The BrainSuite BIDS App

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Introduction:

We developed the BrainSuite BIDS App to provide containerized workflows for processing and analyzing anatomical, diffusion, and functional MRI data primarily using software we have developed for the BrainSuite project. By using the BIDS [1] and BIDS App standards [2], BrainSuite BIDS App can be rapidly deployed to provide a complete framework for performing end-to-end data analysis. We also introduce BrainSuite Dashboard, a browser-based quality control system that can be run concurrently with a set of BrainSuite BIDS App instances to facilitate real-time visual assessment of processing outputs.

Methods:

We implemented the BrainSuite BIDS App as a participant-level workflow comprising three pipelines (Fig. 1A) and a corresponding set of group-level analysis workflows. The BrainSuite Anatomical Pipeline (BAP) extracts cortical surface models from a T1-weighted (T1w) MRI [8], computes cortical thickness [3], and performs surface-constrained volumetric registration to align the T1w MRI to a labeled anatomical atlas [4]. The BrainSuite Diffusion Pipeline (BDP) processes diffusion MRI (dMRI) data by co-registering the dMRI data to the T1w scan, correcting for geometric image distortion, and fitting diffusion models [10]. The BrainSuite Functional Pipeline (BFP) processes functional MRI (fMRI) data by coregistering the fMRI data to the T1w data, then transforming the data to the anatomical atlas space and to the grayordinate space using tools from BrainSuite, FSL (fsl.fmrib.ox.ac.uk), and AFNI (afni.nimh.nih.gov). Group-level BAP and BDP outputs are analyzed using the BrainSuite Statistics in R (bssr) toolbox. BFP outputs can be analyzed using atlas-based or atlas-free statistical analyses using BrainSync [5], which synchronizes time-series data temporally. We also developed the browser-based BrainSuite Dashboard system, which can be run concurrently with a set of subject-level instances to provide rapid review of output data as they are generated (Fig. 1B).

Results:

As a demonstration of its utility, we applied the BrainSuite BIDS App to anatomical (T1w), diffusion, and functional MRI from the Amsterdam Open MRI Collection (AOMIC) Population Imaging of Psychology dataset [9]. After executing the participant-level workflows, we evaluated the outputs using BrainSuite Dashboard, adjusted software settings as needed, and reprocessed the data. We then performed five types of group-level analysis. Four of these examined effects of Raven's Advanced Progressive Matrices (RAPM) scores, a proxy measure for intelligence, on: cortical thickness using surface-based analysis (SBA); volumetric change assessed using tensor-based morphometry (TBM); ROI analysis of left pars opercularis thickness (a region selected post hoc from the SBA result); and analysis of functional connectivity (FC) derived from resting-state fMRI. These analyses focused on the female cohort (N=240; age 22.07±1.74 years), in which we observed larger effect sizes compared to the male cohort. We also examined sex differences in fractional anisotropy (FA) values using a voxel-wise analysis (N=419; age 22.05±1.79 years; 240F/179M). After correcting for multiple comparisons, only SBA, ROI, and FA analyses produced statistically significant results. For SBA and ROI, we found decreased cortical thickness proportional to higher RAPM scores (Fig. 2A&B). In the FA analysis, we found higher FA values in the basal ganglia and lower FA values in the region below the postcentral gyri in males (Fig. 2C). Our findings were consistent with results from Schnack et al. [7] and Menzler et al. [6], who found similar cortical thickness and FA effects, respectively.

Conclusions:

We developed the BrainSuite BIDS App and BrainSuite Dashboard and demonstrated their utility on the AOMIC dataset. These tools provide a practical mechanism for rapidly deploying BrainSuite workflows to perform large-scale studies on data organized according to the BIDS standard. More information can be found at http://brainsuite.org/BIDS.
Figure 1. (A) The BrainSuite BIDS App participant-level workflow for T1w, DWI, and fMRI datasets. Only T1w images are required to run BrainSuite BIDS App, but if DWI or fMRI data are available, they will also be processed. (B) The BrainSuite Dashboard provides a browser-based interface with an interactive view of the participant-level study data as they are being processed. Snapshot images of key stages are generated and displayed in real-time, enabling identification of processing errors as they occur.
Figure 2. BrainSuite BIDS App group analysis of the Amsterdam Open MRI Collection’s Population Imaging of Psychology dataset. (A) Surface-based analysis of the effects of RAPM on cortical thickness in the female cohort (blue and red hues indicate a decrease and increase); (B) ROI analysis of the effects of RAPM on the left pars opercularis grey matter thickness in the same female cohort; (C) voxel-wise analysis of sex differences in FA values on the entire cohort (blue indicates lower FA values in females versus males, and red indicates the opposite). The reports shown in (B) and (C) are the direct outputs of bssr executed within the BrainSuite BIDS App.

Neuroinformatics and Data Sharing:

Workflows 1
Informatics Other 2
**Poster Session:**

Poster Session 3  
Poster Session 4

**Keywords:**

Design and Analysis  
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Other - Software tools

1[2] Indicates the priority used for review

**Abstract Information**

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Yes

Please indicate below if your study was a "resting state" or “task-activation” study.

Resting state

Healthy subjects only or patients (note that patient studies may also involve healthy subjects):

Healthy subjects

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Not applicable

Please indicate which methods were used in your research:

Functional MRI  
Structural MRI  
Diffusion MRI

**Which processing packages did you use for your study?**

Other, Please list - BrainSuite

**Provide references using author date format**


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