fMRI Data Analysis Techniques in Substance Abuse Conditions

A nicotine-addiction case study

Daniel Fratte, Aria Smith, and Anke Meyer-Baese

Florida State University - Department of Scientific Computing

Introduction

Smoking addiction presents enormous health problems most notably leading to 12 million premature deaths of Americans and another 25 million deaths as a result of nicotine related illnesses. Determining individual smoking cessation treatments and measures that improve treatment efficacy are of importance if we are to reduce the drastic health consequences associated with tobacco use. Brain imaging studies identified brain networks that play a key role in nicotine addiction-related behavior. Resting state networks reflect a basic property of functional brain organization and include areas believed to play a key role in reward and addiction[1].

This study will provide the clinical neuroscientist with a fast and accurate computational diagnosis support. Predicting from initial data the relapse likelihood will be beneficial when determining individual therapies for nicotine-addicted subjects and increase the awareness of the addiction problem in nicotine-support groups.

Main Objectives

1. Implement and evaluate novel graph model techniques to determine network integration in relapsing and non-relapsing patients.
2. Identify relevant features for relapse predictions and of measures for regional homogeneity changes.

fMRI Data Pipeline

We refer to the data processing pipeline as a series of consecutive and interrelated steps that guide the entire process of manipulating and transforming our data. Although there is no standardized procedure to follow, it exists a commonly accepted pattern for performing the whole process, and it might vary somewhat between different software packages.

These major components of fMRI analysis are conceived to deal with specific problems on each stage. Each of those can be specifically be listed and described as,

1. Image Reconstruction, when we obtained and do a quality control over the raw data from the scanner.
2. Distortion Correction, where the modifications about spatial distortions that often occur in images take place.
3. Motion Correction: the realignment of images across time to take into account head motion.
4. Slice timing correction: Timing might also present differences between slices of the image, and needs to be corrected.
5. Spatial Smoothing: noise reduction step by implementing the blurring of the data.
6. Spatial Normalization: the alignment of data from different subjects of study into a common framework of reference in order to perform group analysis.
7. Statistical Analysis: the fitting and estimation of a statistical model to the data.

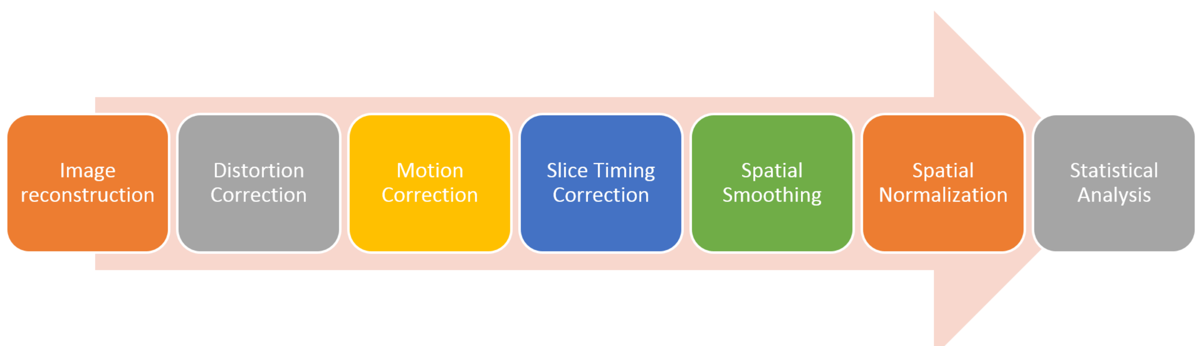

Figure 1: fMRI commonly used workflow

Nicotine Study

The study itself was conducted with 39 patients dealing with heavy problems of nicotine addiction. They participated in a treatment which involved the intake of NAC (a compound used for compulsive/impulsive and addiction symptoms and derived of the cysteine amino acid). The whole data set of patients was separated between those who actually underwent the real drug treatment, and those who were administered a placebo. Before and after the treatment followed its natural course, both groups of study participated in two sessions of anatomical and functional scanning. These sessions produce different type of images, for different analysis purposes.

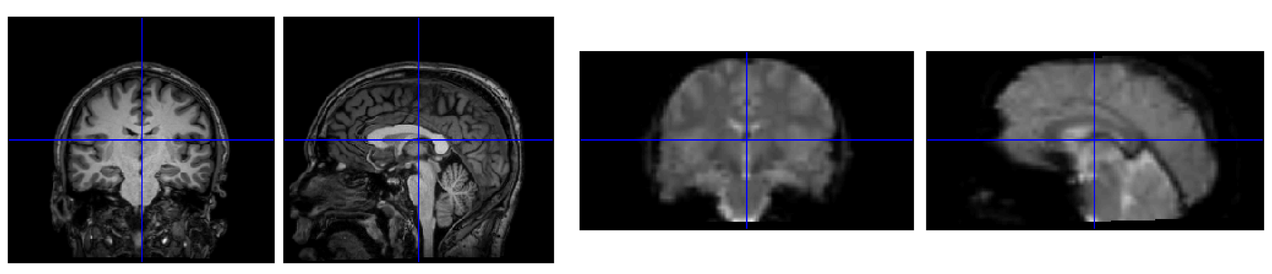

Figure 2: (Left) Anatomical T1 image of patient zero; (Right) Functional $T2^*$ image of patient zero.

Imaging Protocol

Magnetic resonance imaging (MRI) data was obtained using a 3.0 T Philips Achieva 3.2.1 scanner.

During the resting state scan, subjects were instructed to relax, keep their eyes closed and stay awake. After the resting-state scan, subjects were asked whether they managed to stay awake.

Figure 3: fMRI Scanner

Three-dimensional T1-weighted images *(Figure 2 - Left)* are meant to be high resolution, i.e. 3 spatial dimensions of 240×240×220 with a voxel size of 1mm and 1 temporal dimension, in order to facilitate the analysis of structural change in the brain during the different scanning sessions. On the other hand three-dimensional $T2^*$-weighted images *(Figure 2 - Right)* define a low resolution scheme, i.e. spatial resolution of 80×80×37 with a voxel size of 3mm approximately, in which the main objective is to analyze functional connectivity between brain regions.

Methods Utilized

The tools currently used to perform the analysis over the pre-processed data are the following:

Methods	Description	Platform
Pre-Processing	Performs the first pre-processing steps	MATLAB
GroupICA	ICA over whole group of subjects	MATLAB
Brain Connectivity Toolkit	Functional conn. of brain regions	MATLAB

Table 1: Tools used in the analysis

Our approach starts with a MATLAB script developed to fulfill the very first stages of the pre-processing work-flow. First it defines a set of parameters needed to start triggering the built-in functions which will actually transform the data, e.g. time of acquisition, number or slices (size of the z-dimension), number of scanning sessions, among others.

After all the above mentioned steps take place our data is ready as input for further statistical analysis. Before actually moving on with this, it is necessary to do a manual QA process to verify that this output is actually suitable to be used in future experiments and that it is solid to be used as a basis for elaborating hypothesis.

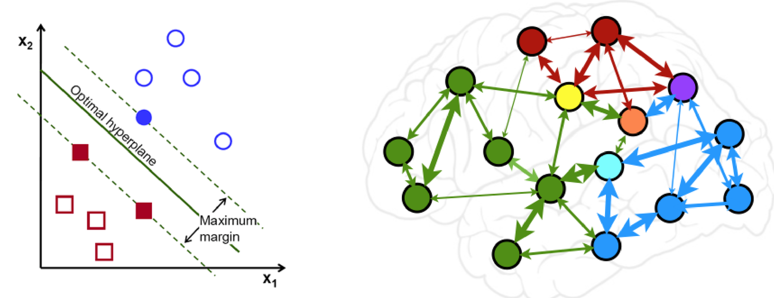

Figure 4: (Left) SVM Classifier learning to distinguish among relapsers and non-relapsers. (Right) Brain network analysis representation to study and determine new interactions between regions.

Summary and Future Work

- Using the MATLAB software, the raw data was pre-processed according to the fMRI data pipeline and parameters given by the collaborators in the Netherlands.
- The pre-processing of the data is key to producing accurate results going forward in the data analysis process.
- The next steps in the analysis will include multivoxel pattern analysis and machine learning techniques, specifically linear support vector machines (SVM), to classify the patients as relapsing and non-relapsing.
- Also, novel graph techniques will be explored to capture the local, mesoscopic and global properties of the functional brain network organization of relapsers and non-relapsers.

References

[1] B. Biswal. Functional connectivity in the motor cortex of resting human brain using echo-planar mri. *Magnetic Resonance in Medicine*, 34(4):537–41, Oct 1995.

[2] Russell A. Poldrack. *Handbook of Functional MRI Data Analysis*. Cambridge University Press, 1st edition, 2011.

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