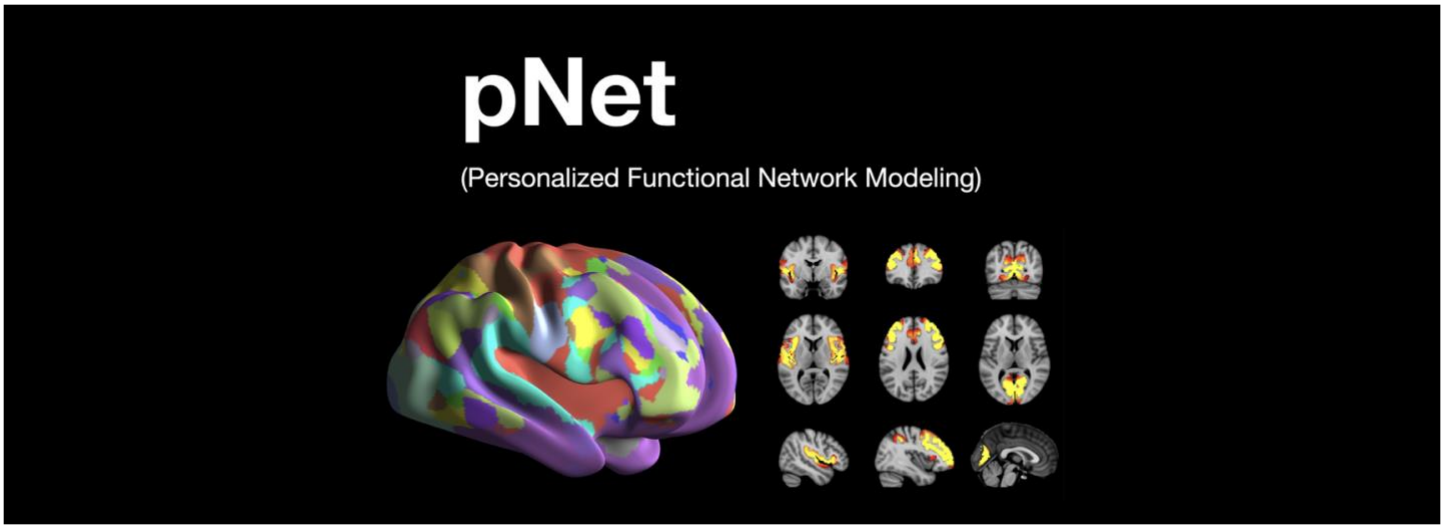


Help Document

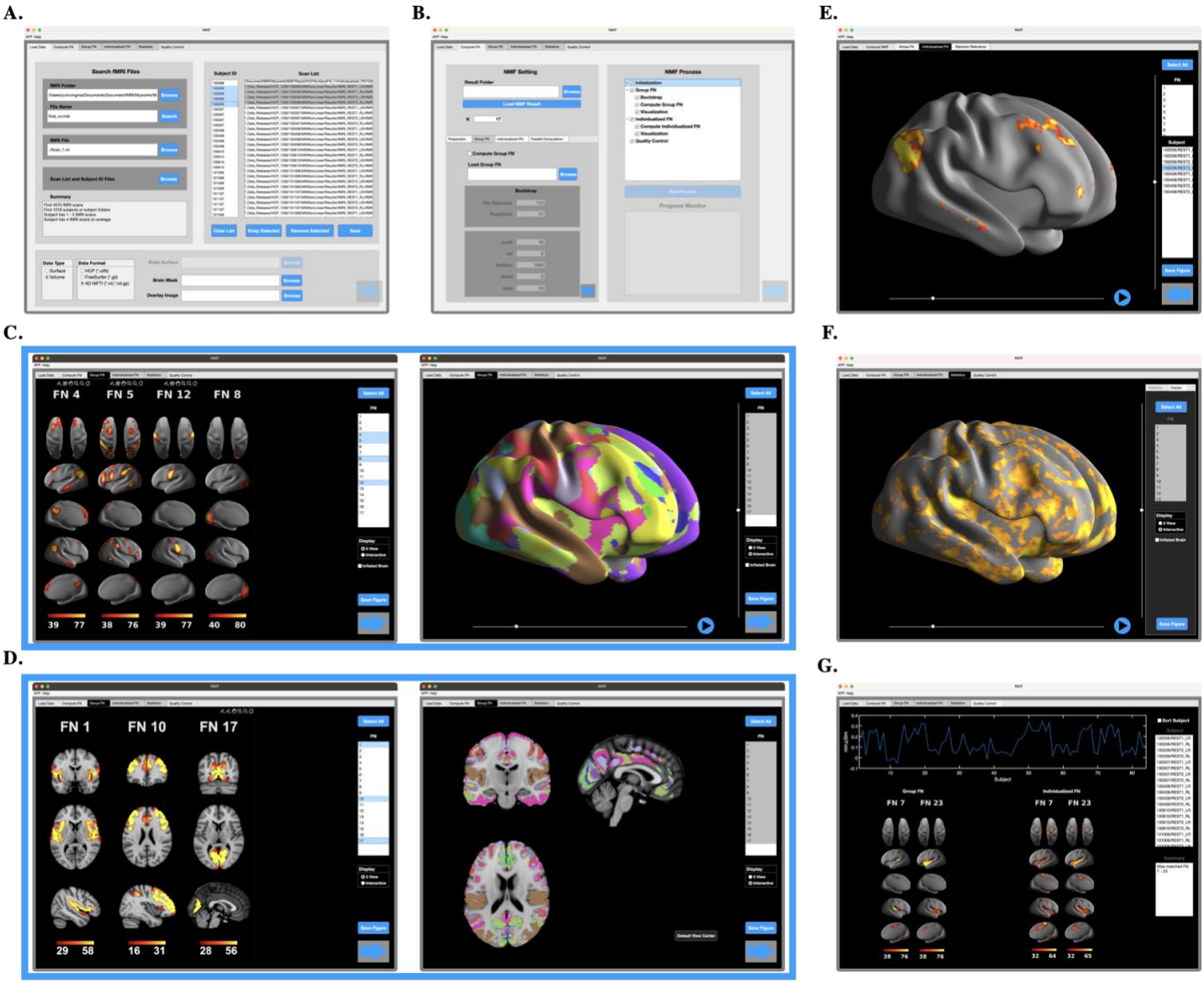
A guideline for pNet

Yuncong Ma

Toolbox Overview

This toolbox is designed to provide a user-friendly interface to perform personalized functional network computation. It is open-source, cross-platform, and expandable, making it easy to use for users with little knowledge about computation, customizable for users with . It allows flexible data search for fMRI scans with support for different data formats. To initialize the computation of personalized FNs (pFN), this toolbox allows user to compute a new gFN based on the data available, or load a precomputed gFN using this toolbox, or from other methods, including group-ICA and GIGICA. Flexible visualization options enhance fast result navigation and customizable in-depth comparisons. It also provides several simple statistical analysis methods to investigate the correlation between the topology of pFNs to behavior data. In addition, quality control is integrated to ensure the spatial correspondence of pFNs with respect to the corresponding gFNs.

This toolbox can be downloaded from https://github.com/YuncongMa/pNet



pNet app snapshots

(A) Welcome page for the toolbox.

(B) A module for loading fMRI scans and brain template files.

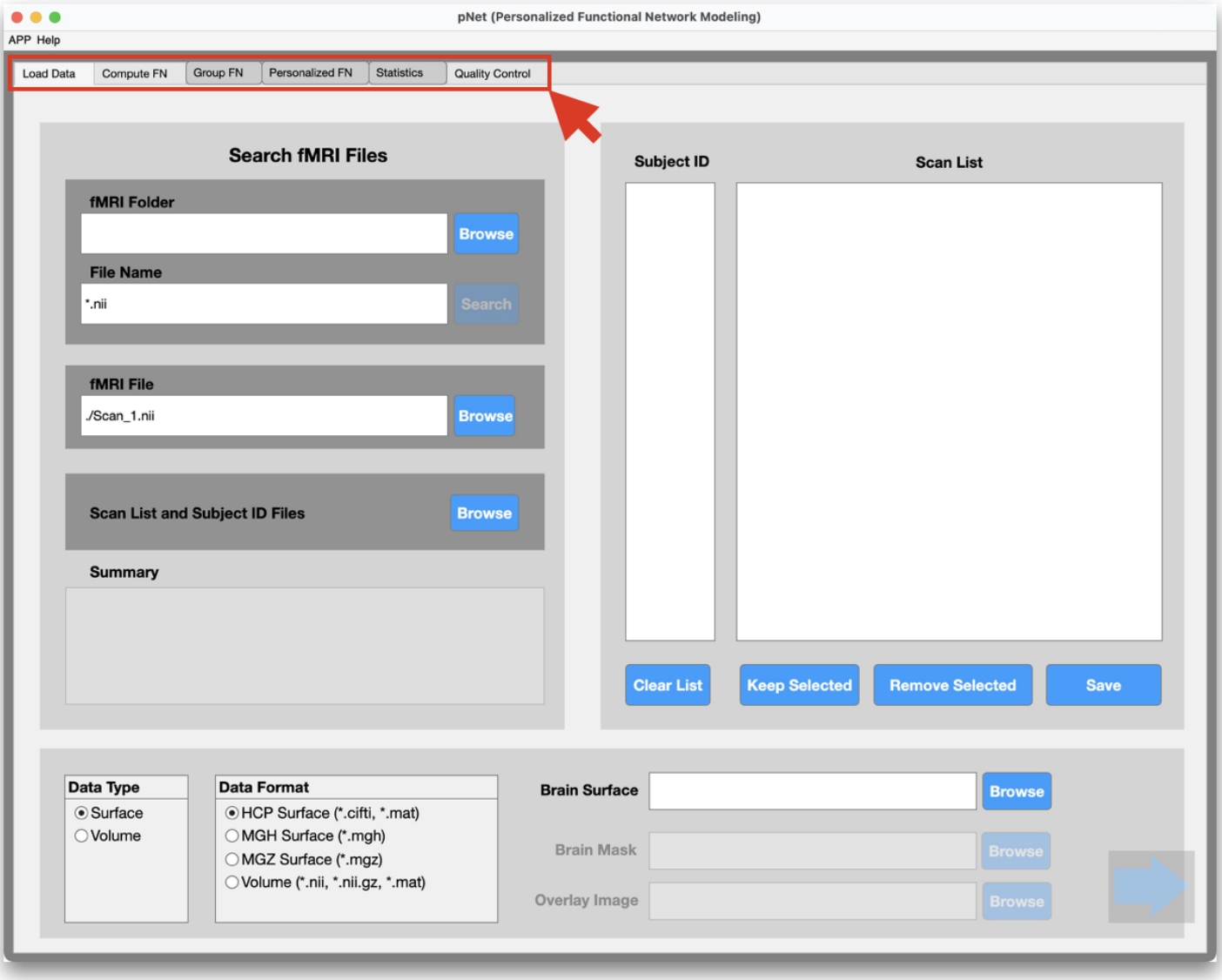
(C) A module to setup computation parameters for both the group-level and individualized FNs.

(D) Surface-based visualization of both group and personalized FNs (k=17) using HCP S1200 dataset, with left panel showing a binarized atlas generated from the group FNs and the right panel showing five views of three personalized FNs. All the color bars of intensity maps were set from the maximum value of the map to its half value.

(E) Volume-based visualization of both group and personalized FNs (k=17) from Zhen's multi-cohort iSTAGING study, with left panel showing a binarized functional atlas generated from the group FNs and the right panel showing a three-slice view of three personalized FNs.

(F) Surface-based visualization of the maximum t value (two sample t-test, FDR correction, p-

value=0.001) of sex differences of individualized FNs (k=50) of the HCP S1200 dataset.
(G) A module for quality control, showing one scan with two FNs mismatched to their group-level counterparts.



Tabs (highlighted in the red box) for different modules to search data, setup FN computation, check results of gFN and pFN, conduct statistics, and quality control.

Content

App Installation

This chapter provides guidelines about ways to run this toolbox. pNet only runs successfully on MATLAB no older than 2021a.

Users can use the toolbox in several ways as shown below:

1. Run from the MATLAB command window.
2. Install pNet as a MATLAB app.

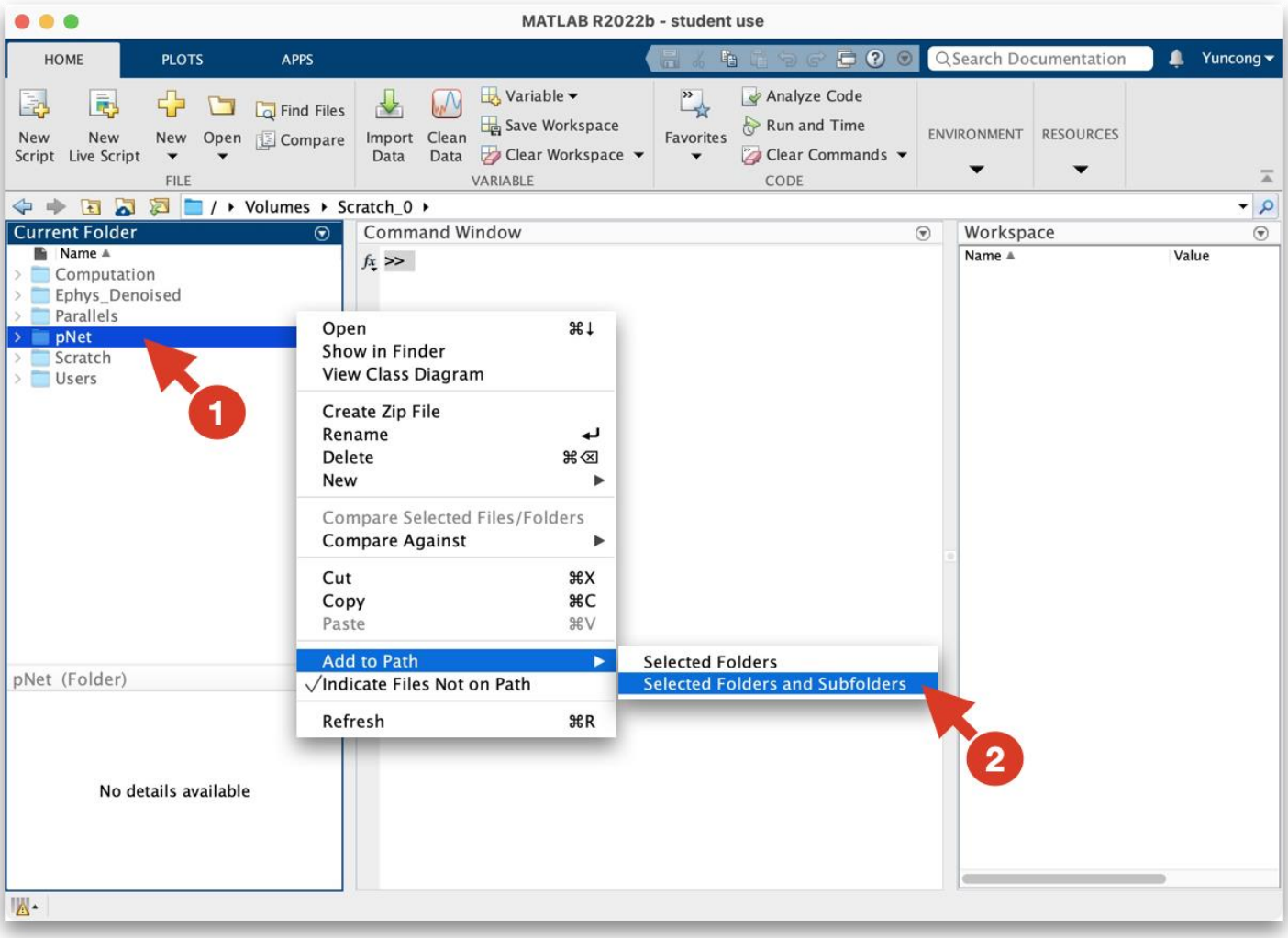
System and hardware requirement

It is recommended to have at least 4 CPU cores, 16GB memory (RAM), and 10GB free disk space. Please be aware that more CPU, memory and disk space will be needed to process bigger data or use parallel computation. MATLAB older than 2021a does not have some essential APP UI functions to give correct UI layout. As pNet is mostly tested on 2022b, it is recommended to use this version or later.

MATLAB	macOS (Intel CPU)	macOS (Apple Silicon)	Linux	Windows 10
2020b				✗
2021a	✓	✓	✓	✓
2021b	✓			✓
2022a	✓			✓
2022b	✓			✓
2023a	✓			✓

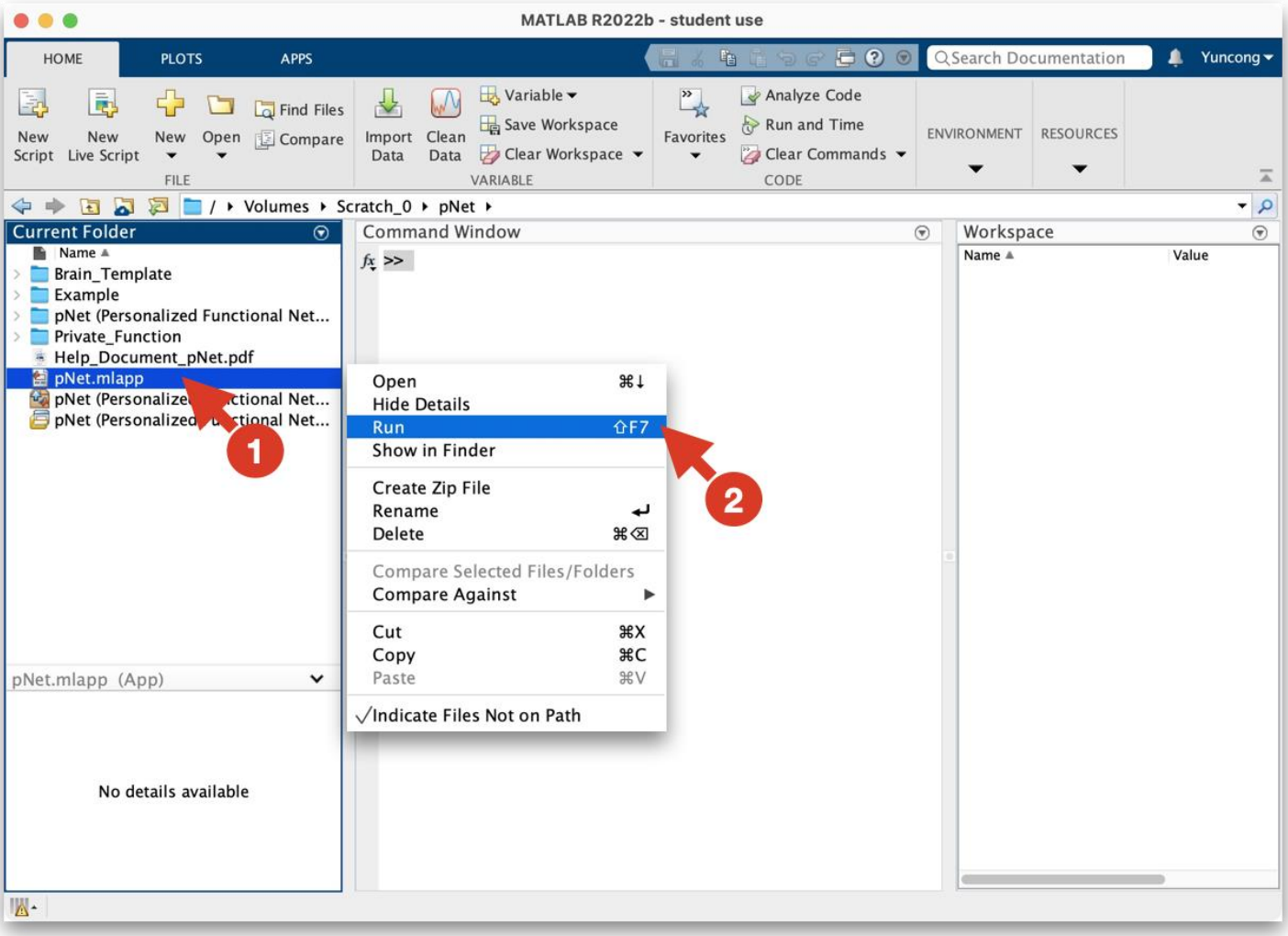
Run in MATLAB

This method requires to download all the functions and app icons to run pNet in MATLAB. Make sure that the subfolder Private_Function and the help document are available in the app folder.



Navigate to the directory contains the pNet folder.

(1-2) Right click the folder to add the folder and subfolders to path.

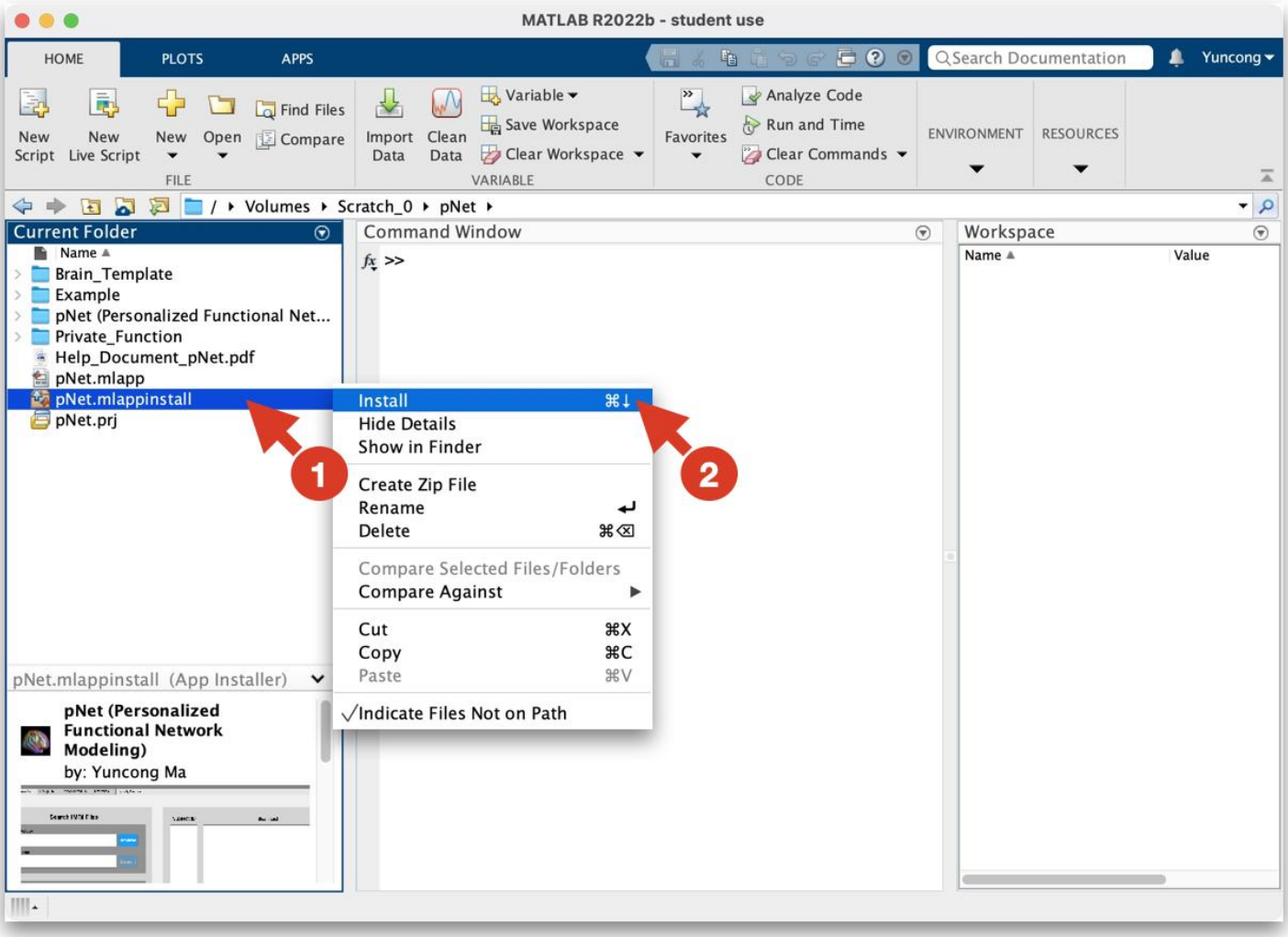


Run the pNet app.

(1-2) Open the pNet folder, and right click the pNet.mlapp, and click the run option.

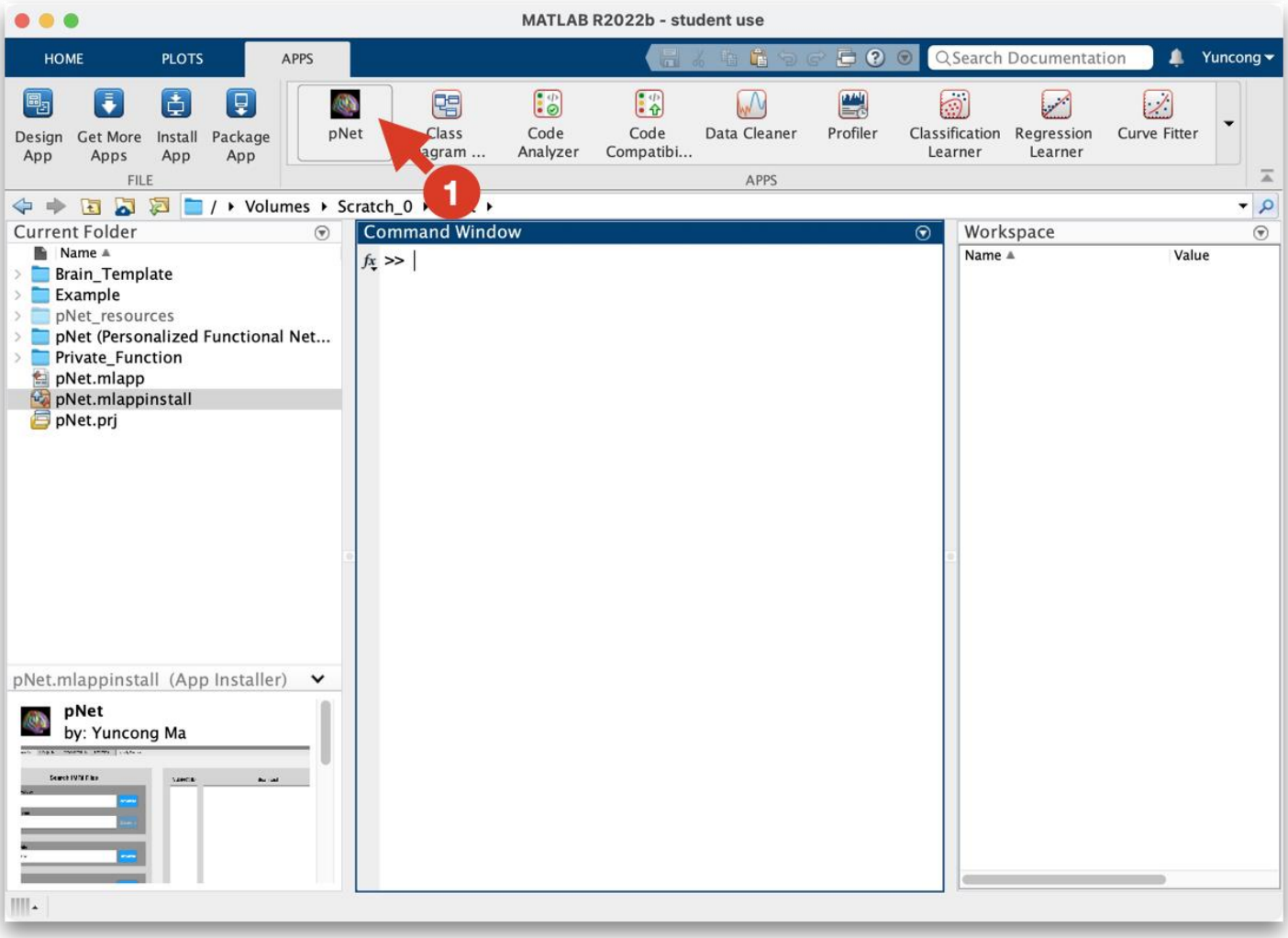
Install pNet as a MATLAB app.

This way will allow users to use the app without navigating to the app folder, or adding the app folder to the path.



Install the pNet app UI.

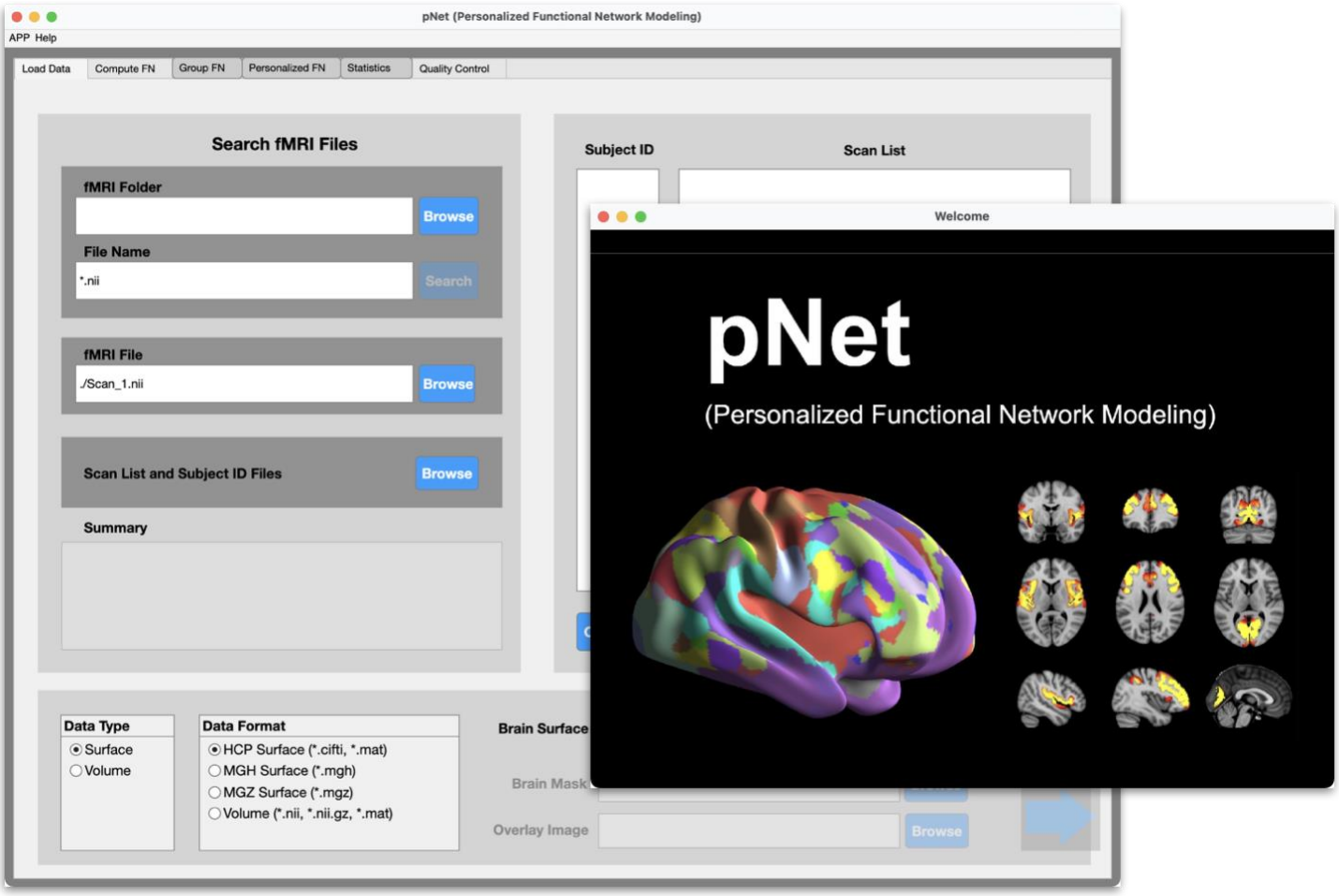
(1-2) Double click or right click on the file “pNet.mlappinstall” to install the software on MATLAB.



Run the pNet app from the APPS menu.

(1) Open the APPS menu tab, and click on the pNet app.

Users will see a welcome page, and a main user interface (UI). The main UI contains multiple tabs on the top for different modules to setup the computation and visualization. Users could simply use the order from left to right to follow the workflow of this toolbox.



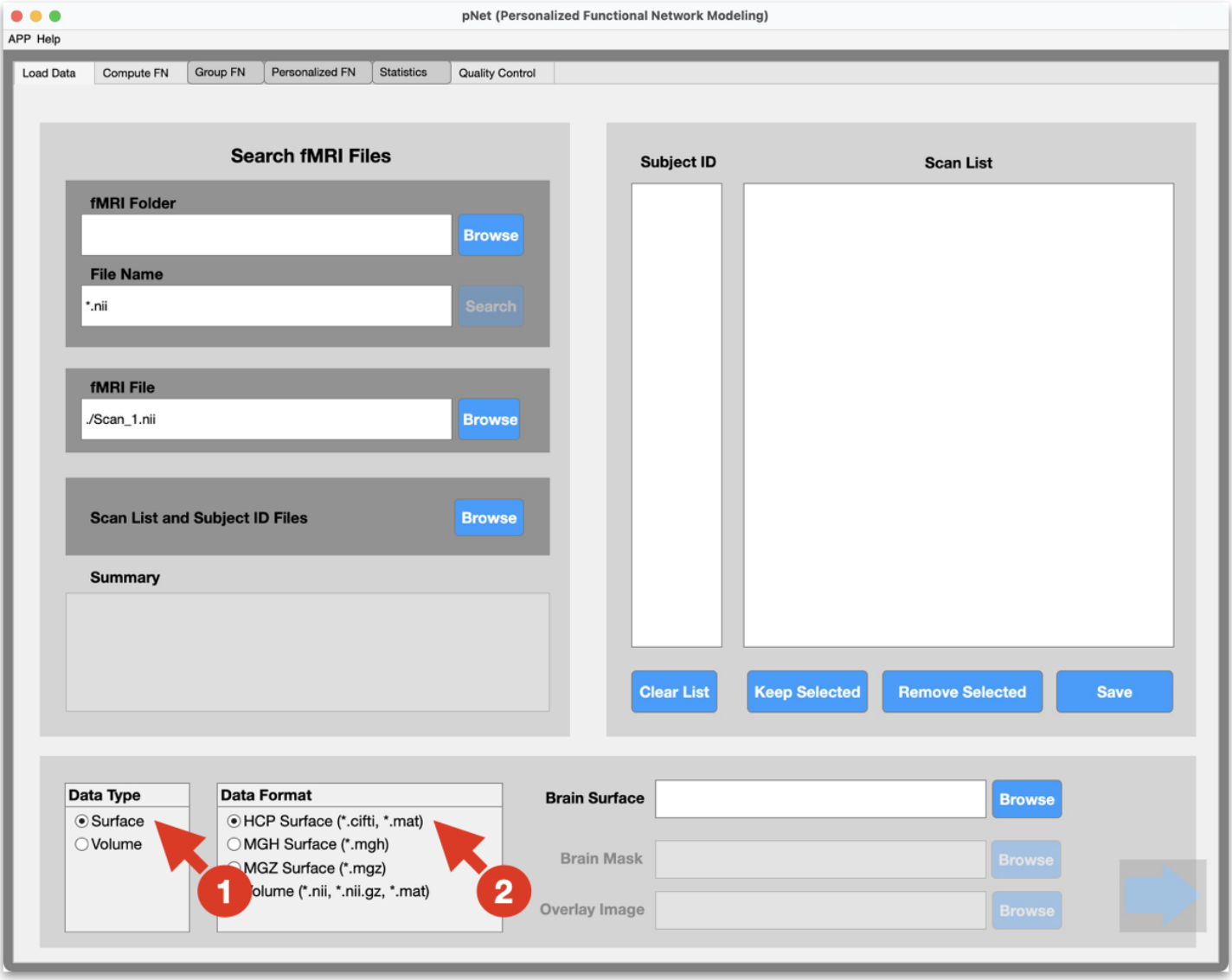
The app welcome page (right window with black background) and the main UI.

Data Loading

This chapter provides guidelines to search and organize fMRI can files, load brain template files.

Search for fMRI files

Users need to firstly select the data type and data format.



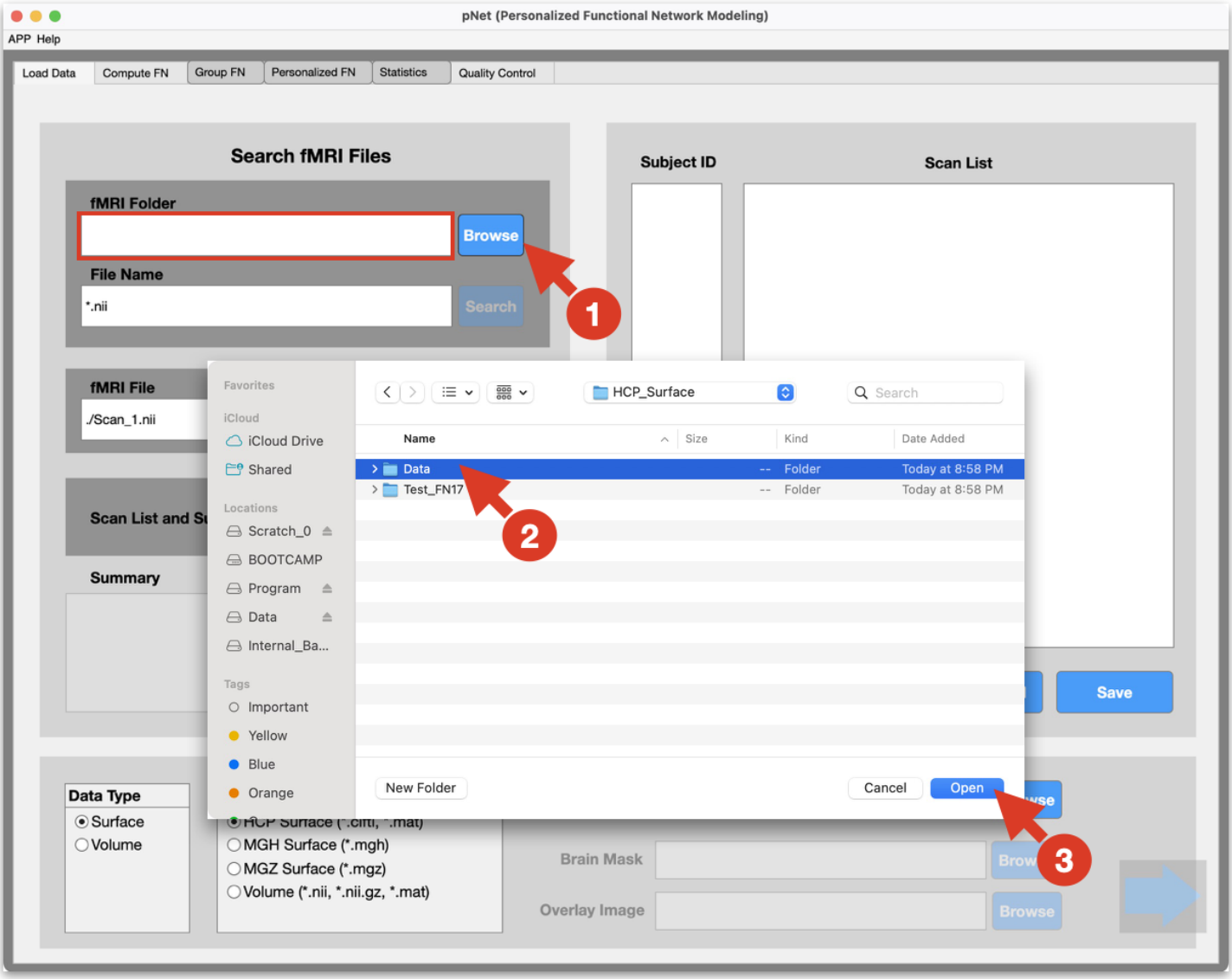
Select the data type and format.

(1) Select the data type.

(2) Select the data format.

The toolbox offers three ways to find fMRI scan files.

1. Search fMRI files based on their extension in a folder.

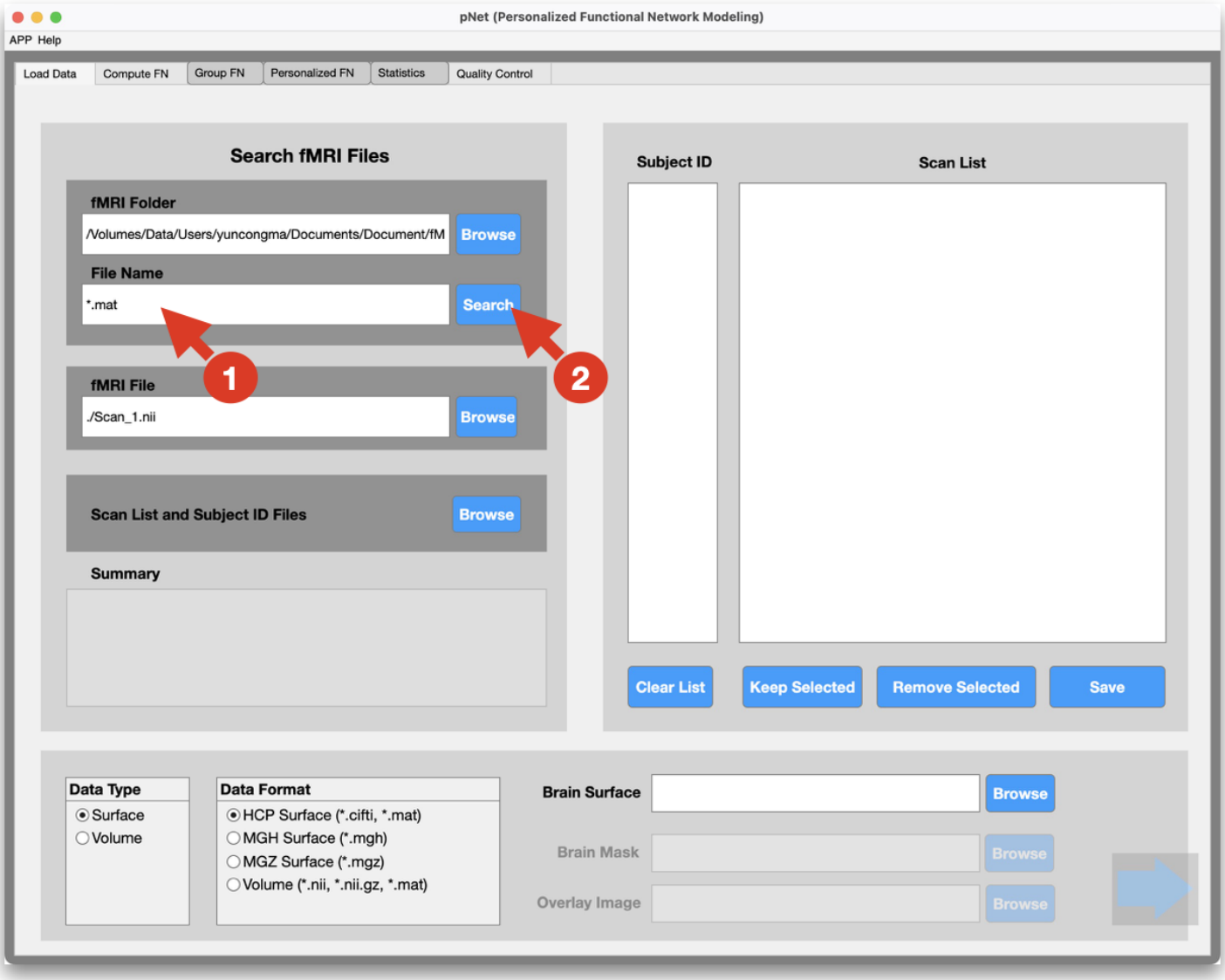


Select the data folder.

(1) Click browse button to open the folder selection window.

(2) Select the folder, and click the open button

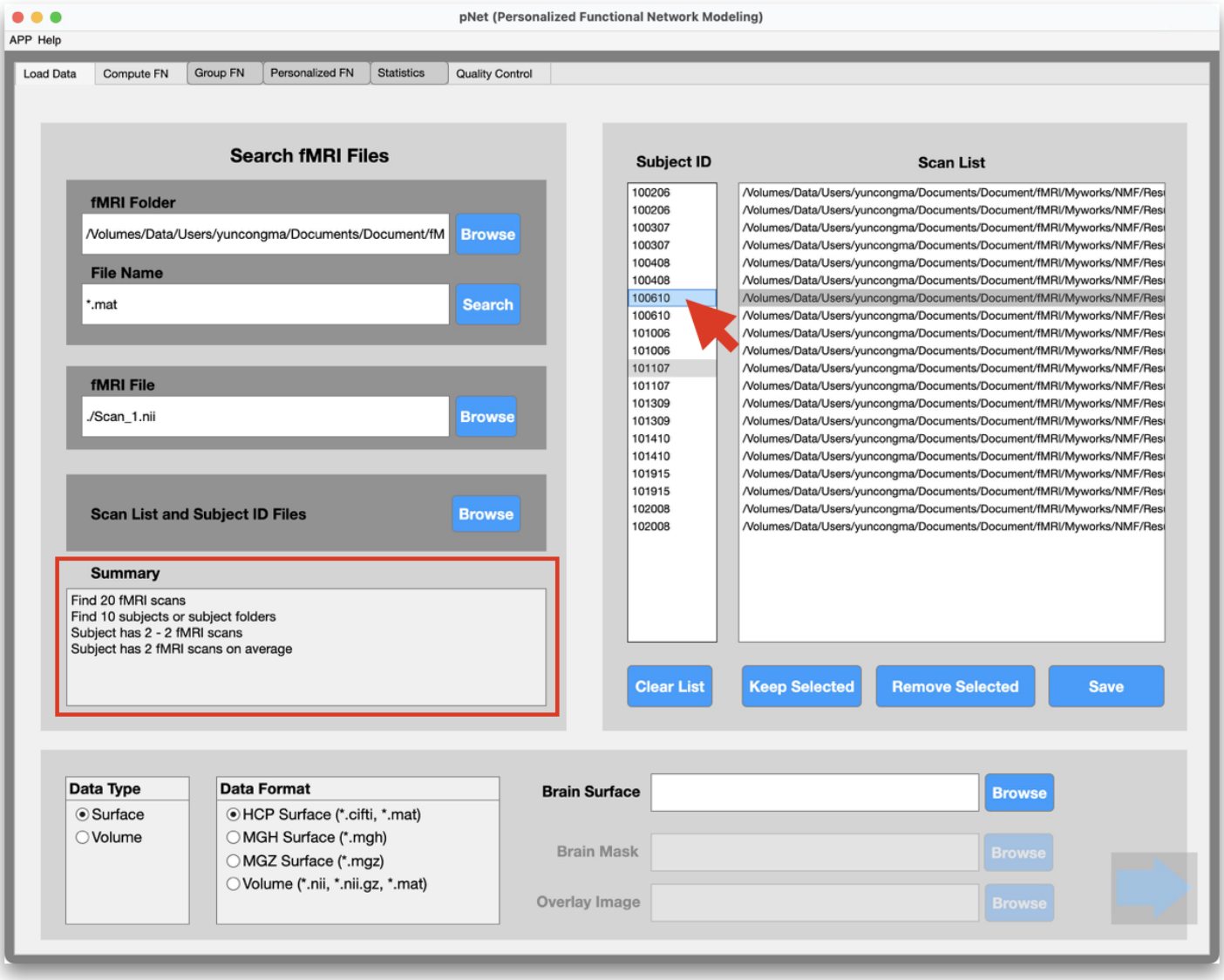
(3) to finish the folder selection. The full folder directory information will appear in the white input field (highlighted in the red box). Users can also type in the full folder directory into the white input field (highlighted in the red box).



Setup the file extension information.

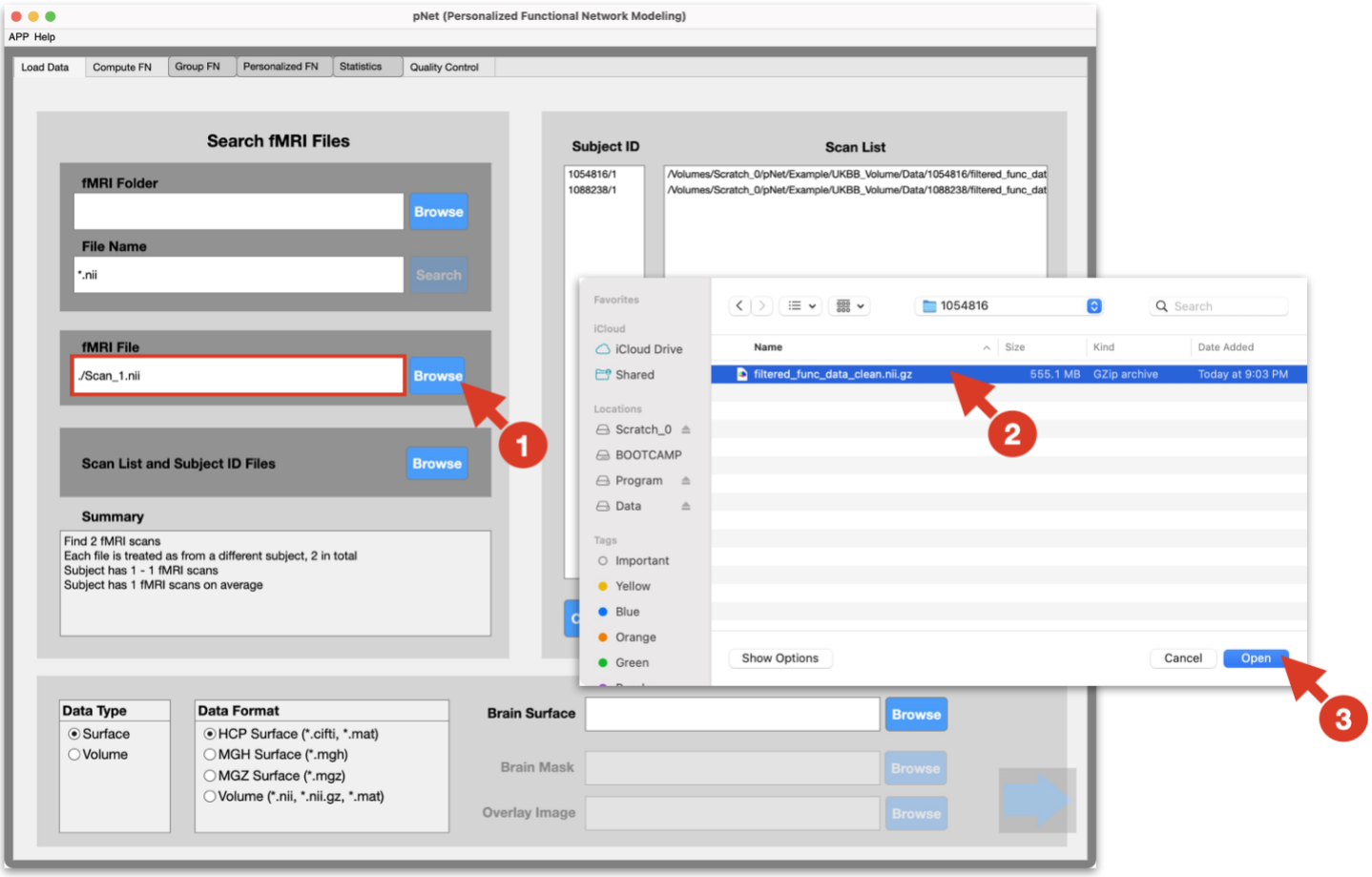
(1) Specify the file extension, such as “*.mat” or “*.nii.gz”.

(2) Click search button to perform file searching function.



Check the summary and navigate through the extracted subject ID and corresponding file directory. Summary module highlighted in the red box shows the total number of files, the range of file number per subject, average file number per subject. Error messages will also be shown if there is any.

2. Select fMRI files



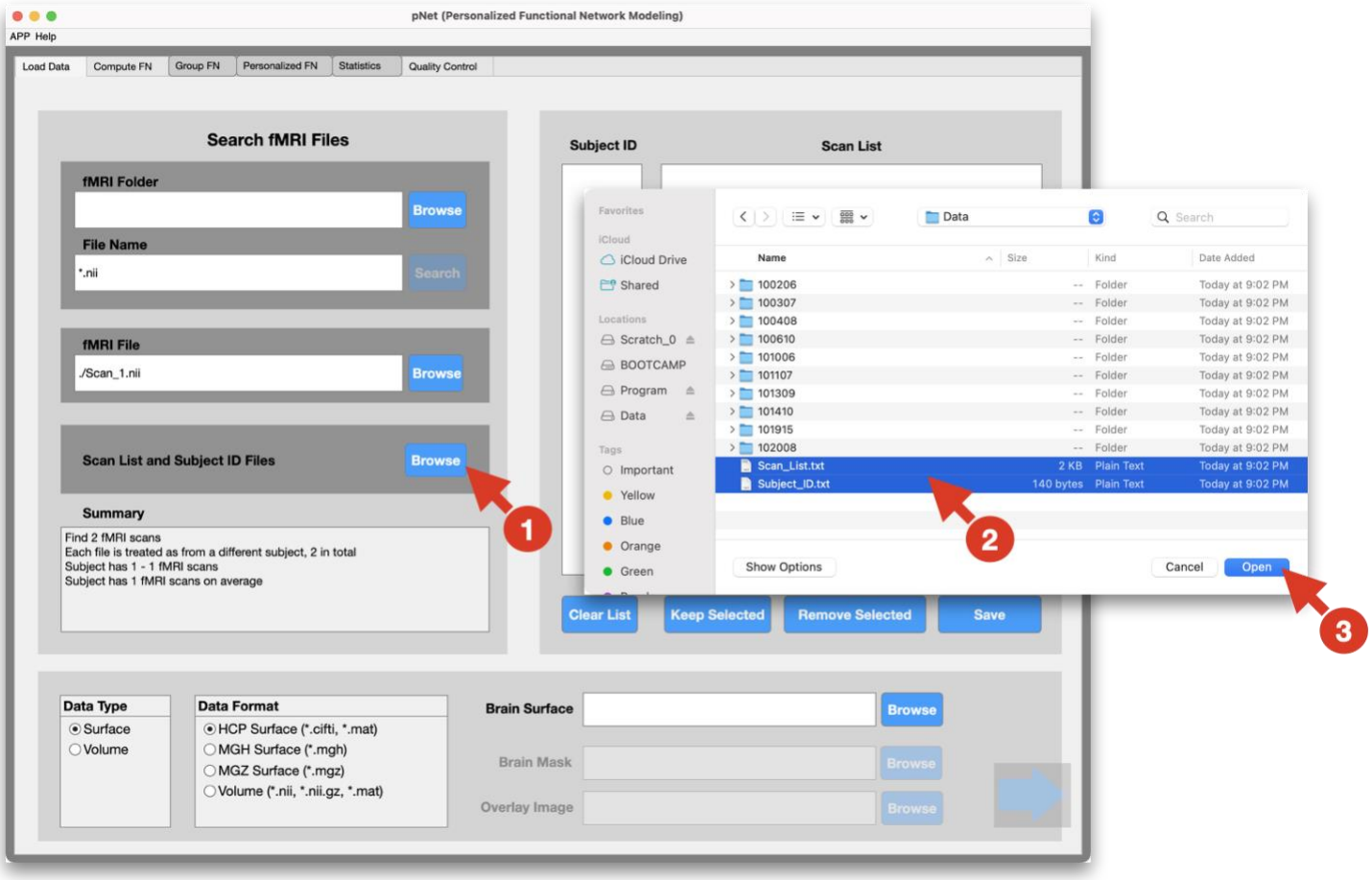
Select fMRI files.

(1) Click the browse button.

(2) Manually select one or multiple fMRI files with supported extensions, and click the open button

(3) to load the full file directories. Users can also use the input field (highlighted in the red box) to type in the full file directories.

3. Load prepared file list information in txt format.



Load fMRI scan list and subject ID files.

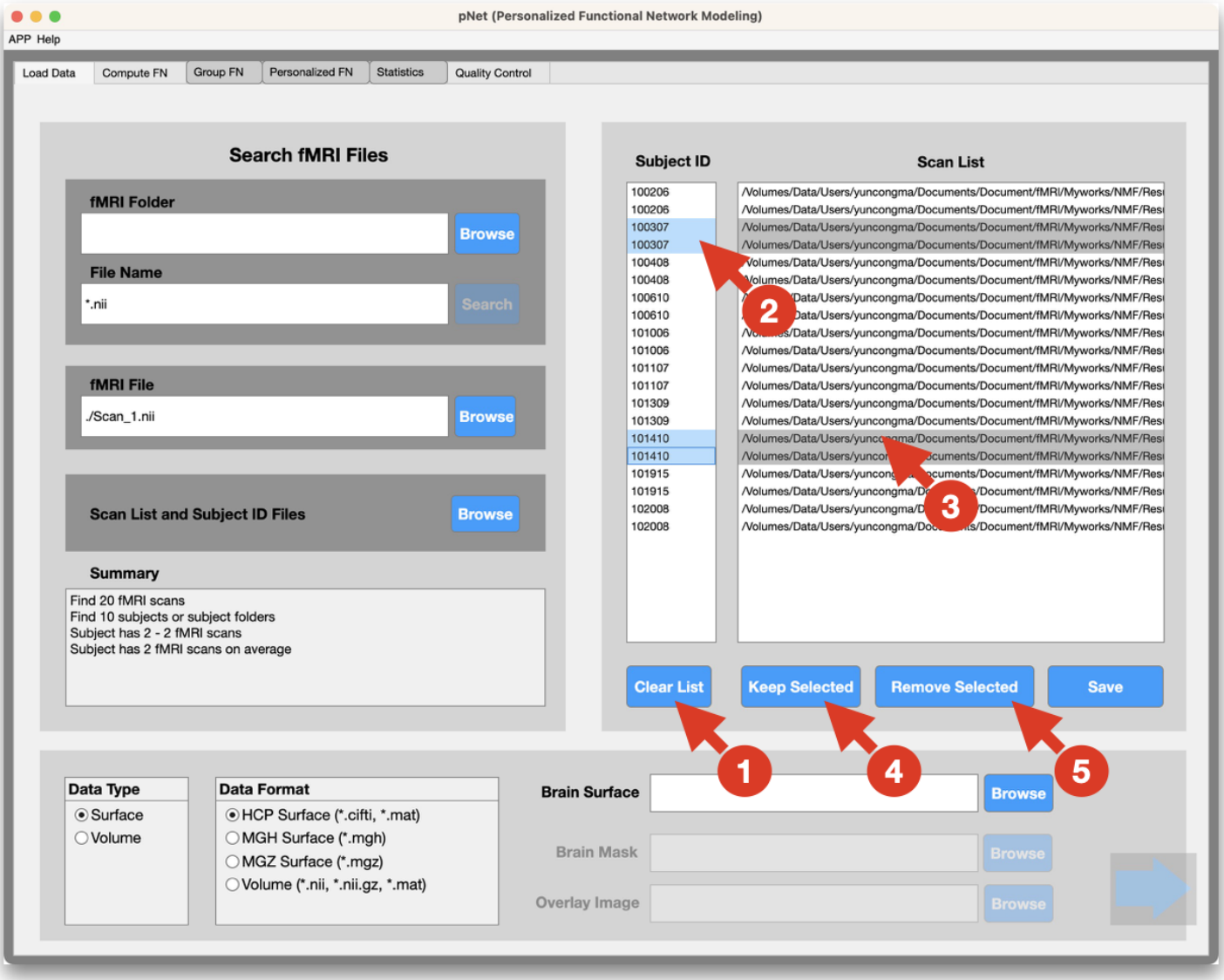
(1) Click the browse button.

(2) Choose the text file containing full directories of fMRI scan files, and another text file containing subject ID information for each corresponding fMRI scan. The subject ID information file is not necessary. When it is not provided, automatic subject ID information will be extracted.

(3) Click the open button to read those files.

Organized fMRI scan files

1. Clear, select or remove fMRI scan files



Remove, select or remove fMRI scan files.

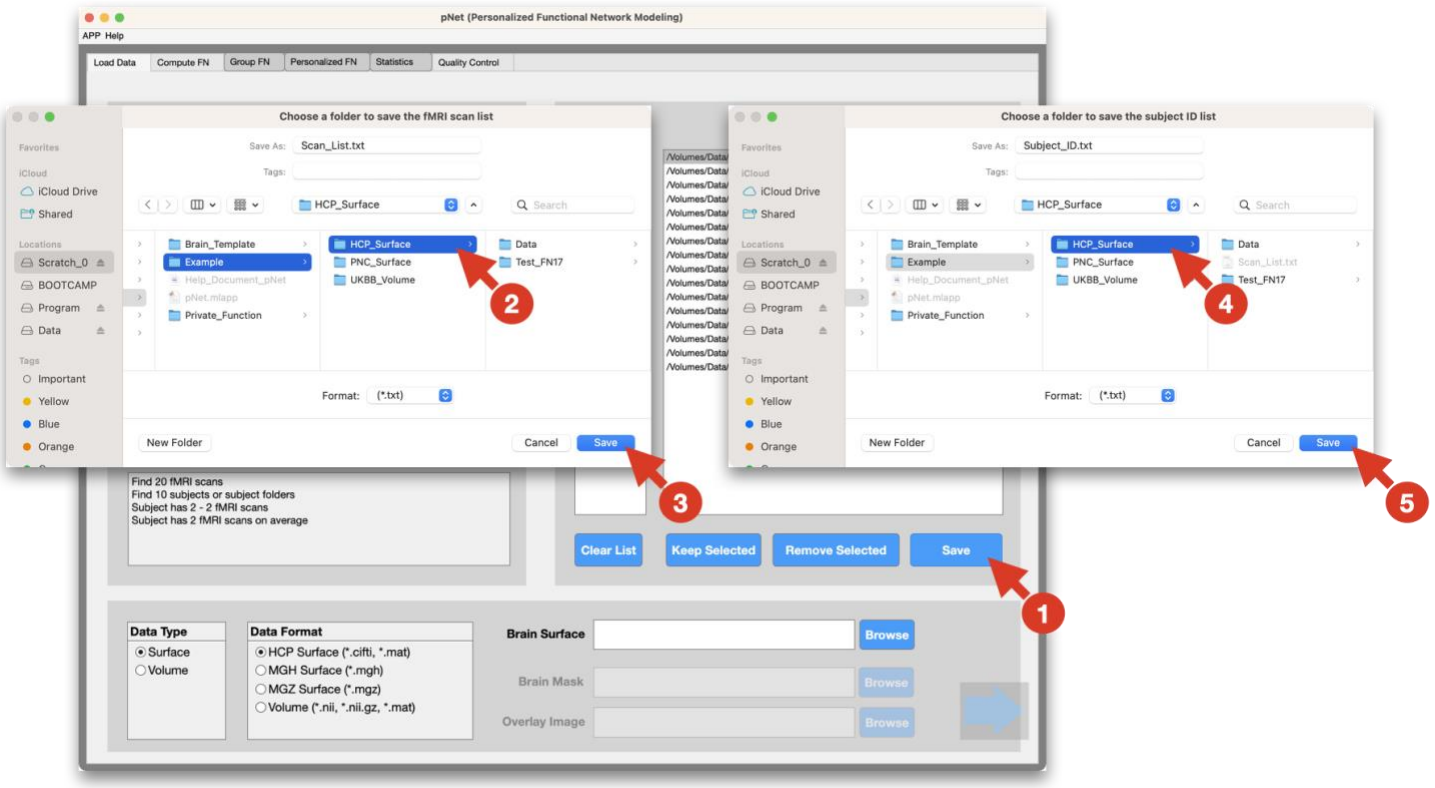
(1) Click the clear list button to empty the subject ID and scan list.

(2-3) Select one or multiple files (hold command key in macOS, or hold control key in Windows and Linux) based on their subject ID or scan list.

(4) Keep the selected fMRI scan files.

(5) Remove selected fMRI scan files.

2. Save the fMRI scan list and subject ID information into text files



Save the subject ID and scan list information into text files.

(1) Click the save button. A new window will be promoted for saving the scan list.

(2) Select the folder to store the scan list file with the name “Scan_List.txt” in default.

(3) Click the save button to save the scan list file.

(4) Select the folder to store the scan list file with the name “Subject_ID.txt” in default.

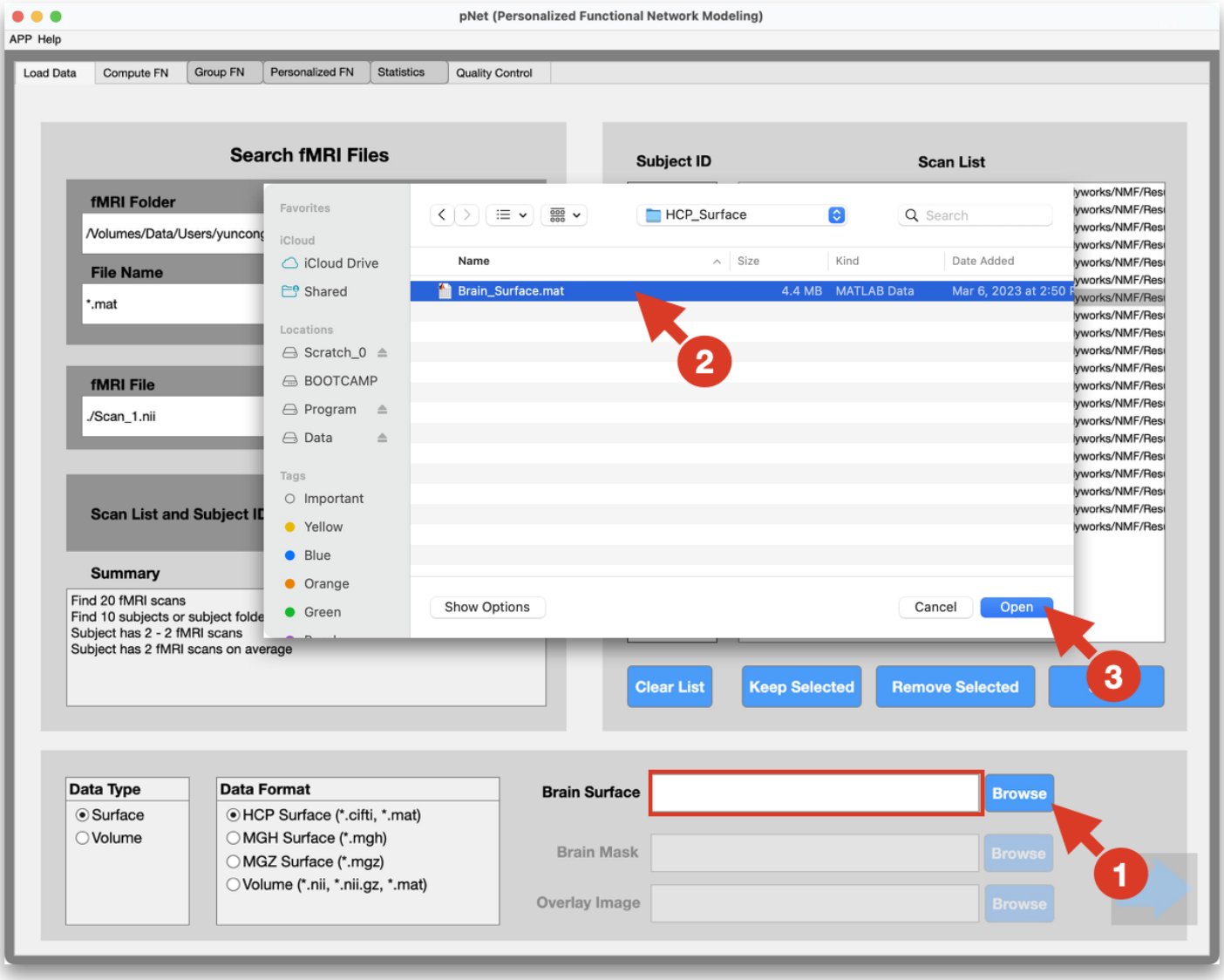
(5) Click the save button to save the subject ID file.

Load brain template

Surface and volume data types require different brain template files for both computation and visualization of gFNs and pFNs.

1. Surface data type.

It requires to load a file called “Brain_Surface.mat”. This file a variable named as “Brain_Surface” with three fields: “Shape”, “Shape_Inflated”, “MW”.



Load the brain surface file for surface data type.

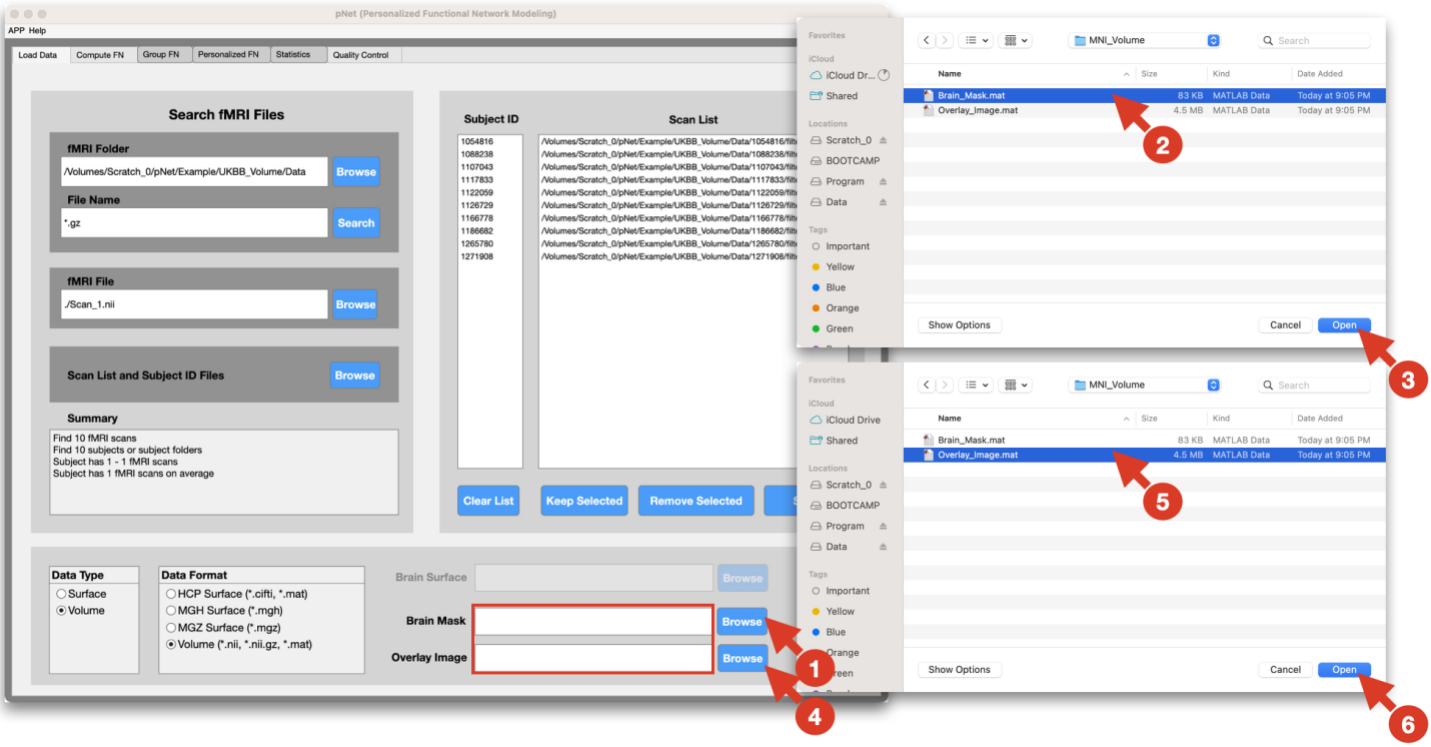
(1) Click the browse button.

(2) Select the file “Brain_Surface.mat”.

(3) Click open or double click the file to load it. Full file directory of the brain surface file will appear in the input field (highlighted in the red box). Users can also type in this information directly into the input field.

2. Volume data type.

It requires to load two files: “Brain_Mask.mat” and “Overlay_Image.mat”. The brain mask file is a binarized 3D mask to specify voxels to contain useful fMRI signals. The overlay image is a 3D image file that will be used as a background for overlaying gFNs and pFNs.



Load brain templates for the volume data type.

(1) Click the browse button to load brain mask file, or use the input field (highlighted in the red box) to type in the full directory of the brain mask file. Example files can be found in the toolbox subfolder "/Brain_Template/MNI_Volume/Brain_Mask.mat".

(2-3) Select the brain mask file, and click open button to load.

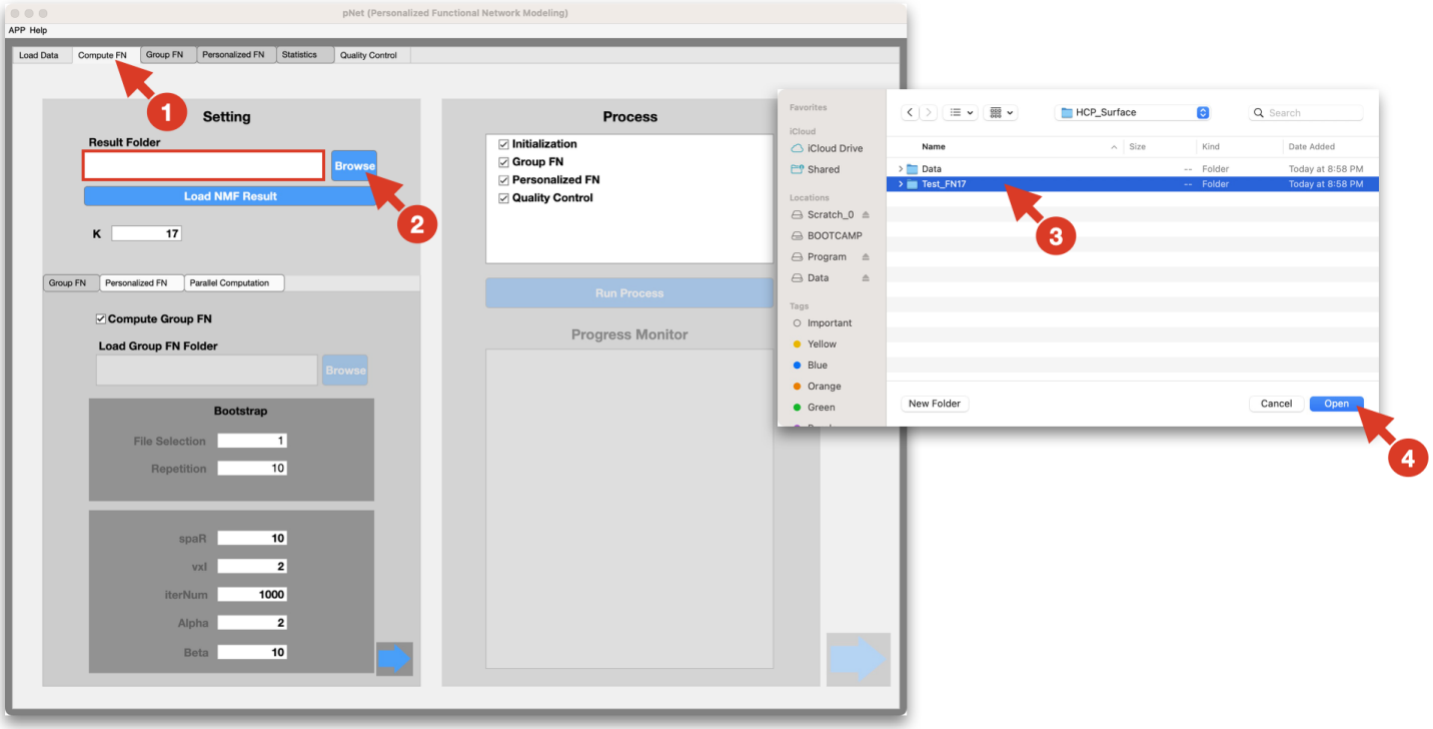
(4) Click the browse button to load the overlay image file, or use the input field (highlighted in the red box) to type in the full directory of the overlay image file. Example files can be found in the toolbox subfolder "/Brain_Template/MNI_Volume/Overlay_Image.mat".

(5-6) Select the overlay image file, and click open button to load.

Setup FN Computation

Setup result folder

The toolbox store all the fMRI file information, brain template files, results and figures of gFN and pFN, and other files in one result folder. The fMRI files will not be stored in the result folder to save storage space.



Select the result folder.

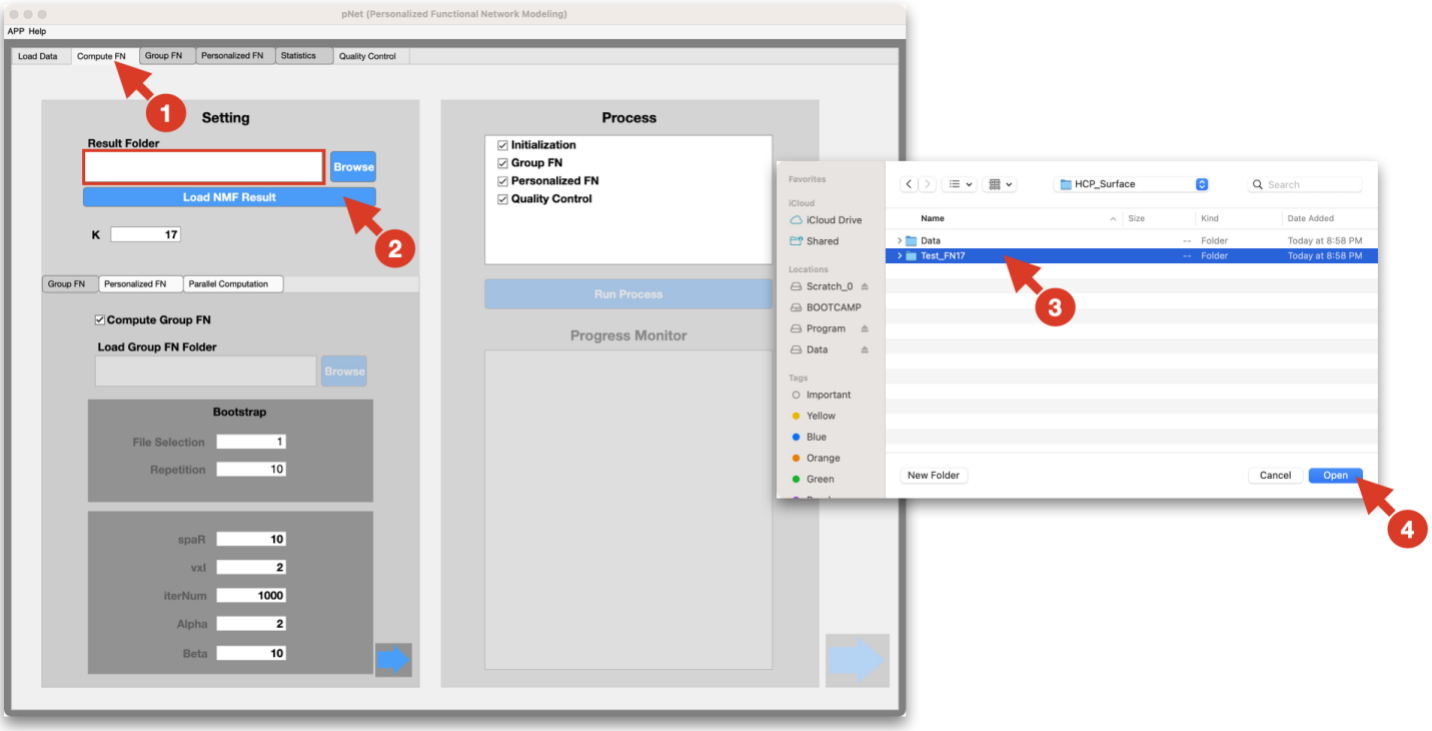
(1) Navigate to the module “Compute FN”.

(2) Click the browse button to select the result folder, or type in the full directory of the desired result folder.

(3-4) Select the folder to store result, and click open button.

Load pre-computed results

The toolbox can automatically load pre-computed results for convenience. Users just need to simply select the result folder, all the information including fMRI scan file and subject ID, number of FNs, parameters of pFN computation will appear on the user interface.



Select the folder containing precomputed results.

(1) Navigate to the module “Compute FN”.

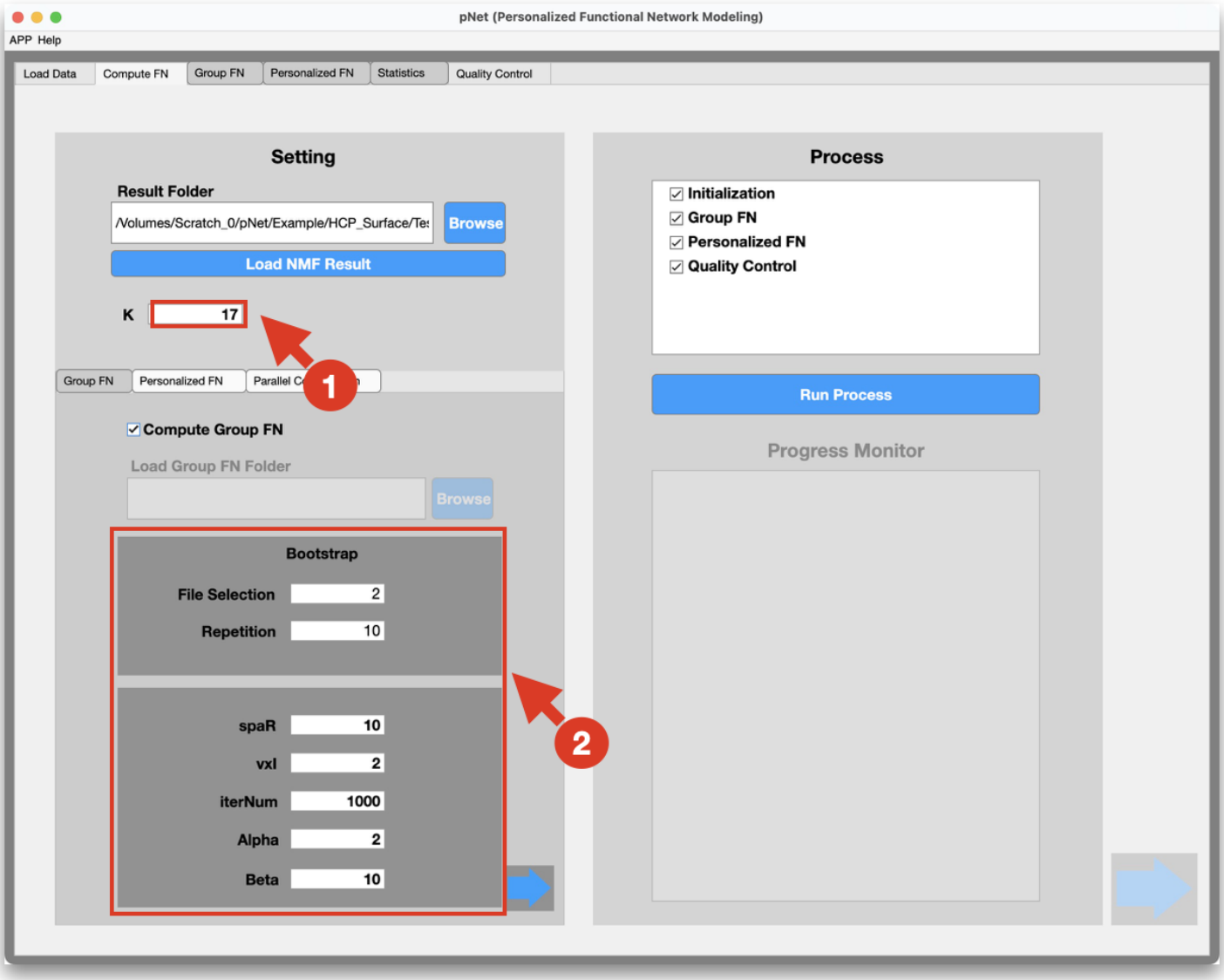
(2) Click the browse button to select the result folder, or type in the full directory of the desired result folder (highlighted in the red box).

(3-4) Select the folder to store result, and click open button. The toolbox will automatically check the integrity of the result folder. Then it will load results and jump to the group FN module to show precomputed group FN figures.

Setup gFN

The toolbox allows users to either load a precomputed gFN or perform the gFN computation using the data available.

1. Setup the gFN computation

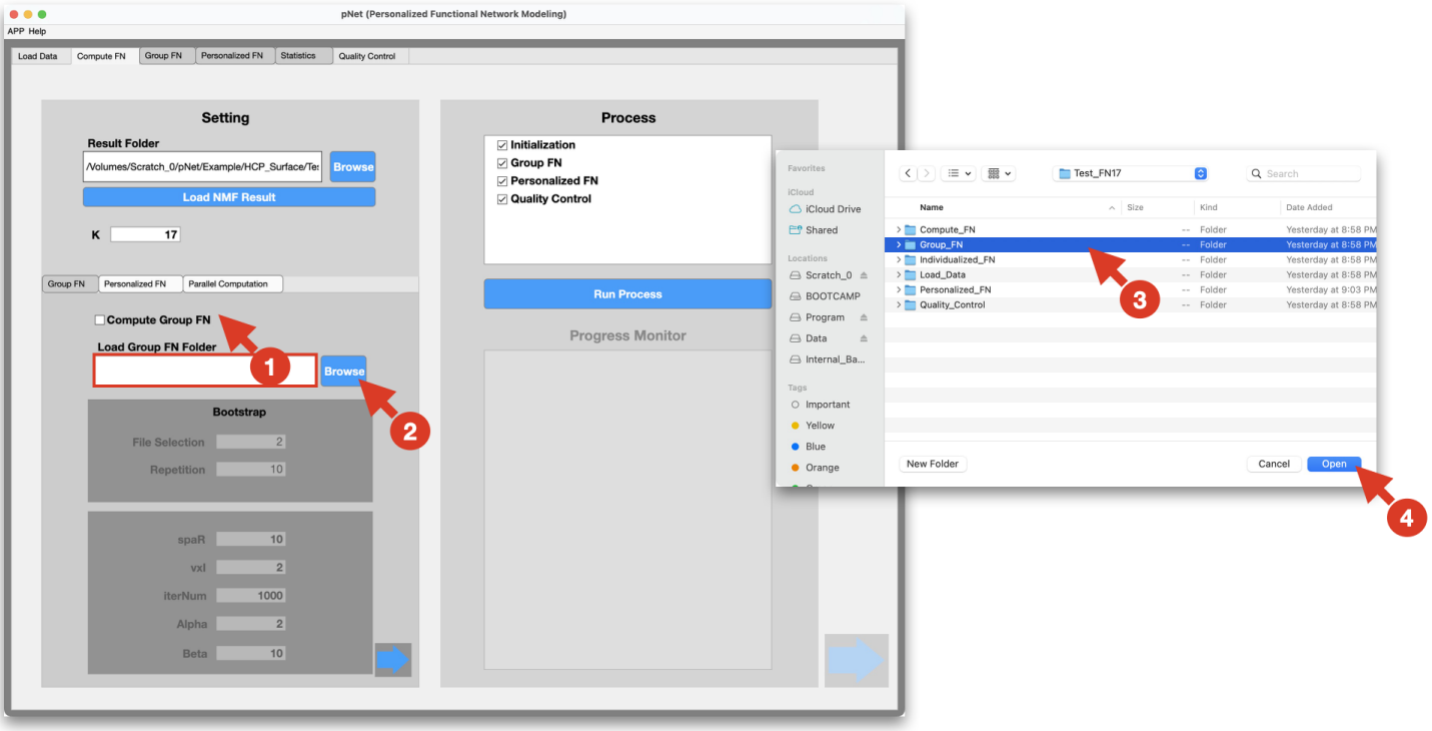


Setup the gFN computation parameters.

(1) Set a desired number of FNs. 7 and 17 have been widely used to get large scale FNs.

(2) Set additional parameters if preferred. The bootstrap section has two parameters that affect how the fMRI scans will be randomly sampled. The parameter “File Selection” is the number of fMRI scans will be selected as a subset to compute gFNs. The parameter “Repetition” is the number of runs to randomly sample a small subset and get multiple different versions gFN to fuse into a robust estimation of gFNs. Other parameters are for advanced users. Their details can be found in the manuscript.

2. Load a precomputed gFN file



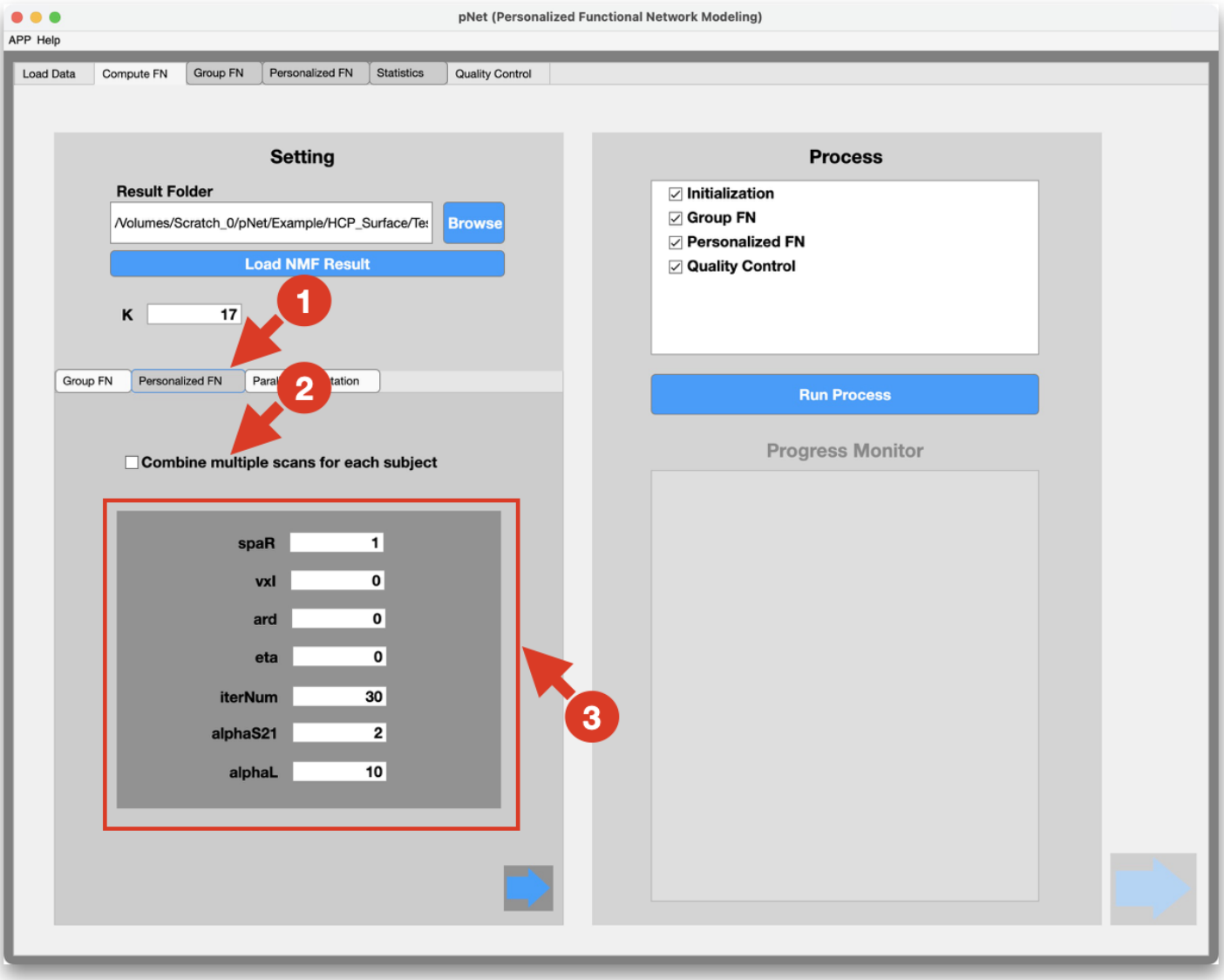
Load precomputed gFN results in a folder.

(1) Click the check box “Compute Group FN” to disable the gFN computation.

(2) Click the browse button or type in the directory of the folder containing group FN results in the input field (highlighted in the red box).

(3-4) Select the gFN folder, and click open button to load the result.

Setup pFN computation



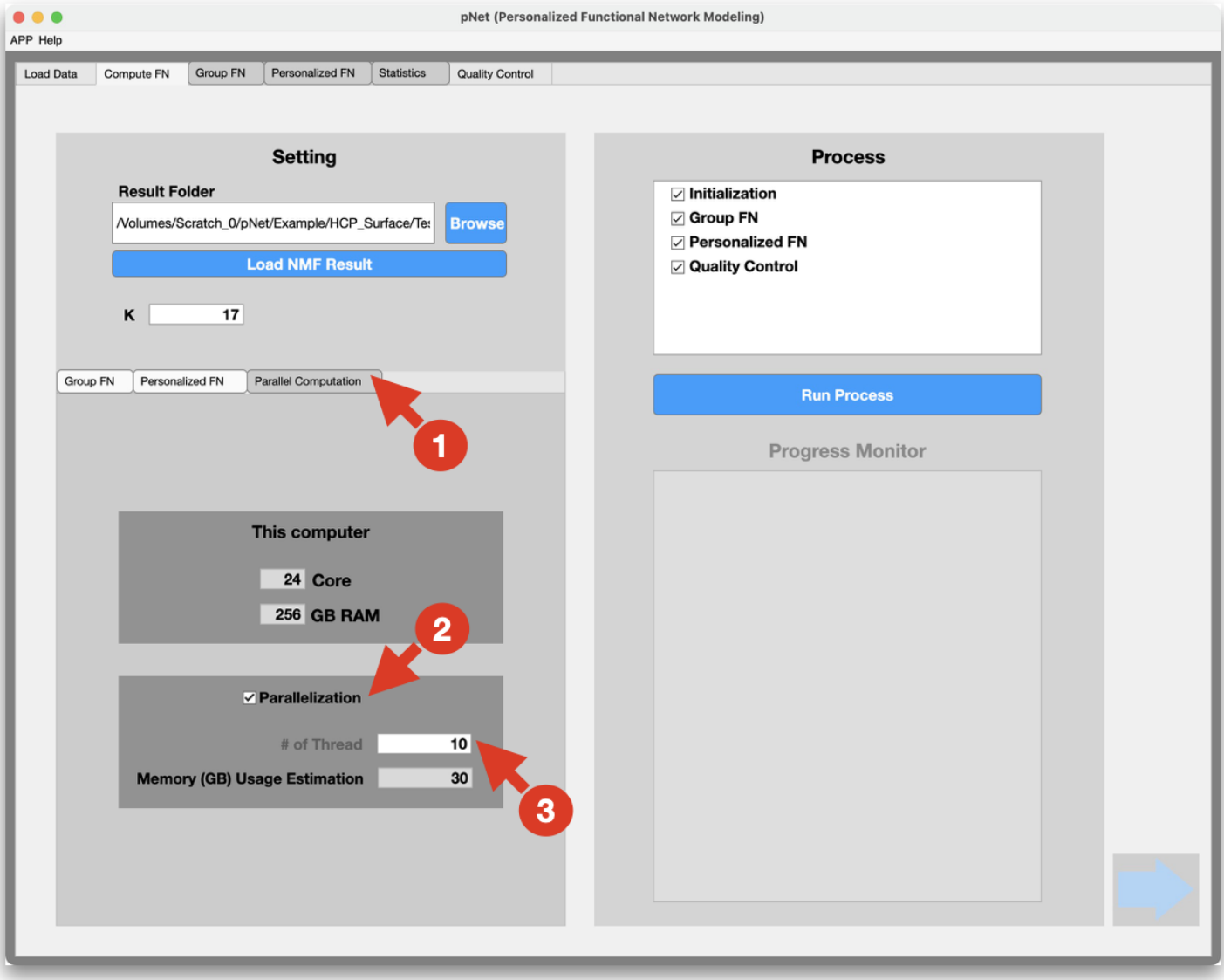
Setup parameters for pFN computation.

(1) Navigate to the module “Personalized FN”.

(2) Click the check box to combine multiple fMRI scans for each subject, if preferred.

(3) Additional parameters for pFN computation, only intented for advanced users.

Setup parallel computation



Setup parameters for parallel computation.

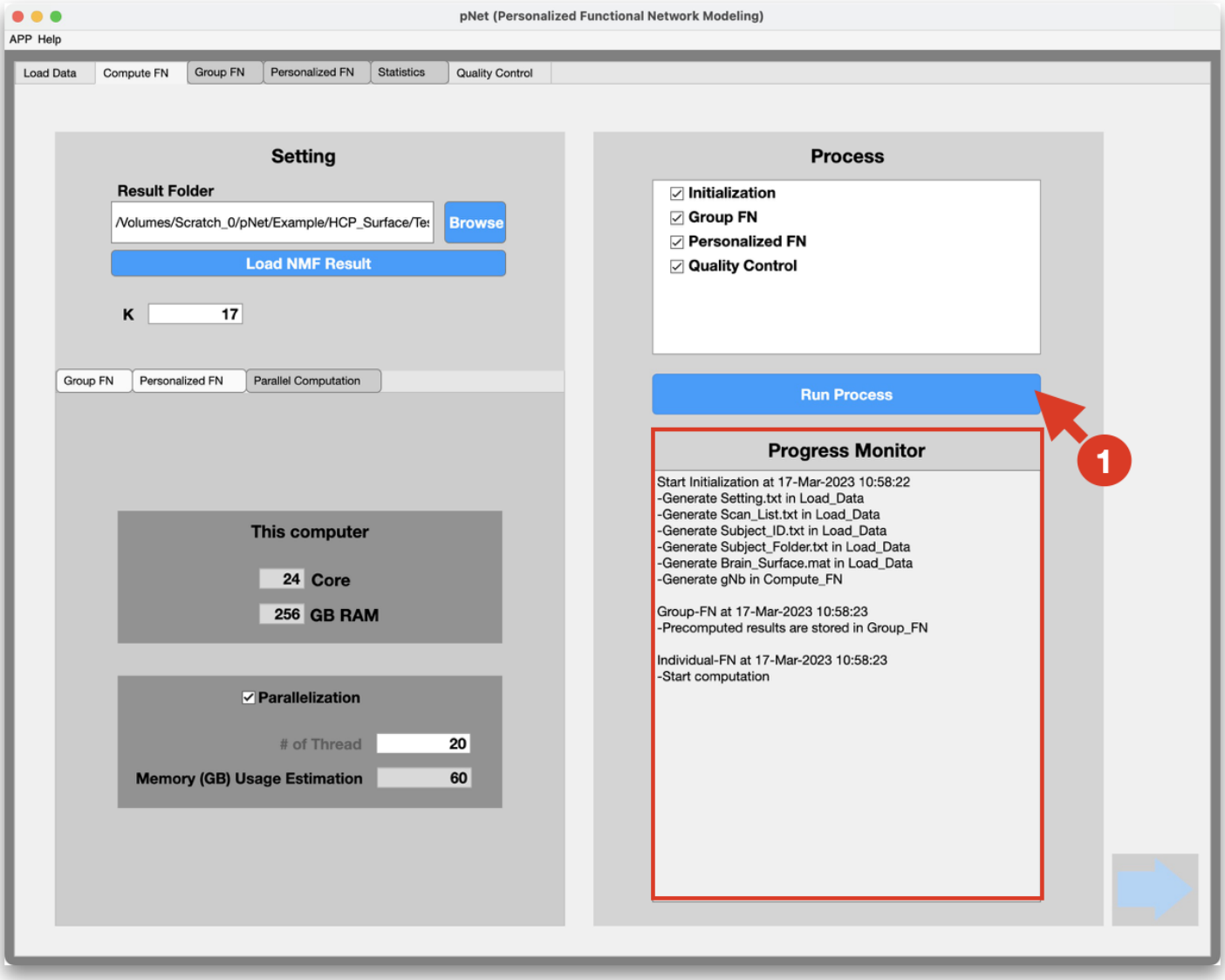
(1) Navigate to the parallel computation module.

(2) Enable parallelization by clicking the check box.

(3) Set a desired number of threads for parallel computation. Please make sure that the estimated memory usage is within the hardware limit, which is displayed in the above section “This computer”.

Run the FN computation

Once all the required settings are done, the button “Run Process” on the right of the “Compute FN” module will be enabled. Simply click it run all the computation and visualization for pFNs.



Run the pFN computation.

(1) Click the button “Run Process”.

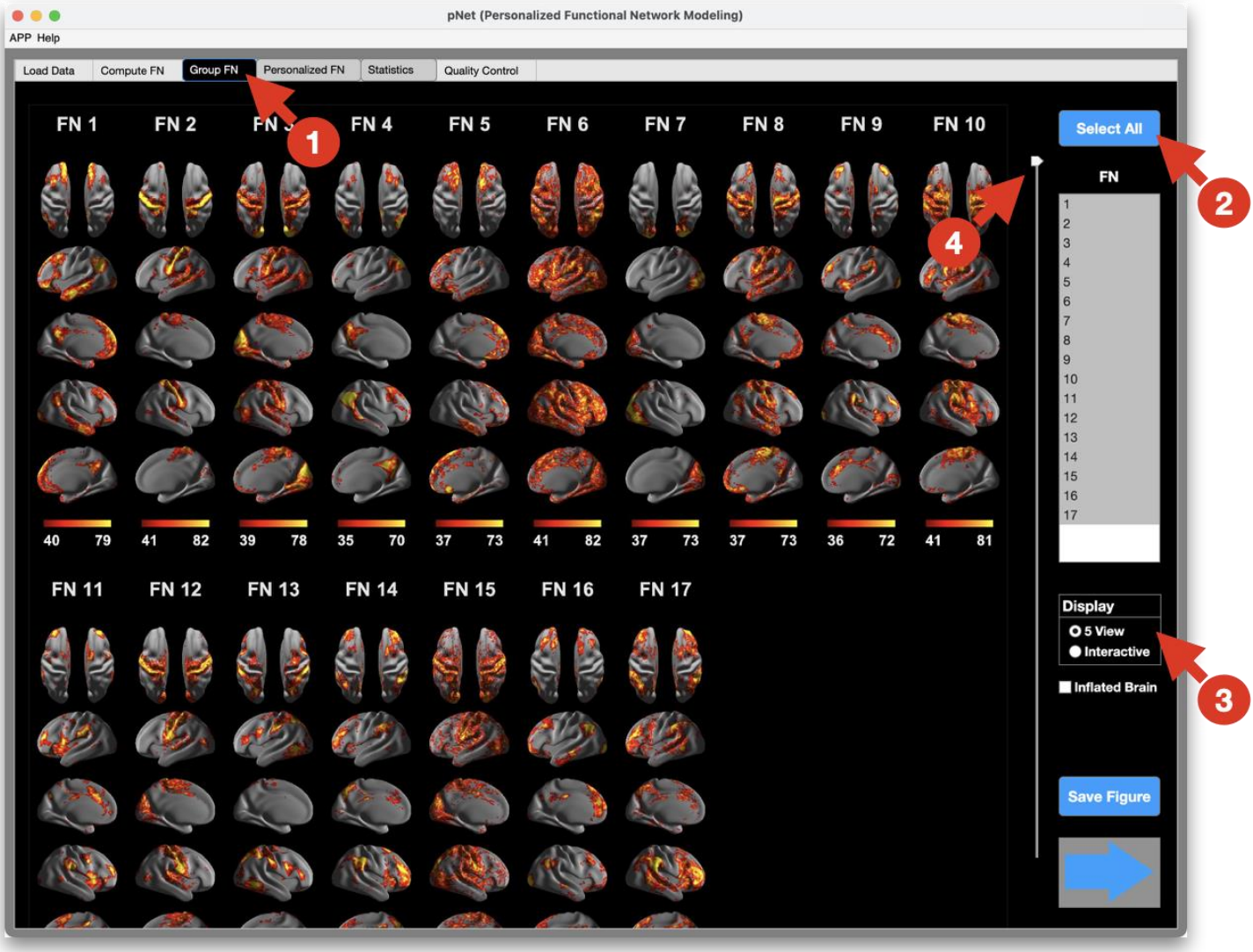
(2) Progress monitor (highlighted in the red box) will show the progress of each major steps of initialization, gFN computation, pFN computation and visualization. The UI will automatically jump to the next module “Group FN” to show gFN results.

Check gFN

This toolbox provides precomputed figures of gFNs for fast navigation, and interactive display to check results according to users' preference.

Surface data

1. Precomputed visualization



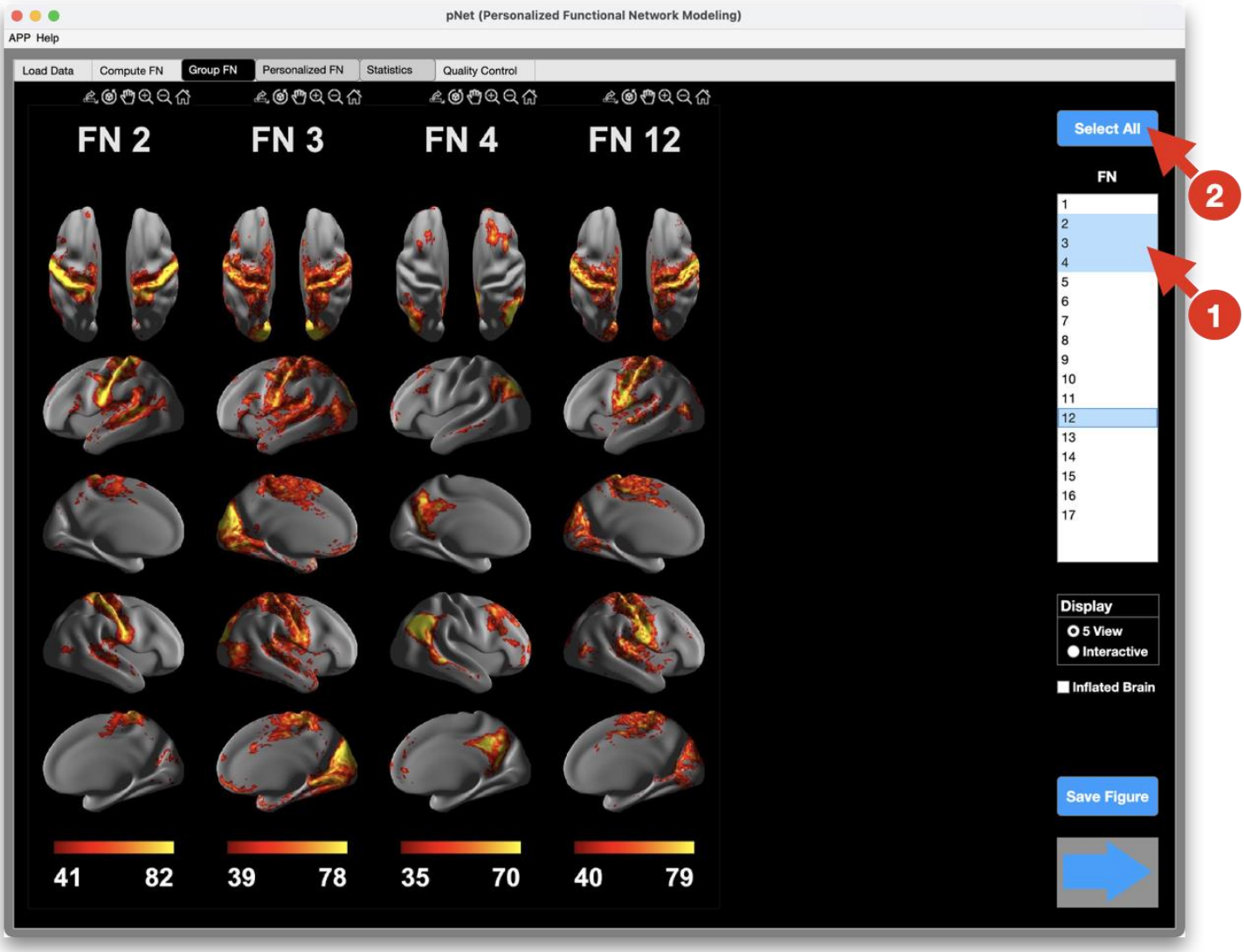
Check all gFNs.

(1) Navigate to group FN module. In default, all gFNs will be displayed in one large figure.

(2) Click the select all button, if needed.

(3) Select the 5 view display option, if needed.

(4) Drag the scroll bar to navigate through the entire figure.



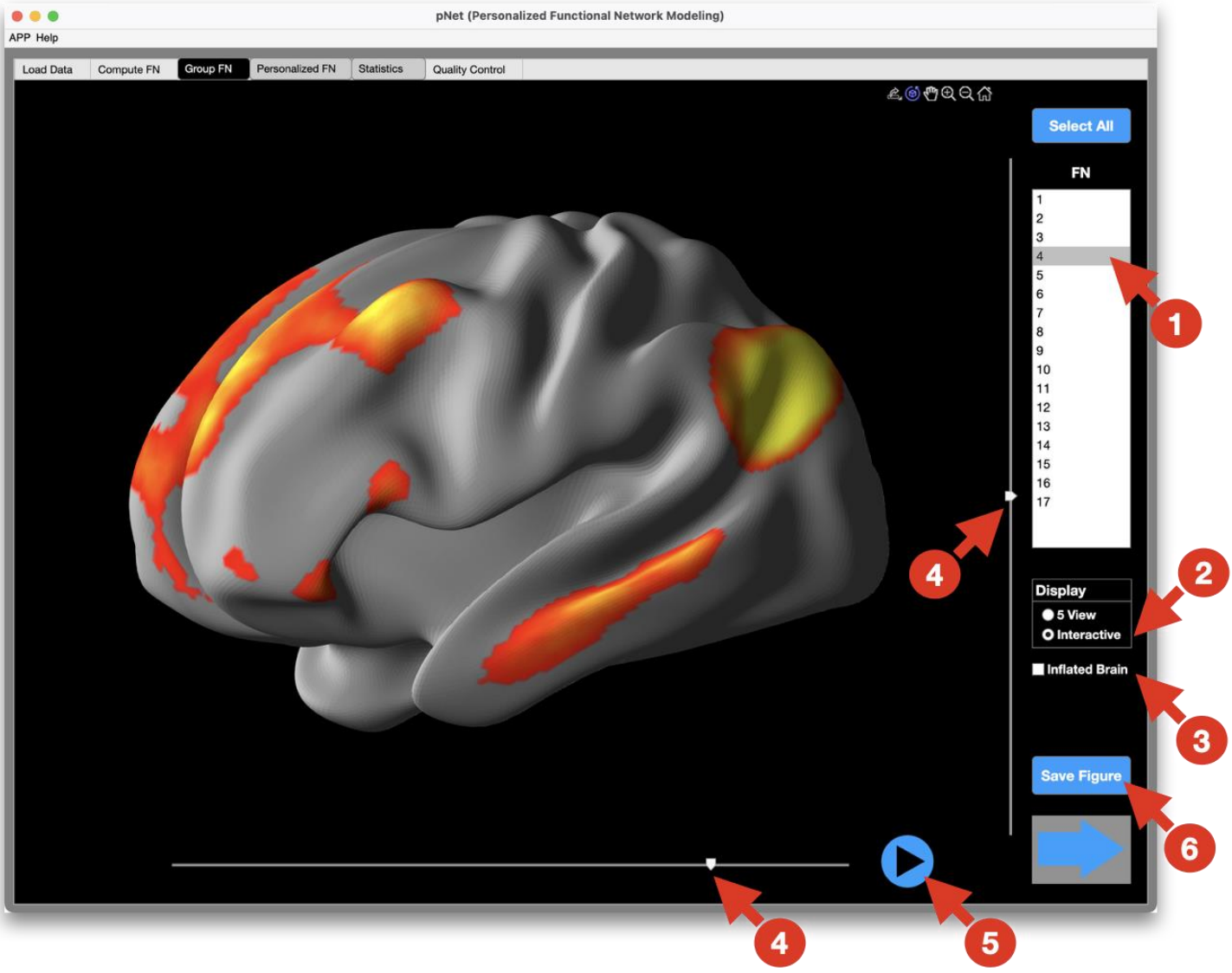
Check selected gFNs.

(1) Select one or multiple gFNs. Hold command key in macOS, or hold control key in Windows or Linux to select multiple gFNs.

(2) Click select all button to go back to the default view of all gFNs selected.

2. Interactive visualization

This interactive visualization allows the user check the gFN from different view angles.



Check a single gFN on the brain surface.

(1) Select one gFN.

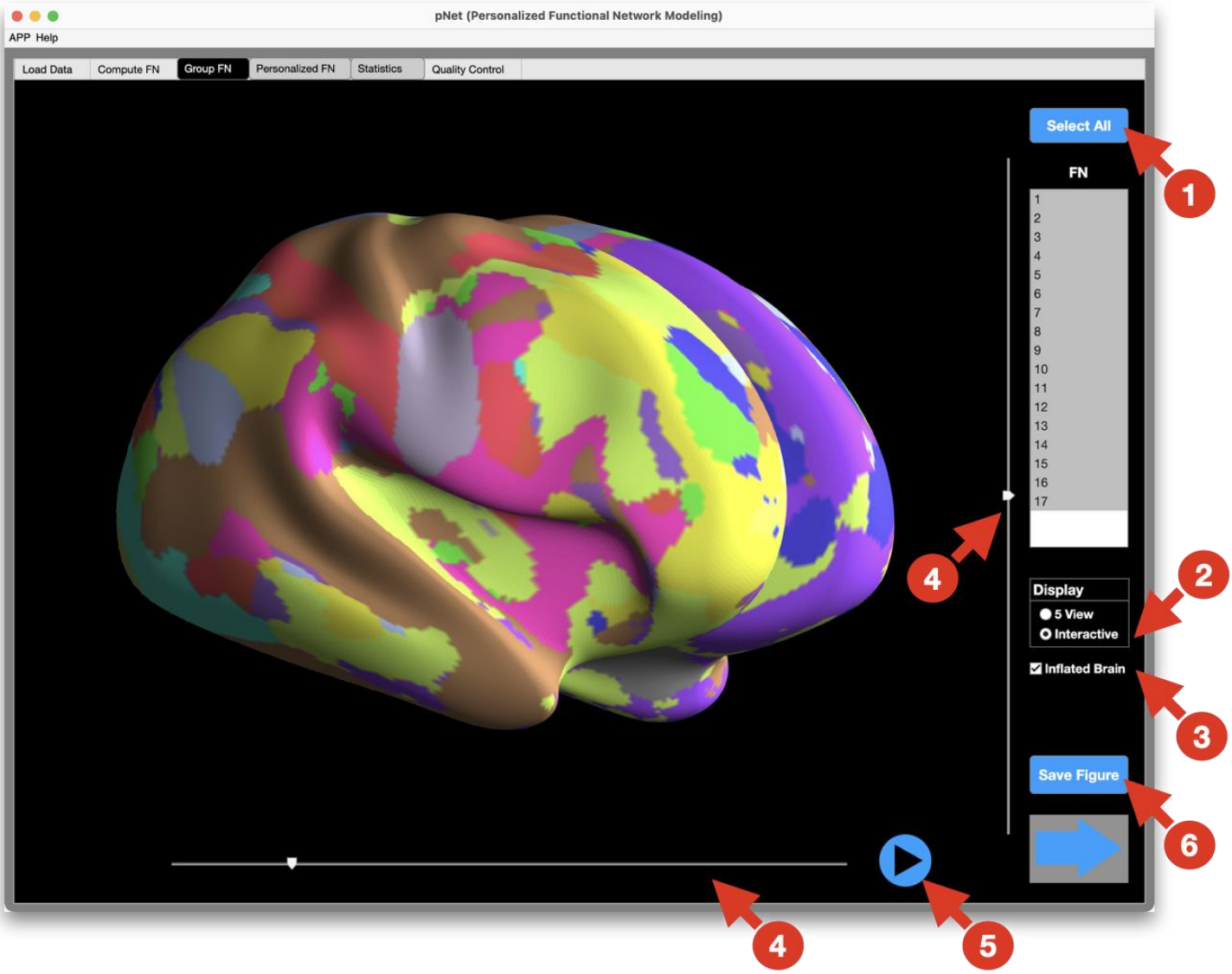
(2) Select the interactive display option.

(3) Click the check box to overlay results on an inflated brain surface, if the inflated brain surface is available.

(4) Drag the vertical or horizontal scroll bar to change the view angle.

(5) Start automatic change of the horizontal scroll bar to have a constantly rotating view of the brain.

(6) Save this figure.



Check the functional atlas for binarized gFNs.

(1) Click the select all button to include all gFNs.

(2) Select the interactive display option.

(3) Click the check box to overlay results on an inflated brain surface, if the inflated brain surface is available.

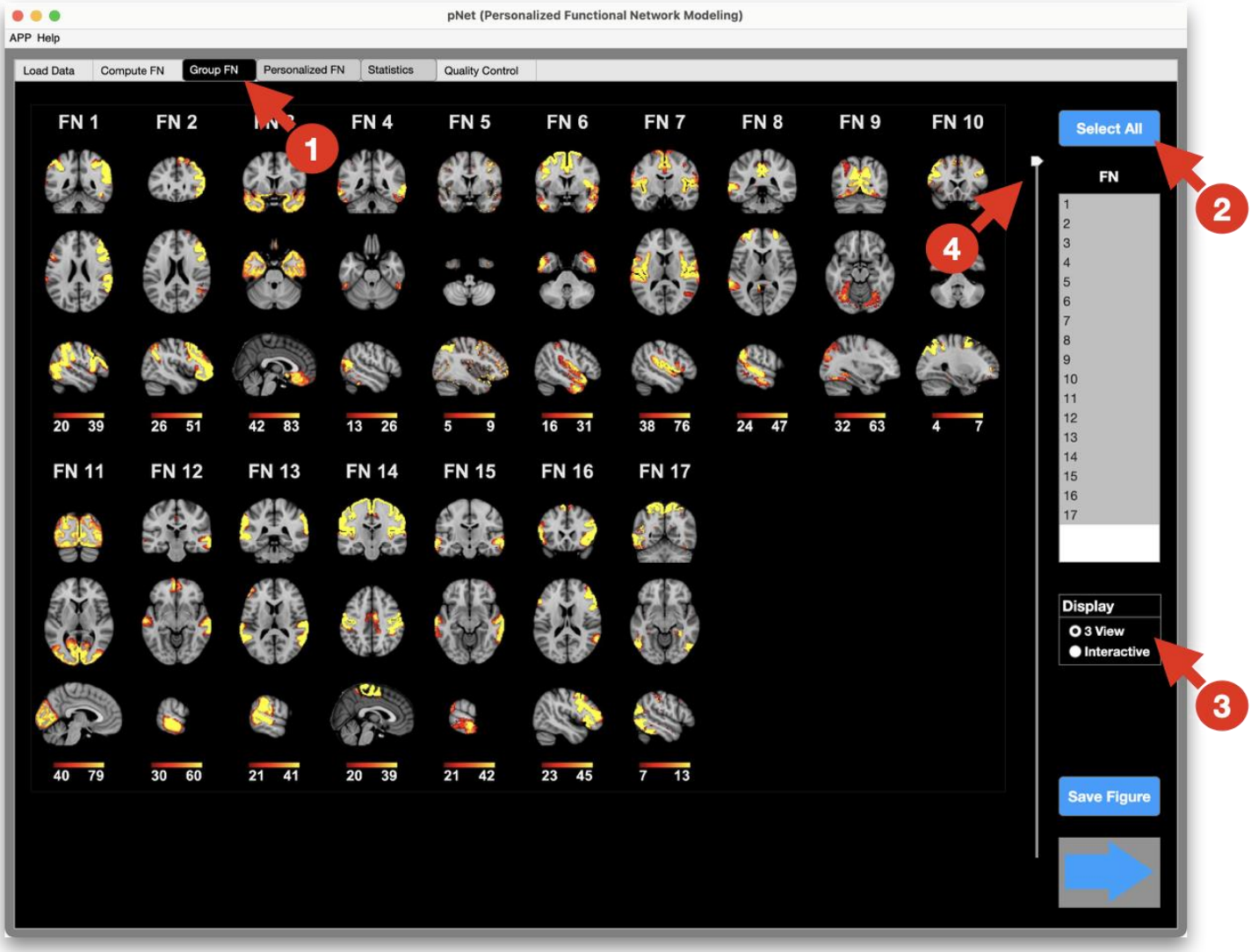
(4) Drag the vertical or horizontal scroll bar to change the view angle.

(5) Start automatic change of the horizontal scroll bar to have a constantly rotating view of the brain.

(6) Save this figure.

Volume data

1. Precomputed visualization



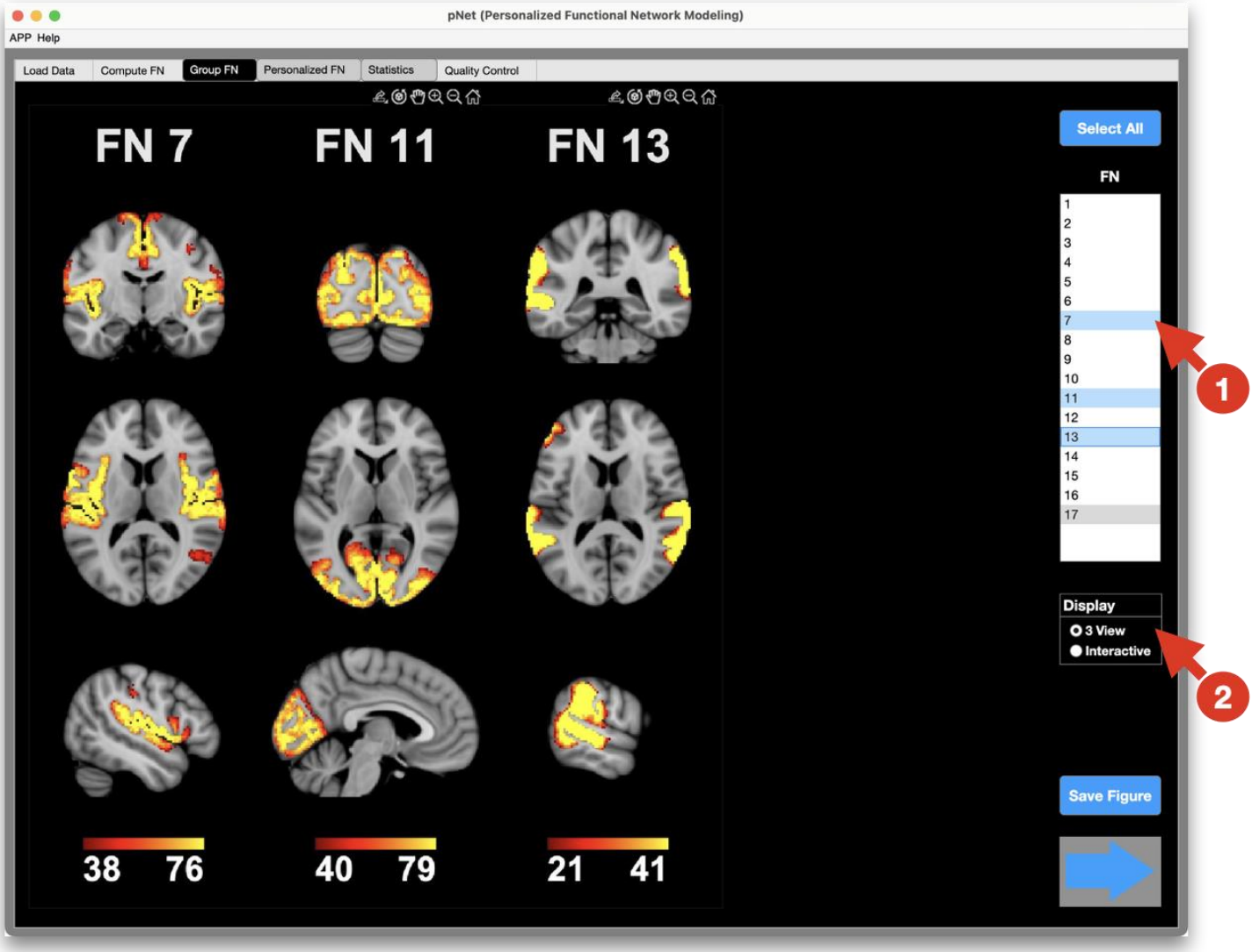
Check all gFNs.

(1) Navigate to group FN module. In default, all gFNs will be displayed in one large figure.

(2) Click the select all button, if needed.

(3) Select the 3 view display option, if needed.

(4) Drag the scroll bar to navigate through the entire figure.

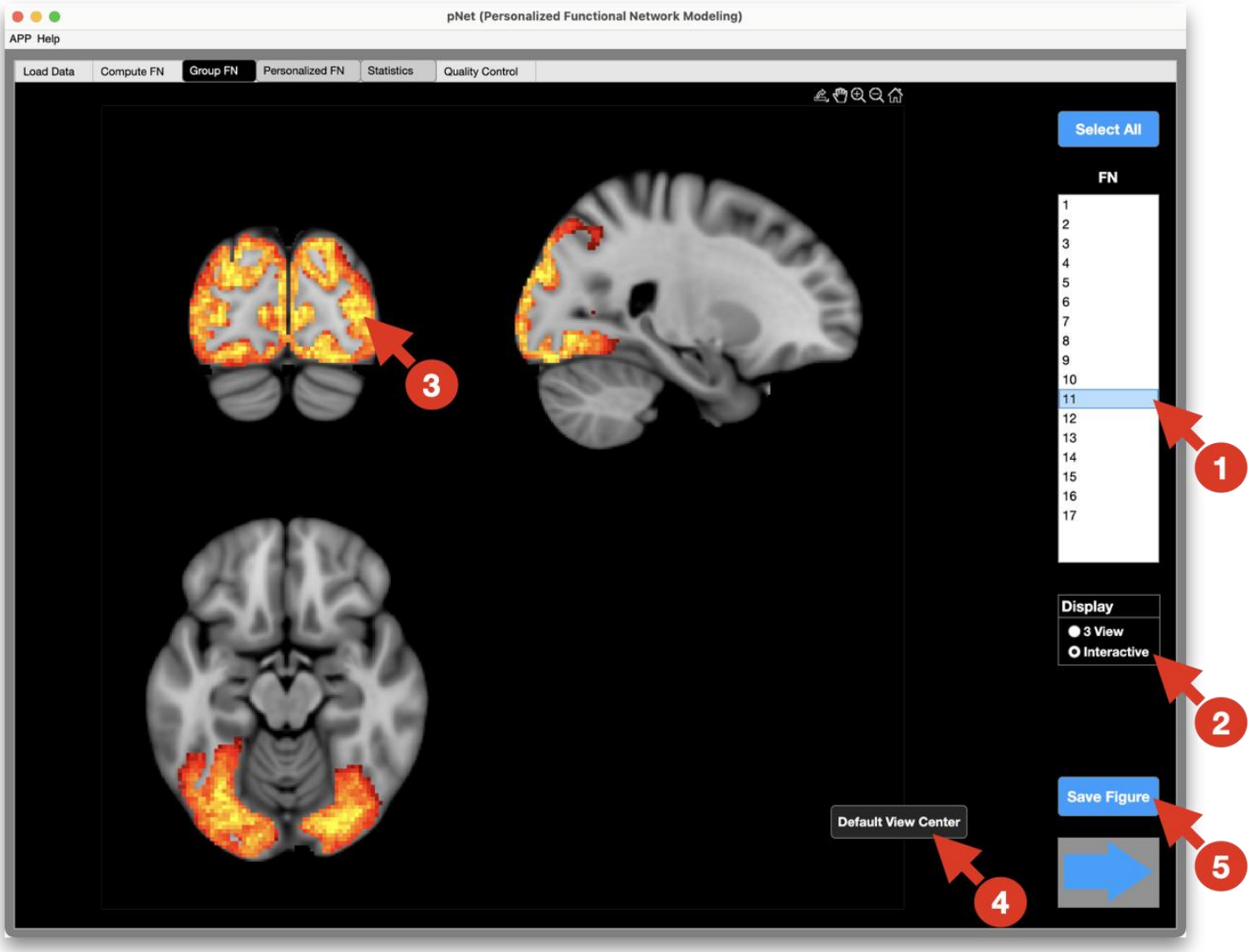


Check selected gFNs.

(1) Select one or multiple gFNs. Hold command key in macOS, or hold control key in Windows or Linux to select multiple gFNs.

(2) Click select all button to go back to the default view of all gFNs selected.

2. Interactive visualization



Check a single gFN

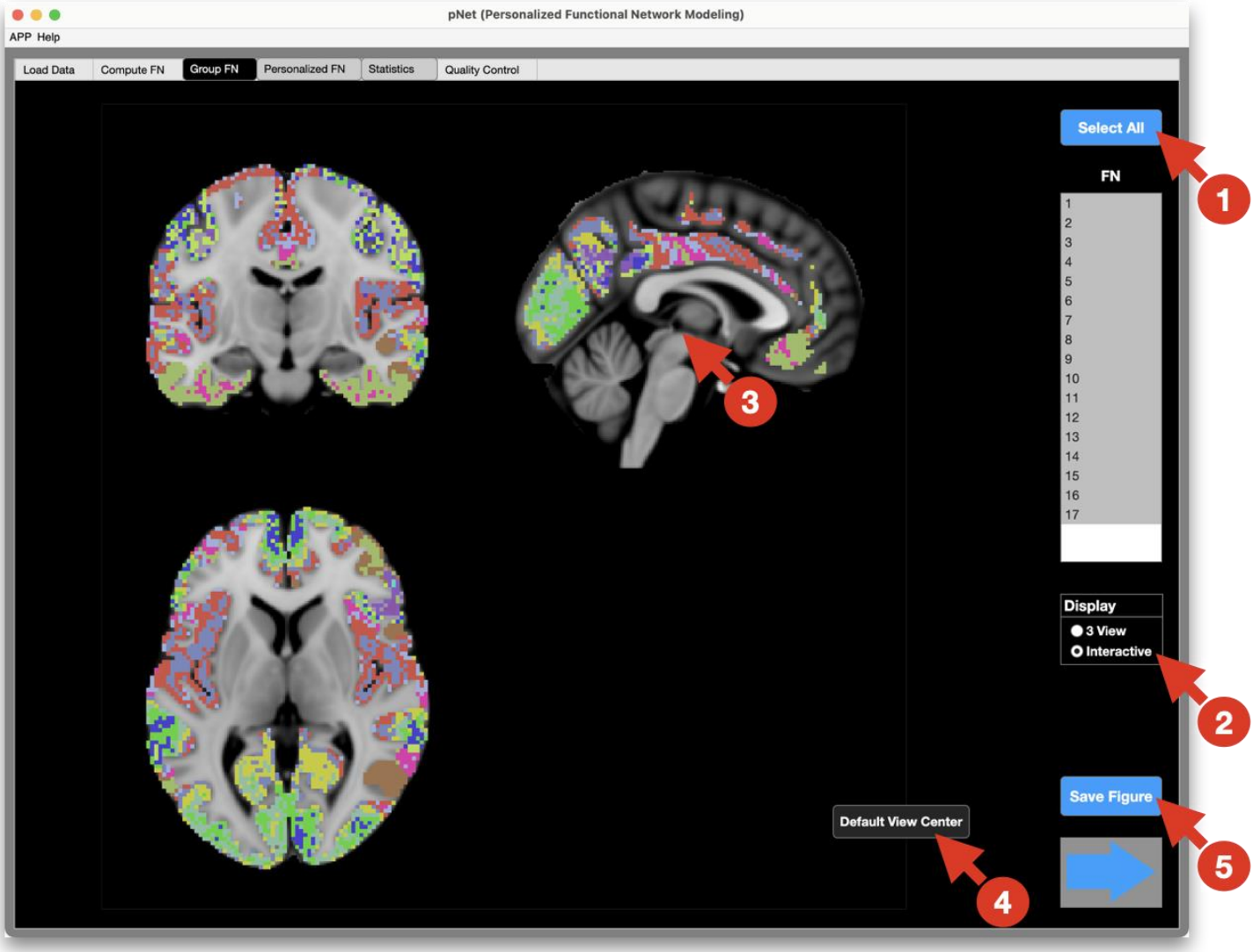
(1) Select one gFN.

(2) Select the interactive display option.

(3) Click on the display to change the view center.

(4) Click the default view center button to go back to the default view center.

(5) Save this figure.



Check functional atlas using binarized gFN results

(1) Click the select all button to include all gFNs.

(2) Select the interactive display option.

(3) Click on the display to change the view center.

(4) Click the default view center button to go back to the default view center.

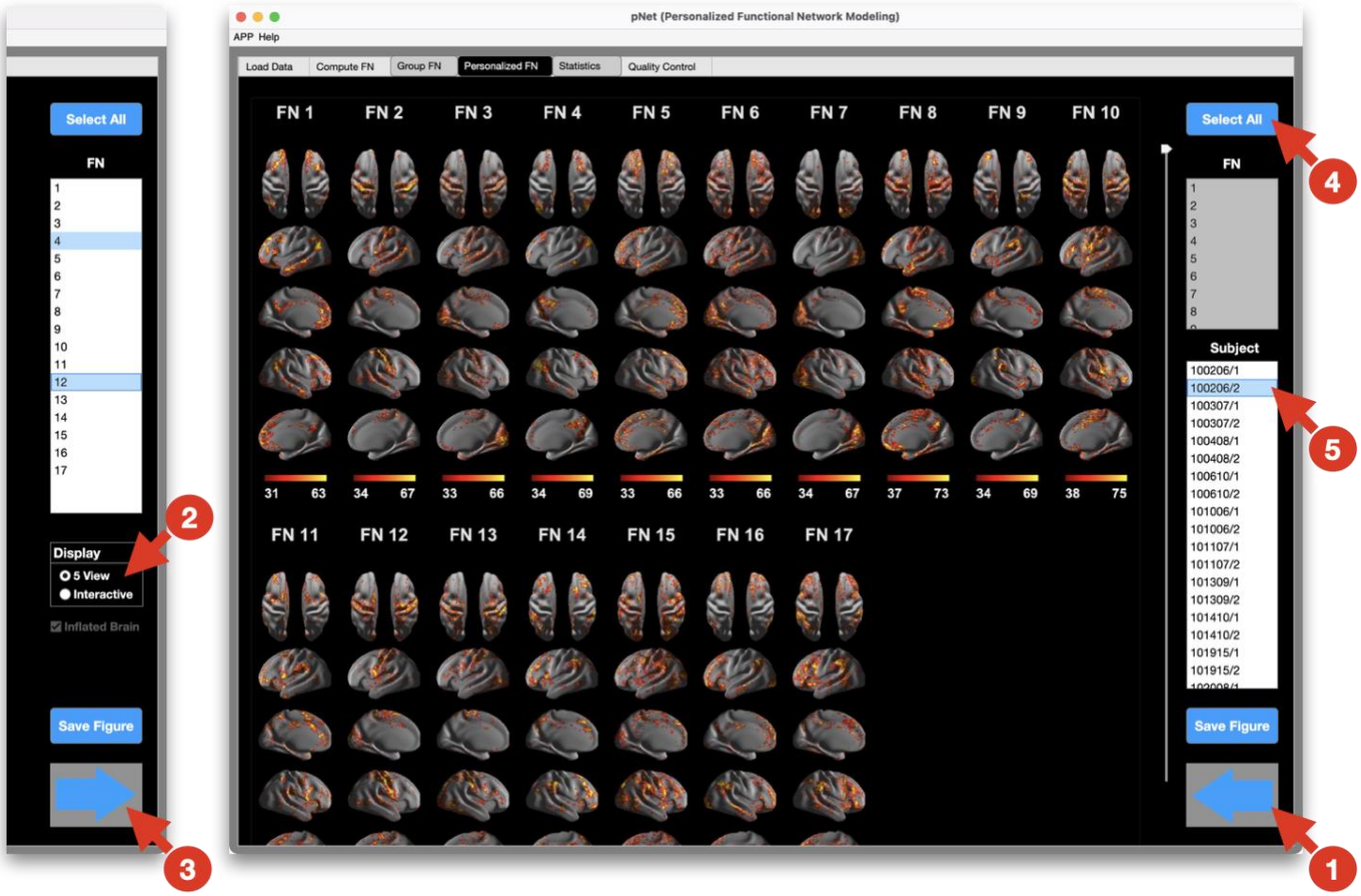
(5) Save this figure.

Check pFN

This toolbox provides precomputed figures of pFNs for fast navigation, and interactive display to check results according to users' preference.

Surface data

1. Precomputed visualization



Check precomputed figures for pFNs.

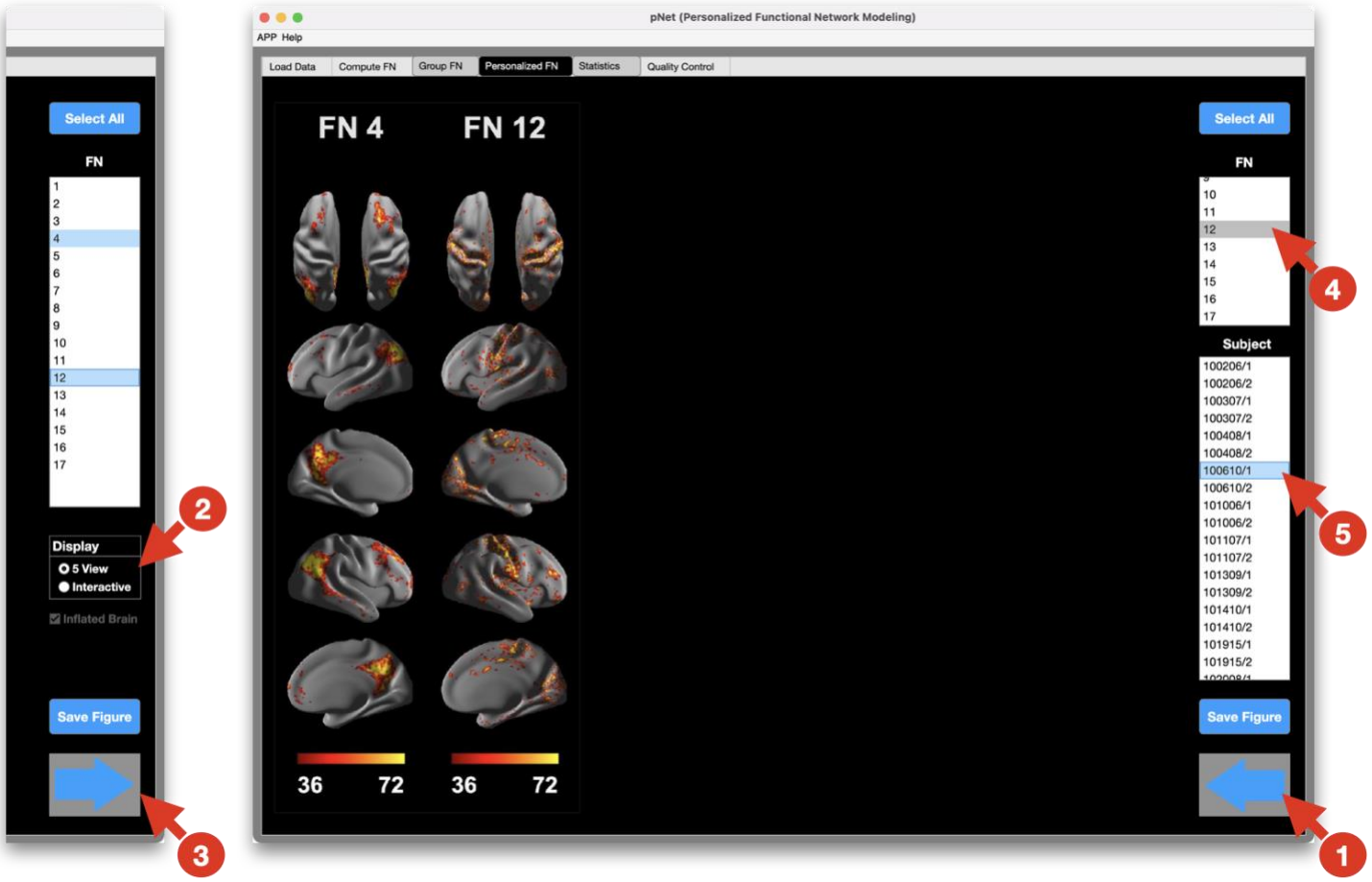
(1) Navigate to the group FN module.

(2) Choose the 5 view display mode.

(3) Navigate to the personalized FN module.

(4) Click the select all button.

(5) Select another subject. Users can also use the up or down arrow key to select the subject above or below.



Check selected pFNs.

(1) Navigate to the group FN module

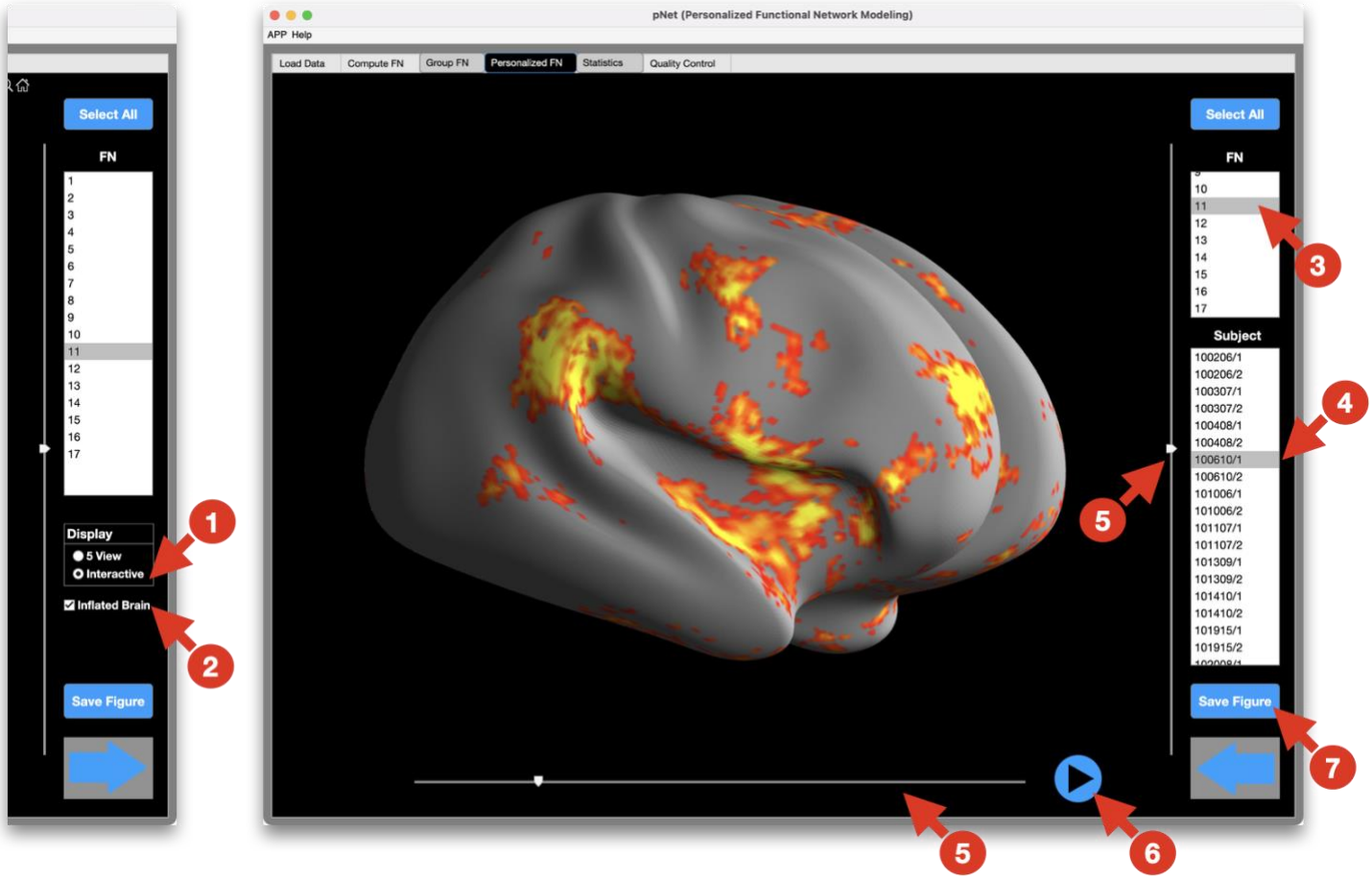
(2) Select the 5 view display option.

(3) Navigate to the personalized FN module.

(4) Select one or multiple pFNs. Hold command key in macOS, or hold control key in Windows or Linux to select multiple pFNs.

(5) Select another subject. Users can also use the up or down arrow key to select the subject above or below.

2. Interactive visualization



Check a single pFN on the brain surface.

(1) Navigate to the group FN module, and select the interactive display option.

(2) Select the inflated brain if desired.

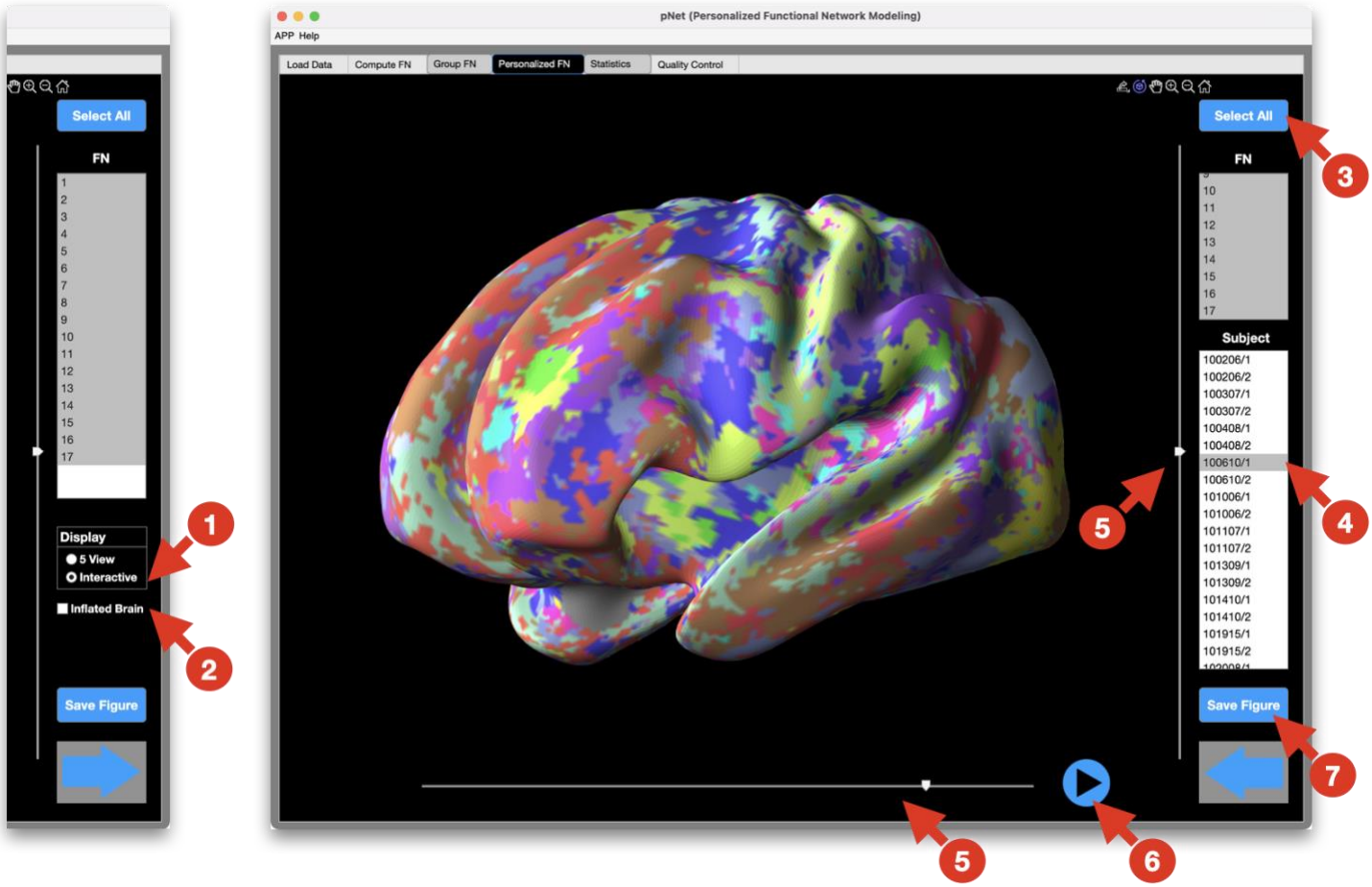
(3) Navigate to the personalized FN module, select one desired pFN for display.

(4) Select another subject. Users can also use the up or down arrow key to select the subject above or below.

(5) Drag the vertical or horizontal scroll bar to change the view angle.

(6) Start automatic change of the horizontal scroll bar to have a constantly rotating view of the brain.

(7) Save this figure.



Check the functional atlas of a single subject.

(1) Navigate to the group FN module, and select the interactive display option.

(2) Select the inflated brain if desired.

(3) Navigate to the personalized FN module, click the select all button if needed.

(4) Select another subject. Users can also use the up or down arrow key to select the subject above or below.

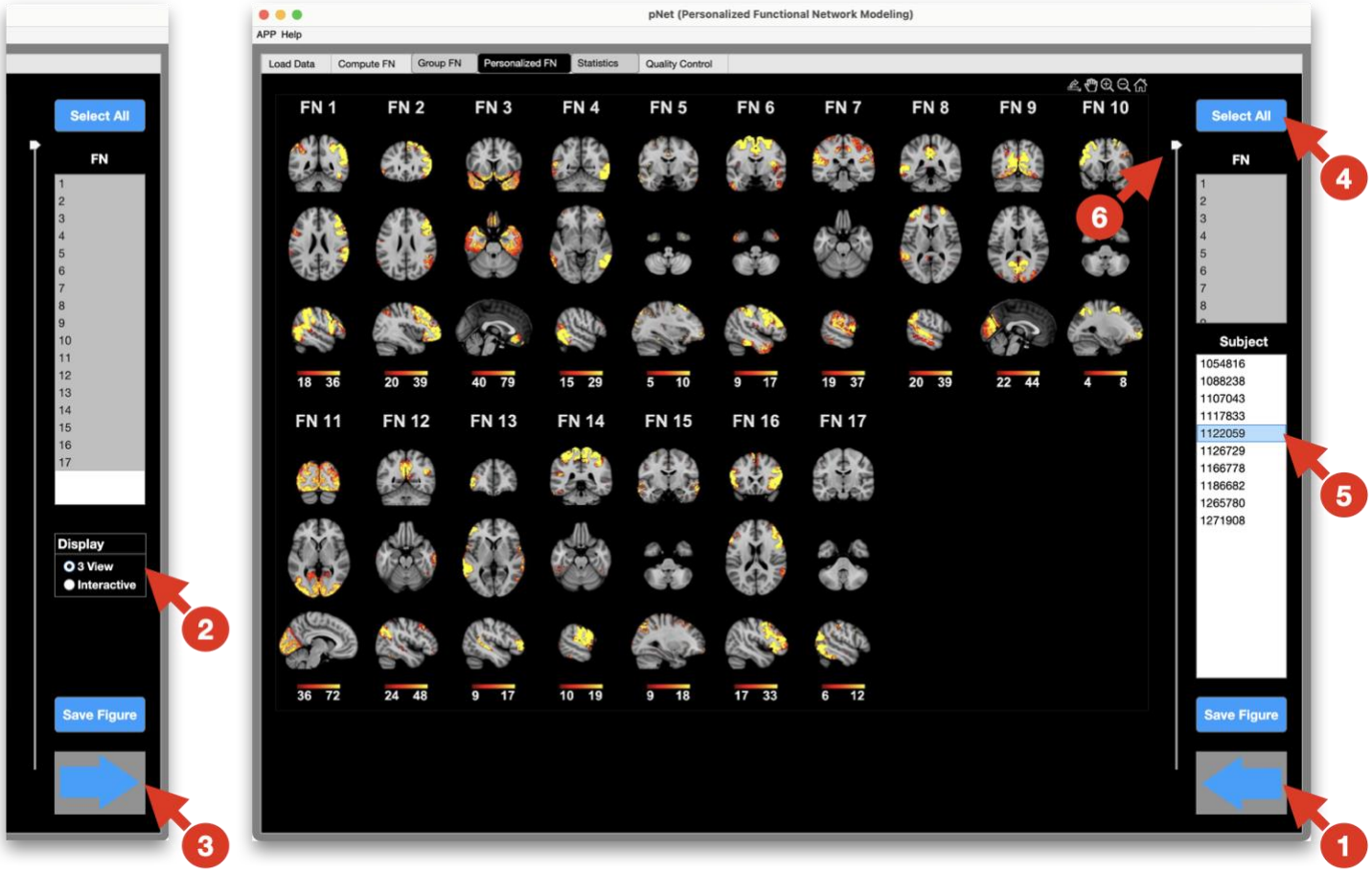
(5) Drag the vertical or horizontal scroll bar to change the view angle.

(6) Start automatic change of the horizontal scroll bar to have a constantly rotating view of the brain.

(7) Save this figure.

Volume data

1. Precomputed visualization



Check precomputed figures for pFNs.

(1) Navigate to the group FN module.

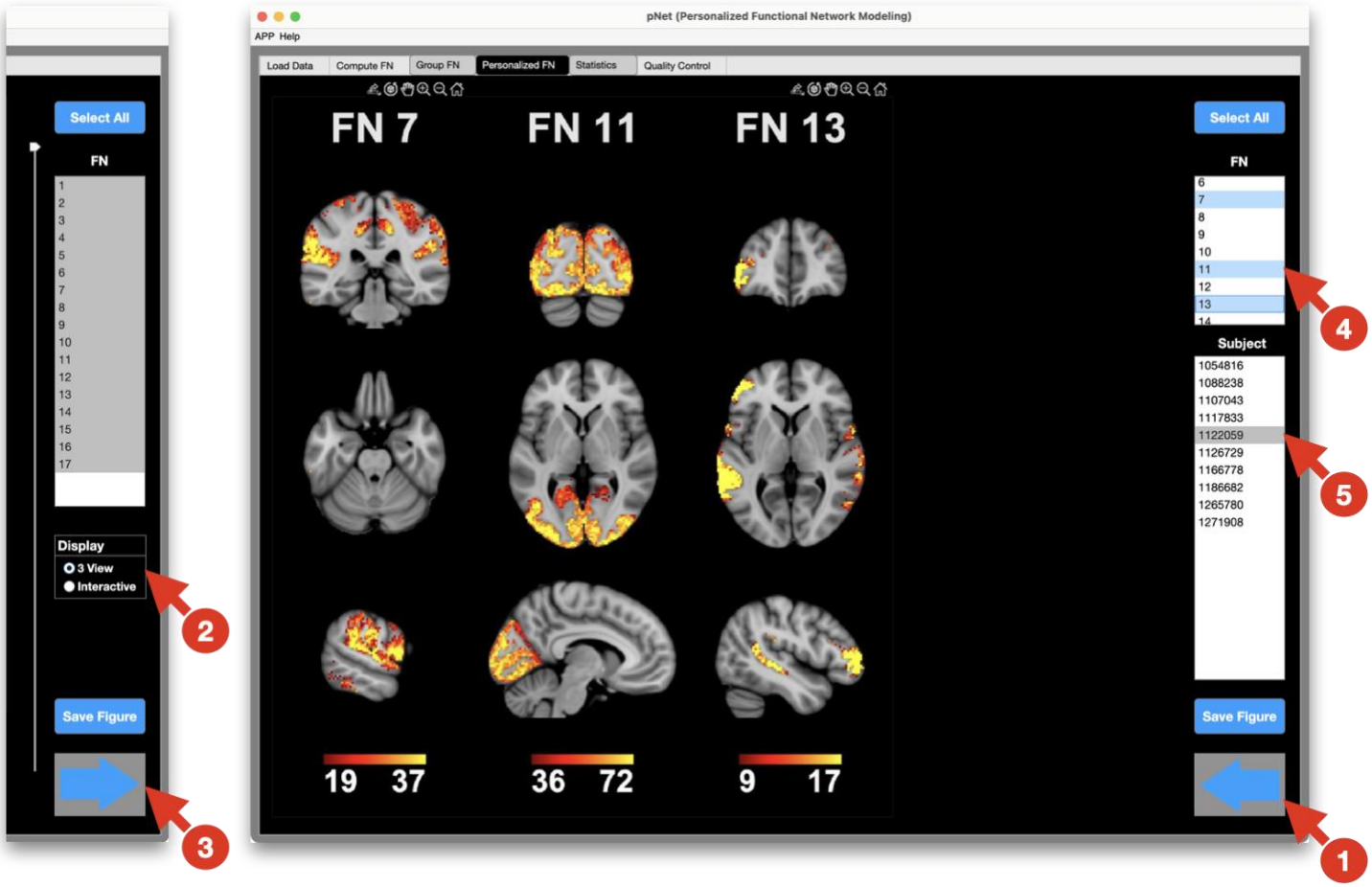
(2) Choose the 3 view display mode.

(3) Navigate to the personalized FN module.

(3) Click the select all button, if needed.

(5) Select another subject. Users can also use the up or down arrow key to select the subject above or below.

(6) Drag the vertical scroll bar, if needed.



Check selected pFNs.

(1) Navigate to the group FN module.

(2) Select the 3 view display option.

(3) Navigate to the personalized FN module.

(4) Select one or multiple pFNs. Hold command key in macOS, or hold control key in Windows or Linux to select multiple pFNs.

(5) Select another subject. Users can also use the up or down arrow key to select the subject above or below.

2. Interactive visualization

Check a single pFN.

(1) Navigate to the group FN module, and select the interactive display option.

(2) Navigate to the personalized FN module

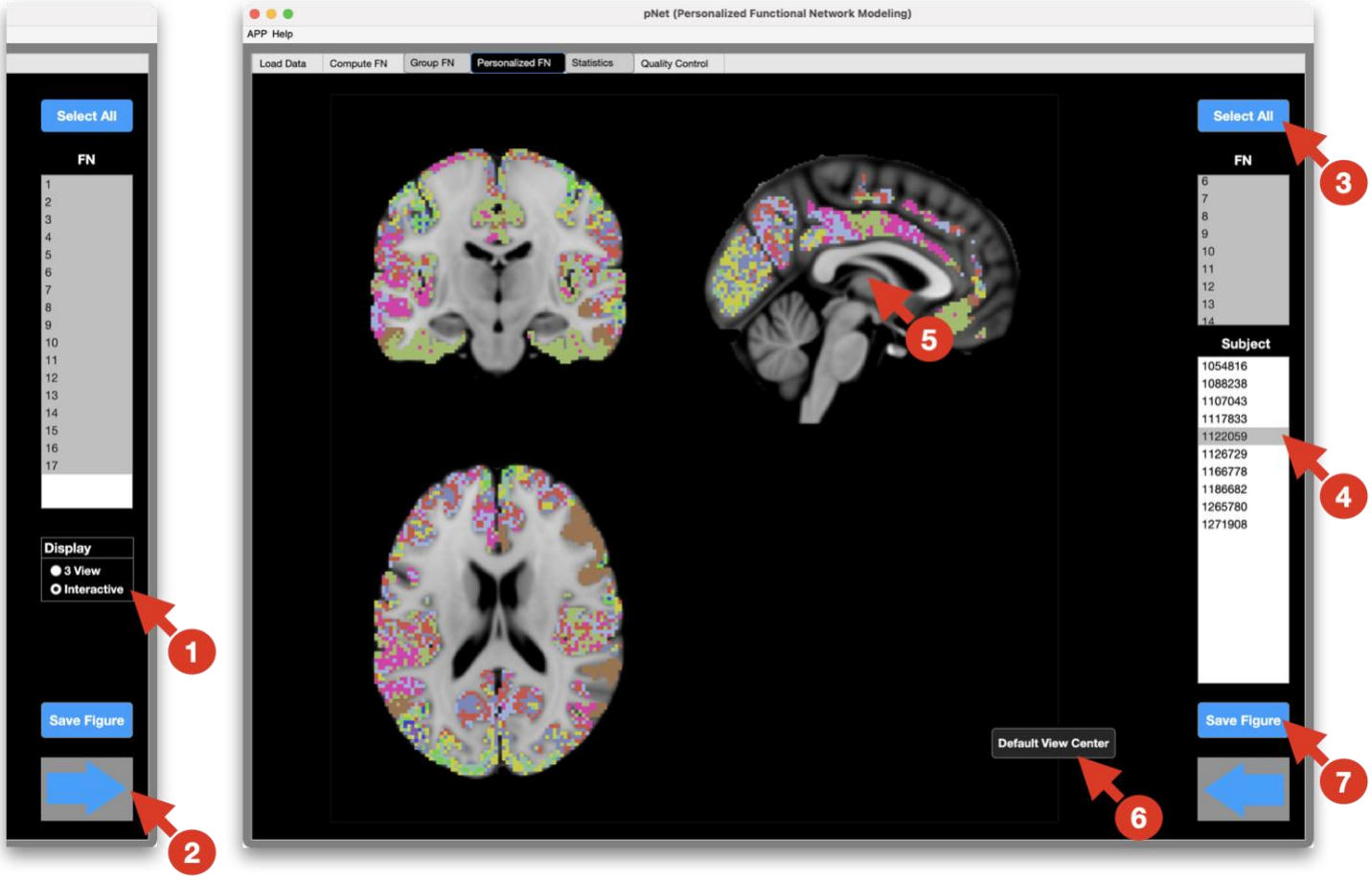
(3) Select one desired pFN for display.

(4) Select another subject. Users can also use the up or down arrow key to select the subject above or below.

(5) Click on the display to change the view center.

(6) Click the default view center button to go back to the default view center.

(7) Save this figure.



Check the functional atlas of a single subject.

(1) Navigate to the group FN module, and select the interactive display option.

(2) Navigate to the personalized FN module.

(3) Click select all button, if needed.

(4) Select another subject. Users can also use the up or down arrow key to select the subject above or below.

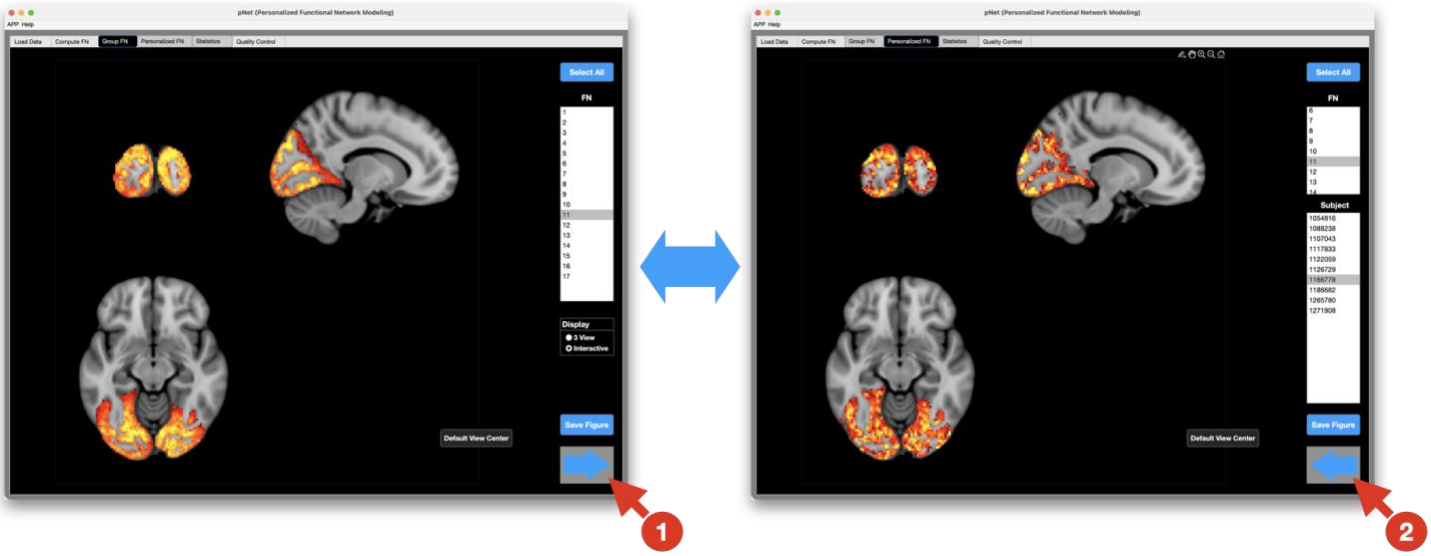
(5) Click on the display to change the view center.

(6) Click the default view center button to go back to the default view center.

(7) Save this figure.

Compare gFN and pFN

Users can easily compare gFNs and pFNs using the fast navigation buttons on the right bottom of the gFN and pFN modules. The display settings for gFNs and pFNs are synchronized automatically for convenience.



Fast navigation between gFN and pFN modules.

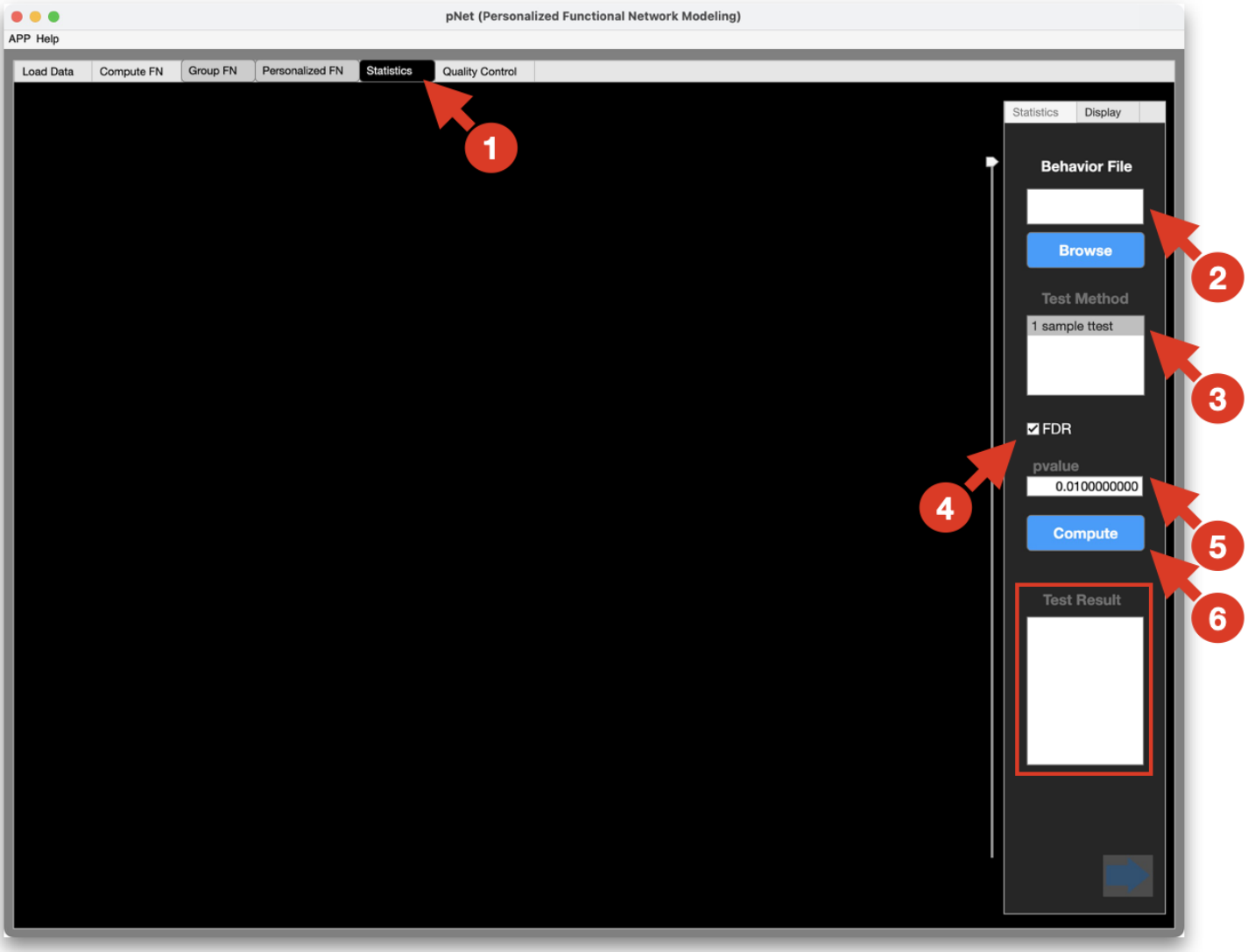
(1) The right arrow button on the gFN module navigates to the pFN module.

(2) The left arrow button on the pFN module navigates to the gFN module.

Statistical Analysis

This toolbox has implemented one-sample t-test to show the significance of each pFN, and two-sample t-test to show the significant difference of each pFN in two groups. The visualization options are as same as those for gFNs and pFNs. In addition, the visualization for statistical results are synchronized with that for gFNs and pFNs. It allows users to navigate to the gFN and pFN modules for fast comparisons.

One-sample t-test



Setup one-sample t-test.

(1) Navigate to the statistics module.

(2) Make sure that the behavior file is empty.

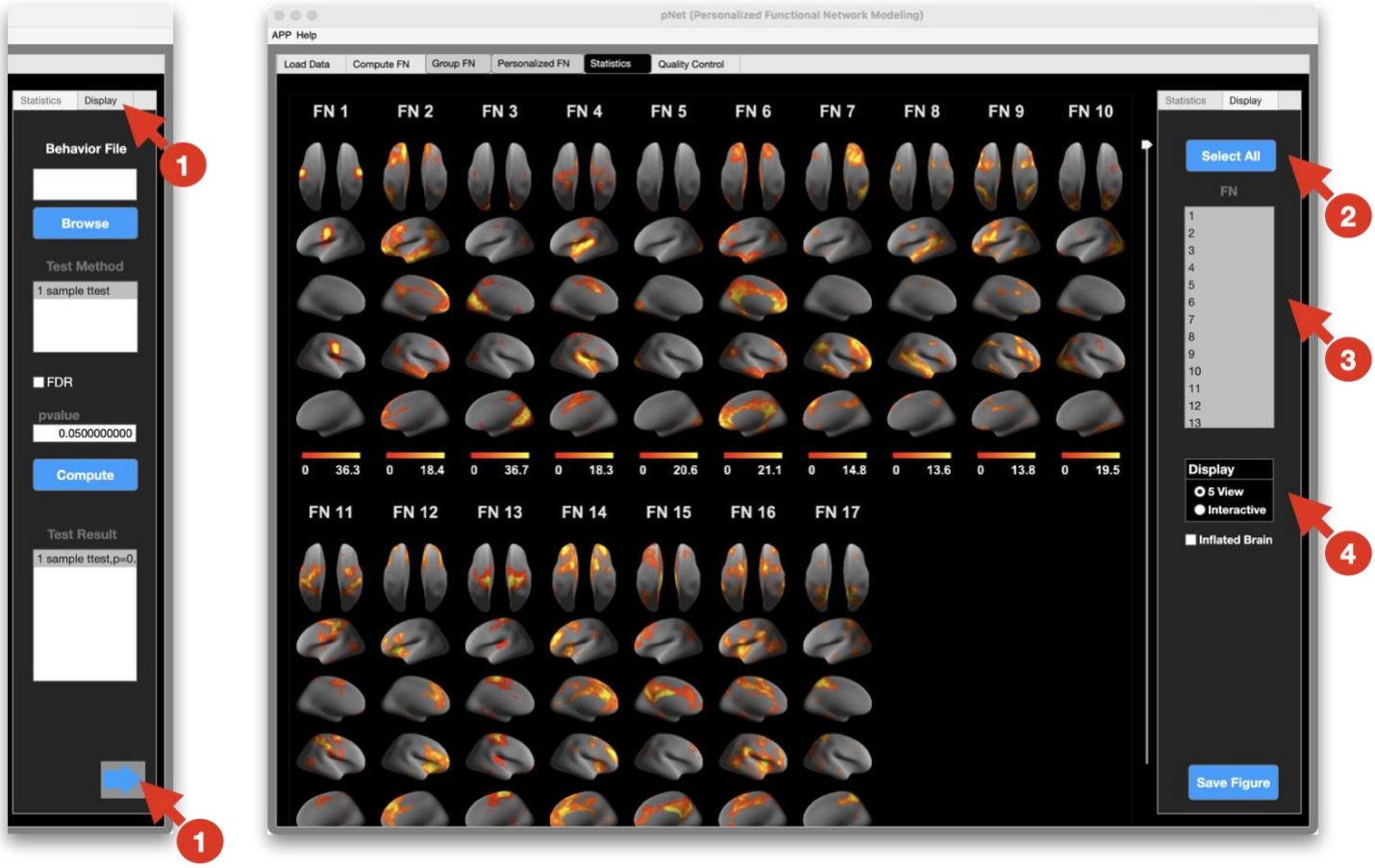
(3) Select the 1 sample t-test method.

(4) Check FDR correction, if needed.

(5) Set the p-value threshold.

(6) Click the compute button to run the statistical analysis. A popup window will show the progress of statistical computation, and another window will show the progress of result visualization.

Once the computation and visualization finish, a new test result will be added into the test result list box.



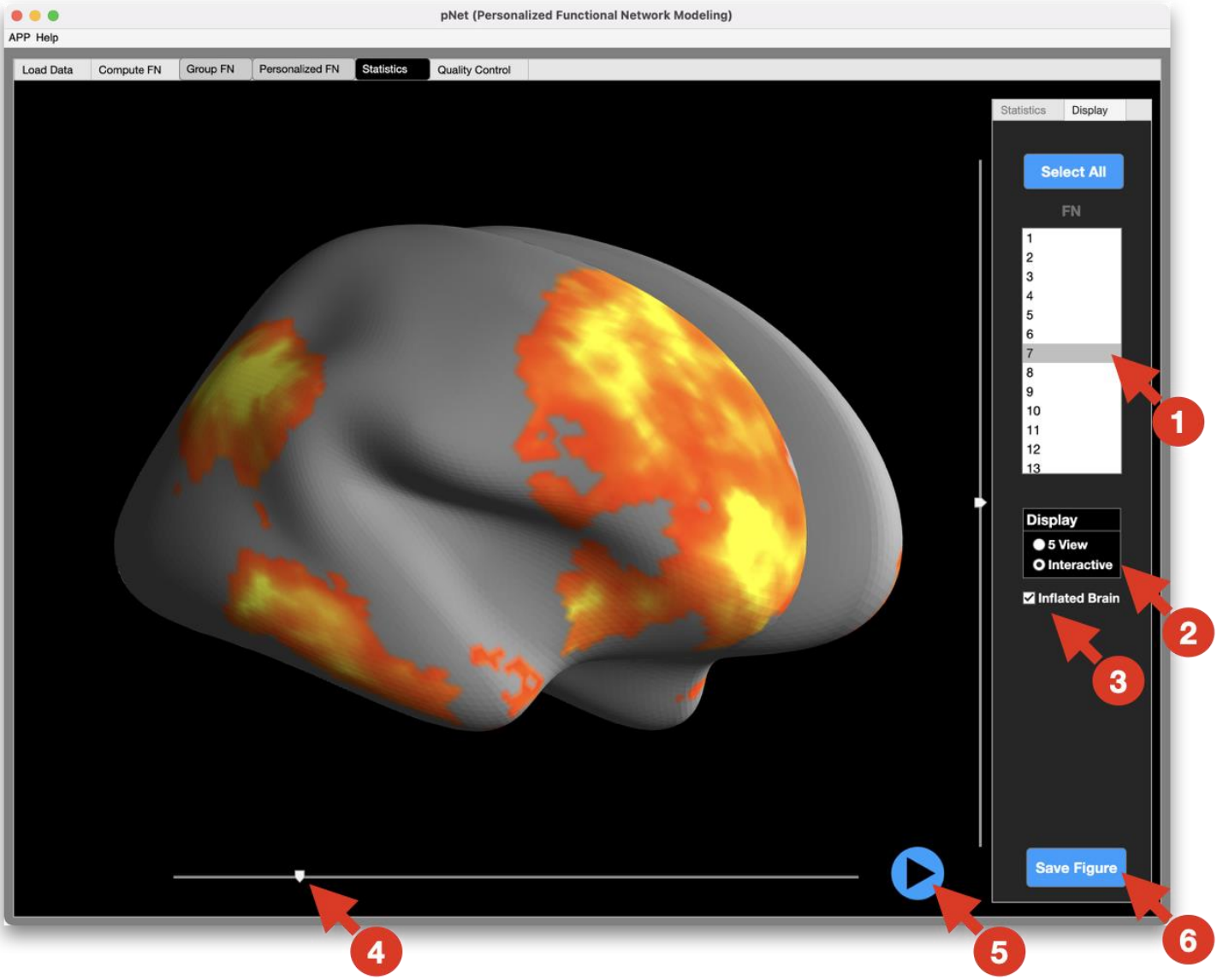
Check precomputed visualization.

(1) Navigate to the display module.

(2) Click the select all button, if needed.

(3) Select one or multiple FNs.

(4) Select the 5 view display option, if needed.



Check interactive visualization.

(1) Select one FN.

(2) Select the interactive display option.

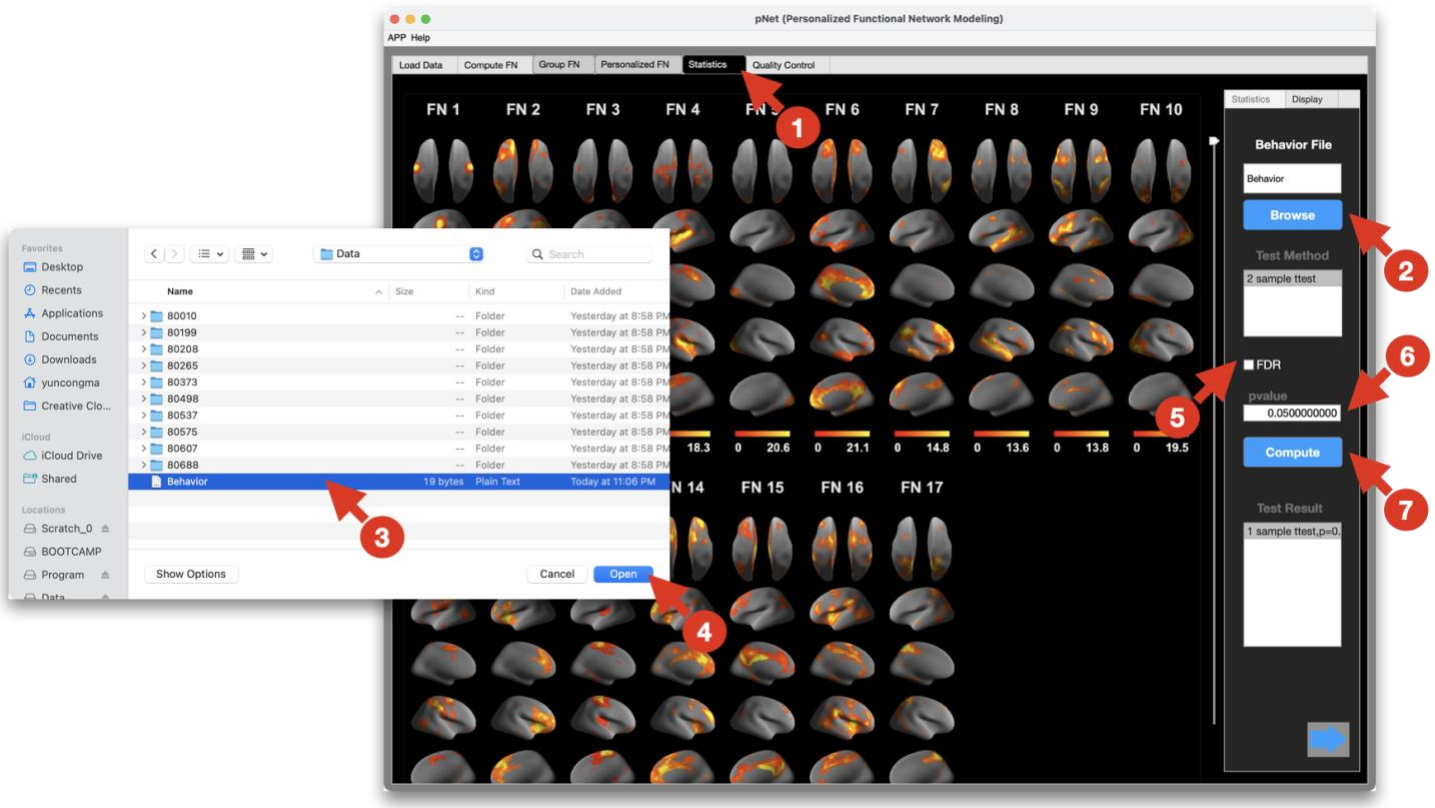
(3) Choose the inflated brain, if preferred.

(4) Drag the scroll bar to change the view angle.

(5) Click the play button to have a constantly rotating view of the brain.

(6) Click the save figure button to save this figure.

Two-sample t-test



Setup the two-sample t-test

(1) Navigate to the statistics module.

(2) Click the browse button to read a behavior file.

(3) Select the behavior file in txt format, which contains a column of 0-1 to specify the two groups.

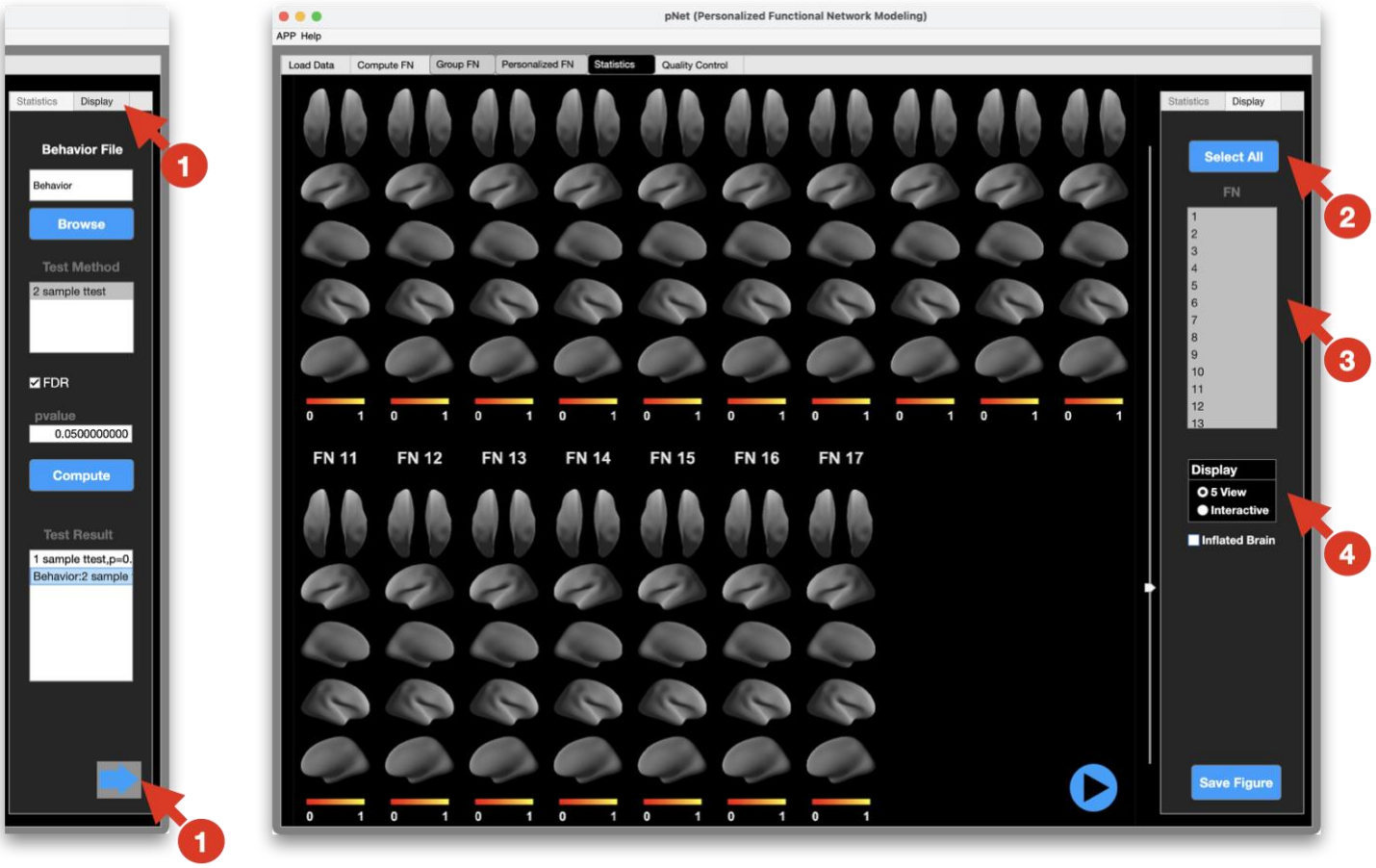
(4) Click open button.

(5) Select the FDR correction, if preferred.

(6) Setup the p-value threshold.

(7) Click the compute button to run the statistical analysis. A popup window will show the progress of statistical computation, and another window will show the progress of result visualization.

Once the computation and visualization finish, a new test result will be added into the test result list box.



Check the two-sample t-test results

(1) Navigate to the display module.

(2) Click the select all button, if needed.

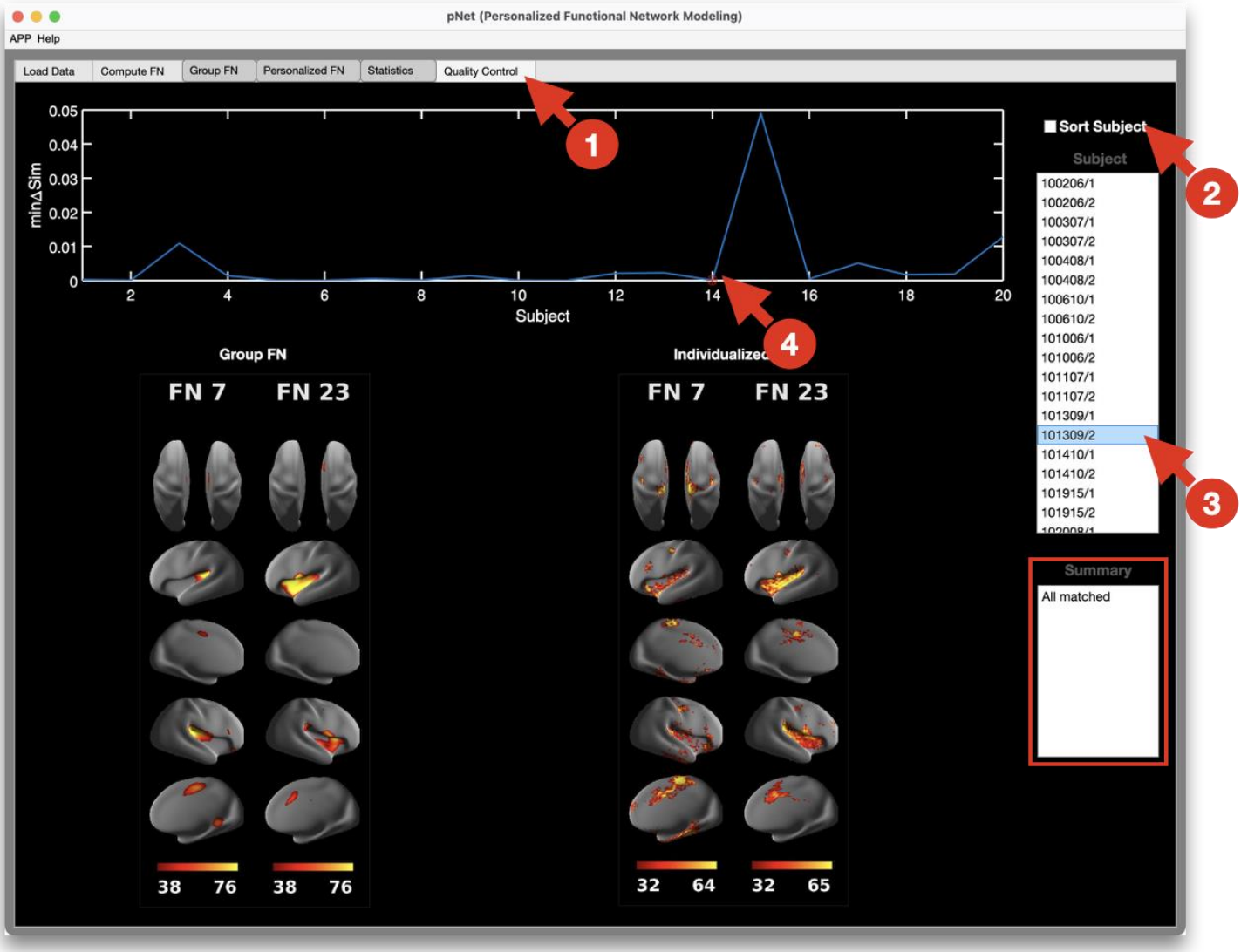
(3) Select one or multiple FNs, if preferred.

(4) Choose the display option.

Quality Control

The quality control is to ensure the spatial correspondence between pFNs and corresponding gFNs. Specifically, the pFN needs to have the highest spatial similarity (defined by Pearson correlation) to its corresponding gFN. The minimum spatial similarity value for all pFNs is noted as the min∆Sim for each subject. If min∆Sim is smaller or equal to 0, it means that there is at least one pFN mismatches to the gFN or has no higher spatial similarity.

Since our pFN computation method has quality assurance built in, all results will meet the quality control. Here we show one example with two mismatched FNs which will not be obtained from the toolbox.



Check quality control.

(1) Navigate to the quality control module.

(2) Unselect the “Sort Subject” box, if needed. This allows to show quality control results of all subjects.

(3) Choose subject to see the quality control result.

(4) Alternatively, click on the top middle figure, quality control index (min∆Sim), to see navigate to the result of that subject.

Quality control summary of the selected subject is shown in the red box.