ARTICLE
Trainingspace: Neuroeducation Without Borders

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Advancements in the field of neuroinformatics have resulted in a massive explosion of raw data of many varieties, yet many traditional neuroscience training programs have not changed their curricula to reflect the urgent need for improved computational skills that would enable trainees to handle, organize, and interrogate such large, multimodal datasets. Thus, the objective of this project was to build an open access hub of neuroscience educational resources to fill the gap between current neuroscience curricula and the computationally focused skillset required to work with big data. To achieve this aim, we invited representatives from the world's leading neuroscience societies and large-scale brain initiatives to form the INCF Training and Education Committee that would provide oversight over the content and capabilities of the online hub. As a result, we developed TrainingSpace (https://training.incf.org/), an open access hub of nearly 500 multimedia courses, lectures, and tool tutorials covering the subspecialisms of neuroscience and neuroinformatics, as well as computer science, data science, and ethics. In addition to course content, TrainingSpace also provides users with access to publicly available datasets through KnowledgeSpace, a discoverability portal and community encyclopedia for neuroscience, as well as a question and answer forum, Neurostars.org. Since its launch in 2019, TrainingSpace has steadily increased in popularity with both trainees and trainers alike. It has also become popular with content providers that want to make their training materials available to the neuroscience community-at-large, as well as integrate their content into the larger TrainingSpace ecosystem.

Keywords: online training, self-guided study, open neuroscience resource, tutorials, conference lectures, courses, neuroinformatics, neuroscience, neuroethics, computational neuroscience

Like other scientific disciplines, the field of neuroscience is becoming more reliant on the use of computational tools to organize, analyze, and visualize the ever-increasing volume of multimodal brain data generated as a result of advancements in neuroinformatics. Most neuroscience trainees, however, receive little to no formal training for the increasingly computational nature of neuroscience. Thus, there is a gap between current neuroscience training curricula and the computational skills and mindset required for handling big data. As a result, the demand for such training is growing worldwide (Akil et al., 2016; Garcia, 2020; Hoy, 2021). To satisfy this demand, many informal in-person workshops, e-learning opportunities, and webinars have been created. Here, we present our effort to bridge the gap between current neuroscience curricula and the computational skillset required to manage big data through the development of an open access, e-learning platform called TrainingSpace (https://training.incf.org/).

MATERIALS AND METHODS

Content

The paradigm for TrainingSpace topical content was devised by the INCF Training and Education Committee composed of representatives from INCF Network, Human Brain Project, Canadian Open Neuroscience Platform, International Brain Research Organization, Society for Neuroscience, Federation of European Neuroscience Societies, Organization for Human Brain Mapping, IEEE Brain, BD2K Training Coordinating Center, and the iNeuro Initiative. The paradigm was heavily influenced by the results of the NSF-funded iNeuro Workshop held in 2014. The Committee elected to have 2 content tracks, one catering to undergraduate trainees and the other for graduate trainees.

For undergraduates, the Committee desired content on: computing, theory, database design, web programming, data structures, statistics, research methodology and design, ethics, intellectual property, and neuroscience.

For graduate trainees, the Committee desired content on: neuroscience methodologies and techniques, data collection, analysis, information and data science, metadata, annotation, data lifecycle management, data formats and standards, data wrangling and integration, data and information bases, standard workflows and software applications, semantic web (vocabularies, lexicons, ontologies, semantics), interoperability, computer science, machine learning, data mining, coding, communication, data visualization, and ethics.

Courses, lectures, and tutorials that fit the content tracks were provided by members of the INCF Network, the organizations with representation on the Committee, or recommended by the community-at-large for inclusion. All materials were vetted by the INCF Training and Education Committee for subject matter quality and the TrainingSpace development team for the quality of production before being posted to TrainingSpace.

Neuroscience	Neuroinformatics	Computational Neuroscience
Computer Science	Data Science/ Open Science	Project Management
Genomics	CInical Neuroscience	Ethics

Table 1. TrainingSpace Topics Categories.

Platform

The Drupal 8 open source content management system was selected as the platform for TrainingSpace due to its large suite of supporting tools, scalability, ease of implementation, ability to interact with different applications, and fewer backend restrictions while still maintaining suitable accessibility and security.

Content Management

TrainingSpace employs a controlled vocabulary and a metadata schema to manage all content using a tagging system. While content providers submit recommended tags for their resources, all tagging is performed centrally by INCF to ensure compliance. The tagging system used captures: title, provider, description, target audience, learning outcomes, required resources, keywords, structure and duration, additional information, and date of the last update.

RESULTS

TrainingSpace was developed as an open access hub of multimedia neuroscience educational content to serve both the neuroscience trainee looking to gain more knowledge about the subspecialisms of neuroinformatics and the computer scientists working in neuroscience looking to gain more knowledge about neuroscience.

Educational Content

To date, TrainingSpace currently contains nearly 500 courses, lectures, and tool tutorials covering the subspecialisms of neuroscience and neuroinformatics, as well as computer science, data science, and ethics—all collected from the world's leading neuroscience institutes and societies (Table 1). The current catalog of training resources is appropriate for beginner to intermediate level trainees (undergraduate to early graduate), although efforts are underway to expand the catalog to include resources for established neuroscientists seeking to learn new, complementary skills and tools. All content in TrainingSpace is released under open access licenses, so content may be used freely by trainers to include in their training activities. Currently, all lectures/tutorials in TrainingSpace contain either videos or audio slide presentations. In addition to the audiovisual content, content providers may also link lecture slides, lecture notes, and suggested reading, as well as Jupyter Notebooks, laboratory exercises, and sample datasets to their lectures/tutorials. To ease a trainee's journey towards becoming a scientist by actively performing science, we have integrated KnowledgeSpace (https://knowledge-space.org/), a data discoverability portal and neuroscience encyclopedia, developed by the INCF, Human Brain Project, and the Neuroscience Information Framework, that provides trainees with access to publicly available data files as well as links to literature references and scientific abstracts

Self-Guided Learning and Content Integration

The INCF Training and Education Committee curated five introductory study tracks in neuroinformatics, neurobiology, computational neuroscience, brain medicine, and ethics in order to facilitate self-guided study. The study tracks combine lectures and courses from multiple content providers and are arranged in a logical order for training with lectures providing a general overview of the subject area and courses providing more in-depth learning of the subject. The *related content* feature at the bottom of each lecture page provides recommendations for other content that serves as: prerequisite, related, or more advanced content related to the content currently being viewed. To further facilitate self-guided study, all TrainingSpace content is described and annotated with a controlled vocabulary of relevant keywords and a metadata schema that provides trainees with information ranging from title to target audience and learning objectives to required resources (Table 2).

Type of metadata	**What is included**
Title	Title of the training material
Author	Speakers name and institution/organization/project arranging the course
Description	Overview of the subject matter and aims of the training
Learning Outcomes	Statement on what the trainee should know upon successful completion
Target Audience	Intended audience and prerequisite knowledge
Required Resources	Links to software, datasets, infrastructure
Keyword	Keywords and tags identifying the topic of the material
Structure And Duration	Description of the structure of the materials and time allocated
Additional Information	Links to the provider
Date Of Last Revision	Date of last update of the materials and version

Table 2. TrainingSpace metadata.

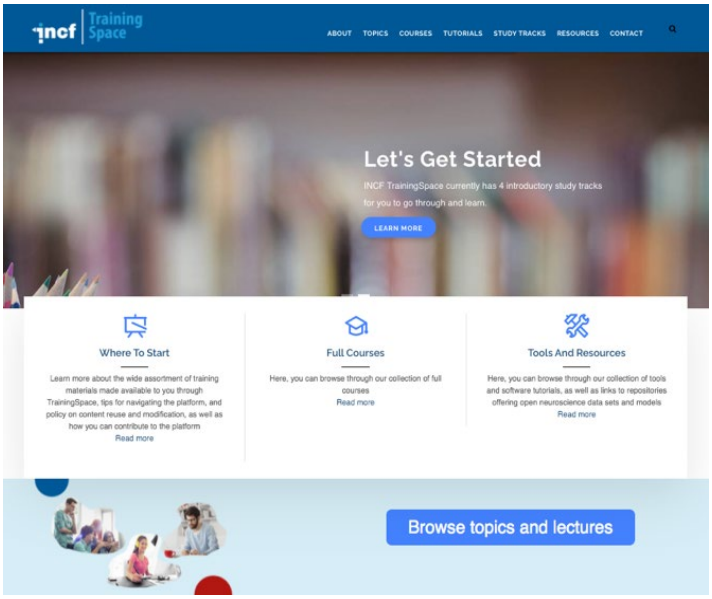

Figure 1. TrainingSpace landing page.

Having a controlled vocabulary enables TrainingSpace to integrate content from multiple providers into a coherent whole. For example, provider A provides a course and indicates the Python programming language as a prerequisite for the course; the course bundle provided by provider A does not contain an introduction to the Python programming language, but a course provided by provider B contains an introduction to the Python Programming language. TrainingSpace offers 2 options for including provider B's content into provider A's course either as a prerequisite or related lecture.

To facilitate reuse of TrainingSpace content, all lectures within a course are uploaded and indexed individually. This enables the INCF Training and Education Committee to create study tracks and courses by reusing existing content, as well as to supplement one provider's content with that of another.

Navigating TrainingSpace

At the TrainingSpace landing page, users have several options for navigating the platform (Figure 1). From the upper banner on the landing page, users can perform quick searches by: i. topic, ii. courses, iii. tutorials, iv. study tracks, or v. keyword search. There is a *where to start* button in the body of the landing page that takes users to TrainingSpace's user guide; and from there, users are able to navigate to the different search options. In addition, there are also buttons that enable users to search by full courses and resources/tools.

When searching by topic, users can further refine their searches using the faceted search feature which allows them to limit the search to: i. topic, ii. difficulty level, and iii. the type of content included in course, lecture, or tutorial, such as videos and slides (Figure 2). Individual content pages provide users with a general description of the content, the topics covered, video, and difficulty level, as well as links to any prerequisite content or required technology. When available, links to slides, tutorials,

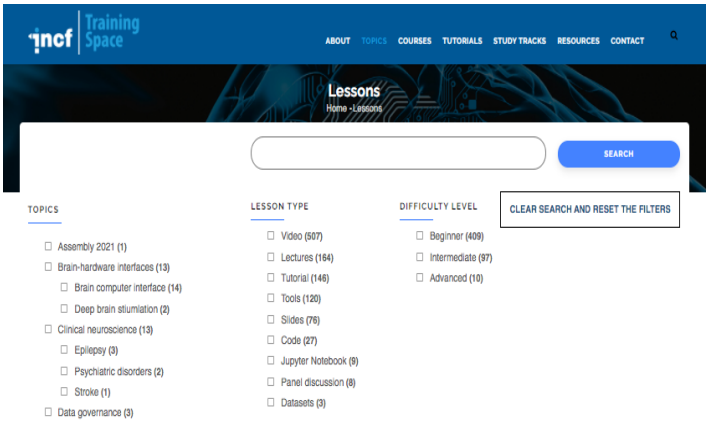

Figure 2. The search by topic interface in TrainingSpace. This interface enables users to refine their searches by clicking all applicable tags in the topics, lesson types, and difficulty level fields.

question and answer forums, and related content are also provided (Figure 3).

Community interaction and adoption

To facilitate interaction between TrainingSpace users, content providers, and the neuroscience community-at large, we integrated Neurostars, a popular question and answer forum maintained by the INCF network, into TrainingSpace. Neurostars provides a searchable archive of questions and answers that is indexed by Google. During 2020, the typical response time was less than 12 hours and more than 89,000 users participated in Neurostars (https://neurostars.org/), either by posting or answering questions. Since its launch in 2019, global, community adoption of TrainingSpace in countries around the world has steadily increased from 3,684 users in 2019 to 33,207 users by September 2021 (Figure 4). It has also become popular with content providers that want to make their training materials available to the neuroscience community-at-large, as well as integrate their content into the larger TrainingSpace ecosystem.

DISCUSSION

Here, we present our effort to bridge the gap between current neuroscience curricula and the computational skills required to work with big data through the development of TrainingSpace, an open access hub of multimedia neuroscience training resources. The increasing user base (3,684 in 2019 to 33,207 in 2021) and the number of requests from content providers to have their content published on TrainingSpace indicates that TrainingSpace does indeed fill the gap. We believe that TrainingSpace's popularity with users is due to the fact that it does not simply provide a content index by title, but also provides users with short descriptions of the content. Furthermore, the controlled vocabularies and metadata schema employed by TrainingSpace enables users to find the content they are looking for by both keyword and faceted search. The integration of the question and answer forum, Neurostars, into TrainingSpace provides learners with a forum to interact with the community which is often lacking in virtual learning. To our surprise, TrainingSpace has also become

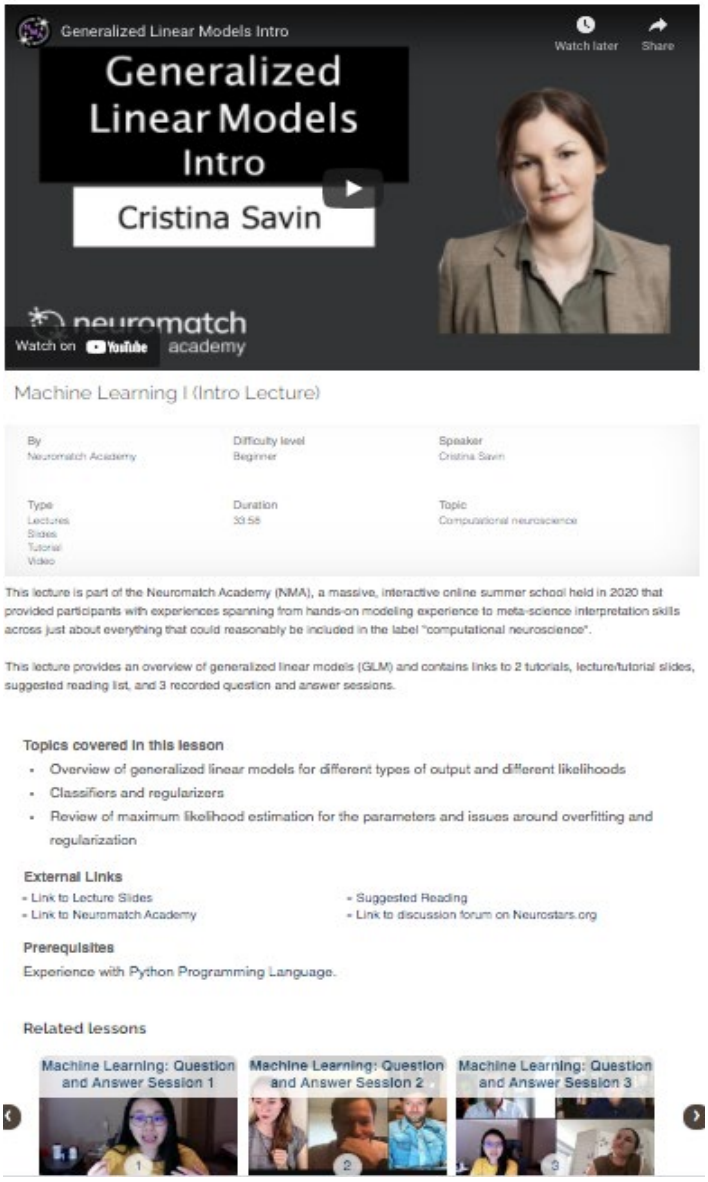

Figure 3. Example of a TrainingSpace content page. The same format is used regardless of whether the content is a lecture, course, or tutorial.

popular with content providers—many citing TrainingSpace's global reach, contextualization of content not found on platforms like YouTube, and open access policy as reasons for wanting to contribute content to TrainingSpace. Moreover, many are also attracted to the Neurostars forum since it provides a searchable archive of questions and answers that is indexed by Google.

The benefits of TrainingSpace are not only for trainees, but also for organizers of in-person workshops, e-learning platforms, and webinars. All content on TrainingSpace is open access, so organizers are able to reuse TrainingSpace content instead of developing new course materials for theirworkshops, e-learning platforms, or webinars. Also, organizers can deposit their modifications and supplements to TrainingSpace content for future reuse. Another benefit of TrainingSpace is that it provides users with community through Neurostars which is often lacking from many e-learning platforms and webinars.

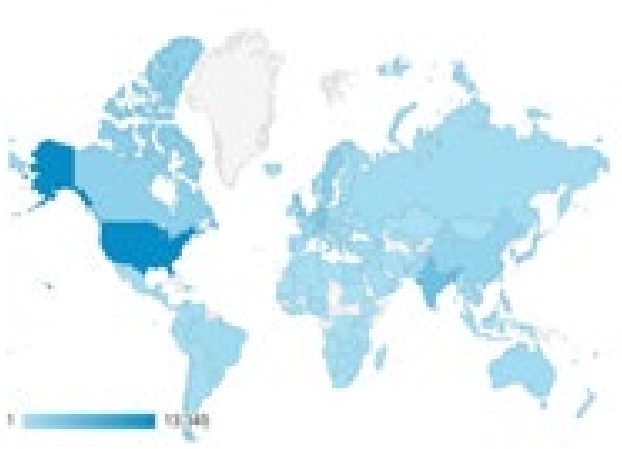

Figure 4. Community adoption of TrainingSpace. Geographic distribution of countries with TrainingSpace users from March 2019 to December 2021.

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