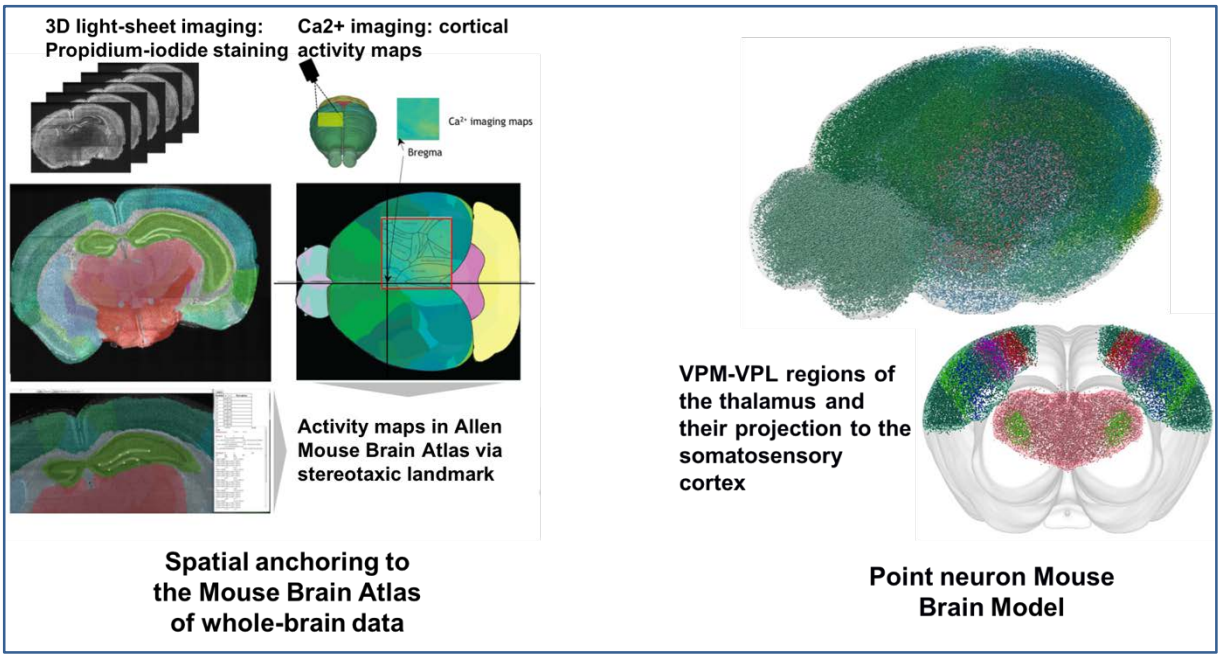
Grant Number:	720270	Grant Title:	Human Brain Project SGA1

Deliverable Title:	D1.5.4 (D5.4 D54) CDP1 Components Report for SGA1 M13-M24
Contractual Number and type:	SGA1 D1.5.4 (D5.4, D54) - Report
Dissemination Level:	PUBLIC
Version / Date:	03 May 2018; ACCEPTED 09 Jul 2018

Abstract:	In this report Key Results of HBP Co-Design Project 1 (CDP1) - Development of Whole Mouse Brain Model and Mouse Brain Atlas- are presented. An HBP Mouse Brain Atlas has been obtained, based on the Allen reference atlas. An operational workflow going from experimental data and metadata submitted by data producers and modellers in HBP has been set up to extract data points and make them discoverable in the reference atlas space. Data delivered in the context of CDP1 (whole brain structural connectivity and cortical activity) have been used to test, adapt and complete the developed workflows. A data driven modelling network-level model (using point neurons) of an entire mouse brain has been pursued, that integrates whole-brain datasets from available atlases and sources, such as the Allen Institute for Brain Science. The model has been then refined for the thalamo-cortical pathway, that mediates the sensory information from the periphery to the cortex. Physical experiments before and after stroke demonstrated that the rehabilitation protocol has a plasticising role promoting the refocus of cortical output and the rewiring of interhemispheric connectivity. A virtuous approach of close-loop workflow between physical experiments and modelling and simulation has been used for validating models and co-designing the implementation of *in* silico experiments on HBP Platforms.

Keywords:	motor learning, rehabilitation, stroke, whole brain model, whole brain atlas



CDP1-relevant data delivered by SP1 groups mapped to the Allen Mouse Brain Atlas (left) and the Mouse Brain Model (Point Neuron, right) developed for CDP1 simulation experiments.

Targeted users/readers	research public
Contributing Work-Package(s):	SGA1 WP1.3, WP10.1, WP10.3, WP10.5, WP4.5, WP5.1, WP5.2, WP5.4, WP5.6, WP6.2, WP6.3, WP6.6, WP7.1, WP7.2, WP7.5
Initially Planned Delivery Date:	SGA1 M24 / 31 Mar 2018

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1. Introduction

The main goal of the Co-Design Platform 1 was to produce two artefacts:

- a 3D model of the mouse brain at the point neuron level integrated in the Brain Simulation Platform (BSP)
- the related 3D mouse brain atlas integrated in the Neuroinformatics Platform (NIP)

We have pursued this goal developing datasets models and tools needed to realise the *in silico* versions on the Neurorobotics Platform (NRP) of the following two reference experiments using a physical motor platform:

1) Spatio-temporal coordinated activity during motor learning
2) Study of rehabilitation-induced cortical remapping after stroke

CDP1 proposed an iterative close-loop workflow between experiments and simulations, to refine and validate models with experimental data and to redesign experiments based on simulations.

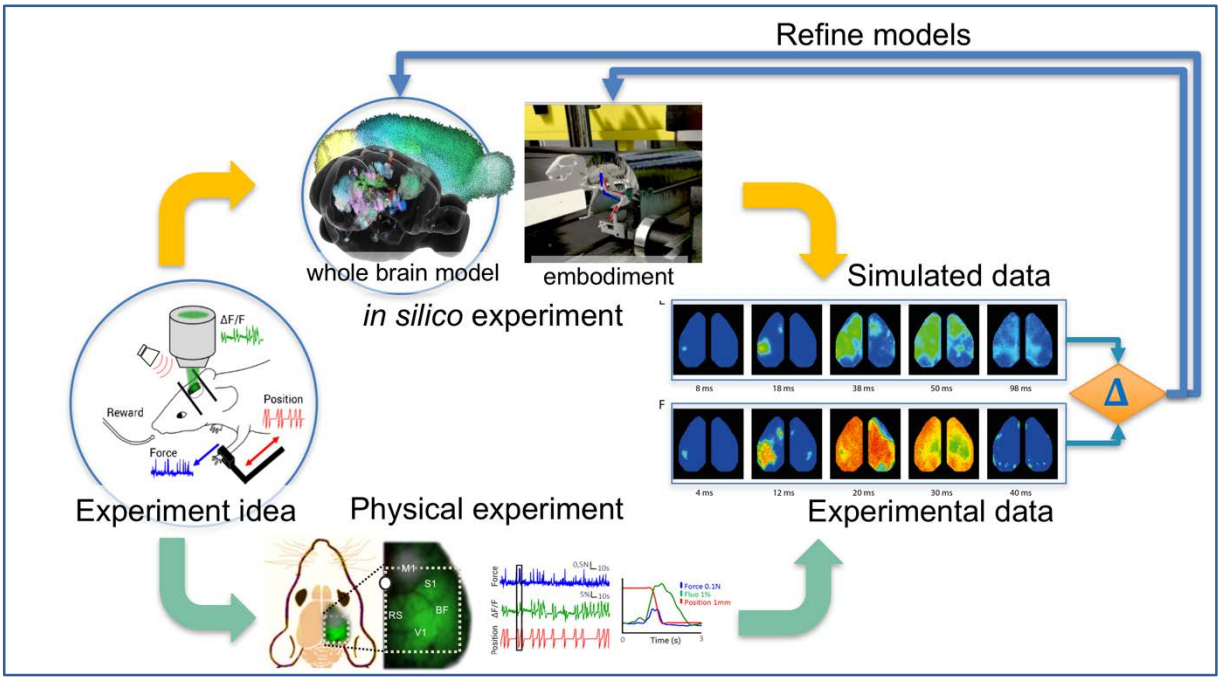

Figure 1 CDP1 close-loop workflow.

The CDP1 activities were carried out through one data product and five software products.

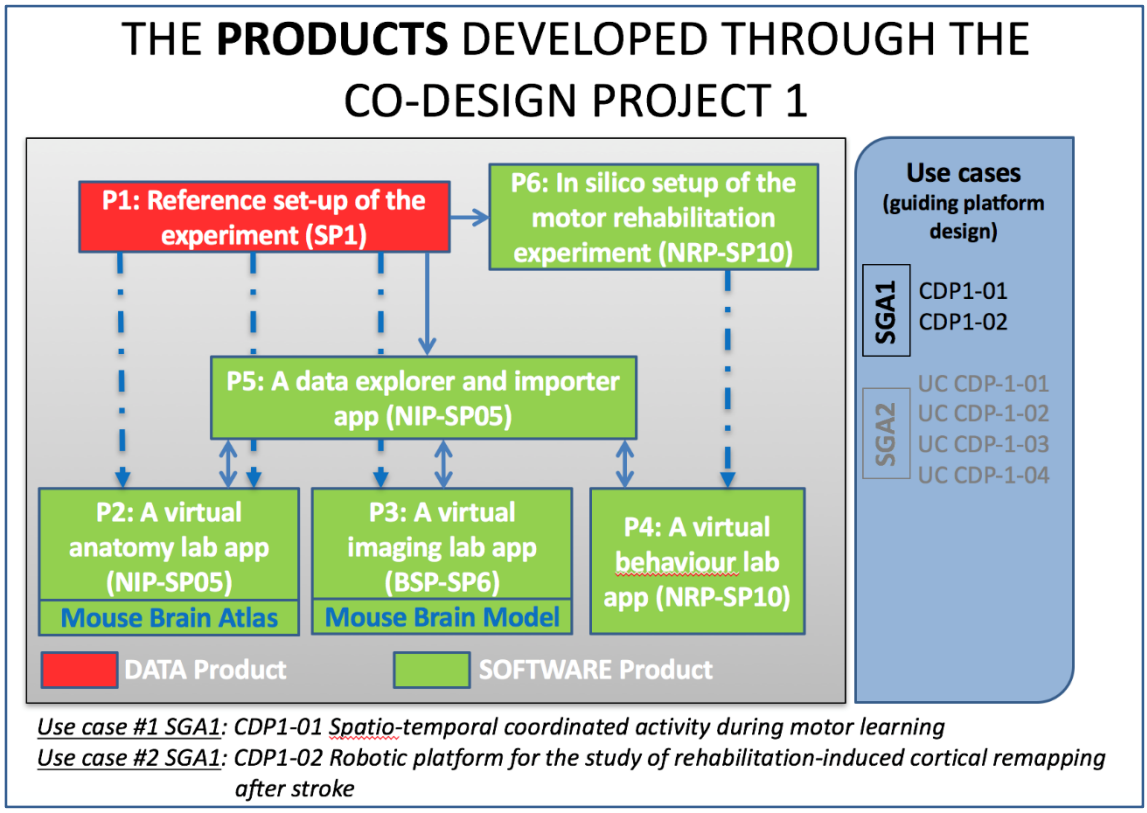

Figure 2 CDP1 Products and their interactions in co-designing platforms

CDP1 has produced a first scaffold model of the whole mouse brain and the associated whole-brain atlas. CDP1 has also demonstrated that the combination of modelling and atlasing on the one side and a concrete scientific context, such as stroke and recovery, on the other side are powerful co-design drivers. Thus, until now, CDP1 achieved two fundamental scientific outcomes, which are relevant both within HBP and for the entire neuroscience community:

- we demonstrated the feasibility of using modelling and simulation to improve our understanding and to predict the effects of rehabilitation after stroke
- we obtained a first *in silico* implementation of the experiments as a common framework to combine and compare brain models at different scales in a functional network context

From a neuroscientific perspective, main achievements are:

- effect of the stroke and rehabilitation on structural and functional organisation and integration of related datasets on NIP
- prediction of network reorganisation after stroke and rehabilitation
- preliminary validation of network models with empirical data

CDP1 has successfully contributed to the user-driven design and development of 3 different HBP Platforms. Tools have been developed and integrated in NIP, BSP and NRP. Regarding the HPAC (High Performance Analytics and Computing) Platform, CDP1 was instrumental in driving the interactive simulation use case on the NRP.

2. Results

This is the list of Key Results, the outputs and outcomes from CDP1 "Development of Whole Mouse Brain Model and Mouse Brain Atlas".

For any questions or insights, please contact the CDP1 leaders:

francesco.pavone@unifi.it, marc-oliver.gewaltig@epfl.ch.

2.1 Reference functional maps in the mouse brain

HBP researchers working on CDP1 Product 1 (Reference set-up of the experiment) studied functional plasticity after stroke through simultaneous wide-field meso-scale imaging and quantitative evaluation of motor performances of awake Thy1-GCaMP6f mice using the an "ad hoc" motor platform. Simultaneous recordings of applied forces and 2D time lapse cortical activity were obtained for three experimental groups, healthy, stroke and rehabilitated animals (recordings of calcium-activity in the cortex of fluorescent mice of these three groups, 3 mice per group, 5 days each, 15 datasets in total). These datasets have been integrated in the Neuroinformatics Platform (NIP).

We demonstrated that the rehabilitation protocol has a plasticising role promoting the refocus of cortical output and the rewiring of interhemispheric connectivity.

Moreover, HBP researchers exploited activity-dependent fluorescence labelling to obtain the whole-brain distribution of activated neurons in resting mice.

The experiments conducted on cortical activation during motor learning, in physiological and pathological settings, have been used to validate a brain network model (see 2.4). Specifications of the rehabilitation platform have been shared with the Neurorobotics team to design the virtual motor platform for stroke rehabilitation experiments (M-platform) integrated in the NRP (see 2.5).

2.1.1 Achieved Impact

- 15 datasets of fluorescence imaging of cortical activity were delivered and integrated with metadata in the NIP
- these datasets were used to validate the related mouse brain model
- resting-state activity mapping in mice with cellular resolution represents an important reference for model validation of mouse brain inside and outside the HBP. Furthermore, reference images obtained can also be used for the development of image processing methods.
- Publication:

  Allegra Mascaro A. L., Conti E., Lai S., Di Giovanna A. P., Spalletti C., Alia C., Quarta E., Panarese A., Sacconi L., Micera S., Caleo M., Pavone F. S., Rehabilitation promotes the recovery of distinct functional and structural features of healthy neuronal networks after stoke, submitted. Preprint available at https://www.biorxiv.org/content/early/2017/08/02/141697

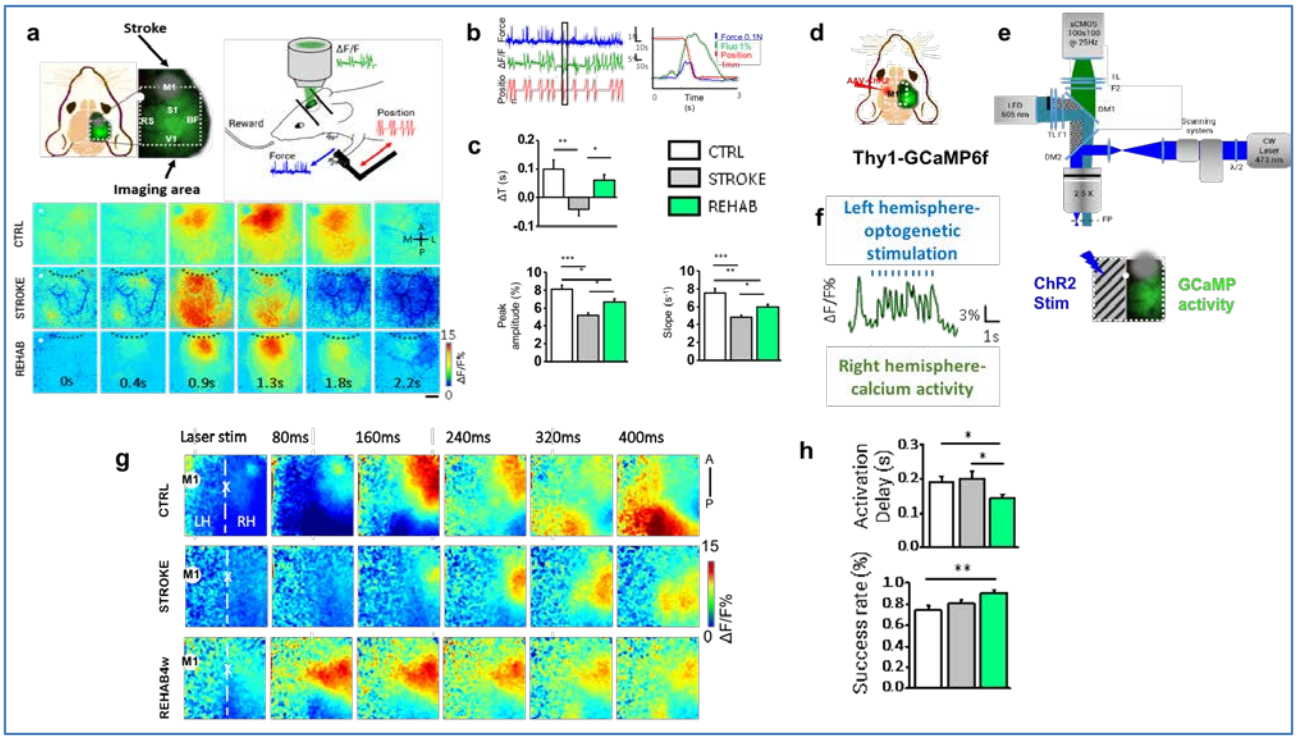

Figure 3 Overview of methods and results obtained investigating functional plasticity.

a) Representation of field of view for wide-field imaging and cartoon of mouse on robotic platform. Example of cortical activation acquired while mice performing the motor task; spot indicates bregma; the dashed line confines the lesion b) Left: example of force trace recorded by the load cell during a motor task on the robotic platform (top) and fluorescence trace (bottom). Right: temporal alignment of forces, fluorescence signal and forelimb position. c) Peak analysis of the calcium traces. On top, the delays in cortical activation in caudal regions are reported for the 4 groups, bottom left the Peak amplitude refers to the maximum of the fluorescence peak. Bottom right the middle graph shows the slope (average ± SEM) of the fluorescence in the rising phase. d) Schematic representation of field of view (i.e. area within white dotted square) for all-optical investigation of inter-hemispheric functional connectivity on Thy1-GCaMP6f mice. Red spot indicates M1 transfected with AAV9-CaMKII-ChR2-mCherry; grey cloud highlights the site of the stroke lesion. e) Wide-field microscope with double illumination path allowing simultaneous light stimulation and fluorescent recording. f) Fluorescent trace of optogenetically-elicited calcium activity. g) Image sequences of ipsilesional cortical activation following laser stimulation on healthy M1 (white spot); cross indicate bregma; LH RH. h) (Top) Delay between the light stimulus and the peak of the contralateral activation (average ± SEM); (Bottom) Quantification of the success rate for optogenetically-induced ipsilesional activation (average ± SEM).

2.1.2 Component Dependencies

Component ID	Component Name	HBP Internal	Comment
552	Fluorescence imaging of cortical activity after stroke	yes	2D lapse recording of calcium-activity in the cortex of fluorescent mice of three experimental groups: control, stroke, rehabilitated. 3 mice per group, 5 days each, 15 datasets total
931	Images of neuronal activation of whole mouse brain	yes	Whole-brain images of neuronal activation in mouse brain acquired with light-sheet microscopy, detecting immediate early genes (IEGs) expression

2.2 Rodent brain data discoverable and accessible from the Neuroinformatics Platform: from experimental data to quantitative data in reference atlas space

The Key Result delivered by CDP1 product 2 (A virtual anatomy lab app) is an operational workflow going from experimental data and metadata submitted by producers of experimental data and models in HBP to extracted data points that are discoverable in the reference atlas space. Data delivered in the context of CDP1 have been used to test, adapt and complete the workflows developed by SP5. The workflows and tools involved are reported in context of SP5 Key Results:

- KR5.1 Established metadata curation approach which makes HBP data and models FAIR (Findable, Accessible, Interoperable, Re-usable) in a consistent and user-friendly way
- KR5.2 Rodent atlasing workflow going from heterogeneous experimental image data to extracted quantitative features defined in rodent atlas space
- KR5.3 Prediction based cell-type specific mesoconnectome
- KR5.4 Spatial metadata assignment to HBP data and models
- KR5.6. A user-driven data sharing and data management infrastructure with necessary features to enable collection, curation and sharing of heterogeneous neuroscience data on a large scale

Using this workflow, heterogeneous 2D and 3D image data have been spatially registered to rodent brain atlas templates, registered with metadata in the HBP Knowledge Graph, and analysed by extracting features of interest as point coordinates in the reference space. HBP data providers can now upload their data and metadata to the HBP infrastructure via the tiered data curation service established by SP5. The Knowledge Graph is now operational and allows researchers to query, access, and explore these data.

The resulting workflow allows users to DISCOVER data by faceted query of metadata organised in the Knowledge Graph, and ACCESS data stored in the HBP Neuroinformatics Platform.

2.2.1 Achieved Impact

- The established workflow and infrastructure makes a substantial amount of heterogeneous, multimodal rodent brain data produced by HBP researchers discoverable and accessible via the Neuroinformatics Platform. A significant impact is that it will now for the first time be possible to demonstrate the added value that can be achieved through accumulation, spatial integration, and sharing of neuroscience data.
- Publications related to the whole-brain dataset:

  Marie-Pierre Adam; Marie Caroline Müllenbroich; Antonino Paolo Di Giovanna; Domenico Alfieri; Ludovico Silvestri; Leonardo Sacconi; Francesco Saverio Pavone, Confocal multispot microscope for fast and deep imaging in semicleared tissues, J. of Biomedical Optics, 23(2), 020503 (2018). doi:10.1117/1.JBO.23.2.020503

  Caroline Müllenbroich, Ludovico Silvestri, Lapo Turrini, Tommaso Alterini, Antonino Paolo Di Giovanna, Irene Costantini, Ali Gheisari, Francesco Vanzi, Leonardo Sacconi, Francesco Saverio Pavone, Increasing sensitivity and accuracy of brain-wide quantitative studies in light-sheet microscopy, bioRxiv 230540; doi: https://doi.org/10.1101/230540

2.2.2 Component Dependencies

Components contributing to the above mentioned SP5 Key Results are detailed in the SP5 deliverable (please see D5.8.3).

Components that produced experimental datasets integrated in the NIP are listed in the table below and detailed in chapter 3.

Component ID	Component Name	HBP Internal	Comment
932	Whole-brain images of selected neuronal types	yes	Whole brain dataset acquired from transgenic animals through high-resolution light-sheet microscopy
552	Fluorescence imaging of cortical activity after stroke	Yes	2D lapse recording of calcium-activity in the cortex of fluorescent mice of three experimental groups: control, stroke, rehabilitated. 3 mice per group, 5 days each, 15 datasets total

2.3 Scaffold model of the whole mouse brain at the level of point neurons

A data driven modelling network-level model (using point neurons) of an entire mouse brain is pursued that integrates whole-brain datasets from available atlases and sources, such as the Allen Institute for Brain Science. The most recent addition to this model is the refinement of the thalamo-cortical pathway. This pathway mediates the sensory information from the periphery to the cortex. Several studies have shown that this information is represented both in the thalamus and the somatosensory cortex, which implies direct connections between these regions. Based on the data given in Hunnicutt *et al.* (2014), we augmented the SP6 Whole Mouse Brain reconstruction workflow, creating a detailed map of the thalamic projections as an addition to the model. A first version of this brain model has been integrated into the Neurorobotics Platform. The whole brain modelling is proceeding to adhere to the structured phase of the newly defined HBP modelling life cycle.

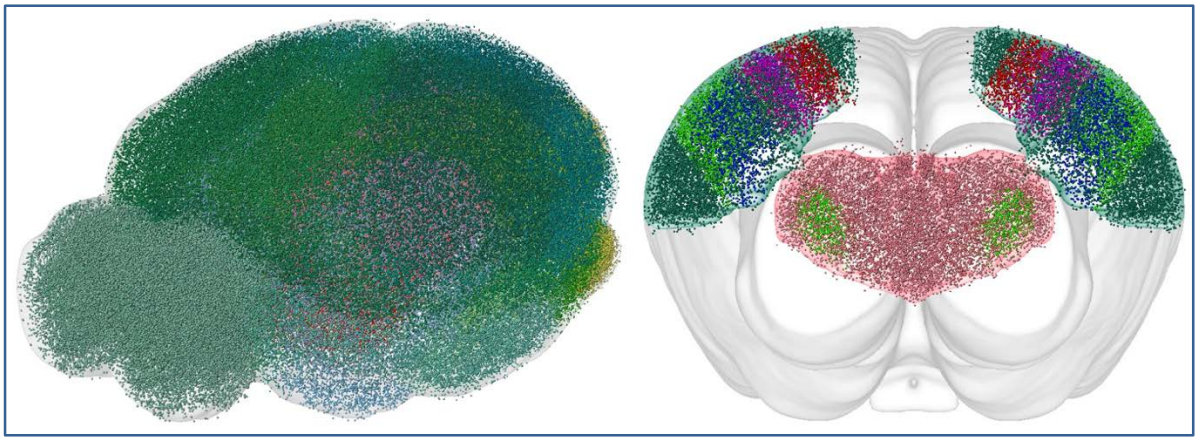

Figure 4 Data driven point-neuron brain mouse model

Left: point neuron mouse brain, 3D representation of the data-driven reconstructed point neuron mouse brain. One percent of the neurons is shown; the colour corresponds to brain regions as defined by the Allen Brain Atlas. Right: extract from the brain model, refinement of the thalamo-cortical regions targeted in SGA1, in particular the VPM-VPL regions of the thalamus and their projection to the somatosensory cortex.

2.3.1 Achieved Impact

- The mouse model can be connected to brain models at the level of point neurons and can thus be used to study details of central and peripheral motor control.
- A simplified version of the model was delivered to the Neuromorphic team for simulation on SpiNNaker.

- A reduced size version of the model was delivered to the Neurorobotic team for inclusion in the NRP. There, it is used for the stroke recovery experiments (CDP1). The model was instrumental in driving the co-design efforts with the Neuromorphic team towards large-scale interactive simulation (NMP with NRP).
- Publication:

  Rössert Christian, Christian Pozzorini, Giuseppe Chindemi, Andrew P. Davison, Csaba Eroe, James King, Taylor H. Newton, Max Nolte, Srikanth Ramaswamy, Michael W. Reimann, Willem Wybo, Marc-Oliver Gewaltig, Wulfram Gerstner, Henry Markram, Idan Segev, Eilif Muller (2017) Automated point-neuron simplification of data-driven microcircuit models. arXiv:1604.00087

2.3.2 Component Dependencies

Component ID	Component Name	HBP Internal	Comment
258	Point-neuron model of the whole mouse brain	yes	(see D6.5.2 for component details)
257	Simplified brain models	yes	(see D6.5.2 for component details)

2.4 Functional and structural connectivity model of mouse brain after stroke

This result consists of a Mouse Brain Model for simulating the rehabilitation experiment defined in CDP1: calcium analysis for a single mouse brain in the first and in the fourth week after stroke, compared to activity of a healthy brain.

Experimental calcium data are used in a close loop validation system to model the cortical activity of the mouse.

The open source tracer dataset of the Allen Institute has been implemented into The Virtual Brain (TVB), thus allowing detailed Structural Connectivity (SC) to be obtained. This is then used to build large-scale brain network models for the resting state Functional Connectivity and the predictive value of the tracer data is compared and validated against SC derived from diffusion MRI scans.

Developed models allow to perform virtual stroke experiments and to closer explore the changes of the function due to the structure, during stroke and recovery. Models will be available on the Collaboratory for HBP and non-HBP members.

2.4.1 Achieved Impact

- Close loop validated mouse brain model
- Characterisation of resection (stroke) strategies and their influence to propagation of excitability
- Functional connectivity model based on calcium imaging
- Publication:

  F. Melozzi, M. M. Woodman, V. K. Jirsa and C. Bernard “The Virtual Mouse Brain: A Computational Neuroinformatics Platform to Study Whole Mouse Brain Dynamics, eNeuro, 2017, 4 (3) ENEURO.0111-17.2017; DOI: https://doi.org/10.1523/ENEURO.0111-17.2017

2.4.2 Component Dependencies

Component ID	Component Name	HBP Internal	Comment
998	Allen Mouse Atlas (AMA) based brain network	yes	Functional connectivity model based on calcium imaging

2.5 Virtual framework to simulate a mouse motor-rehabilitation experiment

To understand how the brain interacts with its environment, SP10 has developed a data-driven skeletal model of a rodent, along with its neuro-muscular systems as a *co-design driver.* SP10 has also developed two pilot experiments to demonstrate how such a virtual body model can be used to study questions ranging from sensory-motor learning to recovery of motor function after a stroke or spinal cord injury. The *in silico* reconstruction of a stroke recovery experiment, uses the data-driven scaffold model of the whole mouse brain from SP6 and demonstrates how a large-scale data-driven brain model can be used in a realistic closed-loop experiment.

The reconstructed setup consists of:

1) A high-fidelity reconstruction of the motor rehabilitation platform (M-platform). It comprises all important M-platform components (i.e. linear actuator, linear slide, handle) and allows the user to define the parameters of different motor experiments. Moreover, it allows to accurately simulate the movement and friction of the actuator and to measure the force applied by the mouse forelimb
2) A biologically accurate mouse body model, comprising a mouse skeleton, Hill-type muscles for the fore- and hind-limbs, as well as a spinal-cord model to generate movement primitives
3) A biological model of proprioceptive sensory information, a necessary feature for the design of brain-inspired neuro-robotic controllers that include complete action-perception loops, has been implemented on NEST and integrated into a spinal cord model to allow control of the forelimb in the rehabilitation experiment and finally tested on the NRP
4) A scaffold model of the whole mouse brain (developed in SP6). The model has been connected to the mouse body. This connection represents an important technical milestone, as it couples for the first time the Brain Simulation Platform with the Neurorobotics Platform.

The virtual framework will be useful for a large class of motor-rehabilitation experiments for HBP and non-HBP research communities.

2.5.1 Achieved Impact

- The virtual mouse offers a common research platform for scientists ranging from neuroscience to neurotechnology and robotics.
- The virtual mouse comprises a set of components for the mouse neuro-musculo-skeletal system (mouse model) can be used individually or in combination.
- We have demonstrated the successful integration of the mouse neuro-musculo-skeletal model in two pilot experiments that also serve as co-design drivers.
- Publications:

  H. Mørk, S. B. Vennemo, H. E. Plesser, "Instrumenting network simulations with the NESTConnectionApp", Bernstein Conference 2017 Abstract, Göttingen, September 2017 (https://abstracts.g-node.org/conference/BC17/abstracts#/uuid/67c89e56-8f49-4ed4-be49-c88b2ecdef51), T6.3.6

L. Vannucci, E. Falotico, C. Laschi (2017), Proprioceptive Feedback through a Neuromorphic Muscle Spindle Model, Frontiers in Neuroscience, vol 11, pp 341

Figure 5 The CDP-1 mouse experiment implemented in the NRP

Full dynamic models of the mouse (neuro-muscular skeletal) and the M-platform.

2.5.2 Component Dependencies

Component ID	Component Name	HBP Internal	Comment
169	World Simulation and Closed-loop engine	yes	development and maintenance of simulation tools for robots in sensory rich environments
920	Integration of the motor rehabilitation scenario with models of rodent brain, body and muscoloskeletal system	yes	implementation of a virtual mouse motor rehabilitation protocol
845	Rodent Body Model for the Neurorobotics Platform	yes	rodent body model (see D10.7.3 for component details)
847	Musculoskeletal models of rodents for the Neurorobotics Platform	yes	musculoskeletal rodent model (see D10.7.3 for component details)

3. Component Details

The following is a list of the newly released internal Components for this deliverable.

3.1 Fluorescence imaging of cortical activity after stroke

Field Name	Field Content	Additional Information
ID	552	
Component Type	Data	
Contact	ALLEGRA MASCARO, Anna Letizia	
Component Description	The role of this component has been to acquire the functional data in custom mouse models, provide reference instances of the stimulation and recording equipment that need to be modelled to replicate the virtual experiments and to provide reference and validation data for the *in-silico* models. Data include functional cortical maps (via calcium indicators), whole-brain activity maps via immediate early genes expression and optogenetics stimulation.	
Latest Release	30.11.2017	
TRL	NA	
Location	data hosted by HPAC Platform	HBP CSCS
Format	TIFF – Tagged Image File Format Txt	• Multi-TIFF file format for the wide-field images • Text file format for applied forces and positions during the experiment on the platform
Curation Status	Tier 2 completed	Metadata are in the HBP Collaboratory: "DataCuration_Pavone_RUP_T1.2.2_SGA1_T1.3.1_1.3.2_1.3.4"
Validation - QC	Pass	ALLEGRA, Letizia
Validation – Users	Yes	two different internal users (Viktor Jirsa and Marc-Oliver Gewaltig)
Validation – Publications	No	
Privacy Constraints	Animal Research	
Sharing	HBP Collaboratory	
License	Attribution NonCommercial ShareAlike	https://creativecommons.org/licenses/by-nc-sa/4.0/

Component Access URL	https://ksproxy.cscs.ch:13000/Pavone_SGA1_1.3.2	Cortical recording: CSCS repository accessible by SP5 team (via Swift protocol)
Technical documentation URL	https://doi.org/10.1101/141697	pre-print publication on cortical recording
Usage documentation URL	https://doi.org/10.1101/141697	pre-print publication on cortical recording
Component dissemination material URL	https://www.biorxiv.org/content/early/2017/12/03/141697.figures-only	

3.2 Images of neuronal activation of whole mouse brain

Field Name	Field Content	Additional Information
ID	931	
Component Type	Data	
Contact	SILVESTRI, Ludovico	
Component Description	Whole-brain activation mapped with cellular resolution	
Latest Release	MS1.3.4 30.11.2017	images of neuronal activation based on early-genes expression (cFos) mapping
TRL	N/A	
Location	data hosted by HPAC Platform	HBP CINECA
Format	3D TIFF – Tagged Image File Format	
Curation Status	Tier 2 completed	Metadata are in the HBP Collaboratory: "DataCuration_Pavone_RUP_T1.2.2_SGA1_T1.3.1_1.3.2_1.3.4"
Validation - QC	Pass	SILVESTRI, Ludovico
Validation – Users	No	
Validation – Publications	No	
Privacy Constraints	Animal Research	
Sharing	HBP Collaboratory	down sampled images
License	Attribution NonCommercial ShareAlike	https://creativecommons.org/licenses/by-nc-sa/4.0/
Component Access URL	https://collab.humanbrainproject.eu/#/collab/5340/nav/41538	HBP Collaboratory accessible by SP5 team
Technical documentation URL	NA	
Usage documentation URL	NA	

Component dissemination material URL	NA	

3.3 Whole-brain images of selected neuronal types

Field Name	Field Content	Additional Information
ID	932	Whole-brain images of selected neuronal types
Component Type	Data	Image stack of different cell types (parvalbumin interneurons, somatostatin interneurons, VIP interneurons and pyramidal cells) across the entire mouse brain
Contact	SILVESTRI, Ludovico (LENS)	
Component Description	Whole brain dataset acquired from transgenic animals through high-resolution light-sheet microscopy	
Latest Release	MS1.3.9 30.11.2017	11 whole-brain datasets (4 with parvalbumin-positive neurons labeled, 4 with VIP-positive and 3 with somatostatin-positive) have been collected. Raw data and down sampled data.
TRL	N/A	
Location	HBP Collaboratory	also in CINECA repository
Format	TIFF – Tagged Image File Format	3D TIFF images
Curation Status	Tier 2 completed	Metadata are in the HBP Collaboratory: "DataCuration_Pavone_RUP_T1.2.2_SGA1_T1.3.1_1.3.2_1.3.4"
Validation - QC	Pass	Silvestri Ludovico, QC based on visual inspection
Validation – Users	No	
Validation – Publications	No	
Privacy Constraints	Animal Research	
Sharing	HBP Collaboratory	
License	Attribution NonCommercial ShareAlike	https://creativecommons.org/licenses/by-nc-sa/4.0/
Component Access URL	https://collab.humanbrainproject.eu/#/collab/5340/nav/41538 LOCALIZOOM	HBP Collaboratory website from Oslo University (UIO)
Technical documentation URL	NA	
Usage documentation URL	NA	
Component dissemination material URL	NA	

3.4 Allen Mouse Atlas (AMA) based brain network

Field Name	Field Content	Additional Information
ID	998	998
Component Type	model	model
Contact	JIRSA, Viktor	JIRSA, Viktor
Component Description	The component represents a whole brain mouse network model of spontaneous resting state activity. It can describe healthy activity, as well as different levels of stroke and rehabilitation. In this way, the model should demonstrate the constraints of network structure upon network function as observed in the mouse experimental data during healthy condition, stroke and recovery.	
Latest Release		work in progress
TRL	3	
Location	data hosted by task providing dataset	
Format	ZIP/HDF5	TVB Simulator
Curation Status	PLA registered	
Validation - QC	Pass	Spase PETKOSKI, work in progress
Validation – Users	No	
Validation – Publications	Yes	The number of new downloads of TVB is ~800 per week. Can be checked on the TVB web-site TVBdownload
Privacy Constraints	Animal Research	
Sharing	HBP Partners	
License	Public authenticated	
Component Access URL	Simulate for Mouse	HBP Collaboratory
Technical documentation URL	TVB Simulator	A public page for downloading the software
Usage documentation URL	Simulate for Mouse	A public Collab page with tutorial for mouse modelling
Component dissemination material URL	TVB Demos	

3.5 World Simulation and Closed-loop engine

Field Name	Field Content	Additional Information
ID	169	
Component Type	software	
Contact	GEWALTIG, Marc-Oliver	
Component Description	development and maintenance of simulation tools for robots in sensory rich environments	
Latest Release	1.3 released November 2017	Next release 2.0 April 2018
TRL	4	The CDP1 lab app is still in the prototype state. Performance enhancements are to be done in SGA2 before it is deployable on the online Neurorobotics Platform.
Location	data hosted by other HBP party	Online deployment (on HPAC resources) will happen when the performances and brain distribution have advanced. For now, the app is available in the local installation of the Neurorobotics Platform and is hosted publicly on our Bitbucket repositories.
Format	software	The app is an experiment in the Neurorobotics Platform and requires dedicated software to have been integrated within, for example for muscle simulation and tactile feedback.
Curation Status	N/A	
Validation - QC	Pass	Agile Quality Assurance
Validation – Users	Yes	Internal CDP1 users only
Validation – Publications	No	
Privacy Constraints	No Privacy Constraint	
Sharing	anonymous	Available from our public Bitbucket repositories
License	GPL2	
Component Access URL	Neurorobotics Platform	The app is embedded in the Neurorobotics Platform, therefore the link points actually to the whole Platform.
Technical documentation URL	Developer Manual	Neurorobotics Platform developer manual
Usage documentation URL	Guide book	Neurorobotics Platform guide book

Component dissemination material URL	NA	

3.6 Integration of the motor rehabilitation scenario with models of rodent brain, body and musculoskeletal system

Field Name	Field Content	Additional Information
ID	920	
Component Type	data	
Contact	GEWALTIG, Marc-Oliver	
Component Description	experiment framework for mouse virtual experiments of motor learning and rehabilitation	
Latest Release	1.3 released November 2017	Nest release 2.0 April 2018
TRL	4	
Location	data hosted by other HBP party	The CDP1 experiment is not yet deployed online (see P4) and is thus available publicly through our Bitbucket repositories for local installation. Sensor models are available through Bitbucket repositories. Control loop and spinal cord model are integrated in the CDP1 experiment.
Format	The format is for: - 3D models: Gazebo SDF - brain and sensors models: PyNN, NEST - experiment files: custom XML and JSON formats	
Curation Status		
Validation - QC	Pass	Agile Quality Assurance
Validation – Users	Yes	Internal CDP1 users, sensor models have been validated by WP10 users
Validation – Publications	No	
Privacy Constraints	No Privacy Constraint	
Sharing	anonymous	Models available from public Bitbucket repositories
License	GPL2	
Component Access URL	CDP1 experiments in Bitbucket repository	
Technical documentation URL	NA	

Usage documentation URL	NA	
Component dissemination material URL	NA	

4. Conclusion and Outlook

CDP-1 has contributed to co-design three of the six HBP platforms, NIP, BSP and NRP, implementing a big effort of cross-SP collaborations for specific CDP1 activities.

Table 1 Overview of WPs contribution to CDP1 Key Results

CDP1 SGA1 Key Results	WPs contributions	HBP Platforms involved
Reference functional maps in the mouse brain	WP1.3, WP7.5	NIP
Rodent brain data discoverable and accessible from the Neuroinformatics Platform: from experimental data to quantitative data in reference atlas space	WP1.3, WP5.1, WP5.2, WP5.4, WP5.6, WP7.5	NIP
Scaffold model of the whole mouse brain at the point neuron level	WP 6.2	BSP
Functional and structural connectivity model of mouse brain after stroke	WP1.3, WP4.5	BSP
Virtual framework to simulate a mouse motor-rehabilitation experiment	WP1.3, WP6.2, WP6.3, WP10.1, WP10.3 WP10.5, WP7.1, WP7.2	NRP, BSP

Resume of main achievements detailed in the following paragraphs:

- 15 functional and 11 structural mouse experimental datasets
- 1 HBP Mouse Brain Reference Atlas
- 1 Knowledge Graph metadata database
- 1 point neuron Brain Model at full scale (75 million neurons, 75 billion connections)
- 1 meso-scale mean field Brain Network Model (540 brain regions)
- 1 *in silico* model of the motor-rehabilitation experiment

The following functionalities to perform simulated experiments are currently available:

- Users can obtain quantitative morphological data from user-selected brain regions, described either as standard atlas partitions (e.g. M1 cortex) or in geometrical terms (e.g. arbitrarily cut slice).
- Moreover, for data simulation, users can also obtain virtual imaging data from selected brain regions, with the same features.
- Users can also obtain long-range connectivity data (ingoing and outgoing) relative to user-selected brain regions. Furthermore, the app provides appropriate cutting geometry needed to preserve user-selected long-range projections intact after slicing, useful in both real and virtual experiments.
- The user can import, explore and export anatomical (morphologies, cell spatial distribution, projections, etc.) and functional data from and to the atlas.
- The above app assures standardisation of metadata and alignment with reference space where applicable. The atlas has been fed initially with 3rd party data (e.g. Allen Institute).

- In the BSP, the user can load, simulate and visualise a point neuron model of the whole mouse brain.
- In the NRP, the user can simulate the motor-rehabilitation experiment, where the mouse brain is connected to a mouse body.
- The user, through the Virtual Brain framework, can specify:
  - portion of the brain to simulate (e.g. whole brain or a single slice – missing at least part of long range projections)
  - model to be used (e.g. high-dimensional, spiking point neurons, population level)
  - physiological/pathological conditions
  - type of imaging (calcium, VSD, early gene expression, fMRI, PET, electrophysiology)
  - details of the imaging system (resolution, acquisition speed, field of view, spatial orientation effects)
- The user, through the Virtual framework to simulate a mouse motor-rehabilitation experiment, can use a virtual mouse (comprising a set of components for the mouse neuro-musculo-skeletal system and a whole brain model) to perform stroke recovery experiments.

Key Results obtained until now in CDP1 have a concrete impact on the HBP Research Infrastructure and the future developments of CDP1, allowing to extend virtual experiments on the Neurorobotics Platform to grasping (in SGA2) and free behaviour (in SGA3), through the same virtuous approach of close-loop workflow between physical experiments and modelling and simulation. In parallel, the HBP Mouse Brain atlas will be enriched with related new datasets and metadata, that will be discoverable and accessible through enhanced functionalities implemented at the Neuroinformatics Platform, and neuronal plasticity features and models after stroke will be investigated for a cross-species comparison.