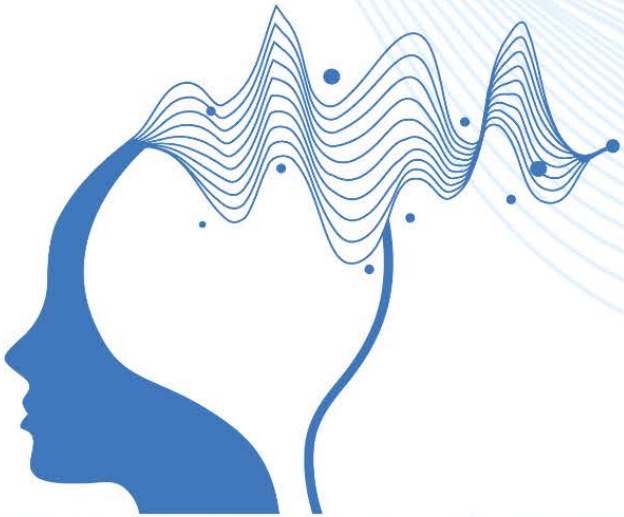
Scientific Instruments



BRAINDANCER

fMRI Dynamic Phantom

Improves signal to noise ratio during fMRI studies.

- Cleaner signal
- Stronger results
- Harmonization of fMRI data across scanners and sites

Scientific Instruments

Problem

Functional Magnetic Resonance Imaging is not currently used as a neurodiagnostic tool for individual subjects. One of the reasons for this is the poor fMRI **signal-to-noise ratio**. Noise contributions to fMRI data, and methods to remove them:

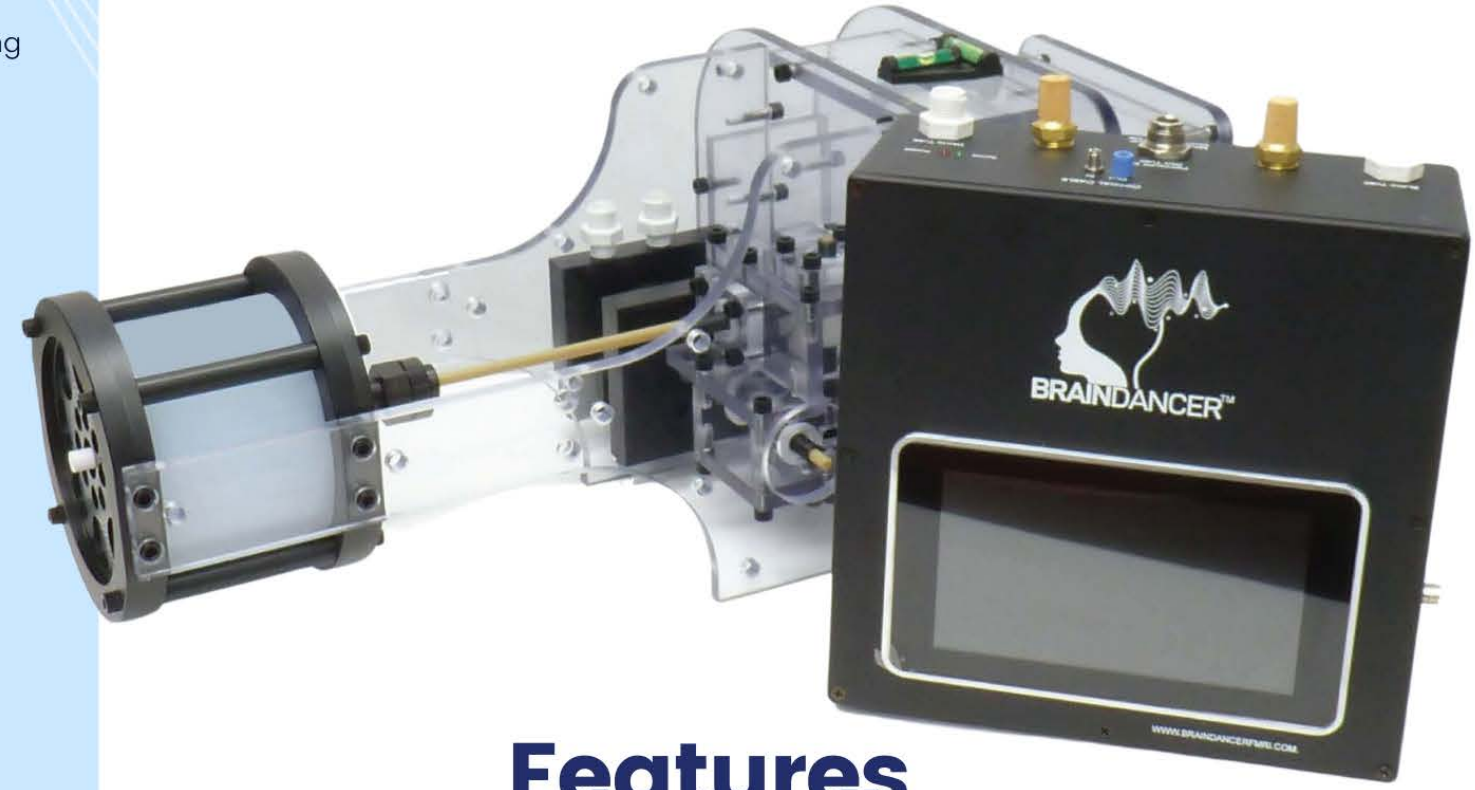
- **Physiological noise** – breathing and heart-rate monitors used for regression.
- **Subject head motion** – motion estimation using image registration.
- **Scanner induced noise** – No ground truth measurements available, until now.
- **Thermal noise** – signal independent additive noise.
- **Multiplicative noise** (scanner instability) – signal dependent multiplicative noise.

Solution

The **BrainDancer®** is a commercial-grade dynamic phantom, designed to **identify and correct systematic scanner-induced noise** using our deep learning algorithm (available as free software).

The BrainDancer® not only **improves the signal-to-noise ratio**, it can also be used for standardization of protocols and harmonization across scanners.

BrainDancer is a rotating gel phantom that is air-powered with no metallic or electronic parts. A control unit operates from the MRI control room. (Compressed air is required)



Features

- **Pneumatically controlled** movement.
- No metallic or electronic components in the phantom.
- Rotating inner cylinder to produce **T2* changes within voxels.**
- **Imitates BOLD amplitudes** of human brains.
- **Externally triggered** user programmable sequences.
- **Deep learning algorithm** available for temporal noise estimation.
- Developing analytical tools for tracking disease trajectories at the **single-subject level.**
- Available for **3T and 7T**

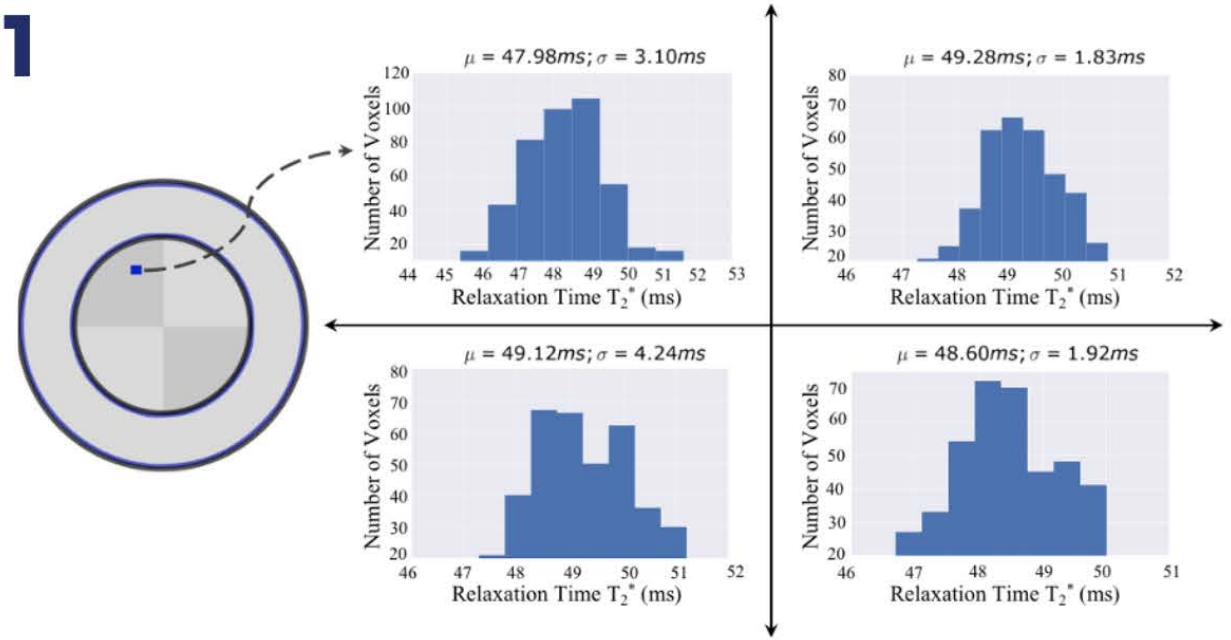
*Ground-truth "resting-state "signal provides data-driven estimation and correction for scanner distortion of fMRI time-series dynamics
https://doi.org/10.1016/j.neuroimage.2020.117584

Figures

1. Distribution of T2* values across voxels in four quadrants at 3T. The agarose gel is prepared using the recipe provided by Friedman and Glover 2006. Even though the agarose gel is prepared only at 2.2% and 2.4% concentration, the heterogeneity in T2* values can be attributed to imperfect agarose network formation, chemical heterogeneity, and polydispersity of gel networks.

2. Creating ground-truth using the Dynamic Phantom. During each phantom scan, 200 static volumes were acquired and were averaged voxel-wise to obtain a close approximation to true intensity values. The mean volume was then rotated 600 times synthetically at angles obtained from the optical encoder during the actual run. This yielded ground-truth volumes, which then were compared to the volumes acquired during the scan.

1



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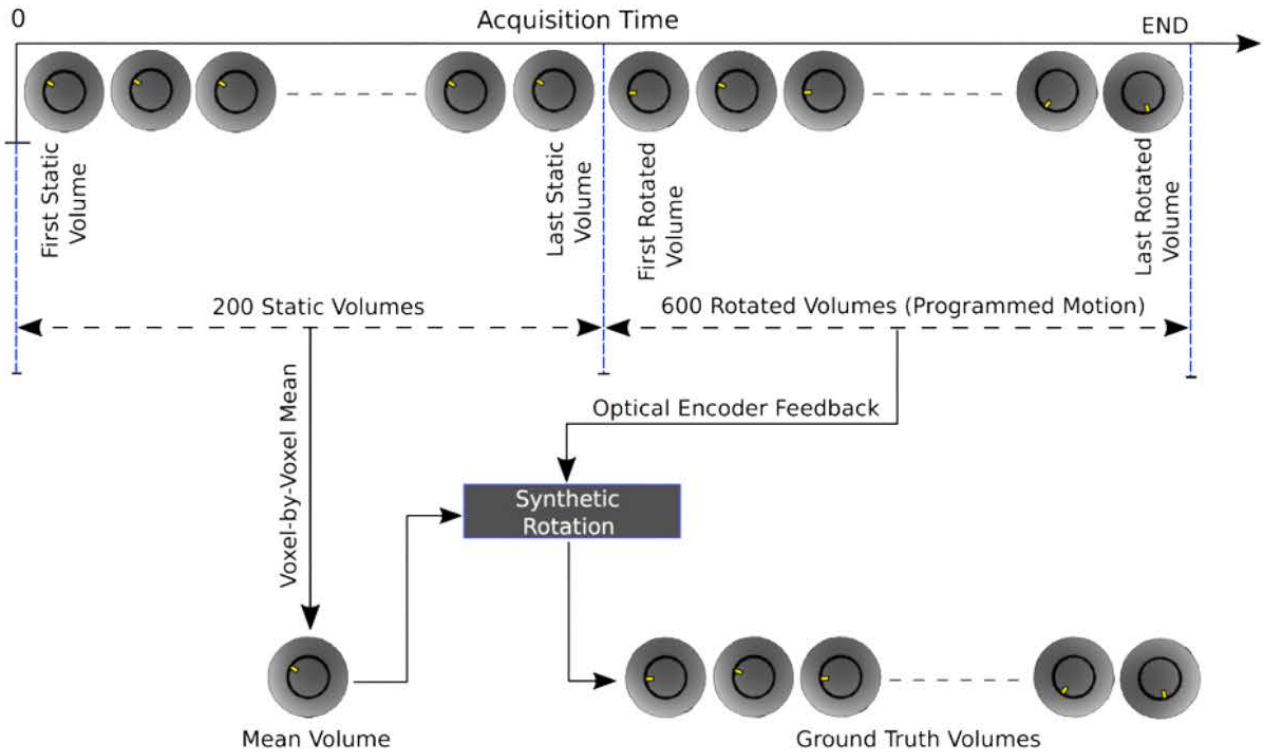

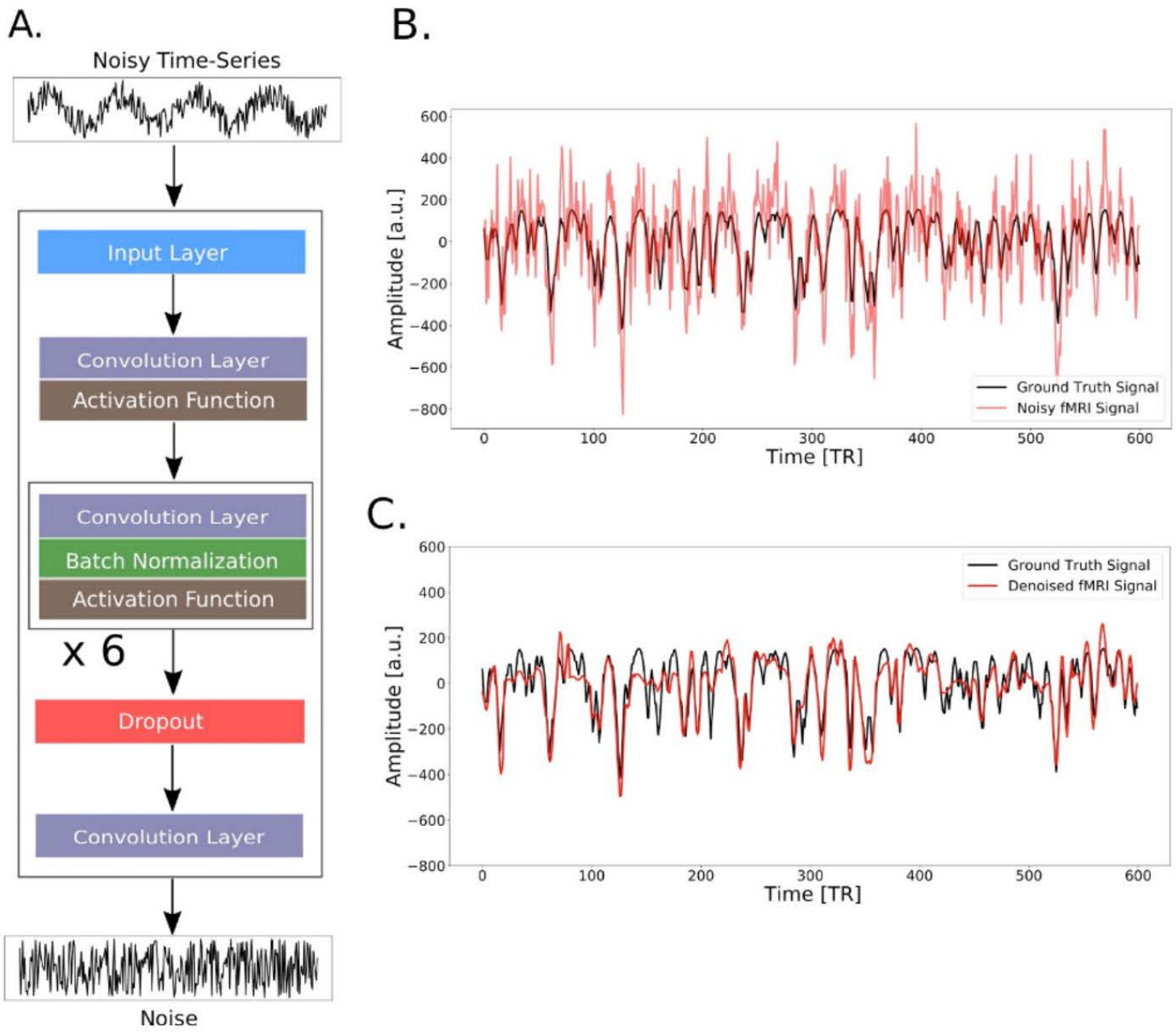

A. Architecture of the convolutional neural network used for discriminative denoising. The CNN learned the unique features of each session's noise, providing a customized temporal filter. Tests on dynamic phantom time-series showed a 4- to 7-fold increase in ST-SNR and about 40–70% increase in Dynamic Fidelity after denoising, with CNN denoising outperforming both the temporal bandpass filtering and denoising using Marchenko-Pastur principal component analysis. Critically, we observed that the CNN temporal denoising pushes ST-SNR to a regime where signal power is higher than that of noise (ST-SNR > 1). Denoising human-data with ground-truth-trained CNN, in turn, showed markedly increased detection sensitivity of resting-state networks. These were visible even at the level of the single-subject, as required for clinical applications of fMRI.

B. Measurement of Ground truth and fMRI signal

C: Ground truth and software denoised fMRI Signal.

Analysis Software

BDTools.jl and BDGUI.jl

The **BrainDancer Dynamic Phantom** comes with Analysis Software (BDTools.jl and BDGUI.jl written using the Julia programming language) in the form of interactive notebooks that provide the following features:

1) Interactive selection of phantom slices that will be used for further analysis.
2) Automated creation of masks for B-field correction.
3) Automated B-field correction.
4) Automated fitting of center, principal radii and orientation of the inner cartridge in each slice.
5) Automated Fitting of rotation axis in 3-D space.
6) Calculate and store Ground truth and signal for each inner voxel.
7) Calculate quality measures: Signal-to-noise ratio, Dynamic fidelity, scanner instability.
8) Train convolutional neural net using time-series and ground truth.
9) Human data cleaning.

Phantom data analysis 1) to 7) can be obtained in **less than 10min per phantom scan**. Training of convolutional neural network takes a few hours. After training, cleaning of human data can be performed in minutes per subject.

Contact Us

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Scan for BrainDancer video

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