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

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Brainhack is an innovative meeting format that promotes scientific collaboration and education in an open, inclusive environment. This NeuroView describes the myriad benefits for participants and the research com-
Q2 Q1 munity and how Brainhacks complement conventional formats to augment scientific progress.
Q3

Introduction

Social factors play a crucial role in the advancement of science. New findings
Q4 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 (https://brainhack.org/) events (or Brainhacks for short) complement these formats in neuroscience with decentralized 2- to 5-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 (Cameron Craddock et al., 2016; Figures 1A and 1B). It is inspired by the hackathon model (see glossary in Table 1), 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

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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 NeuroView, we aim to address two key questions about the

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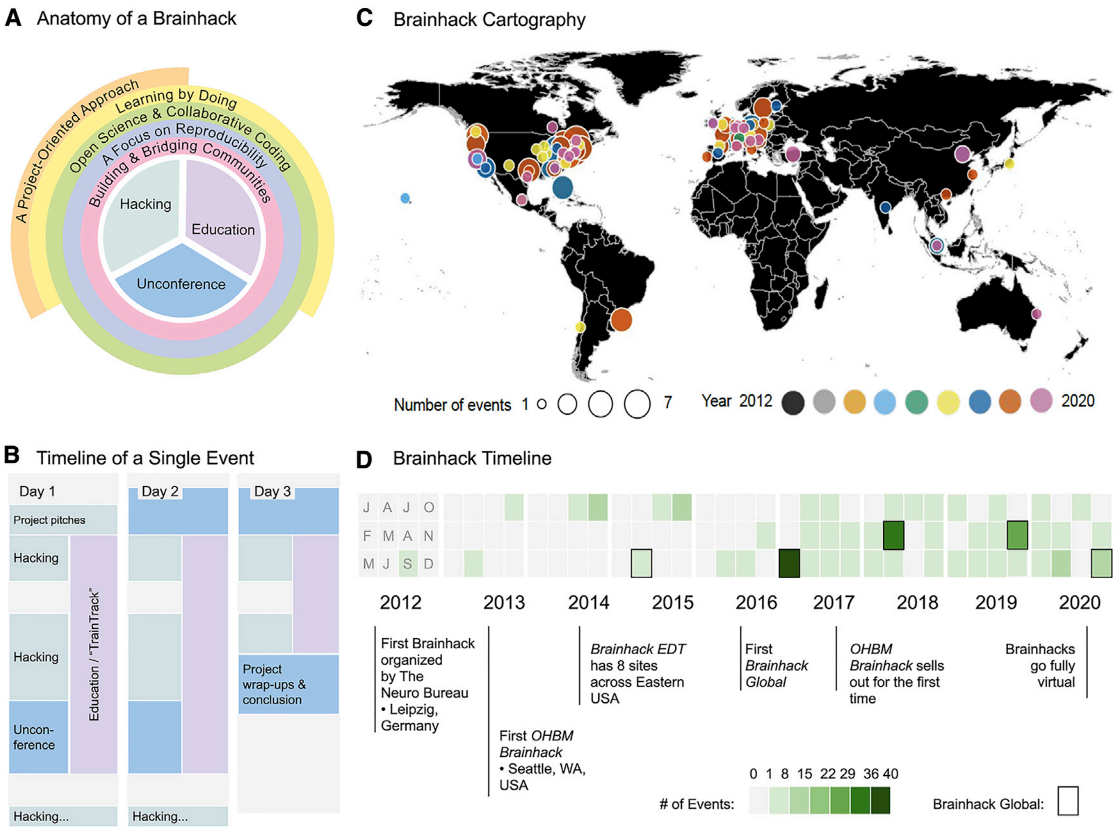

Figure 1. Brainhack in time and space

(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.

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 and 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 on 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 (Figure 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

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).

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 to make meaningful contributions. An example of an impactful project that did not focus on coding is Open Brain Consent (https://open-brain-consent.readthedocs.io/en/stable/; Bannier et al., 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 are 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 determines 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 (https://braincatalogue.org/) 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 (https://brainbox.pasteur.fr/), 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 (https://braindr.us/#/) 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 (https://swipesforscience.org/) 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 (https://github.com/rb643/Autism-Gradients), exploring the cortical hierarchy in individuals with autism, was conceptualized 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 (https://nighres.readthedocs.io/en/latest/), a Python package for processing high-resolution neuroimaging data. The initial project spanned two Brainhacks in 2016 and resulted in a toolbox (https://github.com/juhuntenburg/laminar_python) 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 (https://github.com/duecredit/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 (http://brainhack.org/brainhack_jupyter_book/overview.html).

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, and 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 (Figures 1A and 1B). 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 and 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, 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 that affect 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 among 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 because 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 (https://www.datalad.org/), 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; https://bids.neuroimaging.io/; Gorgolewski et al., 2016), a community standard for the organization of brain imaging data and metadata founded with the International Neuroinformatics Coordinating Facility (INCF; https://www.incf.org/). 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 [http://www.humanbrainmapping.org/files/2016/COBIDASreport.pdf] as well as for EEG and MEG [https://osf.io/a8dhx/]). 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 (Figures 1C and 1D). 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 (https://netscisociety.net/home), 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 (https://ossig.netlify.app/) of OHBM or Neuromatch Academy (https://elifesciences.org/articles/57892), among 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, because their non-hierarchical, self-organizing structure enables individuals to organize a Brainhack anywhere in the world (Figure 1C), while events are kept financially accessible. An online community with more than 4,000 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

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many members become local advocates for the principles of open and collaborative science in their home institutions. Q5

Conclusion and 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, are 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 (Figure 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.

SUPPLEMENTAL INFORMATION

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The present manuscript is part of a growing community effort to collate Brainhack-related insights and expertise into a Jupyter Book (http://brainhack.org/brainhack_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. 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 http://brainhack.org/brainhack_jupyter_book/acknowledgments.html for a full list of individual acknowledgments; an updated list will be maintained in the Jupyter Book). The Brainhack Community member list and contributions of the different authors are detailed at http://brainhack.org/brainhack_jupyter_book/contributors.html. Our crediting system is described here: http://brainhack.org/brainhack_jupyter_book/neuroview_authorship-agreement.html.

DECLARATION OF INTERESTS

Anisha Keshavan is an employee of Octave Bioscience.

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Supplemental information

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

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Supplementary Materials

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