

1        *Stefano Moia<sup>1, 2, 3</sup>, Hao-Ting Wang<sup>1, 4</sup>, Anibal S. Heinsfeld<sup>5, 6</sup>, Dorota Jarecka<sup>7</sup>, Yu-Fang Yang<sup>8</sup>, Stephan Heunis<sup>9</sup>,*  
2        *Michele Svanera<sup>10</sup>, Benjamin De Leneer<sup>1, 11, 12, 13</sup>, Andrea Gondova<sup>1, 14, 15</sup>, Sin Kim<sup>16</sup>, Arshitha Basavaraj<sup>17</sup>, Jo-*  
3        *hanna M. Bayer<sup>1, 18, 19</sup>, Roza G. Bayrak<sup>1, 20</sup>, Pierre-Louis Bazin<sup>21, 22</sup>, Isil Poyraz Bilgin<sup>4, 23</sup>, Steffen Bollmann<sup>24, 25</sup>,*  
4        *Daniel Borek<sup>26</sup>, Valentina Borghesani<sup>1, 27</sup>, Trang Cao<sup>28</sup>, Gang Chen<sup>29</sup>, Alejandro De La Vega<sup>30</sup>, Sebastian Dresbach<sup>31</sup>,*  
5        *Philipp Ehses<sup>32</sup>, Jan Ernsting<sup>33, 34, 35</sup>, Inês Esteves<sup>36</sup>, Oscar Ferrante<sup>37</sup>, Kelly G. Garner<sup>38</sup>, Rémi Gau<sup>39</sup>, Elodie*  
6        *Germani<sup>40</sup>, Tara Ghafari<sup>37</sup>, Satrajit S. Ghosh<sup>7, 41</sup>, Sarah Elizabeth Goodale<sup>42</sup>, Cassandra D. Gould van Praag<sup>43, 44</sup>,*  
7        *Samuel Guay<sup>45</sup>, Omer Faruk Gulban<sup>46, 31</sup>, Yaroslav O. Halchenko<sup>47</sup>, Michael Hanke<sup>9, 48</sup>, Peer Herholz<sup>49</sup>, Katja Heuer<sup>50</sup>,*  
8        *Felix Hoffstaedter<sup>9, 51</sup>, Ruoqi Huang<sup>52</sup>, Renzo Huber<sup>53</sup>, Ole Jensen<sup>37</sup>, Kan Keeratimahat<sup>54</sup>, Julian Q. Kosciessa<sup>55</sup>,*  
9        *Sladjana Lukic<sup>56</sup>, Neville Magielse<sup>9, 57, 58</sup>, Christopher J. Markiewicz<sup>59</sup>, Caroline G. Martin<sup>60</sup>, Camille Maumet<sup>61</sup>,*  
10      *Anna Menacher<sup>62</sup>, Jeff Mentch<sup>7, 63</sup>, Christian Mönch<sup>9</sup>, Shammi More<sup>9, 48</sup>, Leonardo Muller-Rodriguez<sup>64, 65</sup>, Samuel*  
11      *A. Nastase<sup>66</sup>, Eliana Nicolaisen-Sobesky<sup>9</sup>, Dylan M. Nielson<sup>67</sup>, Christopher R. Nolan<sup>38</sup>, François Paugam<sup>68, 69</sup>, Pedro*  
12      *Pinheiro-Chagas<sup>70</sup>, Ana Luísa Pinho<sup>71, 72</sup>, Alessandra Pizzuti<sup>53, 46</sup>, Benjamin Poldrack<sup>64</sup>, Benedikt A. Poser<sup>53</sup>, Roberta*  
13      *Rocca<sup>73</sup>, Jacob Sanz-Robinson<sup>74</sup>, Kelvin Sarink<sup>34</sup>, Kevin R. Sitek<sup>75</sup>, Nadine Spychal<sup>76</sup>, Rüdiger Stirnberg<sup>32</sup>, Michał*  
14      *Szczepanik<sup>9</sup>, Mohammad Torabi<sup>77</sup>, Roberto Roberto Toro<sup>50</sup>, Sebastian GW Urchs<sup>78</sup>, Sofie L. Valk<sup>22, 9, 81</sup>, Adina S.*  
15      *Wagner<sup>9, 80</sup>, Laura K. Waite<sup>9</sup>, Alexander Q. Waite<sup>9</sup>, Lea Waller<sup>81</sup>, Tyler James Wishard<sup>82, 83</sup>, Jianxiao Wu<sup>9, 48</sup>,*  
16      *Yuchen Zhou<sup>84</sup>, Janine D. Bijsterbosch<sup>1, 85</sup>, The physiopy community<sup>86</sup>,*  
17  
18      1. OHBM Open Science Special Interest Group (SIG); 2. Neuro-X Institute, École polytechnique fédérale de Lausanne,  
19      Geneva, Switzerland; 3. Department of Radiology and Medical Informatics (DRIM), Faculty of Medicine, University of  
20      Geneva, Geneva, Switzerland; 3. Centre de recherche de l'Institut universitaire de gériatrie de Montréal, Montréal, QC,  
21      Canada; 4. Centre de recherche de l'Institut universitaire de gériatrie de Montréal, Montreal, Quebec, Canada; 5. Depart-  
22      ment of Psychology, Center for Perceptual Systems, The University of Texas at Austin, Austin, TX, USA; 6. Department  
23      of Computer Science, The University of Texas at Austin, Austin, TX, USA; 7. McGovern Institute for Brain Research,  
24      Massachusetts Institute of Technology, Cambridge, MA, USA; 8. Division of Experimental Psychology and Neuropsychol-  
25      ogy, Department of Education and Psychology, Freie Universität Berlin, Berlin, Germany; 9. Institute of Neuroscience  
26      and Medicine, Research Centre Jülich, Jülich, Germany; 10. Centre for Cognitive Neuroimaging, School of Psychology &  
27      Neuroscience University of Glasgow, UK; 11. Institute of Biomedical Engineering, Polytechnique Montreal, Montreal, QC,  
28      CA; 12. CHU Sainte-Justine Research Center, University of Montreal, Montreal, QC, CA; 13. Department of Computer  
29      Engineering and Software Engineering, Polytechnique Montreal, Montreal, CA; 14. UNIACT, NeuroSpin, CEA, Université

30 Paris-Saclay, Paris, France; 15. NeuroDiderot, Inserm, Université Paris Cité, Paris, France; 16. Brain and Cognitive Engin-  
31 eering, Korea Advanced Institute of Science and Technology, Daejeon, Korea; 17. Data Science and Sharing Team (DSST),  
32 Intramural Research Program, NIMH, Bethesda, USA; 18. Centre for Youth Mental Health, the University of Melbourne,  
33 Australia; 19. Orygen, Melbourne, Australia; 20. Department of Computer Science, Vanderbilt University, Nashville TN,  
34 USA; 21. University of Amsterdam, Amsterdam, Netherlands; 22. Max Planck Institute for Human Cognitive and Brain  
35 Science, Leipzig, Germany; 23. Machine Learning Department and the Neuroscience Institute, Carnegie Mellon University,  
36 Pittsburgh, US; 24. School of Information Technology and Electrical Engineering, The University of Queensland, Brisbane,  
37 Australia; 25. Centre for Innovation in Biomedical Imaging Technology, University of Queensland, Brisbane, Australia; 26.  
38 Department of Data Analysis, Faculty of Psychology and Educational Sciences, Ghent University, Ghent, Belgium; 27.  
39 Department of Psychology, Faculty of Psychology and Science of Education, University of Geneva, Geneva, Switzerland;  
40 28. School of Psychological Sciences, Monash University, Clayton, VIC, Australia; 29. Scientific and Statistical Computing  
41 Core, NIMH, NIH, Department of Health and Human Services, USA; 30. Department of Psychology, University of Texas at  
42 Austin, Austin, TX, USA; 31. Maastricht University, Maastricht, Netherlands; 32. German Center for Neurodegenerative  
43 Diseases (DZNE), Bonn, Germany; 33. Institute for Geoinformatics, University of Münster, Germany; 34. University of  
44 Münster, Institute for Translational Psychiatry, Münster, Germany; 35. Faculty of Mathematics and Computer Science,  
45 University of Münster, Germany; 36. ISR-Lisboa and Department of Bioengineering, Instituto Superior Técnico – Univer-  
46 sidade de Lisboa, Lisbon, Portugal; 37. Centre for Human Brain Health, School of Psychology, University of Birmingham,  
47 UK; 38. School of Psychology, The University of New South Wales, NSW, Australia; 39. Institut de recherche en sci-  
48 ences psychologique, Université catholique de Louvain. Louvain la neuve, Belgique; 40. Univ Rennes, Inria, CNRS, Inserm,  
49 Rennes, France; 41. Department of Otolaryngology - Head and Neck Surgery, Harvard Medical School, Boston, MA, USA;  
50 42. Department of Biomedical Engineering, Vanderbilt University; 43. Alan Turing Institute, London, UK; 44. Department  
51 of Psychiatry, Oxford University, Oxford, UK; 45. Department of Psychology, University of Montreal, Canada; 46. Brain  
52 Innovation, Maastricht, The Netherlands; 47. Department of Psychological and Brain Sciences, Dartmouth college, New  
53 Hampshire, USA; 48. Medical Faculty, Heinrich Heine University Düsseldorf; 49. McGill, Montreal Neurological Institute  
54 - Hospital, Montreal, Quebec, Canada; 50. Institut Pasteur, Université Paris Cité, Unité de Neuroanatomie Appliquée et  
55 Théorique, F-75015 Paris, France; 51. Institute of Systems Neuroscience, Medical Faculty & University Hospital Düsseldorf,  
56 Heinrich-Heine- University, Düsseldorf, Germany; 52. University of Toronto, Toronto, Ontario, Canada; 53. Department of  
57 Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, The Netherlands; 54.  
58 Nuffield Department of Population Health, University of Oxford, Oxford, UK; 55. Donders Institute for Brain, Cognition

59 and Behaviour, Radboud University, Nijmegen, The Netherlands; 56. Ruth S. Ammon College of Education and Health  
60 Sciences, Department of Communication Sciences and Disorders, Adelphi University, San Francisco, CA, USA; 57. Otto  
61 Hahn Cognitive Neurogenetics Group, Max Planck Institute for Human Cognitive and Brain Sciences, Stephanstraße 1A,  
62 04103, Leipzig, Germany; 58. Institute of Systems Neuroscience, Medical Faculty, Heinrich Heine University Düsseldorf,  
63 Moorenstraße 5 40225 Düsseldorf, Germany; 59. Stanford University, CA, USA; 60. Vanderbilt University, Nashville, TN  
64 USA; 61. Inria, Univ Rennes, CNRS, Inserm, Rennes, France; 62. Department of Statistics, University of Oxford, UK; 63.  
65 Program in Speech and Hearing Bioscience and Technology, Harvard University, Cambridge, MA, USA; 64. Psychoinform-  
66 atics Lab, Forschungszentrum Jülich, Jülich, Germany; 65. Cambridge Institute for Music Therapy Research (CIMTR),  
67 Anglia Ruskin University, Cambridge, UK; 66. Princeton Neuroscience Institute, Princeton University, Princeton, NJ,  
68 USA; 67. Machine Learning Team, National Institute of Mental Health, Bethesda, MD, USA; 68. University of Montreal,  
69 Montreal, Quebec, Canada; 69. Mila - Quebec Artificial Intelligence Institute, University of Montreal, Montreal, Quebec,  
70 Canada; 70. Department of Neurology, Memory and Aging Center, University of California, San Francisco, San Francisco,  
71 CA, USA; 71. Western Institute for Neuroscience, Western University, London, Ontario, Canada; 72. Department of Com-  
72 puter Science, Faculty of Science, Western University, London, Ontario, Canada; 73. Department of Culture, Cognition,  
73 and Computation, School of Culture and Society, Aarhus University, Aarhus, Denmark; 74. Neuroscience, McGill Uni-  
74 versity, Quebec, Canada; 75. Department of Communication Science and Disorders, School of Health and Rehabilitation  
75 Sciences, University of Pittsburgh, Pittsburgh, PA, USA; 76. Department of Informatics, University of Sussex, UK; 77.  
76 Graduate Program in Biological and Biomedical Engineering, McGill University, Montreal, Canada; 78. NeuroDataScienc  
77 - ORIGAMI lab, Montreal Neurological Institute-Hospital, McGill University, Montreal, Canada; 79. Institute of Systems  
78 Neuroscience Heinrich Heine University Düsseldorf; 80. Department of Psychology, Heinrich Heine University Düsseldorf,  
79 Düsseldorf, Germany ; 81. Charité Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and Humboldt-  
80 Universität zu Berlin, Department of Psychiatry and Neurosciences CCM, Berlin, Germany; 82. Department of Psychiatry  
81 and Biobehavioral Sciences, University of California Los Angeles, Los Angeles, California, United States; 83. Department of  
82 Neurology, Washington University in St. Louis, St. Louis, Missouri, United States; 84. Department of Psychology, Carnegie  
83 Mellon University, Pittsburgh, USA; 85. Department of Radiology, Washington University in St Louis, Saint Louis, Mis-  
84 souri, USA; 86. physiopy.github.io

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87 Proceedings of the UHBM BrainHack 2022

## Abstract

90 OHBM Brainhack 2022 took place in June 2022. The first hybrid OHBM hack-  
91 athon, it had an in-person component taking place in Glasgow and three hubs around  
92 the globe to improve inclusivity and fit as many timezones as possible. In the buzzing  
93 setting of the Queen Margaret Union and of the virtual platform, 23 projects  
94 were presented after development. Following are the reports of 14 of those, as well  
95 as a recapitulation of the organisation of the event.

## **96** Introduction

The Organisation of Human Brain Mapping BrainHack (shortened to OHBM BrainHack herein) is a yearly satellite event of the main OHBM meeting, organised by the Open Science Special Interest Group following the model of Brainhack hackathons<sup>1</sup>. Where other hackathons set up a competitive environment based on outperforming other participants' projects, Brainhacks foster a collaborative environment in which participants can freely collaborate and exchange ideas within and between projects.

This edition of the OHBM Brainhack, that ran across the world over four days, was particularly special for two reasons: it celebrated the tenth year anniversary of Brainhack, and, like the main OHBM conference, it was the first edition to feature an in-person event after two years of virtual events. For this reasons, the whole organisation rotated around five main principles:

- 108 1. Providing a hybrid event incorporating the positive aspects of in-person and virtual  
109 events alike,

110 2. Celebrating the 10<sup>th</sup> anniversary of the Brainhack by bringing back newcomer-  
111 friendly hands-on hacking and learning experience, enhancing the Hacktrack and  
112 formatting the Traintrack as a collection of materials to consult beforehand and as  
113 spontaneous meetings of the participants aimed to learn together.

- 114     3. Bridging the gap between the Brainhack community and the main neuroimaging  
115       software developer groups, e.g. AFNI, FSL, SPM,
- 116     4. Due to amount of work required to meet the previous three principles, incorporat-  
117       ing from the beginning a team of core organisers with a democratic approach to  
118       organisation, with a member in charge of an aspect of the event,
- 119     5. Brainhack event organisation should always be experimental, trying different solu-  
120       tions and formats to find a way to improve Brainhack events overall.

121       After a quick explanation of each main contribution of the core team, the next pages  
122       are dedicated to the summaries of the projects that were developed during the four days  
123       of hacking.

## 124     1 Hacktrack

125       *Dorota Jarecka, Yu-Fang Yang, Hao-Ting Wang, Stefano Moia*

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127       The key component of each Brainhack is hacking. The hacking part, known as hack-  
128       track, is where attendees collaborate on projects and explore their own ideas. There are  
129       4 elements of hacktrack that were organised: project submission, project pitch, hacking  
130       period and project summary. For the project submission, we used the GitHub issue sub-  
131       mission process that was used during recent years. We updated and simplified a project  
132       template from previous years and asked project leaders to open an issue for each project.  
133       Each issue after quick check was approved by the moderators and automatic workflows  
134       written by the team were responsible for sending project descriptions to the Brainhack  
135       page and setting Discord's channels. We received 38 projects that were submitted using  
136       this system. The project pitch was set for the morning of the first day and everyone had 2  
137       minutes to talk about the suggested project and possible collaborations. After the pitches  
138       people had a chance to talk to each other and join the projects they were interested in.  
139       This year, we tried to maximise the time for hacking by providing a sparse schedule for

140 talks. The closing ceremony of the Brainhack featured 23 project reports, in which teams  
141 talked about their experiences and described the work they accomplished.

142 This edition we allowed remote attendance from other locations. We organised three  
143 hubs aiming to cover all time zones, including 1) Asia-Pacific, 2) Glasgow, Europe, Middle  
144 East, and Africa, and 3) the Americas, to foster inclusiveness in the hybrid conference  
145 format. We also ensured that each hub had one live streamed session with the physical  
146 hub in Glasgow.

## 147 2 Traintrack

148 *Yu-Fang Yang, Dorota Jarecka*

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150 Traintrack is the educational component of Brainhack events. The aim is to introduce  
151 tools and skills for attendees to start hacking. Unlike conventional scientific educational  
152 workshops centred around lectures and talks, data science skills are better learned through  
153 hands-on experience than lectures. With the Brainhack community growing mature, the  
154 community has developed their own curated educational material. *Brainhack School* has  
155 supplied high-quality content for independent study on a variety of themes.

156 This year, we combine the collaborative nature of brainhack projects and educational  
157 content to reimagine the format of taintack. Thus, we replaced tutorial lectures in the  
158 previous editions with curated online educational contents, released them prior to the  
159 main event, and attempted to integrate them with the hacktrack projects. This format  
160 also provides more time (i.e. schedule) and space (i.e. minimising large space not used for  
161 hacking) for attendees to self-organise. Participants were encouraged to form study groups  
162 on five suggested topics: 1) setting up your system for analysis 2) python for data analysis,  
163 3) machine learning for neuroimaging, 4) version control systems, 5) cloud resource. The  
164 curated content was advertised on the main hackathon website. One dedicated channel  
165 was created on the hackathon Discord server. Individuals could determine the nature of  
166 their experiences and the skills they liked to acquire. Participants could form their own

<sub>167</sub> study group and on any selected topic. We would like to continue the experimentation  
<sub>168</sub> on this format in the coming year.

### <sub>169</sub> 3 Platforms, website, and IT

<sub>170</sub> *Anibal Solon Heinsfeld*

<sub>171</sub>

<sub>172</sub> Trying to bring a positive experience for both virtual and in-person attendees, we  
<sub>173</sub> implemented several integrated solutions to ease communication in the different phases  
<sub>174</sub> of the Hackathon, focusing on a single platform for the main event.

<sub>175</sub> The first solution was the project's advertisement, in which the community promotes  
<sub>176</sub> their projects, the goals for the Hackathon, and relevant information to get people inter-  
<sub>177</sub> ested and set to collaborate. To do so, we used the Github Issues feature in the Hackathon  
<sub>178</sub> repository as the entrance for projects. Github Issues has been proven to be accepted by  
<sub>179</sub> the community that relies on Github for code versioning, and was a successful approach  
<sub>180</sub> in past hackathons.

<sub>181</sub> In this edition, we were able to use Github Issue forms, a beta feature in Github. Past  
<sub>182</sub> use of issues for project registration relies on Markdown code to specify which information  
<sub>183</sub> the hacker needs to provide. However, the code can be easily broken and changed, which  
<sub>184</sub> makes it harder to parse the information in automated setups. Towards this issue, the  
<sub>185</sub> Issue Form can lower the barrier when submitting a project. By specifying form fields  
<sub>186</sub> for the participants to fill, they faced a common web form instead of a Markdown editor,  
<sub>187</sub> bringing more structure to their inputs and not requiring them to write code. After  
<sub>188</sub> the organisers' quick validation, the project information was provided to the rest of the  
<sub>189</sub> system. Per an automated pipeline, this information was compiled into the website.

<sub>190</sub> The second solution was the central platform for real-time communication, namely  
<sub>191</sub> Discord. For the first time using the platform for an OHBM Hackathon, Discord showed  
<sub>192</sub> potential in bringing an all-in-one solution. Its track record with different communities  
<sub>193</sub> and their formats was an essential prospect for the success of a hybrid hackathon, together

<sup>194</sup> with the different ways of communicating provided by the platform. Specifically, Discord  
<sup>195</sup> offered chat and audio/video channels, with fine-tuned controls on permissions to see a  
<sup>196</sup> channel, speak and use the camera, and send messages. With these features, we were able  
<sup>197</sup> to create experiences for the attendants, such as text channels for consolidating inform-  
<sup>198</sup> ation about the hackathon, main stages controlled by the hub hosts, a channel to join  
<sup>199</sup> projects and hubs, and integrated text & voice channels for each project. The main stage  
<sup>200</sup> was connected to a laptop in the venue, providing synchronous streaming for announce-  
<sup>201</sup> ments, project pitches and progress reports for those participating virtually. The project  
<sup>202</sup> channels were automatically created together with the Github Issues. However, given  
<sup>203</sup> the thriving number of projects, the Discord server was replete with project channels.  
<sup>204</sup> Such a scenario was overwhelming for the attendants, especially for those approaching  
<sup>205</sup> Discord for the first time. To ameliorate this issue, a main projects channel was created,  
<sup>206</sup> so attendants could automatically join projects via related emoji reactions. The project  
<sup>207</sup> channels were of public access; however, only displayed upon joining the project. Besides  
<sup>208</sup> initial technical hiccups, the platform proved a good alternative for such an event format.

<sup>209</sup> These integrated solutions smoothed the organisation of the event, the virtual platform  
<sup>210</sup> provided great support for the on-line participants. However, there was not a lot of inter-  
<sup>211</sup> action between in-person and online participants, and projects were mainly either virtual  
<sup>212</sup> or in-person (with few exceptions). This is probably because hybrid hacking provides chal-  
<sup>213</sup> lenges for organisation and attendants alike, even just in the physical limitations of being  
<sup>214</sup> able to have a video conference with a split team. It is important to consider, however,  
<sup>215</sup> that this was also the first in-person event for many participants, who preferred in-person  
<sup>216</sup> interaction and collaboration rather than the same on-line interaction that characterised  
<sup>217</sup> such events in the previous two years.

## <sup>218</sup> 4 Project Reports

<sup>219</sup> The peculiar nature of a Brainhack<sup>1</sup> reflects in the nature of the projects developed  
<sup>220</sup> during the event, that can span very different types of tasks. While most projects feature

more ‘hackathon-style’ software development, in the form of improving software integration (Section 4.4), API refactoring (Section 4.11), or creation of new toolboxes and platforms (Sections 4.9, 4.10 and 4.13), the inclusion of newcomers and participants with less strong software development skills can foster projects oriented to user testing (Sections 4.3 and 4.9) or documentation compilation (Section 4.12). The scientific scopes of Brainhacks were reflected in projects revolving around data exploration (Sections 4.1 and 4.7) or model development (Section 4.13), or adding aspects of open science practices (namely, the Brain Imaging Data Structure) to toolboxes (Sections 4.6 and 4.14). Finally, fostering a collaborative environment and avoiding pitching projects against each others not only opens up the possibility for participants to fluidly move between different groups, but also to have projects which sole aim is supporting other projects (Section 4.2), learning new skills with entertaining tasks (Section 4.5), or fostering discussions and conversations among participants to improve the adoption of open science practices (??).

Following are the 14 submitted reports of the 23 projects presented at project wrap-up during the OHBM Brainhack.

## 4.1 Exploring the AHEAD brains together

*Alessandra Pizzuti, Sebastian Dresbach, Satrajit Ghosh, Katja Heuer, Roberto Toro, Pierre-Louis Bazin*

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### 4.1.1 Introduction

One of the long-standing goals of neuroanatomy is to compare the cyto- and myeloarchitecture of the human brain. The recently made available 3D whole-brain post-mortem data set provided by Alkemade and colleagues<sup>2</sup> includes multiple microscopy contrasts and 7-T quantitative multi-parameter MRI reconstructed at 200µm from two human brains. Through the co-registration across MRI and microscopy modalities, this data set provides a unique direct comparison between histological markers and quantitative MRI parameters for the same human brain. In this BrainHack project, we explored this dataset, focusing on: (i) data visualization in online open science platforms, (ii) data in-

<sup>248</sup> tegration of quantitative MRI with microscopy, (iii) data analysis of cortical profiles from  
<sup>249</sup> a selected region of interest.

<sup>250</sup> **4.1.2 Results**

<sup>251</sup> Visualization and annotation of large neuroimaging data sets can be challenging, in  
<sup>252</sup> particular for collaborative data exploration. Here we tested two different infrastruc-  
<sup>253</sup> tures: BrainBox <https://brainbox.pasteur.fr/>, a web-based visualization and an-  
<sup>254</sup> notation tool for collaborative manual delineation of brain MRI data, see e.g. Heuer and  
<sup>255</sup> colleagues<sup>3</sup>, and Dandi Archive <https://dandiarchive.org/>, an online repository of mi-  
<sup>256</sup> croscopy data with links to Neuroglancer <https://github.com/google/neuroglancer>.  
<sup>257</sup> While Brainbox could not handle the high resolution data well, Neuroglancer visualization  
<sup>258</sup> was successful after conversion to the Zarr microscopy format (Figure 1A).

<sup>259</sup> To help users explore the original high-resolution microscopy sections, we also built a  
<sup>260</sup> python notebook to automatically query the stains around a given MNI coordinate using  
<sup>261</sup> the Nighres toolbox<sup>4</sup> (Figure 1B).

<sup>262</sup> For the cortical profile analysis we restricted our analysis on S1 (BA3b) as a part of  
<sup>263</sup> the somato-motor area from one hemisphere of an individual human brain. S1 is rather  
<sup>264</sup> thin ( $\sim$ 2mm) and it has a highly myelinated layer 4 (see arrow Figure 1C). In a future  
<sup>265</sup> step, we are aiming to characterize differences between S1 (BA3b) and M1 (BA4). For  
<sup>266</sup> now, we used the MRI-quantitative-R1 contrast to define, segment the region of interest  
<sup>267</sup> and compute cortical depth measurement. In ITK-SNAP<sup>5</sup> we defined the somato-motor  
<sup>268</sup> area by creating a spherical mask (radius 16.35mm) around the ‘hand knob’ in M1. To  
<sup>269</sup> improve the intensity homogeneity of the qMRI-R1 images, we ran a bias field correction  
<sup>270</sup> (N4BiasFieldCorrection,<sup>6</sup>). Tissue segmentation was restricted to S1 and was obtained  
<sup>271</sup> by combining four approaches: (i) fsl-fast<sup>7</sup> for initial tissues probability map, (ii) semi-  
<sup>272</sup> automatic histogram fitting in ITK-SNAP, (iii) Segmentator<sup>8</sup>, and (iv) manual editing.  
<sup>273</sup> We used the LN2\_LAYERS program from LAYNII open source software<sup>9</sup> to compute  
<sup>274</sup> the equi-volume cortical depth measurements for the gray matter. Finally, we evaluated  
<sup>275</sup> cortical depth profiles for three quantitative MRI contrasts (R1, R2, proton density)

276 and three microscopy contrasts (thionin, bieloschowsky, parvalbumin) by computing a  
277 voxel-wise 2D histogram of image intensity (Figure 1C). Some challenges are indicated  
278 by arrows 2 and 3 in the lower part of Figure 1C.

279 From this Brainhack project, we conclude that the richness of the data set must be  
280 exploited from multiple points of view, from enhancing the integration of MRI with mi-  
281 croscopy data in visualization software to providing optimized multi-contrast and multi-  
282 modality data analysis pipeline for high-resolution brain regions.

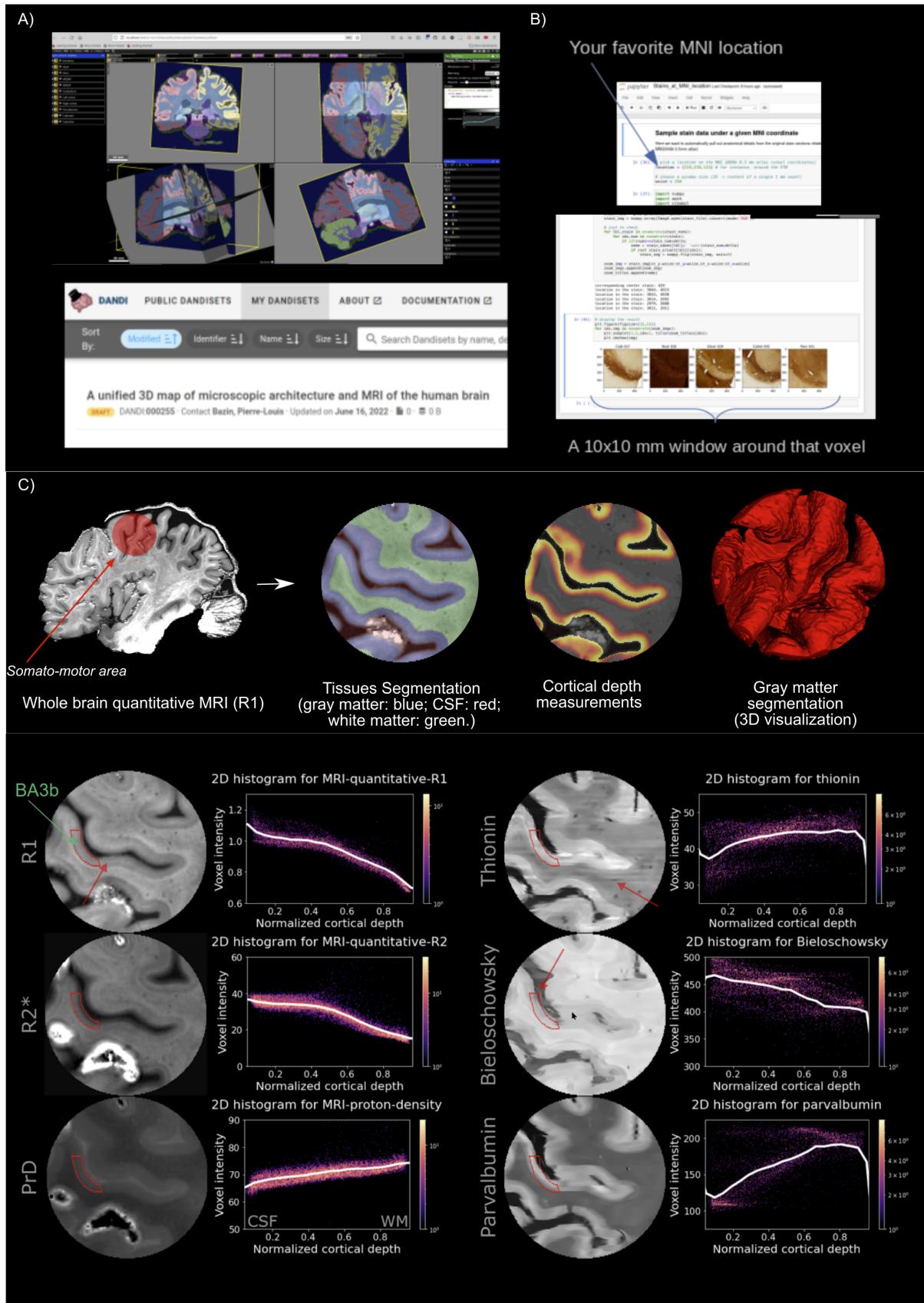


Figure 1: A) Neuroglancer visualization, B) section query notebook, C) Cortical ROI and corresponding depth histograms extracted from the different contrasts available.

283 **4.2 Brainhack Cloud**

284 *Steffen Bollmann, Isil Poyraz Bilgin, Peer Herholz, Rémi Gau, Samuel Guay, Johanna Bayer*

285

286 Today's neuroscientific research deals with vast amounts of electrophysiological, neuroima-  
287 ging and behavioural data. The progress in the field is enabled by the widespread avail-  
288 ability of powerful computing and storage resources. Cloud computing in particular offers  
289 the opportunity to flexibly scale resources and it enables global collaboration across insti-  
290 tutions. However, cloud computing is currently not widely used in the neuroscience field,  
291 although it could provide important scientific, economical, and environmental gains con-  
292 sidering its effect in collaboration and sustainability<sup>10,11</sup>. One problem is the availability  
293 of cloud resources for researchers, because Universities commonly only provide on-premise  
294 high performance computing resources. The second problem is that many researchers lack  
295 the knowledge on how to efficiently use cloud resources. This project aims to address both  
296 problems by providing free access to cloud resources for the brain imaging community  
297 and by providing targeted training and support.

298 A team of brainhack volunteers ([https://brainhack.org/brainhack\\_cloud/admins/  
299 team/](https://brainhack.org/brainhack_cloud/admins/team/)) applied for Oracle Cloud Credits to support open-source projects in and around  
300 brainhack with cloud resources. The project was generously funded by Oracle Cloud for  
301 Research<sup>12</sup> with \$230,000.00 AUD from the 29th of January 2022 until the 28th of Janu-  
302 ary 2024. To facilitate the uptake of cloud computing in the field, the team built several  
303 resources ([https://brainhack.org/brainhack\\_cloud/tutorials/](https://brainhack.org/brainhack_cloud/tutorials/)) to lower the entry  
304 barriers for members of the Brainhack community.

305 During the OHBM 2022 Brainhack, the team gave a presentation to share the cap-  
306 abilities that cloud computing offers to the Brainhack community, how they can place  
307 their resource requests and where they can get help. In total 11 projects were onboarded  
308 to the cloud and supported in their specific use cases: One team utilised the latest GPU  
309 architecture to take part in the Anatomical Tracings of Lesions After Stroke Grand Chal-  
310 lenge. Others developed continuous integration tests for their tools using for example a  
311 full Slurm HPC cluster in the cloud to test how their tool behaves in such an environ-

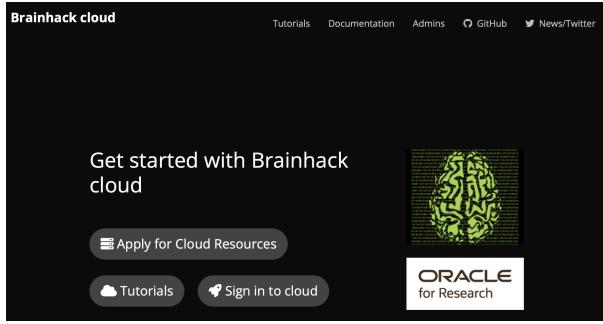


Figure 2: A team of brainhack volunteers, applied for Oracle Cloud Credits to support open source projects in and around brainhack with powerful cloud resources on the Oracle Cloud: [https://brainhack.org/brainhack\\_cloud/](https://brainhack.org/brainhack_cloud/)

<sup>312</sup> ment. Another group deployed the Neurodesk.org<sup>13</sup> project on a Kubernetes cluster to  
<sup>313</sup> make it available for a student cohort to learn about neuroimage processing and to get  
<sup>314</sup> access to all neuroimaging tools via the browser. All projects will have access to these  
<sup>315</sup> cloud resources until 2024 and we are continuously onboarding new projects onto the  
<sup>316</sup> cloud ([https://brainhack.org/brainhack\\_cloud/docs/request/](https://brainhack.org/brainhack_cloud/docs/request/)).

<sup>317</sup> The Brainhack Cloud team plans to run a series of training modules in various Brain-  
<sup>318</sup> hack events throughout the year to reach researchers from various backgrounds and in-  
<sup>319</sup> crease their familiarity with the resources provided for the community while providing  
<sup>320</sup> free and fair access to the computational resources. The training modules will cover how  
<sup>321</sup> to use and access computing and storage resources (e.g., generating SSH keys), to more  
<sup>322</sup> advanced levels covering the use of cloud native technology like software containers (e.g.,  
<sup>323</sup> Docker/Singularity), container orchestration (e.g., Kubernetes), object storage (e.g, S3),  
<sup>324</sup> and infrastructure as code (e.g., Terraform).

### <sup>325</sup> 4.3 DataLad Catalog

<sup>326</sup> Stephan Heunis, Adina S. Wagner, Alexander Q. Waite, Benjamin Poldrack, Christian Mönch, Julian Kosciessa,  
<sup>327</sup> Laura Waite, Leonardo Muller-Rodriguez, Michael Hanke, Michał Szczepanik, Remi Gau, Yaroslav O. Halchenko

<sup>328</sup>  
<sup>329</sup> The importance and benefits of making research data Findable, Accessible, Interoper-  
<sup>330</sup> able, and Reusable are clear<sup>14</sup>. But of equal importance is our ethical and legal obligations  
<sup>331</sup> to protect the personal data privacy of research participants. So we are struck with this

332 apparent contradiction: how can we share our data openly... yet keep it secure and pro-  
333 tected?

334 To address this challenge: structured, linked, and machine-readable metadata presents  
335 a powerful opportunity. Metadata provides not only high-level information about our re-  
336 search data (such as study and data acquisition parameters) but also the descriptive as-  
337 pects of each file in the dataset: such as file paths, sizes, and formats. With this metadata,  
338 we can create an abstract representation of the full dataset that is separate from the ac-  
339 tual data content. This means that the content can be stored securely, while we openly  
340 share the metadata to make our work more FAIR.

341 In practice, the distributed data management system DataLad<sup>15</sup> and its extensions  
342 for metadata handling and catalog generation are capable of delivering such solutions.  
343 `datalad` ([github.com/datalad/datalad](https://github.com/datalad/datalad)) can be used for decentralised management of  
344 data as lightweight, portable and extensible representations. `datalad-metlad` ([github.](https://github.com/datalad/datalad-metlad)  
345 [com/datalad/datalad-metlad](https://github.com/datalad/datalad-metlad)) can extract structured high- and low-level metadata  
346 and associate it with these datasets or with individual files. And at the end of the work-  
347 flow, `datalad-catalog` ([github.com/datalad/datalad-catalog](https://github.com/datalad/datalad-catalog)) can turn the struc-  
348 tured metadata into a user-friendly data browser.

349 This hackathon project focused on the first round of user testing of the alpha ver-  
350 sion of `datalad-catalog`, by creating the first ever user-generated catalog ([https://jkosciessa.github.io/datalad\\_cat\\_test](https://jkosciessa.github.io/datalad_cat_test)). Further results included a string of new  
351 issues focusing on improving user experience, detailed notes on how to generate a catalog  
352 from scratch, and code additions to allow the loading of local web-assets so that any  
353 generated catalog can also be viewed offline.

## 355 4.4 DataLad-Dataverse integration

356 *Benjamin Poldrack, Jianxiao Wu, Kelvin Sarink, Christopher J. Markiewicz , Alexander Q. Waite , Eliana Nicolaisen-*  
357 *Sobesky, Shammi More, Johanna Bayer, Jan Ernsting, Adina S. Wagner, Roza G. Bayrak , Laura K. Waite, Michael*  
358 *Hanke, Nadine Spychala*

359

360        The FAIR principles<sup>14</sup> advocate to ensure and increase the Findability, Accessibil-  
361        ity, Interoperability, and Reusability of research data in order to maximize their impact.  
362        Many open source software tools and services facilitate this aim. Among them is the Data-  
363        verse project<sup>16</sup>. Dataverse is open source software for storing and sharing research data,  
364        providing technical means for public distribution and archival of digital research data, and  
365        their annotation with structured metadata. It is employed by dozens of private or public  
366        institutions worldwide for research data management and data publication. DataLad<sup>15</sup>,  
367        similarly, is an open source tool for data management and data publication. It provides  
368        Git- and git-annex based data versioning, provenance tracking, and decentral data dis-  
369        tribution as its core features. One of its central development drivers is to provide stream-  
370        lined interoperability with popular data hosting services to both simplify and robustify  
371        data publication and data consumption in a decentralized research data management  
372        system<sup>17</sup>. Past developments include integrations with the open science framework<sup>18</sup> or  
373        webdav-based services such as sciebo, nextcloud, or the European Open Science Cloud<sup>19</sup>.

374        In this hackathon project, we created a proof-of-principle integration of DataLad  
375        with Dataverse in the form of the Python package `datalad-dataverse` ([github.com/  
376        datalad/datalad-dataverse](https://github.com/datalad/datalad-dataverse)). From a technical perspective, main achievements include  
377        the implementation of a git-annex special remote protocol for communicating with Data-  
378        verse instances, a new `create-sibling-dataverse` command that is added to the DataLad  
379        command-line and Python API by the `datalad-dataverse` extension, and standard re-  
380        search software engineering aspects of scientific software such as unit tests, continuous  
381        integration, and documentation.

382        From a research data management and user perspective, this development equips  
383        DataLad users with the ability to programatically create Dataverse datasets (containers  
384        for research data and their metadata on Dataverse) from DataLad datasets (DataLad's  
385        Git-repository-based core data structure) in different usage modes. Subsequently, DataLad  
386        dataset contents, its version history, or both can be published to the Dataverse dataset via  
387        a 'datalad push' command. Furthermore, published DataLad datasets can be consumed  
388        from Dataverse with a `datalad clone` call. A mode parameter configures whether Git

389 version history, version controlled file content, or both are published and determines  
390 which of several representations the Dataverse dataset takes. A proof-of-principle imple-  
391 mentation for metadata annotation allows users to supply metadata in JSON format, but  
392 does not obstruct later or additional manual metadata annotation via Dataverse’s web  
393 interface.

394 Overall, this project delivered the groundwork for further extending and streamlining  
395 data deposition and consumption in the DataLad ecosystem. With DataLad-Dataverse  
396 interoperability, users gain easy additional means for data publication, archival, distribu-  
397 tion, and retrieval. Post-Brainhack development aims to mature the current alpha version  
398 of the software into an initial v0.1 release and distribute it via standard Python package  
399 indices.

## 400 4.5 Exploding brains in Julia

401 *Ömer Faruk Gülbán, Leonardo Müller-Rodriguez*

402

403 Particle simulations are used to generate visual effects (in movies, games, etc.). In this  
404 project, we explore how we can use magnetic resonance imaging (MRI) data to generate  
405 interesting visual effects by using (2D) particle simulations. Aside from providing an  
406 entertaining avenue to the interested participants, our project has further educational  
407 utility. For instance, anatomical MRI data analysis is done in two major frameworks:  
408 (1) manipulating fixed regularly spaced points in space (also known as Eulerian point of  
409 view), and (2) manipulating moving irregularly spaced points in space (Lagrangian point  
410 of view). For instance, bias field correction is commonly done from Eulerian point of view  
411 (e.g. computing a bias field is similar to computing a particle velocity field in each frame  
412 of the explosions), whereas cortical surface inflation is commonly done from Lagrangian  
413 point of view of the MRI data (e.g. computing the inflated brain surface is similar to  
414 computing the new positions of particles in each frame of the explosion). Therefore, our  
415 project provides an educational opportunity for those who would like to peek into the  
416 deep computational and data structure manipulation aspects of MRI image analysis.

<sup>417</sup> We note that we already made two hackathon projects in 2020 (see below) and were first  
<sup>418</sup> inspired by a blog post ([https://nialltl.neocities.org/articles/mpm\\_guide.html](https://nialltl.neocities.org/articles/mpm_guide.html))  
<sup>419</sup> on the material point method<sup>20,21,22</sup>. Our additional aim in Brainhack 2022 is to convert  
<sup>420</sup> our previous progress in Python programming language to Julia. The reason why we  
<sup>421</sup> have moved to Julia language is because we wanted to explore this new programming  
<sup>422</sup> language's potential for developing MRI image analysis methods as it has convenient  
<sup>423</sup> parallelization methods that speeds-up the particle simulations (and any other advanced  
<sup>424</sup> image manipulation algorithms).

<sup>425</sup> \_\_\_\_\_

<sup>426</sup> Our previous efforts are documented at:

- <sup>427</sup> 1. 2020 OpenMR Benelux: [https://github.com/OpenMRBenelux/openmrb2020-hackathon/](https://github.com/OpenMRBenelux/openmrb2020-hackathon/issues/7)  
<sup>428</sup> issues/7
- <sup>429</sup> 2. 2020 OHBM Brainhack: <https://github.com/ohbm/hackathon2020/issues/124>
- <sup>430</sup> 3. Available within the following github repository: [https://github.com/ofgulban/](https://github.com/ofgulban/slowest-particle-simulator-on-earth)  
<sup>431</sup> slowest-particle-simulator-on-earth

<sup>432</sup> \_\_\_\_\_

<sup>433</sup> As a result of this hackathon project, we delivered a video compilation of our anim-  
<sup>434</sup> ations (Figure 3) which can be seen at [https://youtu.be/\\_5ZDctWv5X4](https://youtu.be/_5ZDctWv5X4). We highlight  
<sup>435</sup> that in addition to its educational value, our project provided stress relief by means of  
<sup>436</sup> entertaining the participants after the pandemic. We believe that our project provides  
<sup>437</sup> a blueprint for the future brainhacks where MRI science, computation, and education  
<sup>438</sup> can be disseminated within an engaging and entertaining context. Our future efforts will  
<sup>439</sup> involve sophisticating the particle simulations, the initial simulation parameters to gen-  
<sup>440</sup> erate further variations of the visual effects, and potentially synchronizing the simulation  
<sup>441</sup> effects with musical beats.

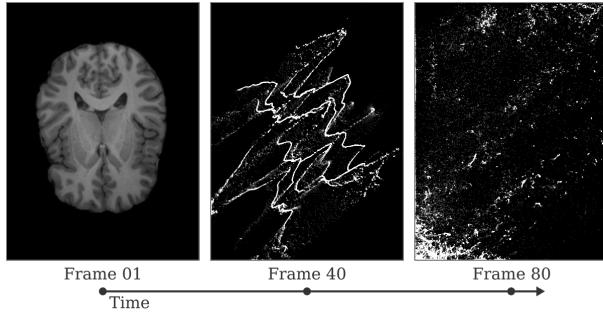


Figure 3: A video compilation of brain explosions can be seen at [https://youtu.be/\\_5ZDctWv5X4](https://youtu.be/_5ZDctWv5X4).

## 442 4.6 FLUX: A pipeline for MEG analysis and beyond

443     *Oscar Ferrante, Tara Ghafari, Ole Jensen*

444  
 445     FLUX<sup>23</sup> is an open-source pipeline for analysing magnetoencephalography (MEG)  
 446     data. There are several toolboxes developed by the community to analyse MEG data.  
 447     While these toolboxes provide a wealth of options for analyses, the many degrees of free-  
 448     dom pose a challenge for reproducible research. The aim of FLUX is to make the analyses  
 449     steps and setting explicit. For instance, FLUX includes the state-of-the-art suggestions  
 450     for noise cancellation as well as source modelling including pre-whitening and handling  
 451     of rank-deficient data.

452     So far, the FLUX pipeline has been developed for MNE-Python<sup>24</sup> and FieldTrip<sup>25</sup>  
 453     with a focus on the MEGIN/Elekta system and it includes the associated documents as  
 454     well as codes. The long-term plan for this pipeline is to make it more flexible and versatile  
 455     to use. One key motivation for this is to facilitate open science with the larger aim of  
 456     fostering the replicability of MEG research.

457     These goals can be achieved in mid-term objectives, such as making the FLUX pipeline  
 458     fully BIDS compatible and more automated. Another mid-term goal is to containerize  
 459     the FLUX pipeline and the associated dependencies making it easier to use. Moreover,  
 460     expanding the applications of this pipeline to other systems like MEG CTF, Optically  
 461     Pumped Magnetometer (OPM) and EEG will be another crucial step in making FLUX  
 462     a more generalized neurophysiological data analysis pipeline.

463     During the 2022 Brainhack, the team focused on incorporating the BIDS standard into

<sup>464</sup> the analysis pipeline using MNE\_BIDS<sup>26</sup>. Consequently, an updated version of FLUX  
<sup>465</sup> was released after the Brainhack meeting.

<sup>466</sup> **4.7 Evaluating discrepancies in hippocampal segmentation pro-**  
<sup>467</sup> **tocols using automatic prediction of MRI quality (MRIQC)**

<sup>468</sup> *Jacob Sanz-Robinson, Mohammad Torabi, Tyler James Wishard*

<sup>469</sup>

<sup>470</sup> **4.7.1 Introduction**

<sup>471</sup> Neuroimaging study results can vary significantly depending on the processing pipelines  
<sup>472</sup> utilized by researchers to run their analyses, contributing to reproducibility issues. Re-  
<sup>473</sup> searchers in the field are often faced with multiple choices of pipelines featuring similar  
<sup>474</sup> capabilities, which may yield different results when applied to the same data<sup>27,28</sup>. While  
<sup>475</sup> these reproducibility issues are increasingly well-documented in the literature, there is  
<sup>476</sup> little existing research explaining why this inter-pipeline variability occurs or the factors  
<sup>477</sup> contributing to it. In this project, we set out to understand what data-related factors  
<sup>478</sup> impact the discrepancy between popular neuroimaging processing pipelines.

<sup>479</sup> **4.7.2 Method**

<sup>480</sup> The hippocampus is a structure commonly associated with memory function and  
<sup>481</sup> dementia, and the left hippocampus is proposed to have higher discriminative power for  
<sup>482</sup> identifying the progression of Alzheimer's disease than the right hippocampus in multiple  
<sup>483</sup> studies<sup>29</sup>. We obtained left hippocampal volumes using three widely-used neuroimaging  
<sup>484</sup> pipelines: FSL 5.0.9<sup>30</sup>, FreeSurfer 6.0.0<sup>31</sup>, and ASHS 2.0.0 PMC-T1 atlas<sup>32</sup>. We ran the  
<sup>485</sup> three pipelines on T1 images from 15 subjects from the Prevent-AD Alzheimer's dataset<sup>33</sup>,  
<sup>486</sup> composed of cognitively healthy participants between the ages of 55-88 years old that  
<sup>487</sup> are at risk of developing Alzheimer's Disease. We ran MRIQC<sup>34</sup> - a tool for performing  
<sup>488</sup> automatic quality control and extracting quality measures from MRI scans - on the 15  
<sup>489</sup> T1 scans and obtained Image Quality Metrics (IQMs) from them. We then found the

<sup>490</sup> correlations between the IQMs and the pairwise inter-pipeline discrepancy of the left  
<sup>491</sup> hippocampal volumes for each T1 scan.

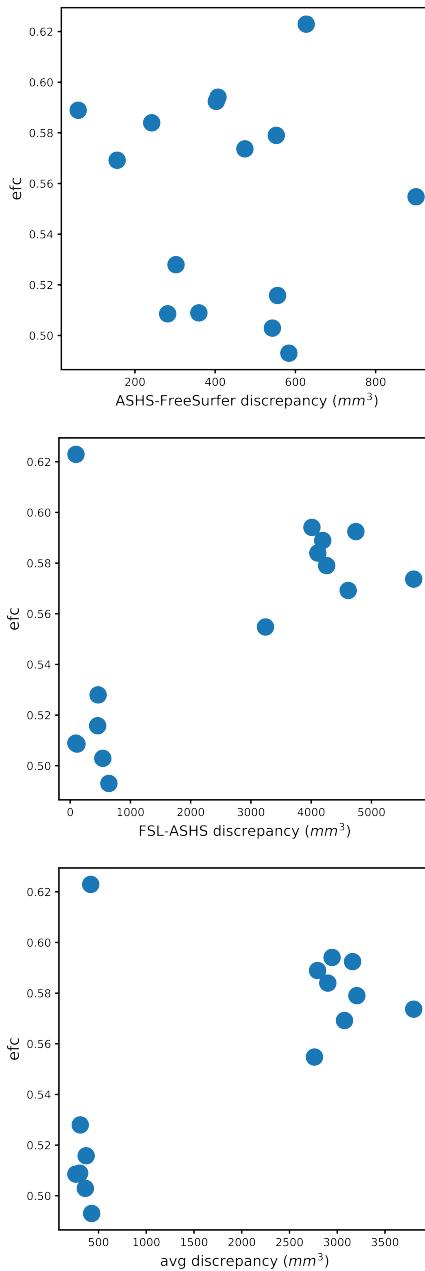


Figure 4: Plots showing the association between left hippocampal volume discrepancies and MRIQC's EFC quality measure for each of the pipeline pairings.

<sup>492</sup> **4.7.3 Results**

<sup>493</sup> We found that for The FSL-FreeSurfer and FSL-ASHs discrepancies, MRIQC's EFC  
<sup>494</sup> measure produced the highest correlation, of 0.69 and 0.64, respectively. The EFC “uses

495 the Shannon entropy of voxel intensities as an indication of ghosting and blurring induced  
496 by head motion”<sup>35</sup>. No such correlations were found for the ASHS-FreeSurfer discrepan-  
497 cies. Figure 4 shows a scatter plot of the discrepancies in left hippocampal volume and  
498 EFC IQM for each pipeline pairing. The preliminary results suggest that FSL’s hippo-  
499 campal segmentation may be sensitive to head motion in T1 scans, leading to larger  
500 result discrepancies, but we require larger sample sizes to make meaningful conclusions.  
501 The code for our project can be found on GitHub at this link.

#### 502 4.7.4 Conclusion and Next Steps

503 In this project, we investigated the correlation between MRIQC’s IQMs and discrep-  
504 ances in left hippocampal volume derived from three common neuroimaging pipelines on  
505 15 subjects from the Prevent-AD study dataset. While our preliminary results indicate  
506 image ghosting and blurring induced by head motion may play a role in inter-pipeline  
507 result discrepancies, the next steps of the project will consist of computing the corre-  
508 lations on the full 308 subjects of the Prevent-AD dataset to investigate whether they  
509 persist with the full sample.

## 510 4.8 Accelerating adoption of metadata standards for dataset descriptors

511 *Cassandra Gould van Praag, Felix Hoffstaedter, Sebastian Urchs*

512

513 We have used the space of the brainhack to discuss challenges that are hindering  
514 wide adoption of metadata standards in the neuroimaging community and to brainstorm  
515 possible solutions to accelerate it. Although our project was conceptual and we did not  
516 develop any tools during the project, the outcome of our discussions have directly influ-  
517 enced the development of tools such as neurobagel<sup>36</sup> (<https://neurobagel.org/>) after  
518 the brainhack.

519 Thanks to efforts of the neuroimaging community, not least the brainhack community<sup>1</sup>,  
520 datasets are increasingly shared on open data repositories like OpenNeuro<sup>37</sup> using stand-  
521 ards like BIDS<sup>38</sup> for interoperability. As the amount of datasets and data repositories

522 increases, we need to find better ways to search across them for samples that fit our  
523 research questions. In the same way that the wide adoption of BIDS makes data sharing  
524 and tool development easier, the wide adoption of consistent vocabulary for demographic,  
525 clinical and other sample metadata would make data search and integration easier. We  
526 imagine a future platform that allows cross dataset search and the pooling of data across  
527 studies. Efforts to establish such metadata standards have had some success in other  
528 communities<sup>39,40</sup>, but adoption in the neuroscience community so far has been slow.

529 We believe that an important social challenge for the wider adoption of metadata  
530 standards is that it is hard to demonstrate their value without a practical use case. We  
531 therefore think that rather than focusing on building better standards, in the short term  
532 we need to prioritize small, but functional demonstrations that help convey the value of  
533 these standards and focus on usability and ease of adoption. Having consistent names  
534 and format for even a few metadata variables like age, sex, and diagnosis already allows  
535 for interoperability and search across datasets. Selecting a single vocabulary that must  
536 be used for annotating e.g. diagnosis necessarily lacks some precision but avoids the need  
537 to align slightly different versions of the same terms. Accessible tools can be built to  
538 facilitate the annotation process of such a basic metadata standard. The best standard  
539 will be poorly adopted if there are no easy to use tools that implement it. Efforts like the  
540 neurobagel project (<https://neurobagel.org/>) are trying to implement this approach  
541 to demonstrate a simple working use case for cross dataset integration and search. Our  
542 goal is to use such simpler demonstrations to build awareness and create a community  
543 around the goal of consistent metadata adoption.

544 Our long term goal is to use the awareness of the value of shared metadata standards  
545 to build a community to curate the vocabularies used for annotation. The initially small  
546 number of metadata variables will have to be iteratively extended through a community  
547 driven process to determine what fields should be standardized to serve concrete use cases.  
548 Rather than creating new vocabularies the goal should be to curate a list of existing ones  
549 that can be contributed to where terms are inaccurate or missing. The overall goal of  
550 such a community should be to build consensus on and maintain shared standards for

551 the annotation of neuroimaging metadata that support search and integration of data for  
552 an ever more reproducible and generalizable neuroscience.

553    **4.9 The NARPS Open Pipelines Project**

554        *Elodie Germani, Arshitha Basavaraj, Trang Cao, Rémi Gau, Anna Menacher, Camille Maumet*

555

556        The goal of the NARPS Open Pipelines Project is to provide a public codebase that  
557        reproduces the 70 pipelines chosen by the 70 teams of the NARPS study<sup>41</sup>. The project is  
558        public and the code hosted on GitHub at [https://github.com/Inria-Empenn/narps\\_](https://github.com/Inria-Empenn/narps_open_pipelines)  
559        [open\\_pipelines](#).

560        This project initially emerged from the idea of creating an open repository of fMRI  
561        data analysis pipelines (as used by researchers in the field) with the broader goal to  
562        study and better understand the impact of analytical variability. NARPS – a many-  
563        analyst study in which 70 research teams were asked to analyze the same fMRI dataset  
564        with their favorite pipeline – was identified as an ideal usecase as it provides a large array  
565        of pipelines created by different labs. In addition, all teams in NARPS provided extensive  
566        (textual) description of their pipelines using the COBIDAS<sup>42</sup> guidelines. All resulting  
567        statistic maps were shared on NeuroVault<sup>43</sup> and can be used to assess the success of the  
568        reproductions.

569        At the OHBM Brainhack 2022, our goal was to improve the accessibility and reusab-  
570        ility of the database, to facilitate new contributions and to reproduce more pipelines. We  
571        focused our efforts on the first two goals. By trying to install the computing environ-  
572        ment of the database, contributors provided feedback on the instructions and on specific  
573        issues they faced during the installation. Two major improvements were made for the  
574        download of the necessary data: the original fMRI dataset and the original results (stat-  
575        istic maps stored in NeuroVault) were added as submodules to the GitHub repository.  
576        Finally, propositions were made to facilitate contributions: the possibility to use of the  
577        Giraffe toolbox<sup>44</sup> for contributors that are not familiar with NiPype<sup>45</sup> and the creation  
578        of a standard template to reproduce a new pipeline.

579        With these improvements, we hope that it will be easier for new people to contribute  
580        to reproduction of new pipelines. We hope to continue growing the codebase in the future.

581    **4.10 NeuroCausal: Development of an Open Source Platform**  
582        **for the Storage, Sharing, Synthesis, and Meta-Analysis of**  
583        **Neuropsychological Data**

584        *Isil Poyraz Bilgin, Francois Paugam, Ruoqi Huang, Ana Luísa Pinho, Yuchen Zhou, Sladjana Lukic, Pedro Pinheiro-*

585        *Chagas, Valentina Borghesani*

586

587        Cognitive neuroscience has witnessed great progress since modern neuroimaging em-  
588        braced an open science framework, with the adoption of shared principles<sup>14</sup>, standards<sup>38</sup>,  
589        and ontologies<sup>46</sup>, as well as practices of meta-analysis<sup>47,48</sup> and data sharing<sup>43</sup>. However,  
590        while functional neuroimaging data provide correlational maps between cognitive func-  
591        tions and activated brain regions, its usefulness in determining causal link between specific  
592        brain regions and given behaviors or functions is disputed<sup>49,50</sup>. On the contrary, neuropsy-  
593        chological data enable causal inference, highlighting critical neural substrates and opening  
594        a unique window into the inner workings of the brain<sup>51</sup>. Unfortunately, the adoption of  
595        Open Science practices in clinical settings is hampered by several ethical, technical, eco-  
596        nomic, and political barriers, and as a result, open platforms enabling access to and  
597        sharing clinical (meta)data are scarce<sup>52</sup>.

598        With our project, NeuroCausal (<https://neurocausal.github.io/>), we aim to build  
599        an online platform and community that allows open sharing, storage, and synthesis of  
600        clinical (meta) data crucial for the development of modern, transdiagnostic, accessible,  
601        and replicable (i.e., FAIR: Findability, Accessibility, Interoperability, and Reusability)  
602        neuropsychology. The project is organized into two infrastructural stages: first, published  
603        peer-reviewed papers will be scrapped to collect already available (meta)data; second,  
604        our platform will allow direct uploading of clinical (de-identified) brain maps and their  
605        corresponding metadata.

606        The meta-analysis pipeline developed for the first stage of the project is inspired by  
607        and built upon the functionalities of NeuroQuery<sup>47</sup>, a successful large-scale neuroimaging  
608        meta-analytic platform. The first stage is the development of the code base allowing (1)

609 downloading and filtering of neuropsychological papers, (2) extraction of reported brain  
610 lesion locations and their conversion into a common reference space (3) extraction of  
611 clinical and behavioral symptoms and their translation into a common annotation scheme,  
612 (4) learning the causal mapping between the neural and neuropsychological information  
613 gathered.

614 The second stage of the study aims at creating an online platform that allows for the  
615 direct uploading of clinical brain maps and their corresponding metadata. The platform  
616 will provide a basic automated preprocessing and a data-quality check pipeline, ensuring  
617 that all the ethical norms regarding patient privacy are met. The platform will automatic-  
618 ally extract and synthesize key data to ultimately create probabilistic maps synthesizing  
619 transdiagnostic information on symptom-structure mapping, which will be dynamically  
620 updated as more data are gathered.

621 The nature of the project requires expertise in different fields (from clinical neuros-  
622 cience to computer science) in order to overcome both technical and theoretical chal-  
623 lenges. The OHBM Brainhack 2022 gave us the opportunity to set the first stones. In  
624 small subteams, we worked on developing three key building blocks: (1) the input filter-  
625 ing pipeline to ensure the downloaded papers are neuropsychological in nature and offer  
626 causal symptom-structure mapping; (2) the extraction of key terms occurrences in the  
627 text as to assess which neural space is reported (as they will have to be converted to a  
628 common one), (3) the curation of clinical ontology mapping specific neuropsychological  
629 batteries and tasks to the cognitive term(s) they touch upon. During the hackathon we  
630 worked on developing three key building blocks in small subteams. First, we prepared an  
631 input filtering pipeline to ensure that the downloaded papers are neuropsychological in  
632 nature (and thus offer causal symptom-structure mapping): we count the occurrences of  
633 clinically relevant terms, and papers are included only if they pass an arbitrary threshold.  
634 Second, we coded a script automatically returning for each paper information on the  
635 neural spaced used (e.g., which atlas? MNI coordinates?), a crucial step to enable future  
636 conversion to a common reference space. Finally, we curated a list of clinically relevant  
637 terms and constructs (a clinical ontology) that maps specific neuropsychological batteries

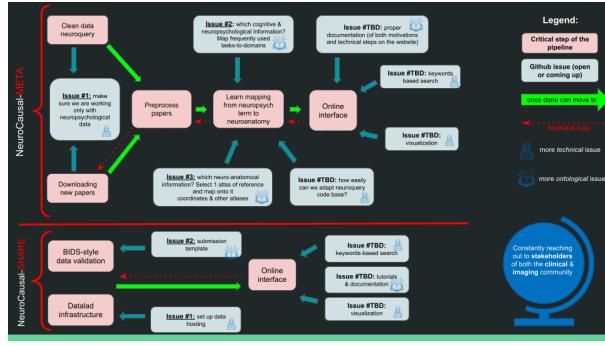


Figure 5: NeuroCausal: The future of neuropsychology, i.e. brain lesions-symptom mapping, will be transdiagnostic, open, and FAIR: we set out to provide the field with an open-source platform fostering storage, sharing, synthesis, and meta-analysis of clinical data.

and tasks to the cognitive term(s) they touch upon.

As we keep tackling our roadmap (Figure 1), we believe our efforts will help promote open science practices in clinical neuroscience to the benefit of both the neuroscientific and the clinical communities.

**Acknowledgments :** The authors would like to thank Eric Earl, Samuel Guay, Jerome Dockès, Bertrand Thirion, Jean Baptiste Poline, Yaroslav Halchenko, Sara El Gebali and the whole Open Life Science team for their help and support.

## 4.11 Neuroscout: A platform for fast and flexible re-analysis of (naturalistic) fMRI studies

*Alejandro De La Vega, Roberta Rocca, Sam Nastase, Peer Horholz, Jeff Menth, Kevin Sitek, Caroline Martin, Leonardo Muller-Rodriguez, Kan Keeratimahat, Dylan Nielson*

649

Neuroscout is an end-to-end platform for analysis of naturalistic fMRI data designed to facilitate the adoption of robust and generalizable research practices. Neuroscout's goal is to make it easy to analyze complex naturalistic fMRI datasets by providing an integrated platform for model specification and automated statistical modeling, reducing technical barriers. Importantly, Neuroscout is at its core a platform for reproducible analysis of fMRI data in general, and builds upon a set of open standards and specifications to ensure analyses are Findable, Accessible, Interoperable, and Reusable (FAIR).

657 In the OHBM Hackathon, we iterated on several important projects that substantially  
658 improved the general usability of the Neuroscout platform. First, we launched a revamped  
659 and unified documentation which links together all of the subcomponents of the Neur-  
660 oscout platform (<https://neuroscout.github.io/neuroscout-docs/>). Second, we fa-  
661 cilitated access to Neuroscout’s data sources by simplifying the design of Python API,  
662 and providing high-level utility functions for easy programmatic data queries. Third, we  
663 updated a list of candidate naturalistic and non-naturalistic datasets amenable for index-  
664 ing by the Neuroscout platform, ensuring the platform stays up to date with the latest  
665 public datasets.

666 In addition, important work was done to expand the types of analyses that can be  
667 performed with naturalistic data in the Neuroscout platform. Notably, progress was made  
668 in integrating Neuroscout with Himalaya, a library for efficient voxel wide encoding mod-  
669 eling with support for banded penalized regression. In addition, a custom image-on-scalar  
670 analysis was prototyped on naturalistic stimuli via the publicly available naturalistic fea-  
671 tures available in the Neuroscout API. Finally, we also worked to improve documentation  
672 and validation for BIDS StatsModels, a specification for neuroimaging statistical models  
673 which underlies Neuroscout’s automated model fitting pipeline.

## 674 4.12 Physiopy - Documentation of Physiological Signal Best Prac- 675 tices

676 *Sarah E. Goodale, Ines Esteves, Roza G. Bayrak, Neville Magielse, Stefano Moia, Yu-Fang Yang, The Physiopy*  
677 *Community*

678

679 Physiological data provides a representation of a subject’s internal state with respect  
680 to peripheral measures (i.e., heart rate, respiratory rate, etc.). Recording physiological  
681 measures is key to gain understanding of sources of signal variance in neuroimaging data  
682 that arise from outside of the brain<sup>53</sup>. This has been particularly useful for functional  
683 magnetic resonance imaging (fMRI) research, improving fMRI time-series model accuracy,  
684 while also improving real-time methods to monitor subjects during scanning<sup>54,55</sup>.

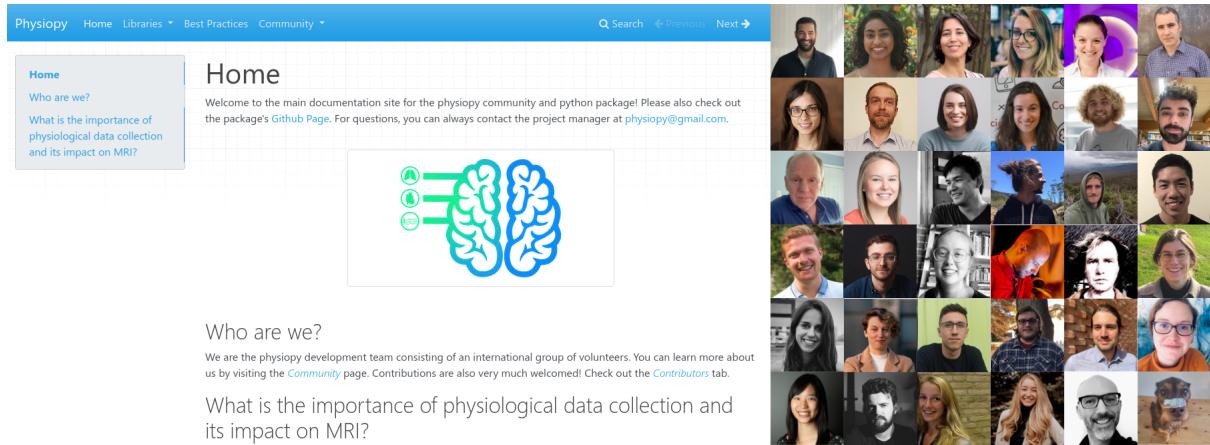


Figure 6: Left: Current version of the documentation homepage; Right: Physiopy Contributors

685 Physiopy (<https://github.com/physiopy>) is an open and collaborative community,  
 686 formed around the promotion of physiological data collection and incorporation in neuroima-  
 687 ging studies. Physiopy is focused on two main objectives. The first is the community-based  
 688 development of tools for fMRI-based physiological processing. At the moment, there are  
 689 three toolboxes: *phys2bids* (physiological data storage and conversion to BIDS format<sup>56</sup>),  
 690 *peakdet* (physiological data processing), and *phys2denoise* (fMRI denoising). The second  
 691 objective is advancing the general knowledge of physiological data collection in fMRI  
 692 by hosting open sessions to discuss best practices of physiological data acquisition, pre-  
 693 processing, and analysis, and promoting community involvement. Physiopy maintains  
 694 documentation with best practices guidelines stemming from these joint discussions and  
 695 recent literature.

696 At the OHBM 2022 Brainhack, we aimed to improve our community documentation  
 697 by expanding on best practices documentation, and gathering libraries of complementary  
 698 open source software. This provides new users resources for learning about the process  
 699 of physiological collection as well as links to already available resources. The short-term  
 700 goal for the Brainhack was to prepare a common platform (and home) for our docu-  
 701 mentation and repositories. We prioritised fundamental upkeep and content expansion,  
 702 adopting Markdown documents and GitHub hosting to minimise barriers for new con-  
 703 tributors. Over the course of the Brainhack, and with the joint effort within three hubs  
 704 (Glasgow, EMEA and Americas), we were able to improve the current community web-

site by rethinking its structure and adding fundamental content relative to who we are, contributions, and updated best practices, such as creating home pages, easy to find and navigate contribution tabs, adding new information from community best practices discussions as well as links to relevant software and datasets. Additionally, we aggregated the information scattered across different repositories, allowing important information for both the community and new collaborators to be accessible in a single location.

The long-term goals of the community are to develop and sustain knowledge and instruments for physiological signal adoption in fMRI settings. Our aim is to facilitate the coming-together of researchers that are just starting to include physiological measures and experienced users. This community will then provide consensus guidelines for standardised data collection and preprocessing. Building on what we have already achieved, we will continue to promote and document best practices. Further development is ongoing and anyone that is interested in physiological signal collection for fMRI data, independently of their level and type of expertise, is highly encouraged to check Physiopy out, to join the community, or to contribute in any way.

## 4.13 Handling multiple testing problem through effect calibration: implementation using PyMC

*Lea Waller, Kelly Garner, Christopher R. Nolan, Daniel Borek, Gang Chen*

723

### 4.13.1 Introduction

Human brain imaging data is massively multidimensional, yet current approaches to modelling functional brain responses entail the application of univariate inferences to each voxel separately. This leads to the multiple testing problem and unrealistic assumptions about the data such as artificial dichotomization (statistically significant or not) in result reporting. The traditional approach of massively univariate analysis assumes that no information is shared across the brain, effectively making a strong prior assumption of a uniform distribution of effect sizes, which is unrealistic given the connectivity of the

<sup>732</sup> human brain. The consequent requirement for multiple testing adjustments results in the  
<sup>733</sup> *calibration of statistical evidence* without considering the estimation of effect, leading to  
<sup>734</sup> substantial information loss and an unnecessarily heavy penalty.

<sup>735</sup> A more efficient approach to handling multiplicity focuses on the *calibration of effect*  
<sup>736</sup> *estimation* under a Bayesian multilevel modeling framework with a prior assumption of,  
<sup>737</sup> for example, normality across space<sup>57</sup>. The methodology has previously been implemented  
<sup>738</sup> at the region level into the AFNI program RBA<sup>58</sup> using Stan through the R package brms<sup>59</sup>.

<sup>739</sup> We intend to achieve two goals in this project:

- <sup>740</sup> (i) To re-implement the methodology using PyMC improve the performance and flexi-  
<sup>741</sup> bility of the modeling approach.
- <sup>742</sup> (ii) To explore the possibility of analyzing voxel-level data using the multilevel modeling  
<sup>743</sup> approach

#### <sup>744</sup> 4.13.2 Implementation using PyMC

<sup>745</sup> We used the dataset from Chen and colleagues<sup>57</sup> to validate our PyMC implement-  
<sup>746</sup> ation. The data contain the subject-level response variable  $y$  and a predictor of the  
<sup>747</sup> behavioral measure  $x$  from  $S = 124$  subjects at  $R = 21$  regions. The modeling framework  
<sup>748</sup> is formulated for the data  $y_{rs}$  of the  $s$ th subject at the  $r$ th region as below,

$$\begin{aligned} y_{rs} &\sim \mathcal{N}(\mu_{rs}, \sigma^2) \\ \mu_{rs} &= \alpha_0 + \alpha_1 x_s + \theta_{0r} + \theta_{1r} x_s + \eta_s \\ \begin{bmatrix} \theta_{0r} \\ \theta_{1r} \end{bmatrix} &\sim \mathcal{N}(\mathbf{0}_{2 \times 1}, \mathbf{S}_{2 \times 2}) \\ \eta_s &\sim \mathcal{N}(0, \tau^2) \end{aligned} \tag{1}$$

where  $r = 1, 2, \dots, R$  and  $s = 1, 2, \dots, S$

<sup>749</sup> In the model,  $\mu_{rs}$  and  $\sigma$  are the mean effect and standard deviation of the  $s$ th subject  
<sup>750</sup> at the  $r$ th region,  $\alpha_0$  and  $\alpha_1$  are the overall mean and slope effect across all regions and

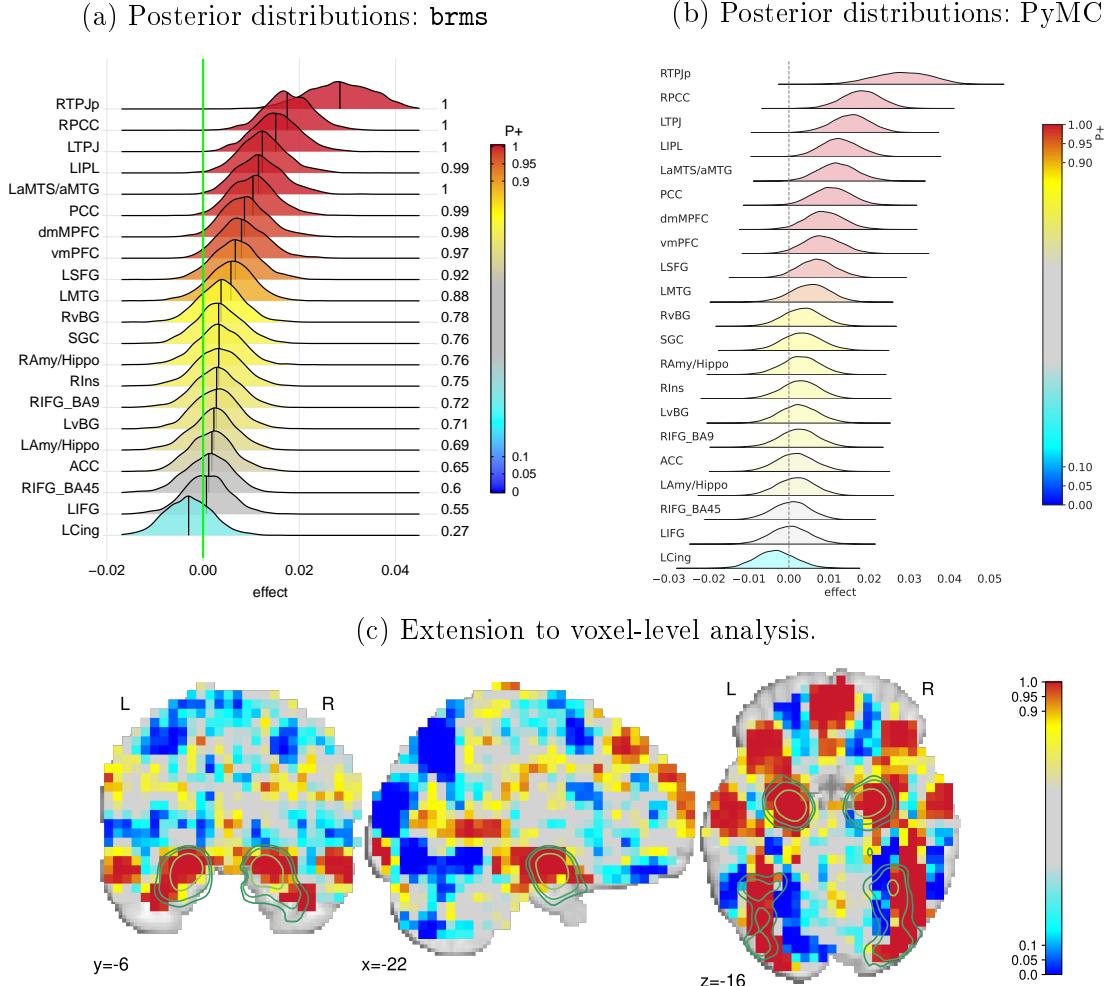


Figure 7: Validation of implementation using PyMC. (A) Posterior distributions of region-level behavior effects using `brms`. (B) Posterior distributions of region-level behavior effects using PyMC. (C) Posterior probabilities of the voxel-level effects being positive or negative, obtained using PyMC (plotted using Nilearn and overlaid in green with the NeuroQuery<sup>47</sup> map for the term “emotional faces”).

751 subjects,  $\theta_{0r}$  and  $\theta_{1r}$  are the mean and slope effect at the  $r$ th region,  $\eta_s$  is the mean effect  
 752 of the  $s$ th subject,  $\mathbf{S}_{2 \times 2}$  is the variance-covariance of the mean and slope effect at the  $r$ th  
 753 region, and  $\tau$  is the standard deviation of the  $s$ th subject’s effect  $\eta_s$ .

754 We implemented this model using the PyMC probabilistic programming framework<sup>60</sup>,  
 755 and the Bayesian Model-Building Interface (BAMBI)<sup>61</sup>. The latter is a high-level interface  
 756 that allows for specification of multilevel models using the formula notation that is also  
 757 adopted by `brms`. A notebook describing the implementation is available here. Our PyMC  
 758 implementation was successfully validated: as shown in Figure 7a and Figure 7b, the  
 759 posterior distributions from the PyMC implementation matched very well with their

760 counterparts from the `brms` output.

#### 761 4.13.3 Extension of Bayesian multilevel modeling to voxel-level analysis

762 After exploring the model on the region level, we wanted to see if recent computational  
763 and algorithmic advances allow us to employ the multilevel modeling framework on the  
764 voxel level as well. We obtained the OpenNeuro dataset `ds000117`<sup>62</sup> from an experiment  
765 based on a face processing paradigm. Using `HALFpipe`<sup>63</sup>, which is based on `fMRIPrep`<sup>64</sup>,  
766 the functional images were preprocessed with default settings and  $z$ -statistic images were  
767 calculated for the contrast “famous faces + unfamiliar faces versus 2 · scrambled faces”.

768 We applied the same modeling framework and PyMC code as for region-based ana-  
769 lysis, but without the explanatory variable  $x$  in the model (Equation (1)). To reduce  
770 computational and memory complexity, the  $z$ -statistic images were downsampled to an  
771 isotropic resolution of 5mm. Using the GPU-based `nuts_numpyro` sampler<sup>65</sup> with default  
772 settings, we were able to draw 2,000 posterior samples of the mean effect parameter for  
773 each of the 14,752 voxels. Sampling four chains took 23 minutes on four Nvidia Tesla  
774 V100 GPUs.

775 The resulting posterior probabilities are shown in Figure 7c overlaid with the meta-  
776 analytic map for the term “emotional faces” obtained from NeuroQuery<sup>47</sup>. The posterior  
777 probability map is consistent with meta-analytic results, showing strong statistical evid-  
778 ence in visual cortex and amygdala voxels. The posterior probability maps also reveal  
779 numerous other clusters of strong statistical evidence for both positive and negative ef-  
780 ffects.

781 This implementation extension shows that large multilevel models are approaching  
782 feasibility, suggesting an exciting new avenue for statistical analysis of neuroimaging  
783 data. Next steps will be to investigate how to interpret and report these posterior maps,  
784 and to try more complex models that include additional model terms.

785 **Acknowledgements**

786 Computation has been performed on the HPC for Research cluster of the Berlin  
787 Institute of Health.

788 **4.14 MOSAIC for VASO fMRI**

789 *Renzo (Laurentius) Huber, Remi Gau, Rüdiger Stirnberg, Philipp Ehses, Ömer Faruk Gülbán, Benedikt A. Poser*

790

791 Vascular Space Occupancy (VASO) is a functional magnetic resonance imaging (fMRI)  
792 method that is used for high-resolution cortical layer-specific imaging<sup>66</sup>. Currently, the  
793 most popular sequence for VASO at modern SIEMENS scanners is the one by Stirnberg  
794 and Stöcker<sup>67</sup> from the DZNE in Bonn, which is employed at more than 30 research labs  
795 worldwide. This sequence concomitantly acquires fMRI BOLD and blood volume signals.  
796 In the SIEMENS' reconstruction pipeline, these two complementary fMRI contrasts are  
797 mixed together within the same time series, making the outputs counter-intuitive for  
798 users. Specifically:

- 799 • The ‘raw’ NIfTI converted time-series are not BIDS compatible (see <https://github.com/bids-standard/bids-specification/issues/1001>).  
800
- 801 • The order of odd and even BOLD and VASO image TRs is unprincipled, making  
802 the ordering dependent on the specific implementation of NIfTI converters.

803 Workarounds with 3D distortion correction, results in interpolation artifacts. Altern-  
804 ative workarounds without MOSAIC decorators result in unnecessarily large data sizes.

805 In the previous Brainhack<sup>1</sup>, we extended the existing 3D-MOSAIC functor that was  
806 previously developed by Benedikt Poser and Philipp Ehses. This functor had been previ-  
807 ously used to sort volumes of images by dimensions of echo-times, by RF-channels, and by  
808 magnitude and phase signals. In this Brainhack, we successfully extended and validated  
809 this functor to also support the dimensionality of SETs (that is representing BOLD and  
810 VASO contrast).

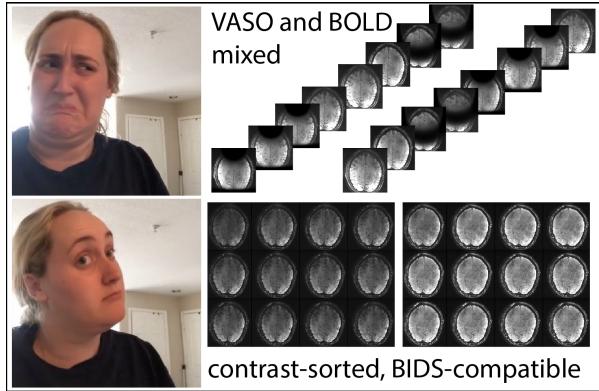


Figure 8: Previously, most VASO sequences provided unsorted image series of MRI contrasts. This was not BIDS compatible and could suffer from gradient non-linearity artifacts in the scanner’s MR-reconstruction pipeline. In Brainhack 2022, we adapted the SIEMENS reconstruction and to sort volume series by fMRI contrasts. This is BIDS compatible and does not require non-linearity corrections.

811 We are happy to share the compiled SIEMENS ICE (Image Calculation Environment)

812 functor that does this sorting. Current VASO users, who want to upgrade their recon-  
813 struction pipeline to get the MOSAIC sorting feature too, can reach out to Renzo Huber  
814 (RenzoHuber@gmail.com) or Rüdiger Stirnberg (Ruediger.Stirnberg@dzne.de).

815 Furthermore, Remi Gau, generated a template dataset that exemplifies how one could  
816 to store layer-fMRI VASO data. This includes all the meta data for ‘raw and ‘derivatives’.  
817 Link to this VASO fMRI BIDS demo: [https://gin.g-node.org/RemiGau/ds003216/  
818 src/bids\\_demo](https://gin.g-node.org/RemiGau/ds003216/src/bids_demo).

819 Acknowledgements: We thank Chris Rodgers for instructions on how to overwrite  
820 existing reconstruction binaries on the SIEMENS scanner without rebooting. We thank  
821 David Feinberg, Alex Beckett and Samantha Ma for helping in testing the new reconstruc-  
822 tion binaries at the Feinbergtron scanner in Berkeley via remote scanning. We thank  
823 Maastricht University Faculty of Psychology and Neuroscience for supporting this project  
824 with 2.5 hours of ‘development scan time’.

## 825 5 Conclusion and future directions

826 *Stefano Moia, Hao-Ting Wang*

827

828        Approaching the organisation of an event as an experiment allows incredible freedom  
829        and dynamicity, albeit knowing that there will be risks and venues of improvement for  
830        the future.

831        The organisation managed to provide a positive onsite environment, aiming to allow  
832        participants to self-organise in the spirit of the Brainhack<sup>1</sup>, with plenty of moral - and  
833        physical - support.

834        The technical setup, based on heavy automatisation flow to allow project submission  
835        to be streamlined, was a fundamental help to the organisation team, that would benefit  
836        even more from the improvement of such automatisation flows.

837        This year, representatives of AFNI, FSL, and SPM (among the major neuroscience  
838        software developers) took part in the event, and their presence was appreciated both by  
839        other participants and themselves. In the future, connecting to more developers, not only  
840        from the MRI community, might improve the quality of the Brainhack even more.

841        The most challenging element of the organisation was setting up an hybrid event.  
842        While this element did not go as smoothly as it could have, this experimental setup seemed  
843        to have worked, allowing the participation of about 70 participants online. However, there  
844        is still a lot to improve for a truly hybrid event. For instance, it is important to allow spaces  
845        (both in time and space) for participants on-site to interact with online participants, and  
846        more attention, time, volunteers, and equipment has to be put to achieve a smooth  
847        online participation. For this reason, the Open Science Special Interest Group instituted  
848        a position to have a dedicated person for the hybridisation process. The other challenge  
849        was to welcome newcomers into this heavily project-development-oriented event. While  
850        newcomers managed to collaborate with projects and self-organise to learn open science  
851        related skills, this integration of pre-event train track and beginner friendly process will  
852        benefit from more attention.

853        Overall this OHBM Brainhack was a successful outcome for the organisation team  
854        experiment, and we hope that our findings will be helpful to future Brainhack events  
855        organisations.

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