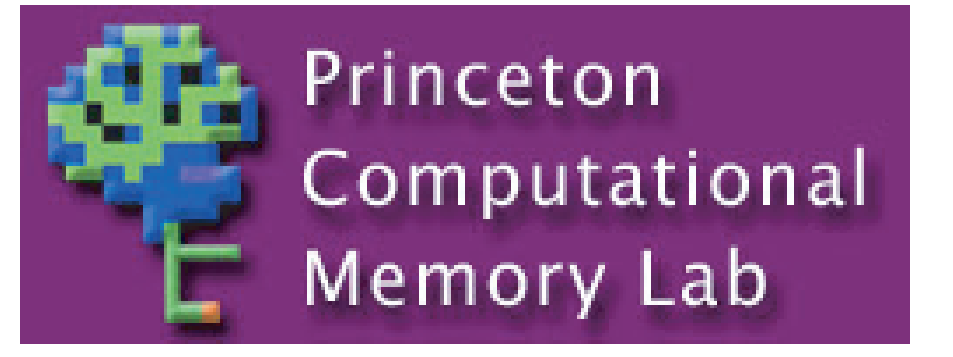


A Matlab-based toolbox to facilitate multi-voxel pattern classification of fMRI data.

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Abstract

We introduce a Matlab-based toolbox to facilitate pattern classification analyses on fMRI neuroimaging data. The toolbox will be released and supported by Center for the Study of Brain, Mind, and Behavior at Princeton University in late Summer/early Fall 2005.

The philosophy of this effort is to create a set of open-source functions in a widely used language to facilitate exploration of multi-voxel pattern analysis techniques and to reduce the 'startup costs' for knowledgeable users eager to apply pattern classification algorithms to their imaging data. By developing the toolbox in the Matlab environment, users are able to take advantage of the vast array of existing functions. The data structures used and generated by the toolbox are designed to facilitate exploration and further script development.

Tools

The toolbox scripts are divided into four categories: import, manipulation, classification, and export.

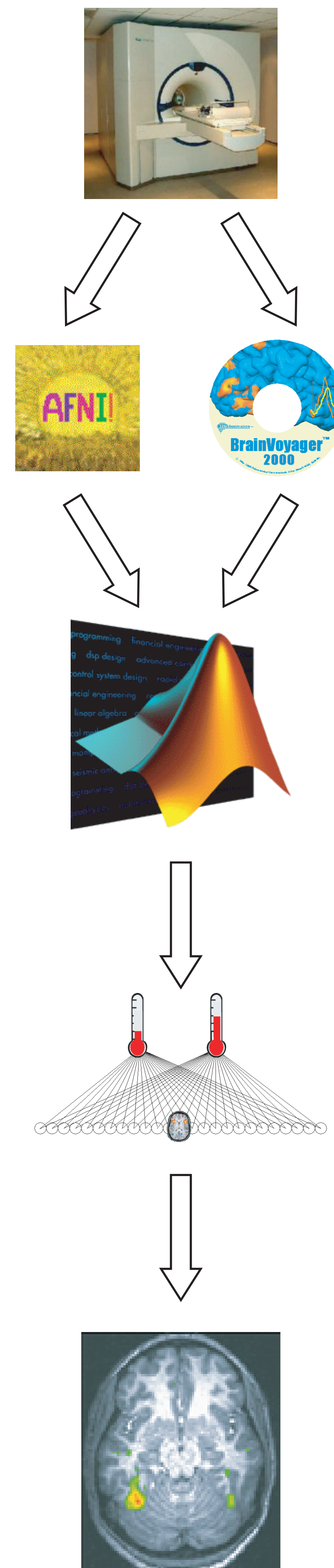
Import: the toolbox imports AFNI and BrainVoyager file formats, converting imaging data into a standardized data structure within the Matlab environment.

Manipulation: common types of preprocessing, e.g. z-scoring within a voxel's timecourse; selecting voxels that vary significantly across some subset of experimental conditions, as measured by an analysis of variance (ANOVA).

Classification: includes backpropagation (Hanson et al, 2004; Polyn et al, 2004) and correlation-based (Haxby et al, 2001) classifiers. Generalization can be measured using a standard leave-one-out cross-validation procedure, e.g. train on all but one run's worth of data, and test on that remaining run. New classifier algorithms can easily be added.

Export: Export back to AFNI or BrainVoyager to visualize the analysis results, e.g. classifier-derived maps of voxel selectivity/informativeness based on the neural network's weight structure.

Documentation, benchmark dataset and tutorial: Includes fMRI data from the Haxby et al (2001) investigation of object-category related distributed patterns of brain activity. Tutorial and sample scripts walk through the analysis procedure. Can be used to benchmark the relative performance of different classification algorithms on a common dataset.



Data is imported from either AFNI or BrainVoyager into Matlab, pre-processed and fed into the classifier, before being exported back again.

Structure

After being imported from AFNI or BrainVoyager, each subject's data is stored in a single Matlab *subj* structure comprised of three main parts:

Patterns: imaging data. Users can store different versions of the data in different cells of the patterns structure, e.g. raw data, z-scored raw data, after anatomical mask has been applied, wavelet coefficients, GLM beta weights.

Regressors: information about the conditions in the experiment, e.g. binary regressors detailing condition onset/offset, hemodynamically convolved versions

Selectors: labels to break the timecourse into subparts. Used by classification routines to decide what to train on and what to test on, e.g. by scan session, by scanner run, by condition, by experiment phase.

This toolbox allows users to store multiple kinds of patterns, as well as multiple versions of the regressors or multiple selector labels for each pattern. The toolbox includes a set of accessor scripts that manage the data, insulating the user from the low-level details of implementation. The scripts automatically append useful metadata to the *subj* structure, allowing the user to retrace their steps if necessary.

A separate *results* structure is created when a classification routine is run on the data. This structure contains all of the information pertinent to classification, e.g. the outputs from a neural network, the targets it was trained on, optional classification arguments and performance statistics.

Data analysed with this toolkit

Benchmark data set (Haxby et al., 2001, Science) - classification of brain patterns into 8 categories, including face, house, shoe, bottle, cat, etc.

Seven finer-grained categories (Polyn et al., 2004, OHBM) - classification of brain patterns into 7 categories, including male face, female face, monkey face and dog face, etc.

Free recall (see sidebar; Polyn et al., 2004, SFN)

Task-switching (Lenartowicz et al., 2005, CNS) - tracking representations for different tasks, using only the PFC, and relating their activity to behavioural task performance

Retrieval orientation (Robison & Norman, 2005, SFN - tracking the targeting of memories, using only the PFC

Gender-slimness - brain patterns of subjects viewing human faces are characterized along two dimensions: gender of the viewed face, and slimness of the face.

Delayed saccades - determining the location being held in spatial working memory (Detre et al., 2005, SFN)

Novel/familiar - classifying whether subjects are viewing novel or familiar stimuli, using only the medial temporal lobe (Ezzyat et al., 2005, SFN; Preston et al., 2004, SFN)

Example application: Free recall (Polyn, Natu, Norman and Cohen, in preparation)

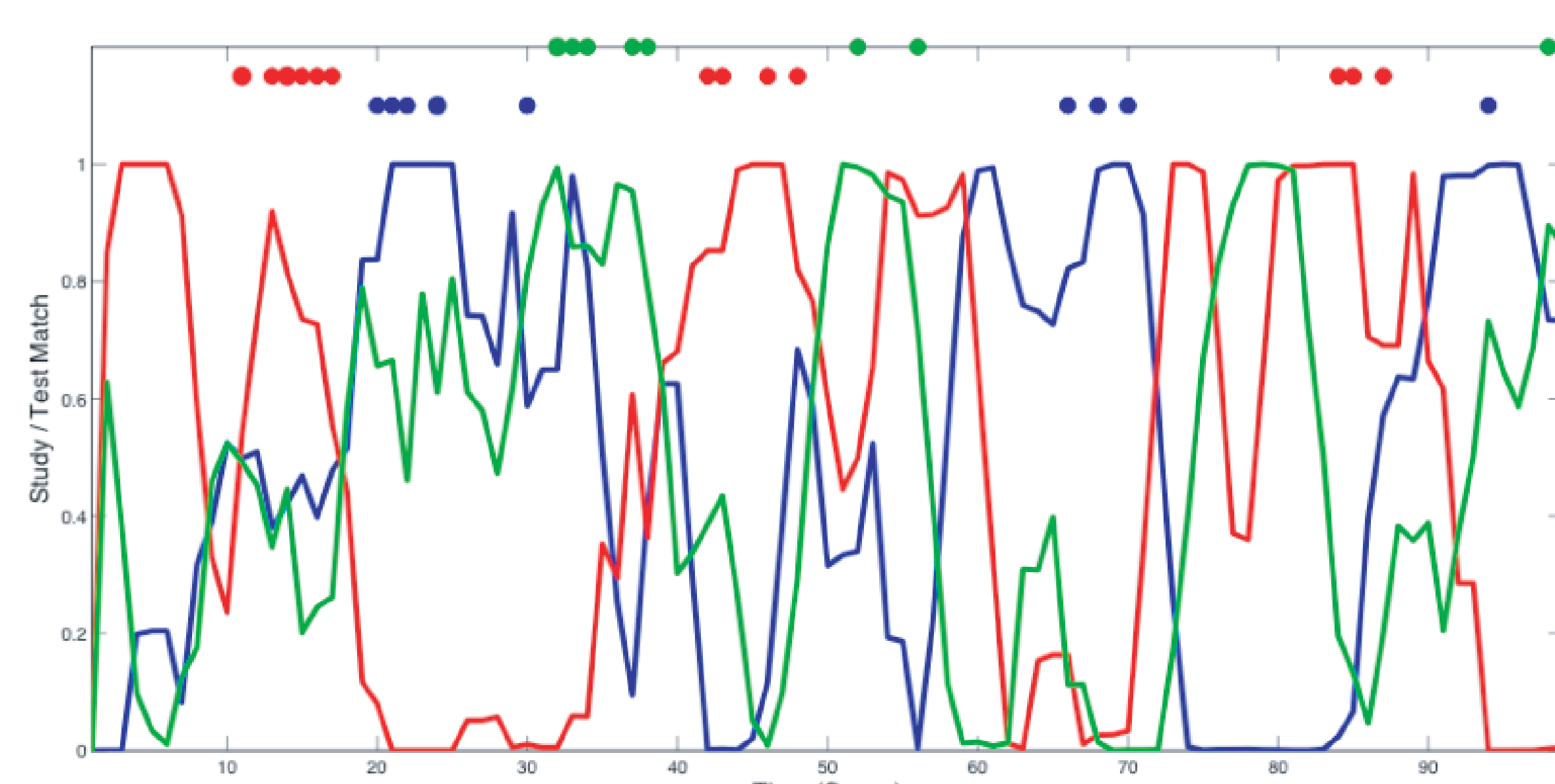
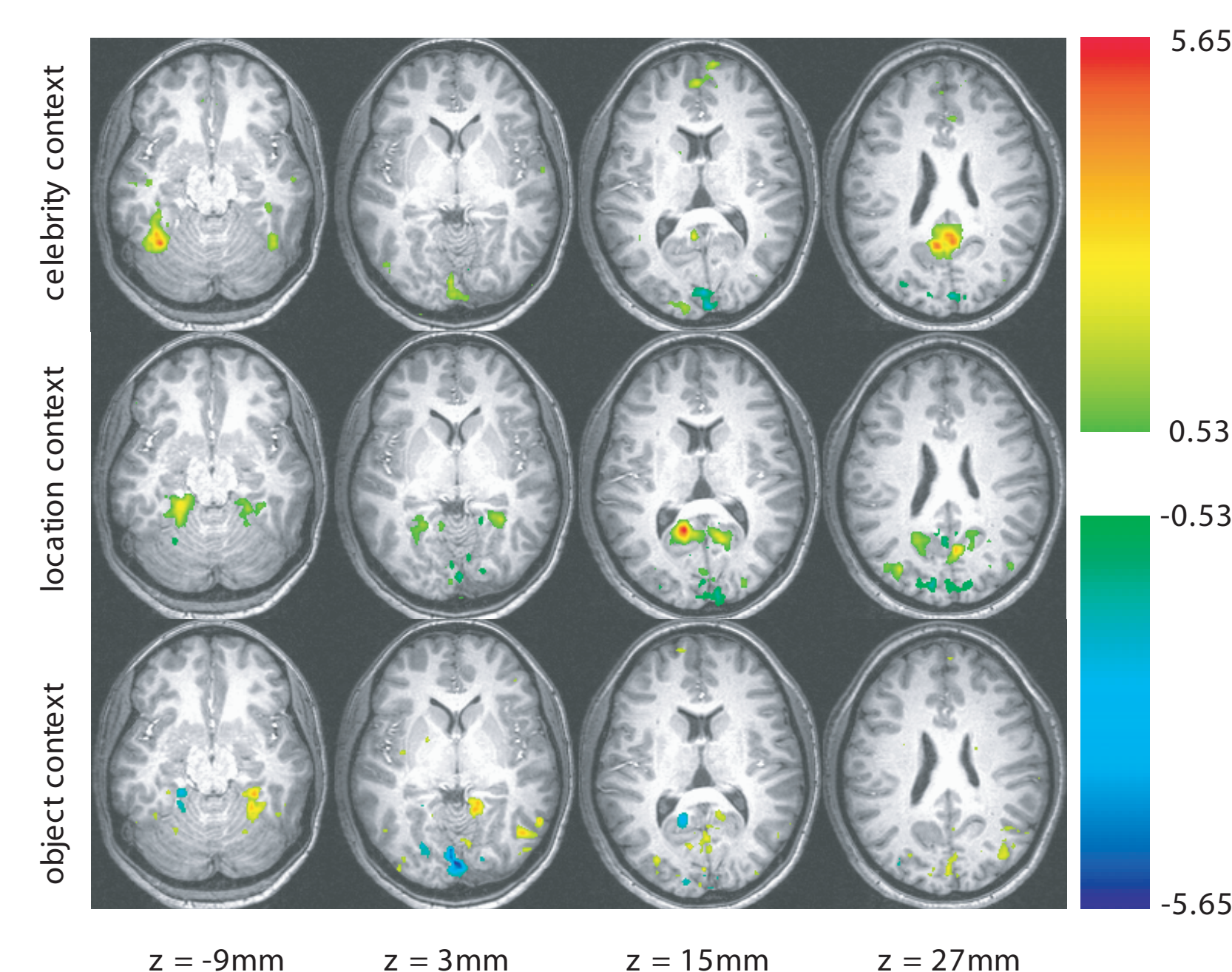


Study phase: each trial contains a celebrity face, famous location or household object stimulus.

Free recall phase: Recall items from all three categories, in any order (by speaking into a microphone in the scanner)

Train the neural network to classify the three categories of stimulus from the study phase.

When tested on the free recall data, the classifier provides a time-varying trace of how much the brain resembles its state at encoding for each category. Classifier output correlates strongly with behavioral recall data. Neural reinstatement of category-related activity precedes verbal recall: the classifier can be used to predict which category will be recalled, up to 5 seconds before recall actually occurs.



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