DIPF
Leibniz-Institut für Bildungsforschung und Bildungsinformation

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

IDeA
Individual Development and Adaptive Education

Session 2: Hands-on exercise: BOLD Signal and Design Matrix

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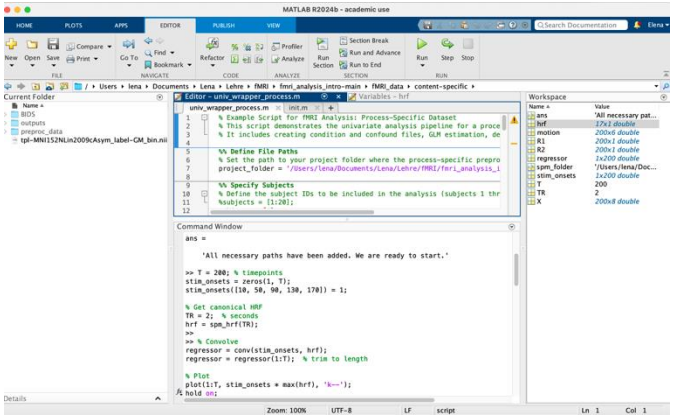
Hands-on exercises



Topics and questions

-Matlab Basics
-HRF
-BOLD Signal
-Design Matrix

1.Why do we convolve condition onsets with the HRF?
2. Why are nuisance regressors not convolved?
3. What is a beta estimate?
4. How do we interpret contrasts?
5. What do condition files contain?
6. What do confound files contain?
7. Why use first-level (subject-level) models?

Setup Requirements

Download Jimmy Shen's toolbox:

https://www.mathworks.com/matlabcentral/fileexchange/8797-tools-for-nifti-and-analyze-image

Add it to your MATLAB path:

```
addpath(genpath('/your/path/to/nifti_toolbox'));
```

load_nii and load_untouch_nii are pure MATLAB and compatible with .nii.gz files without needing compiled MEX or toolbox dependencies.

Exercise 0: MATLAB Basics for Neuroimaging Analysis

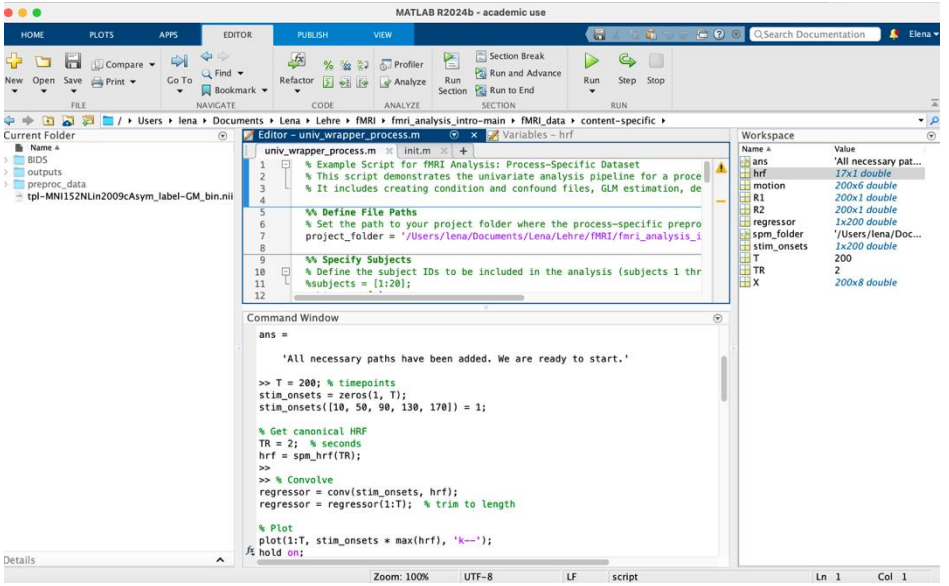
Learn to:

- Use the Command Window
- Create and manipulate variables
- Plot simple functions
- Write and run scripts
- Navigate the file system

Exercise 0: MATLAB Basics for Neuroimaging Analysis

The MATLAB Environment

- Command Window – Try things out interactively
- Editor – Write reusable scripts
- Workspace – See variables in memory
- Current Folder – Navigate and manage your files



Exercise 0: MATLAB Basics for Neuroimaging Analysis

Variables and Simple Math

%Code:

```
2 + 3

a = 2 + 3

disp(a)
```

Try it out:

- Change the numbers
- Use multiplication *, division /, or power ^

Exercise 0: MATLAB Basics for Neuroimaging Analysis

Create and Plot a Signal

```
%Code:

t = 0:0.1:10;

y = sin(t);

plot(t, y);

title('Sine Wave');

xlabel('Time (s)');

ylabel('Amplitude');
```

Exercise 0: MATLAB Basics for Neuroimaging Analysis

Navigate Folders and Files

%Code:

pwd

dir

cd('/your/folder/path')

Exercise 0: MATLAB Basics for Neuroimaging Analysis

Create Your First Script

1. Click New Script
2. Write code, e.g.:

```
x = 0:0.01:2*pi;
y = cos(x);
plot(x, y);
title('Cosine Function’);
```

3. Save as yourscriptname.m
4. Click Run

Exercise 0: MATLAB Basics for Neuroimaging Analysis

Bonus – Loops and Display

%Code:

```
for i = 1:5
    disp(['This is loop number ', num2str(i)])
end
```

Exercise 0: MATLAB Basics for Neuroimaging Analysis

Combine for loops and if statements

Code Example:

```
for i = 1:5
    if mod(i, 2) == 0
        disp(['Loop ', num2str(i), ': even number'])
    else
        disp(['Loop ', num2str(i), ': odd number'])
    end
end
```

Exercise 1: Simulate a Hemodynamic Response

Goal: Understand convolution with HRF.

```
% Simulate onsets
T = 200; % timepoints
stim_onsets = zeros(1, T);
stim_onsets([10, 50, 90, 130, 170]) = 1;

% Get canonical HRF
TR = 2;  % seconds
hrf = spm_hrf(TR);

% Convolve
regressor = conv(stim_onsets, hrf);
regressor = regressor(1:T);  % trim to length

% Plot
plot(1:T, stim_onsets * max(hrf), 'k--');
hold on;
plot(1:T, regressor, 'r');
legend('Stimulus', 'Convolved');
title('HRF Convolution');
```

Exercise 2: Visualize the BOLD Signal in a Voxel

```
% Load NIfTI data using load_nii from Jimmy Shen's NIfTI toolbox
data_folder = '/Users/lena/Documents/Lena/Lehre/fMRI/content_data/sub-01/func';

cd(data_folder)

nii = load_nii('sub-01_task-LTM_run-1_bold.nii.gz');
% Automatically handles .nii or .nii.gz

Y = nii.img;  % Dimensions: [x, y, z, time] % Extract 4D data array

x = 53; y =62; z = 25; % Choose voxel coordinates

ts = squeeze(Y(x, y, z, :)); % Extract the time series at the voxel

% Plot the time series
plot(ts);
xlabel('Time (TRs)');
ylabel('BOLD signal intensity');
title(sprintf('Time series at voxel [%d %d %d]', x, y, z));
```

Goal: Inspect time series in a single voxel to see BOLD signal variability.

Exercise 3: Design Matrix Visualization

```
% Create 2 regressors (conditions)
T = 200;
R1 = zeros(T,1); R2 = zeros(T,1);
R1(20:40) = 1; R2(80:100) = 1;

% Create 6 motion regressors
motion = randn(T,6)*0.1;

% Combine into design matrix
X = [R1 R2 motion];

% Visualize
imagesc(X); colormap(gray);
xlabel('Regressors'); ylabel('Timepoints');
title('Design Matrix');
```

Goal: Build a simple GLM with two conditions and motion regressors.

Hands-on exercises

Questions

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