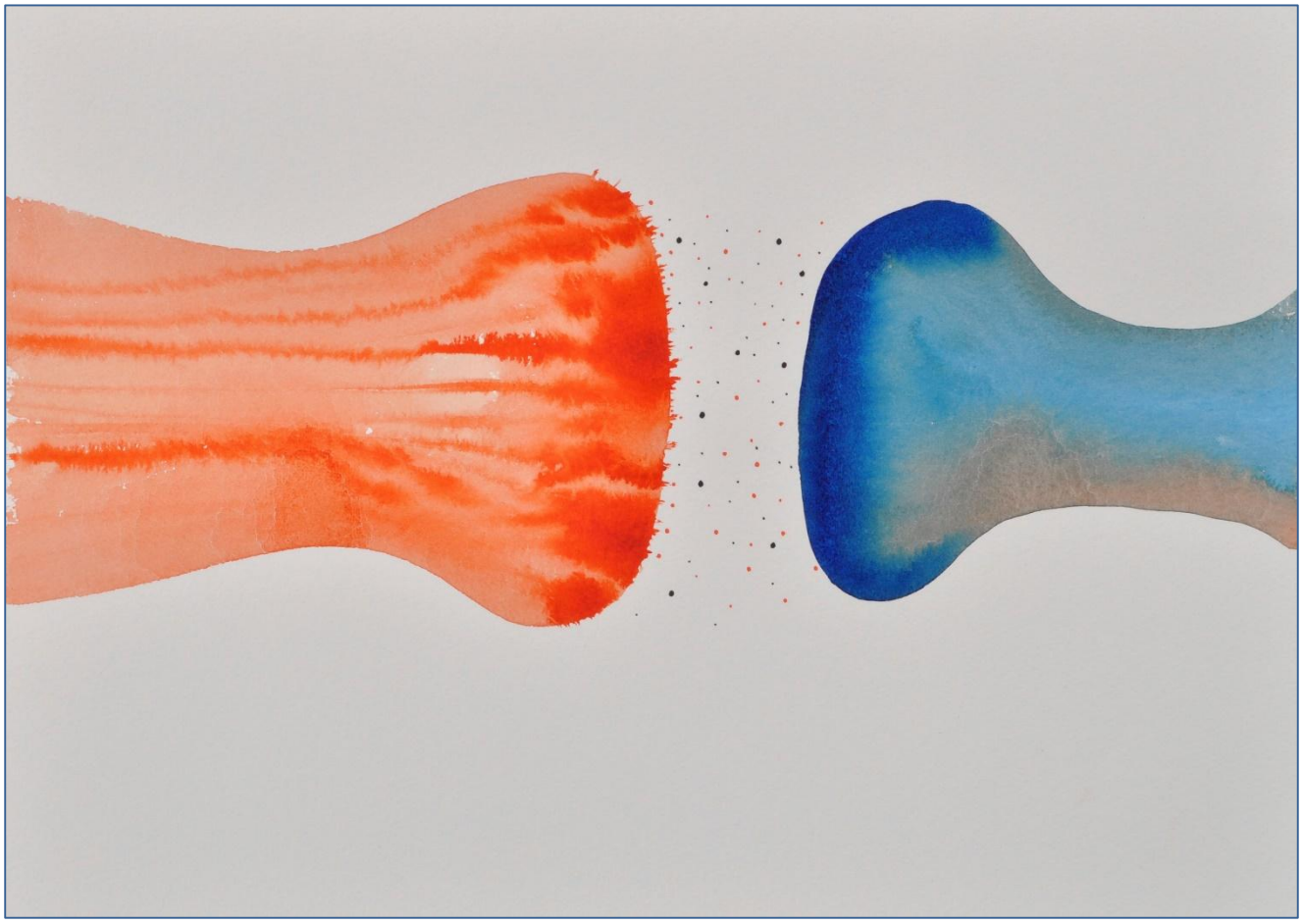
SP12-SGA2 Foresight Lab & Researchers Awareness background report 2 (D12.1.1 – SGA2)

Formal and Informal Infrastructures of Collaboration in the EU's Human Brain Project



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Abstract:	This report builds on analytical insights gained through long-term engagement with the Human Brain Project, in addition to a recent round of interviews with scientists and engineers in the HBP. We seek to address the following questions: How do small communities of collaborative practices grow and/or merge into large-scale, multicentric research and innovation communities? How are they supported, or hindered, by infrastructure? Our interviews show that while the HBP research infrastructure was designed to facilitate collaboration between scientists within and outside of the project, scientists have been collaborating using alternative means. While much of the literature on infrastructure focuses on 'top-down', formal infrastructural design, we pay attention to the informal, invisible infrastructural assemblage involved in large-scale interdisciplinary collaborations. We suggest that the formal infrastructure built to facilitate and structure collaboration within large scale interdisciplinary research projects can sometimes render the informal infrastructure and collaborations invisible. Scientists and engineers within the HBP were often engaging in collaborations that were not visible to the project leadership, administration, and to the European Commission because they were not using the formal infrastructure built to support, and account for, these same collaborations.
Keywords:	Infrastructure, collaboration, interdisciplinarity, community, social studies of science
Target Users/Readers:	HBP community, consortium members, funders, policymakers, EBRAINS designers and managers, scientific community, infrastructure and platform studies researchers

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1. Introduction

To address the 'grand challenges' facing our societies, science policy makers and research funding bodies increasingly stress the need to create interdisciplinary networks of researchers, collaborating internationally in communities that can combine their intellectual and technical resources. They seek to go beyond exhortation to interdisciplinarity, to create durable infrastructures to establish and sustain such collaborations, and integrate them into translation pathways to bring innovative research to market. Yet studies of interdisciplinarity have demonstrated that interdisciplinarity takes many forms and obeys multiple dynamics. There is no single model for success, and indeed genuine scientific collaboration between disciplines, and between researchers, technological innovators and industrial partners is often resistant to imposition from above. The context-dependent process by which informal and often serendipitous multidisciplinary collaborations are able to successfully develop into robust interdisciplinary research and innovation communities make them remarkably difficult to 'programme'.

The Human Brain Project (HBP) is one of the Future and Emerging Technology Flagship Initiatives funded by the European Commission to address EU 'grand challenges' of "understanding the human brain and its diseases [and] to advance brain medicine and computing technology"[1]. Commencing in 2013, the HBP is a ten-year multidisciplinary collaborative initiative in neuroscience, medicine and computing which brings together more than 500 scientists from more than 100 institutions in 20 countries across Europe, and has a strong element of international cooperation.[2] The original aim of the Project was to build multi-level computational models for the simulation of mouse and human brains. The project is divided into 12 Subprojects which span: data collection (to gather 'missing' mouse and human data needed to complete these large-scale and detailed models), cognitive and theoretical neuroscience (to develop theories to link the brains' various spatial and temporal scales, from cells to networks, to brain systems), and 6 computing Platforms that support the modelling and simulation efforts.

The Platforms include: 1) a Neuroinformatics Platform (NP - to standardise data and to make them open access for researchers within and outside of the project), 2) a Brain Simulation Platform (BSP - which makes available a suite of software tools for brain simulations at different levels of description), 3) a High Performance Analytics and Computing Platform (HPAC - which provides neuroscientists within and outside the project access to supercomputers to run their simulations on), 4) a Medical Informatics Platform (MIP - which allows researchers to access genetic, imaging, and other clinical data from hospital and research archives), 5) a Neuromorphic Computing Platform (NCP - which develops and provides access to brain-inspired computing hardware), and finally 6) a Neurorobotics Platform (NRP - which allows researchers to connect their brain models to digital and analog robotic bodies).

Early in the life of the HBP, in 2014, more than 800 neuroscientists across Europe and the United States signed an open letter expressing concerns both about the scientific feasibility of the project, and about its governance. These concerns were addressed in the 2015 review of the Project by the European Commission's external reviewers which resulted in recommendations to the Project's leadership. These mainly focused on developing closer collaboration between the different Subprojects and the Platform developers, and on building a user community that would both develop and use these Platforms within and outside of the Project. One of the outcomes of this review process was the development of Co-Design Projects (CDPs), which we discuss in more detail throughout this paper. Crucially, for the concerns of the present report, the review also articulated the aim of transforming the HBP Platforms into a research infrastructure. This was for two main reasons. First, to ensure that the achievements of the Human Brain Project would become a durable contribution

[1] "Human Brain Project (HBP) Flagship" (2019) https://ec.europa.eu/digital-single-market/en/human-brain-project

[2] The HBP was funded in a number of phases: a 30-month Ramp Up Phase (RUP), followed by a series of two-year phases each funded by a Specific Grant Agreement (SGA1, SGA2) each of which had to be negotiated and approved by the European Commission. This funding structure enabled the EC and its reviewers to exert considerable sway over the direction and priorities of the Project. In this report we will not discuss the implications of this regime, but some of them will become apparent.

to the European research and development landscape. Second, to ensure that the Human Brain Project was not, and was not seen to be, an isolated programme of research, but contributed to research in neuroscience and information and communication technologies across Europe. Ensuing discussions between the HBP leadership and EC had the aim of enabling the HBP to join the European Strategy Forum on Research Infrastructures which would give the Project continuity and support from the member states.

Since 2015, the Foresight Lab has been exploring the challenges that scientists and administrators in the HBP have faced in designing and building the Project's public-facing research infrastructure and in building a user community for it[3]. This report builds on this previous research and seeks to address the following questions: how does infrastructure hinder or support interdisciplinary collaboration in large-scale scientific projects? Our research makes it clear that while the HBP Research Infrastructure was designed to facilitate collaboration between scientists within and outside of the Project, scientists have been collaborating using alternative means. Research Infrastructures, specifically within the EU context, are defined as "facilities that provide resources and services for research communities to conduct research and foster innovation" that include scientific equipment or instruments, databases, and/or computing systems and communication networks. In this report, we use a broader understanding of the term, consonant with the social science research that has examined and analysed previous knowledge infrastructures; this includes the social elements of infrastructures which research has shown to be as crucial to the development of operational research infrastructures as the technological elements.

While much of the literature on infrastructure focuses on 'top-down', formal infrastructural design, we pay attention to the informal, invisible infrastructural assemblages involved in large-scale scientific collaboration. Scientists and engineers within the HBP were often engaging in collaborations that were not visible to the Project leadership, administration, and to the European Commission because they were not using the formal infrastructure built to support, and account for, these same collaborations. Our findings suggest that the formal infrastructure often renders such informal infrastructure and collaborations invisible.

2. Methodology

This report is based on social scientific research conducted since January 2014 by the King's College London's Foresight Lab, including extensive review and critical analysis of existing social science literature on research infrastructures, participant observation of meetings between scientists, engineers and project administrators between 2017-2019, 11 interviews with Platform users and developers, and analysis of HBP and EC documents relating to community building, collaboration, and infrastructure development. Interviewees were selected to represent various levels of expertise within the Project - ranging from experimental neuroscientists, to computational neuroscientists, to hardware developers, and project administrators. This selection process was guided by knowledge of the Project developed over 6 years of engagement in the HBP. We have deliberately not specified the selection process in detail or the profile of the researchers and administrators interviewed in order to reduce the possibility of identification. Ethical Clearance for this study was provided by the King's College London Research Ethics Office. Research participants gave written or oral consent to have interviews recorded or annotated, and were informed that their responses would contribute to the Foresight Lab's report on Community Building & Infrastructure Development in the HBP.

The questions posed to participants included: differences between collaboration in science and in engineering; reflecting on what they considered good collaborations and the features that made them so; whether collaboration required specific forms of expertise; how participants became involved in various HBP collaborations; how participants organise and manage their collaborations; and how they evaluated the tools and instruments that the HBP provides for collaboration. Thematic

[3] See "Foresight Report on Future Neuroscience" (2015, RUP, D12.1.2), "Building a Neuroscience Community: Community Modelling and Data Repositories" (2015, https://kclpure.kcl.ac.uk/portal/files/86508305/KCLForesightLab_2015_Future_Neuroscience.pdf), and "Infrastructure and Community Building: A briefing report for the Human Brain Project" (2018, SGA1).

analysis was conducted, and the main themes that were identified through this process were informal and informal infrastructure and their contribution to the visibility or invisibility of collaborations in the HBP.

3. Literature Review

Research in the humanities and social sciences on infrastructure and community building has revealed many differences in how these terms are understood and implemented. Social and historical studies of infrastructure have tended to focus on the social and political networks and structures that enable the development, running and maintenance of an infrastructure, bringing to the fore the non-technical dimensions and decisions that are involved in building, regulating, managing and using them. In this section, we focus specifically on research (or knowledge) infrastructures and the tensions that arise between formal and informal infrastructures.

3.1 Knowledge and Research Infrastructures

The HBP Platforms are what Paul Edwards, Geoffrey Bowker and colleagues have called knowledge infrastructures - networks of people, artefacts, and institutions that generate, share, and maintain knowledge about the human and natural worlds (Edwards *et al*., 2013; Bowker *et al*. 2010). The aim is to develop tools and services for neuroscience, medical research, neuromorphic computing and neurorobotics that will contribute to the broader aim of the HBP, which is to "understand the human brain".

We agree with Paul Edwards that "infrastructures can be characterized as complex, adaptive sociotechnical systems, made up of many interacting agents and components. Some of these are technological: buildings, devices, software and other artefacts. Others are social: organizations, standards, laws, budgets and political arrangements. Finally, some are human individuals who contribute to the infrastructure's development and maintenance or simply make use of it in their daily lives." (Edwards in Kornberger *et al*., 2019: 356).

The HBP Platforms, and the EBRAINS infrastructure (https://ebrains.eu/) built around them that will provide full access to their tools and services once the HBP finishes in 2023, are knowledge, or research infrastructures. Among the many challenges facing those who seek to build knowledge and research infrastructures are the following (Edwards *et al*., 2013):

1) What counts as knowledge is always changing, so knowledge infrastructures need to be adaptive and able to transform in the light of new knowledge.
2) Tacit knowledge is fundamentally important to scientific and engineering practices (Collins 2010). Such knowledge, seldom articulated, is not easily captured in the technologically mediated forms of collaboration across physical distances such as Google Docs, Skype, DropBox, etc.
3) Data sharing in knowledge and research infrastructures requires standardisation of ontologies and practices which is not always easy to achieve. At one extreme, this entails top-down imposition of standards; at the other, it requires bottom-up consensus: both depend on changes in the research practices of individuals or research groups.
4) Infrastructure building requires the difficult work of alignment of different temporalities, for example funding cycles, individual scientists' career cycles, differing technological development timeframes, differing scientific research timeframes, rapid technological obsolescence (Bowker *et al*. 2010).
5) Despite funders' interest in interdisciplinary collaboration within the sciences, and the push towards open science, the structures of scientific assessment and reward do not adequately value the labour involved. Indeed, interdisciplinary research is widely acknowledged as a risky career path for doctoral students and early career researchers and as presenting dubious career benefits for older ones. It requires time to develop, does not fit standard time cycles for research evaluation, offers few career-advancing incentives and lacks appropriate reward systems (Boix

Mansilla *et al.*, 2006; Frodeman *et al.*, 2010: part 4; Cuevas-Garcia, 2015; Frickel *et al.*, 2016: part 1).

Our research shows that researchers in the HBP have encountered all these challenges. In particular, as suggested in Point 5 above, those who have played a key role in creating and maintaining multidisciplinary collaborations - often described as "bridge scientists" (Anbar, 1986) – are doubly undervalued. Not only is such interdisciplinary work undervalued, much of this labour of network construction and maintenance is informal, and outside of the procedures within the formal infrastructure.

Attention to the human and social dimensions of infrastructure is often framed by a focus on formally organised knowledge production and maintenance. STS scholars Ingrid Erickson and Steven Sawyer have noted that "infrastructures are not always large-scale systems, but sometimes rather mundane structures set into place by individuals to accomplish their goals" (p. 331). In order to pay attention to the informal, distributed and collaborative forms of infrastructural organisation, they propose to think of what they call "the contemporary knowledge worker" as an "infrastructural bricoleur". Knowledge workers, they argue, draw on a "bricolage of material, mental, social and cultural resources to adapt to seamful situations and advance accordingly" (Erickson and Sawyer 2019). We need to attend to such 'bottom-up', tacit, and informal practices in order to grasp the ways that scientists and engineers draw on an assemblage of tools in large-scale interdisciplinary collaborations such as the HBP.

3.2 Informal/Formal Infrastructure

To think through the tensions between formal and informal infrastructure, we turned to urban and planning theory where this categorisation has been much debated. Colin McFarlane's (2012) view of informality and formality as "co-constitutive, mutually enabling or delimiting, or increasingly asymmetrical" forms of practice is particularly helpful for trying to understand the dynamics and relationship between the formal and informal infrastructures of the HBP. These categories, McFarlane emphasises, are not fixed or mutually exclusive, and people move between formal and informal activities and arrangements. Bricolage, he argues, blurs the lines between formal and informal, one embedding into the other or resisting it in a dynamic, ever changing re-configuration. "Sometimes new bureaucratic institutions", he says, "do not embed into informality because they are seen as cumbersome, time-intensive, and out-of-touch with people's everyday worlds, perhaps because they bypass forms of authority and cooperation that people already use. Equally, new formalised institutions can become embedded through bricolage, effectively shifting the dividing line between informal and formal relations, and assembling a new kind of institution." (p.103).

In the case of the HBP, our research has shown that scientists and engineers frequently rely on an informal, bricolage infrastructure to collaborate, and that these forms of collaboration are not always embedded in the formal HBP Research Infrastructure which is meant to facilitate and organise collaborations within and outside of the project.

4. The Formal Infrastructure of the HBP

4.1 The Collaboratory

The HBP has always been in part a Research Infrastructure building project with the expected delivery of six open ICT Platforms accessible to users through a common portal.

The HBP 'Vision' Document, published in August 2013, stated that: "The HBP will build, operate and continuously update an integrated system of six ICT platforms providing high-quality services to researchers and technology developers inside and outside the HBP. All the platforms will be remotely accessible through a single HBP web portal." This web portal was initially named the "Unification Portal" - in an effort to signify how the portal would enable the unification of neuroscience data and knowledge. The developers working on designing and building the portal were based in the

Simulation Subproject, headed by Henry MARKRAM. The portal was being designed to service what was the main goal of the Project - to build a simulation of the human brain. With simulation at the core, the Platforms existed to support the data collection, standardisation, model development, and computing needs.

After the mediation efforts of the European Commission following the 2014 controversy, this "Unification Portal" was renamed the "Collaboratory" to emphasise the collaborative nature of the project. The Collaboratory provides access for HBP researchers to all 6 Platforms. External access to the Platforms is by invitation only, via a request by an HBP Project Member, or "sending a support request to the HBP High Level Support Team (HLST)". The Platforms have struggled to attract a significant enough number of external users and hence the HBP's leadership has been making efforts to build a user community for them. But this has come late into the Project's timeline; and besides, the Collaboratory was at first built specifically to support the needs of users internal to the Project.

Even within the HBP, the Collaboratory achieved varying degrees of acceptance among HBP users. Some have found the Collaboratory helpful for internal collaboration because of the embedded Jupyter Notebooks - an open-source web application that enables the creating and sharing of code, equations, visualisations and text. In the 'bricolage' infrastructure that enables collaboration between HBP researchers, such non-HBP specific, open-access software packages as Google Docs and Jupyter Notebooks are used in conjunction with, and often instead of, the formal Collaboratory: the formal and informal infrastructures intermingle.

However, other HBP modellers who work with researchers external to the project have not found the Collaboratory helpful. The formality of the infrastructure - registration of access, for example - stood in the way of working with researchers external to the Project. But there was no way around it. The registration of users was a quantitative Key Performance Indicator, and this became a priority for the EC and the HBP leadership as they began to discuss the continuity of the HBP Research Infrastructure, and the possibility of joining the European Strategy Forum on Research Infrastructures.

In fact, active efforts to engage with potential communities of users came very late into the Project. The EC oversight and accountability mechanisms focussed on ensuring collaboration across Subprojects within the HBP, and hence the infrastructure developers within the project did not prioritise the work of building the external user community needed to ensure the continuity of the Project. These issues have become more critical as the HBP has begun the process of preparing to apply for the European Strategy Forum on Research Infrastructures (ESFRI).

4.2 European Strategy Forum on Research Infrastructures

The ESFRI, the European Strategy Forum on Research Infrastructures, "is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach … ESFRI operates at the forefront of European and global science policy and contributes to its development translating political objectives into concrete advice for RI in Europe".[4] The idea of joining an ESFRI roadmap (a new one is launched every 2 or 3 years) was floated quite soon after the HBP's change of goal in 2015, but it was not specified in detail. One consequence was that the complex configuration of decision makers in HBP governance, including the EC programme officers who have played an increasingly active role in managing the Project, continually redefined the scope, content and organisational form that the HBP Research Infrastructure would take.

The Research Infrastructure to be delivered by the HBP, now branded EBRAINS, is currently in the first formal stages of embodying this image of an ESFRI-geared infrastructure. The HBP is preparing EBRAINS' application to join the ESFRI Roadmap 2021 and it must abide by ESFRI's definition of what counts as a research infrastructure and by its associated requirements.[5] As specified in the ESFRI Roadmap 2021, "RI are facilities, resources and services that are used by the research communities

[4] https://www.esfri.eu/forum, 02/01/2020
[5] https://www.esfri.eu/esfri-roadmap-2021

to conduct research and foster innovation in their fields. They include: major scientific equipment (or sets of instruments), knowledge-based resources such as collections, archives and scientific data, e-infrastructures, such as data and computing systems and communication networks and any other tools that are essential to achieve excellence in research and innovation".[6] This definition is notably vague on scientific goals. It also seems unaware of the findings of dozens of studies of infrastructure, because it seems to conceive of research infrastructures solely in terms of technological components, overlooking the human and social dimensions that are so crucial. Several of our interviewees drew attention to the way that this focus on the technological rather than the human and social had shaped the evolution of the Project over time.

Moving infrastructure building to the forefront of the HBP's objectives had major implications for the Project. The HBP now had to think past the end of its funding in 2023 and to address questions about how to ensure the sustainability of the distributed, networked Research Infrastructure that would be its main legacy. This also meant that the HBP had to start thinking about who might be its potential user community - or communities - beyond HBP collaborators and beyond the end of the HBP. It was also the case that this enduring Research Infrastructure that the HBP was to become no longer had a well-identified and delimited scientific goal.

In the process, HBP researchers were increasingly unclear about the nature of the interdisciplinary research that was to be engaged. Our interviews found discrepancies between the ambitions of HBP researchers themselves and this new infrastructural vision, which was largely driven by the European Commission and their project reviewers. In particular, they understood the rationality driving the decision to target a wide user community of 'beginners' but questioned its consequences for the 'expert' users such as themselves; one interviewee put this strongly, arguing that it ensured that HBP researchers would bypass the formal infrastructure and continue to use their informal arrangements, which were more convenient and saved them time: they didn't need the level of hand holding that users less familiar with computational neuroscience would require, and they had direct contact with the different groups managing the underlying resources, so why go through the inevitably lengthier process of accessing those via EBRAINS, which user interface would have to take a step-by-step approach for fear of confusing the less skilled users?

4.3 Scaffold Infrastructure

We have spoken so far of the 'target' research infrastructure that is now to become the HBP legacy. But infrastructure building requires itself a scaffold of tools enabling, coordinating - and monitoring - the multidisciplinary collaborations necessary to this effort. A number of formal 'scaffolding tools' - social, managerial, organisational, financial as well as technological - were included in the HBP, some from the start, some over the course of the Project. However, like a scaffold, they were usually thought of as external to the research infrastructure itself, useful only in the infrastructure building phase. They were not understood as continuing elements that would be integral to any dynamic, constantly evolving Research Infrastructure which would outlive the HBP. This is clear if we consider some examples of these formal scaffolding tools and the ways that they were conceived and used, by the HBP governance.[7]

[6] https://www.esfri.eu/sites/default/files/ESFRI_Roadmap2021_Public_Guide_Public.pdf

[7] The Partnering Projects were part of this 'scaffold infrastructure, but we will not discuss them in detail in this report. The Partnering Projects were selected via FLAG-ERA Joint Transnational Calls, which "supports research projects in synergy with the two FET Flagships, the Graphene Flagship and the Human Brain Project. It is designed to expand the current Flagships with new research contributing to the Flagship objectives in selected areas. New researchers and researchers already in the Flagships are equally eligible." Selected projects are integrated in the Flagships as Partnering Projects, "essential to create synergies between the Flagship[s] and [research] activities receiving funding at regional, national or transnational level" (https://www.humanbrainproject.eu/en/collaborate/become-partnering-project, consulted 06/01/2020).

4.3.1 The Management (and Coordination) Subproject

The HBP included a managerial Subproject from the start. The name changed with the different phases of the project, from Management, to Central Services, to Management and Coordination. Its organisation and the scope of its attributions also changed significantly between the start of the HBP (the RUP), and the following phase of the project (SGA1). SGA1 implemented the major change of governance and of overall direction of the Project that was required following the 2014 mediation process and the 2015 review recommendations. For our purpose, the main changes which affected the managerial Subproject were as follows. First, the scientific direction and the management of the HBP became separate and independent from one another which meant that the managerial Subproject could make requests from the scientific and infrastructural Subprojects but had no authority to enforce them. Second, the managerial Subproject became tasked with providing support for the development and monitoring of collaboration within and outside the HBP, the perceived lack of which was flagged as a major weakness by reviewers. Third, the managerial Subproject now included the coordination of the Research Infrastructure and was tasked with implementing the roadmap outlined in a white paper entitled "Transforming the Human Brain Project Platforms into a Community-Driven Infrastructure for Brain Research"[8], although much of the technical integration proper of the Research Infrastructure has been under the responsibility of other Subprojects and increasingly so in SGA2, the phase of the Project running between April 2018 and March 2020, with the creation of a HBP Joint Platform Support Work Package and the move of Infrastructure Operations under the Neuroinformatics Platform Subproject.

4.3.2 The Project Life-cycle App (PLA) and PLUS

After the major change of governance and overall direction of the HBP in 2015, the HBP's main project management tool (called EMDESK) was considered to be insufficient to support the heightened need for coordination and collaboration demanded by the EC programme officers and reviewers. It was also insufficient for the monitoring of this collaboration which was now considered key to ensuring that it actually happened. In order to show that more collaborations were happening across the HBP and also that the management had a grip on coordinating, organising and directing the Project, it was felt that a finer-grained parcellation of the work was necessary. Each Task was now to be split into a number of elementary 'Components', and Components were to be associated together into 'workflows' through links of 'dependencies', constituting 'Use Cases' that would lead the infrastructure's design. This particular work planning and management model was explicitly inspired by modelling approaches used in information systems design and software engineering, such as object-oriented design in UML, the Unified Modelling Language. As such, it was familiar to computer scientists and engineers whose work in the HBP was also the most easily translatable into this modelling approach. This was not so much the case for many other researchers and their Tasks. Yet from late 2015 all the HBP's planning and monitoring was required to follow this model.

The first version of software provided by the managerial Subproject to accomplish this work was known as the PLA. Initially a small application for limited internal use, it was first coded by a non-programmer in the Project's Coordination Office (PCO), with the aim of demonstrating that the HBP's management had both knowledge and control over what was going on in the Project. The visualisations of interconnections it provided pleased both the Project management and its external governance. These rendered a peculiar interpretation of 'collaboration' visible, in 3D visuals that could be explored further by rotating and zooming in on the visualisation. But this custom-built and developed PLA – to which no budget was assigned in SGA1 - never reached a satisfactory level of usability and robustness.

In the SGA2, the current phase of the Project (SGA2), some budget was allocated to improve internal software development for science coordination. Some argued that a ready-made system should be

[8] This was annexed to the Framework Partnership Agreement (FPA) signed with the EC in 2016; it would provide the broad frame of the HBP for the 3 phases under H2020 (downloadable at https://www.humanbrainproject.eu/en/about/governance/framework-partnership-agreement/, 06/01/2020).

purchased from an external supplier but the HBP management once more opted for an internally designed system, and the PLA was 're-made' into an app now called PLUS. This had some additional functionalities, but still followed the same modelling approach and hence remained difficult to use for those unfamiliar with such a system.

The PLA created much ill will across the Project, for lack of usability, slowness, instability, and also for its underlying model which was highly ill-suited to certain parts of the HBP's work. Some worried that this could eventually discriminate in favour of certain disciplinary contributions against others. But there were other concerns. The PLA was initially presented by its creator as *the* tool that would make collaborations happen by making their potentiality visible, and hence would foster a lively HBP community. Hence, a technological 'fix' was used to address a largely social question. But it was always unclear how much this visibility would also be used for reporting purposes. This led to sometimes heated discussions at the regular cross-HBP Science Coordination meetings. The PLA's promoters argued that it could both enhance communication *and* reporting, but PLA sceptics argued the researchers they represented were not prepared to crystallise their collaborative work in this way, because it was often in an early and tentative stage of development. They were concerned that this would not just make it visible to EC programme officers and reviewers, but also mean that it was subject to accountability in terms of fixed targets and timeframes.[9]

The introduction of PLUS is recent, and it is too early to assess its usability and acceptability. It has received some positive comments, yet many remain doubtful that this enhances transparency and legibility for programme officers and reviewers. In addition, HBP researchers have now accepted the fact that the content of the PLA, and of its enhanced version PLUS, is fed into contractual work plans and subject to reporting and reviewing; they are tailoring their inputs accordingly. PLA and PLUS were intended to help enable HBP researchers to identify potential collaborators within the HBP, and to catalyse the development of an interdisciplinary research community. Technological tools such as these were always unlikely to achieve these objectives on their own. However, once these became tools for monitoring and evaluation, their potential to enhance genuine researcher-led collaboration was greatly reduced.

4.3.3 The Co-Design Projects (CDPs)

Another scaffolding tool introduced by the project coordination office alongside the PLA and with rather similar goals were the Co-Design Projects (CDPs).[10] They aimed at finding synergies between research groups across the scientific and infrastructural Subprojects and thus to implement a user-led design approach to building the HBP infrastructure. In so doing, they aimed at 'de-siloing' the HBP by fostering multidisciplinary collaborations across the Project.

User-led design originally comes from the world of information systems, more precisely from the field of Human-Computer Interaction. The CDPs' idea was indeed initially introduced by a senior research engineer of the High-Performance Computing Platform, who led the writing of the white paper entitled "Transforming the Human Brain Project Platforms into a Community-Driven Infrastructure for Brain Research" mentioned earlier. In fact, the 'Use Case' modelling approach behind the PLA was also at the heart of the CDP idea. This 'de-siloing' part of the CDPs' goal has had most impact on the researchers we have interviewed.

User-led design raises the obvious question: who are the users? This problematic question was raised repeatedly, notably when we asked whether the CDPs' biggest benefits were towards building infrastructure or towards building collaborations. Indeed, the CDPs' user-led design approach raises a major issue. The users leading the design, the 'power users' as they are described by one of our interviewees, may not in fact use the formal HBP research infrastructure. Indeed, it seems that they are more likely to bypass it and access its resources through the web of informal infrastructural practices that they have developed.

[9] Source: interviews. In addition, one of the authors of the present report was SP12 science coordination officer from the inception of cross-HBP Science Coordination in 2015 until the Spring of 2017.
[10] https://www.humanbrainproject.eu/en/about/project-structure/codesign-projects/

The lack of cross-HBP face time allocated to talking about actual science has been a recurring source of complaint among researchers. Thus, unlike the PLA, the CDP proposal, which required scientists and engineers to actually talk to each other about scientific ideas rather than budgetary and other bureaucratic issues was taken up with some enthusiasm after an initial phase of circumspection. Following a process of ideas generation, thematic group discussions, selection and planning, five CDPs came into existence at the start of the SGA1 phase of the HBP. They varied in their level of success, but they were successful enough overall to continue into SGA2 with the addition of a sixth CDP. Two more CDPs were added by Calls in the SGA2 phase.

However, a major stumbling block for the less successful CDPs was temporality. The distributed and networked research infrastructure of the HBP, together with its six ICT Platforms, is a scientific information infrastructure. For Bowker and colleagues such "large-scale information infrastructures … [which] aim at supporting research practices through a vast array of community digital services and resources (collaboratories and centers, data and code repositories, best practices and standards development, visualization tools and high performance computing, and so on)" are facing two main issues: first, the idea of a shared infrastructure in the sense of a public good; second, the idea of sustainability, of supporting research over the long term" (Bowker *et al*, 2010: 99).

This raises number of temporal problems, which were expressed by our interviewees when describing some of the challenges encountered in the CDPs. First, the long-term vision of information infrastructure building, required the development of technologies "that look farther ahead than immediate research concerns" (Bowker *et al*, 2010: 101). Second, there was the difficult work of aligning different time scales during infrastructure building (e.g. funding cycles, individual scientists' career cycles, differing technological development timeframes, differing scientific research timeframes, rapid technological obsolescence). "Heterochrony in cyberinfrastructure development is a major issue." (Bowker *et al*, 2010: 107-108) This temporal alignment work has been the cause of much concern and problems in the HBP. And third, to be truly a durable public good, an information infrastructure requires a financial and organisational commitment to long-term support and maintenance, and in the case of the HBP, the form that this will take is not always clear.

4.3.4 The European Institute for Theoretical Neuroscience (EITN)

The EITN is a formal scaffold instrument destined to foster collaborations inside and outside the HBP. Contrary to the PLA/PLUS or the CDPs, it was inscribed from the start into the description of work of the HBP, although its attributions somewhat expanded over time (for instance, a programme of co-supervised postdocs based at EITN was added from the next phase of the project (SGA1), to replace the initial co-supervision programme of postdocs based in their home institutions). The EITN was created in March 2014 as part of the HBP's Theoretical Neuroscience activities and is operated by Neuro-PSI (the Paris-Saclay Institute of Neuroscience), a unit of the French CNRS (https://www.eitn.org/). Its missions as stated on its webpages are "To create strong interactions between theoreticians and experimentalists in neuroscience" and "To broadcast theoretical neuroscience ideas from the Human Brain Project to the community, but [also to] bring new ideas and theories to the project", and it aims to do this via workshops, visitor program and co-supervised postdocs, for which it can provide funding.[11] In practice, this meant all HBP researchers (i.e. including neuromorphic computing, neurorobotics, etc) could use the facilities and opportunities offered by the EITN as long as the proposed activities intersected with the goals and research themes of the HBP Subproject running the EITN (SP4). The EITN also welcomed scientists from outside the HBP conducting relevant research. We discuss the EITN in more detail in the section on 'Spatialities of Collaboration'.

[11] https://www.eitn.org/index.php/general-information/about-eitn, last consulted 06/01/2020

4.3.5 Funding instruments

Another formal scaffolding instrument aimed this time at fostering collaboration between HBP participants and outside research groups, a Voucher programme worth a total of 1.3 million euros, was launched in October 2018 with the objective "to open the HBP's Research Infrastructure to meet the needs of the user community in a new dynamic way and to establish collaborations that pursue technology innovation and engineering solutions of mutual interest and benefit." A Call for applications was opened, aimed at "all non-HBP researchers, with target groups from academic, non-academic and medical research (including hospitals), and industry and pharma (SMEs and companies)." It was an 'in-kind' programme, through which Vouchers winners did not receive any direct money but would be able "to direct an equivalent value of work from the HBP Platform engineering teams. They will work with the team to implement the feature requests of the external projects in the HBP Platform infrastructure. The size of each voucher will depend on the personnel and travel costs required to put the selected projects into practice and to guarantee intensive exchange between the participants. The Vouchers are worth between 6 to 12 months of engineering/development time, plus travel costs."[12] This proved valuable to some of the HBP researchers we interviewed who were interested in collaborating with specific external groups because it left the form and content of the collaborations open to development by the researchers themselves. However, for other HBP researchers, the in-kind mechanism of the voucher programme was not necessarily well understood.

5. The HBP Informal Infrastructure

The Research Infrastructure built by the HBP embodied a particular image in which multidisciplinary collaboration and its growth into an interdisciplinary research / user community was the key to making the HBP 'successful'.[13] As we have seen, this led to the development of a growing set of formal 'scaffolding tools' to remedy the perceived lack of collaboration across the HBP and with outside research groups, with variable success. But if we follow McFarlane (2012) in conceiving of formality and informality as entwined forms of practices, what was actually going on at ground level? Were the research groups as 'siloed' as perceived through the formal monitoring, reporting and reviewing tools? How did HBP researchers come to collaborate, or not, between themselves and with outside researchers? Which informal infrastructural 'bricolage' did they assemble to support their collaborative endeavours? Which tools do they feel were missing, that would have facilitated their collaborations? Which existing formal tools did they appropriate and re-purpose into informal practices? Charlotte Lee, Paul Dourish and Gloria Mark (2006) argue that there is a "human infrastructure" that underpins large-scale distributed collaboration. This highlights the personal networks that exist alongside traditional collaborative structures, and the importance of physical meeting spaces in constructing cyber infrastructure which this section will discuss.

5.1 Pre-existing Communities

Rachel Ankeny and Sabina Leonelli have argued that successful scientific communities in biology develop what they call a "repertoire": "a stock of skills, behaviors, methods, materials, resources, and infrastructures that a group habitually uses to conduct research and train newcomers who want to join the group" (Ankeny & Leonelli, 2016). Successful repertoires need to be flexible and interdisciplinary and require a significant amount of "attention and care devoted by researchers to

[12] https://www.humanbrainproject.eu/en/follow-hbp/news/the-human-brain-project-launches-voucher-programme/, consulted 06/01/2020

[13] HUMAN BRAIN PROJECT FRAMEWORK PARTNERSHIP AGREEMENT (https://sos-ch-dk-2.exo.io/public-website-production/filer_public/0d/95/0d95ec21-276a-478d-a2a9-d0c5922fb83a/fpa_annex_1_part_b.pdf), Annex 1 Part B, 15 Oct. 2015. See in particular Appendix 3: White Paper "Transforming the Human Brain Project Platforms into a Community-Driven Infrastructure for Brain Research, and Appendix 4: Community Engagement.

material and social elements beyond the specific research questions under consideration." They demonstrate that successful community initiatives begin as small groups, develop shared repertoires, and grow incrementally.

It is significant to note that many of the participating individuals and laboratories in the HBP were previously partners or participants in other EC projects, such as FACETS (Fast Analog Computing with Emergent Transient States) between 2005-2010, and BrainScaleS between 2011-2015. If we assume that successful communities build shared repertoires (Ankeny and Leonelli 2015), then one of the major results of the FACETS and BrainScaleS projects was the development of PyNN – "a simulator-independent language for building neuronal network models" which is being used within the HBP as the standard programming language for enabling collaboration in brain modelling and simulation, but also in accessing computing Platforms.

Our interviews show that collaborations between engineers and neuroscientists were crucial in developing computing hardware. Many of these collaborations remain in the HBP, and we argue that they form part of the informal human infrastructure that supports continuing and developing collaborations in the HBP - such as the Co-Design Projects (CDP's). Through our involvement with the Project and through our interviews, we have found that the successful collaborations within the HBP - whether formal or informal - had as their basis members of these previous projects. The HBP did introduce new members, and we discuss in the next section how the mechanisms for dealing with the spatial distribution of the Project have facilitated these introductions.

5.2 Spatialities of Collaboration

For members continuing previous collaborations, much interaction took place online, over email, in what they called "virtual space". However, there was recognition amongst our interviewees that there was also a need for physical meetings. This is a finding that complements what many other social scientists, such as Lee, Dourish and Mark (2006), have reported about the rise of digital technologies for collaboration.

Annual summits helped balance between virtual and physical spaces of collaboration. These are 3-day gatherings in different European cities where members of all the Subprojects come together to share ongoing work and participate in plenaries and parallel meetings. These summits, which have formal collaboration meetings of Subprojects, have also become a part of the informal infrastructure of collaboration - a space to meet new people and pursue informal research interests. Our interviewees felt that that there is a need for more Project-wide meetings but acknowledged the economic cost and the carbon cost of EC projects and the importance of ensuring that meetings were not redundant.

The need to communicate at the "Project-wide" scale, without the dedicated resources to do so outside of the summits, meant that other parts of the Project have taken on the role of creating physical spaces for collaboration. One of these, purpose-built within the HBP, is the EITN. As we have described above, the EITN provides a space for free to the rest of the HBP for organising workshops of up to an optimal number of 25-30 participants[14], in the centre of Paris. One downside is the price of accommodation in Paris, which some have found exorbitant even if the venue is free. However, many research groups in the HBP used the EITN facilities to organise interdisciplinary workshops, bringing together experimentalists and theoreticians for instance, from across and outside the HBP, around specific topics. An advantage of the EITN is that it provides a space where researchers can feel somewhat protected from the permanent gaze of the HBP's evaluators - a friendly space where they could bounce around ideas informally - which is important for the growth of interdisciplinary communities (Aicardi, 2014). From SGA1, the EITN also provided a different way of creating physical links and exchanges between research groups, more narrowly but deeply focused, through a programme of co-supervised postdocs based at the EITN, who would move

[14] Although the EITN can accommodate up to 70 people, it appears that around 30 proved the best number for efficient gatherings to see emerge new or consolidation of existing collaborations.

between their co-supervisors' labs and whose work would materialise the collaboration between the two or more labs involved.

Another HBP instrument, which was somewhat re-purposed into creating physical spaces for collaboration, is the HBP Education programme. The HBP Education Programme, which was a part of the managerial Subproject, was never intended as a collaboration scaffolding tool. Its aim from the start of the Project has been to "[offer] innovative learning packages for early career researchers working in and across the fields of neuroscience, information and communications technology (ICT) and medicine. The programme especially targets advanced master's-level and PhD students, as well as early postdoctoral researchers, from within and outside the HBP."[15] Yet some research groups used it creatively as an informal instrument of collaboration. A senior researcher explained to us that because the HBP provided little travel money for physical meetings, he used the HBP Education Programme's support to develop collaborations with researchers outside the HBP.

5.3 Invisible Collaboration

While these spaces of collaboration did help to introduce new members into the Project, many of our interviewees reflected on how the formal infrastructure did not do a great deal to start new collaborations, but simply rendered already existing collaborations visible. There was also reflection on whether the bureaucratic labour involved in formalising the collaborations and making them visible through the CDP structure was worth the effort. Indeed, many collaborations remained invisible despite all the efforts to document them. The benefit of formalising the collaborations, of 'naming' them, did not help with the allocation of resources, but did help to build a research community. This allowed the researchers allocated time to meet at physical meetings, which were financially covered by the Project. What was perceived as "bringing people closer together" through the formalisation of the collaboration infrastructure helped to balance against the burden of enacting visibility.

However, this requirement of visibility and accountability to those involved in managing the HBP did not work in the reverse direction. In line with the findings in the recent report 'Horizon Europe co-design – implementation: Report on the results of the online consultation and the European Research & Innovation days event'[16], researchers often complained about the opacity of decision-making processes, of communication within the Project, and procedures implemented by the Project's leadership. These were tied into complaints about layered and increasingly inconsistent reporting tools, often imposed by the the EC. The asymmetry between expected / enforced transparency and visibility on the side of the researchers and the lack of reciprocation from managerial instances is a source of ongoing concern for researchers in the Project, and indeed this perhaps shows why informal and 'invisible' collaborations have become so important in enabling the kinds of human and social relations that constitute the indispensable informal infrastructure of large and distributed scientific projects.

6. Conclusion

The interviews we have conducted have highlighted the coexistence of a formal infrastructure (the Collaboratory and EBRAINS) whose design has evolved from being user-led by internal HBP users to being primarily targeted to external users.[17] But this formal infrastructure has co-existed with an uncoordinated, informal 'bricolage infrastructure, a parallel, informal, invisible, tacit infrastructure that researchers and engineers in the HBP are using to collaborate. In some cases, the informal infrastructure is facilitating the development of the official HBP infrastructure. However, in some cases the tools that have been put in place by the Commission or by HBP management to underpin

[15] https://www.humanbrainproject.eu/en/education/education-overview/, last consulted 06/01/2020
[16] https://ec.europa.eu/info/files/horizon-europe-co-design-implementation_en
[17] Presentation by HBP Infrastructure Operations Director Jan Bjaalie at the official EBRAINS pre-launch, 25/11/2019 https://www.youtube.com/watch?v=LlOGRorRb8w

a formal infrastructure are actually perceived by our interviewees as hindering the way collaboration works.

Informal infrastructures are never planned or designed. In the HBP, as elsewhere, they are neither coherent nor coordinated, but rather are haphazard assemblages, made of a range of diverse more or less independent people and pieces which have been appearing, tinkered with, removed, without an overall vision. One consequence of the fact that the key role of this bricolage infrastructure has not been recognised within the HBP, is that some of the pieces benefit collaboration, some hinder it, some are appropriated in unexpected ways, and their interlinked influences are not appreciated or even considered when some pieces are removed, altered, or new ones introduced.

To emphasise the importance of such an informal HBP infrastructure is also to highlight a key dimension that was not recognised in the conception of the EU FET Flagship projects both on the part of the EC and of the HBP Consortium. The guiding idea behind the Flagships was that addressing grand challenges required large multidisciplinary collaborative consortiums of a new kind, or rather on a new scale, as opposed to the traditional model of funding small scale research projects run by a few collaborating PIs. Yet although these large multicentric research (and innovation) consortiums were expected to do science on a new scale, it seems that it was assumed that they would function in much the same way as the traditional model in terms of management and coordination: that is to say, it seemed to be understood as a question of simply scaling up existing organisational practices such as BrainScaleS, FACETS, or the Blue Brain Project. Moreover, lessons did not seem to have been learned from existing studies of the complexities and challenges of virtual organisations (e.g. Cummings et al, 2008) despite the fact that a Consortium such as the HBP, composed of more than 100 geographically dispersed labs, was bound to be such a virtual organisation.

A further important issue arises from the assumption that the HBP researchers would be the first users of the HBP infrastructure, that they would be building it for their own use. This was implicit, for example, in the creation of the Co-Design Projects (CDPs), aimed at providing user-led design to the HBP target infrastructure as much as de-siloing the HBP. However, despite this emphasis on 'user-led' design of the formal infrastructure, the informal infrastructure remains crucial for the actual work of the researchers, and often is used to by-pass formal collaboration regimes. Thus, for example, EBRAINS is sometimes regarded as something for external researchers rather than for the HBP itself. Indeed, EBRAINS as it is currently imagined is meant to attract a wide range of external users categorised as having lower skill levels and different needs. These imagined users of EBRAINS do not form a single 'user community' and because they are regarded as a number of different 'user communities' with different skills and needs, they are seen to raise new challenges of 'community management'.

Paul Edwards analyses three mechanisms of architectural invisibility. The major one concerns the physical aspects of infrastructures that are often deliberately hidden (e.g. sewer systems, electrical cabling, etc). A second is the perceptual mechanism of habituation - we just stop noticing its existence). The third one is less obvious: infrastructure "becomes embedded in the *habits and skills* of individuals. In a process I sometimes call 'infrastructuration' (playing on Anthony Giddens's notion of 'structuration'), infrastructure both shapes and relies upon the continual performances or rehearsals of agents, that is, users" (Giddens, 1984 in Kornberger *et al.*, 2019: 358). In this report, we argue for another mechanism of infrastructural invisibility: when the formal infrastructure renders the informal one invisible. As the HBP formal infrastructure continues to develop and is incorporated into larger EC frameworks such as ESFRI, it will be important to continue to explore the (evolving) relationship between the formal and informal infrastructures of collaboration. It remains an open question whether EBRAINS as currently envisioned will offer the required facilities to grow the HBP-linked research community - or maybe rather, communities – in the way that its creators and funders intend.

7. Recommendations

The proposal for SGA3, the last phase of the HBP to start in April 2020, includes a 1.9 M€ investment aimed at deploying a user engagement strategy for creating an inclusive EBRAINS Community. In order to maximise the success of this endeavour, we recommend:

- **Consulting with key potential users in the infrastructure design process.** A technological infrastructure, in this case a research infrastructure, reflects and embodies social and political relations and hierarchies. Hence, for some issues, technological fixes cannot replace social solutions. Building an infrastructure to support neuroscience research in Europe must go hand in hand with supporting a community that can make use of this infrastructure, and also wants to do so. It is therefore necessary to consult with and include well-identified potential users in the design process.
- **Providing incentives and success metrics for new academic profiles** (curators; 'bridge scientists') to adequately recognise and reward collaborative and interdisciplinary labour.
- **Create evaluation mechanisms that can adequately acknowledge, recognise and capture informal collaborations without undermining their flexible informal nature**. Successful collaborations require trust and mutual understanding between researchers and between researchers and their evaluators. Researchers are, of course, accountable to taxpayers who fund their research. However, the bureaucratic instruments designed to monitor and evaluate collaborations need to be flexible in acknowledging informal forms of collaboration that may not be possible to represent quantitatively through existing KPIs.
- **Undertake social science research to examine the advantages and disadvantages of large-scale, distributed and digitised collaborations**. The HBP is a science policy experiment in that it is testing new forms of organising and funding scientific collaboration. More research is needed to understand the advantages and disadvantages of such large-scale, distributed and digitised collaborations. Such research needs to be used by HBP members to critically reflect on the Project developments, and to make necessary adjustments and improvements in light of the recommendations.
- **Evaluate the challenges of building a user community for the HBP.** Systematic research needs to be conducted to document and evaluate the challenges of building a user community for the HBP infrastructure. We recommend that systematic in-depth interviews are conducted with researchers within and outside the HBP, specifically with PhD students and early career researchers who are doing most of the work on the ground.
- **Undertake a targeted effort to engage research groups that have exited the HBP funding structure, as potential EBRAINS users.** A large number of research groups are leaving the HBP at the end of SGA2. They have actively contributed to building the HBP Platforms and enriching them with models, data, analytical tools, etc., and have developed collaborations with other HBP research groups in the process. We thus recommend that the HBP user engagement strategy should include a specific engagement effort targeting these research groups as potential low-hanging fruits in the first phase of recruiting EBRAINS users.

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