nanning, China

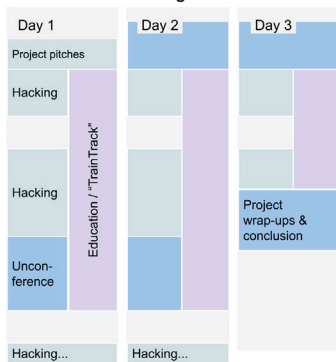
A Anatomy of a Brainhack



C Brainhack Cartography



B Timeline of a Single Event



D Brainhack Timeline

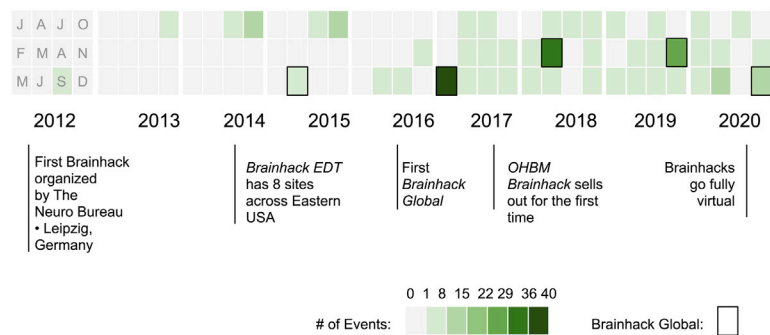


Figure 1. Brainhack in time and space

(A) Anatomy of a Brainhack shows how the components of Brainhack events relate to overarching topics that lead to scientific and professional opportunities in neuroscience.

(B) Timeline of a single event describes the typical daily schedule throughout a Brainhack. Project work and educational activities occur simultaneously interspersed with unconferences.

(C) Brainhack cartography displays cities across the world that have hosted a Brainhack. Marker color indicates the year in which each city hosted its first Brainhack, and marker size indicates the number of events hosted in each city.

(D) The Brainhack timeline displays the number of events per month since the inaugural Brainhack in September 2012, along with notable happenings throughout the years. Months are only denoted in the first year with a single letter; this ordering is repeated for all subsequent years.

See the latest version of this figure at http://brainhack.org/brainhack_jupyter_book/neuroview_figure.html.

Table 1. Glossary of selected terminology

Term	Definition
Open Science	Movement and practices within science aimed at increasing the transparency, accessibility, diversity, and inclusivity of scientific practices and output. This is often reflected in open science practices, such as publishing open access manuscripts; making research data findable, accessible, interoperable, and reusable (FAIR); and open sourcing code and software, etc.
Hackathon	The term hackathon is a portmanteau of “hacking” and “marathon.” Traditionally, it is an event in which people and teams gather to collaboratively work on projects over the course of multiple days. These events often historically feature competitions between teams. Brainhacks instead emphasize collaboration over competition.
Hacking	In this context, hacking does not indicate trying to break into computer systems by breaching security. Instead, it refers to tinkering with a system to better understand its working and subsequently laying a foundation for its advancement.
Unconference	This refers to a short session in which participants either present their research or prompt a discourse on any topic of interest in an informal setting. The content of an unconference may be decided impromptu and is often inspired by ongoing team discussions during the course of the Brainhack.
TrainTrack	A series of educational workshops that run in parallel with the projects enabling attendees to acquire specific skills during the course of their projects. The content of TrainTrack ranges from tutorials teaching skills useful to successfully navigate diverse projects in the Brainhack (such as code version control using Git) to more generalized education relevant to neuroscientific research (like MATLAB, BIDS, etc.).

Terms highlighted here either are defined in a unique way for this community or are important for appreciating the text. For detailed definitions, see [Cameron Craddock et al. \(2016\)](#) and the Brainhack Jupyter Book Glossary (http://brainhack.org/brainhack_jupyter_book/glossary.html).