Statistical Analysis of EEG

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Contents

1 Install

1.1 EAV and libMFF

```
/Shared/Users/Erik/EAV/systemPython/EAV.app.tar.gz
/Shared/Users/Erik/libMFF/build_python/libMFF.so
```

- EAV will be installed in /Applications/EAV/
- Put libMFF.so in GeoPy/mff_python/

1.2 anaconda

```
http://continuum.io/downloads
```

- Download Mac OS X - 64 Bit Python 27 Graphical Installer
- Install Anaconda-2.2.0-MacOSX-x86_64.pkg
- In .profile: will be added

```
# added by Anaconda 2.2.0 installer
export PATH="/Users/jesong1126/anaconda/bin:$PATH"
```

1.3 RabbitMQ

- Downloading and Installing RabbitMQ from http://www.rabbitmq.com/
  Installation Guide
  Mac OS X: Homebrew
  Open a terminal.

```
jesong1126$ brew update
jesong1126$ brew install rabbitmq
==> Downloading https://homebrew.bintray.com/bottles/rabbitmq-3.4.4.mavericks.bo
######################################################################## 100.0%
==> Pouring rabbitmq-3.4.4.mavericks.bottle.tar.gz
==> Caveats
Management Plugin enabled by default at http://localhost:15672

Bash completion has been installed to:
  /usr/local/etc/bash_completion.d

To have launchd start rabbitmq at login:
    ln -sfv /usr/local/opt/rabbitmq/*.plist ~/Library/LaunchAgents
Then to load rabbitmq now:
    launchctl load ~/Library/LaunchAgents/homebrew.mxcl.rabbitmq.plist
Or, if you don't want/need launchctl, you can just run:
    rabbitmq-server
==> Summary
??  /usr/local/Cellar/rabbitmq/3.4.4: 1030 files, 27M
jasminesongspro:Cellar jesong1126$ cd /usr/local/sbin
jasminesongspro:sbin jesong1126$ ls
rabbitmq-defaults rabbitmq-plugins  rabbitmqadmin
rabbitmq-env      rabbitmq-server   rabbitmqctl
jasminesongspro:sbin jesong1126$ ./rabbitmq-server -detached
Warning: PID file not written; -detached was passed.
```

- In .profile

```
export PATH=/usr/local/sbin:$PATH
```

- In Chrome

```
localhost:15672/#/
id: guest
pw: guest
```

1.4 pika

1.4.1 python

- In ternimal

```
jasminesongspro:~ jesong1126$ sudo pip install pika==0.9.8
Password:
Downloading/unpacking pika==0.9.8
  Downloading pika-0.9.8.tar.gz (56kB): 56kB downloaded
  Running setup.py (path:/private/tmp/pip_build_root/pika/setup.py) egg_info for package pika

Installing collected packages: pika
  Running setup.py install for pika

Successfully installed pika
Cleaning up...
jasminesongspro:~ jesong1126$
```

- In .profile

```
export PYTHONPATH=$PYTHONPATH:/usr/local/lib/python2.7/site-packages
```

1.4.2 anaconda ipython

```
jesong1126$ conda install -c https://conda.binstar.org/auto pika
Fetching package metadata: ......
Solving package specifications: .
Package plan for installation in environment /Users/jesong1126/anaconda:

The following packages will be downloaded:

    package                    |            build
    ---------------------------|-----------------
    conda-env-2.1.4            |           py27_0          15 KB
    pika-0.9.13                |           py27_0          96 KB
    pip-6.1.1                  |           py27_0         1.4 MB
    ------------------------------------------------------------
                                           Total:         1.5 MB

The following NEW packages will be INSTALLED:

    pika:      0.9.13-py27_0

The following packages will be UPDATED:
```

```
    conda-env: 2.1.3-py27_0 --> 2.1.4-py27_0
    pip:       6.0.8-py27_0 --> 6.1.1-py27_0

Proceed ([y]/n)? y

Fetching packages ...
conda-env-2.1. 100% |################################| Time: 0:00:00 178.07 kB/s
pika-0.9.13-py 100% |################################| Time: 0:00:00 374.93 kB/s
pip-6.1.1-py27 100% |################################| Time: 0:00:01   1.35 MB/s
Extracting packages ...
[      COMPLETE      ]|##################################################| 100%
Unlinking packages ...
[      COMPLETE      ]|##################################################| 100%
Linking packages ...
[      COMPLETE      ]|##################################################| 100%
jesong1126$
```

1.5 GeoPy

Unzip GeoPy_04102015.zip

2 PermuStat

This manual is a tutorial for PermuStat. To start Python and type in terminal:

```
$ python PermuStat.py
```

1. Data: select the segmented mff file. Then it reads all events and Categories will be listed in Test tab later that you can choose. If you select Head Model folder and Method, then the sources are estimated.
2. Source: Scalp vs Source
3. Level: Individual vs Group
4. Parametric: Parametric vs Nonparametric: For parametric test, it can perform both one sample, two sample t-tests, paired sample t-tests and anova. For nonparametric test, it can only perform two sample t-test and takes a time to finish the statistics.
5. Stat:
   - Significant Level: type your significant level
   - Output Suffix : type the suffix for the output files (Stat, Pval).
   - Num. Simulation: For nonparametric, type the number of resampling.
6. Test: For parametric test, you can choose both one sample and two sample t-tests.
   - Category 1: For one sample t-test, choose one category.
   - Category 2: For two sample t-test, choose another category.
7. Run: The tests are performed on the data. and some image plots will be showed.
8. Save: the files are save with output suffix and open EAV.
9. When EAV is open, load Head model folder.
10. specify the time point, channel and dipole to view.
11. Close: PermuStat will be closed.

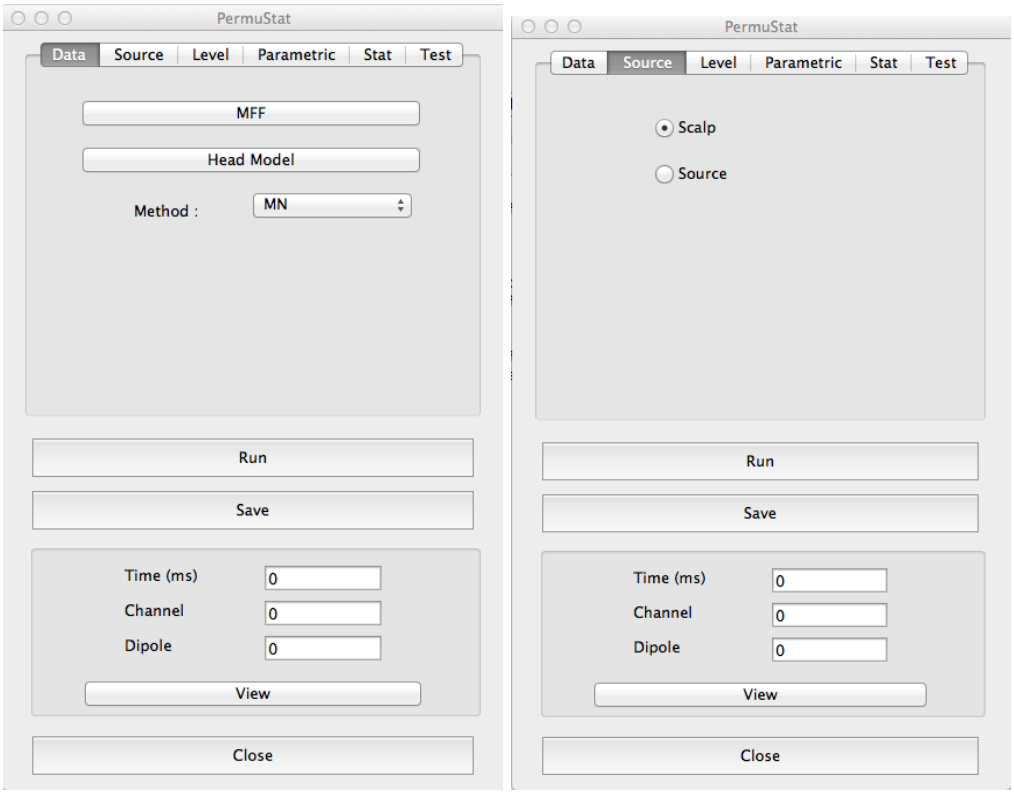

Figure 1: Python GUI PermuStat

Figure 2: Python GUI PermuStat

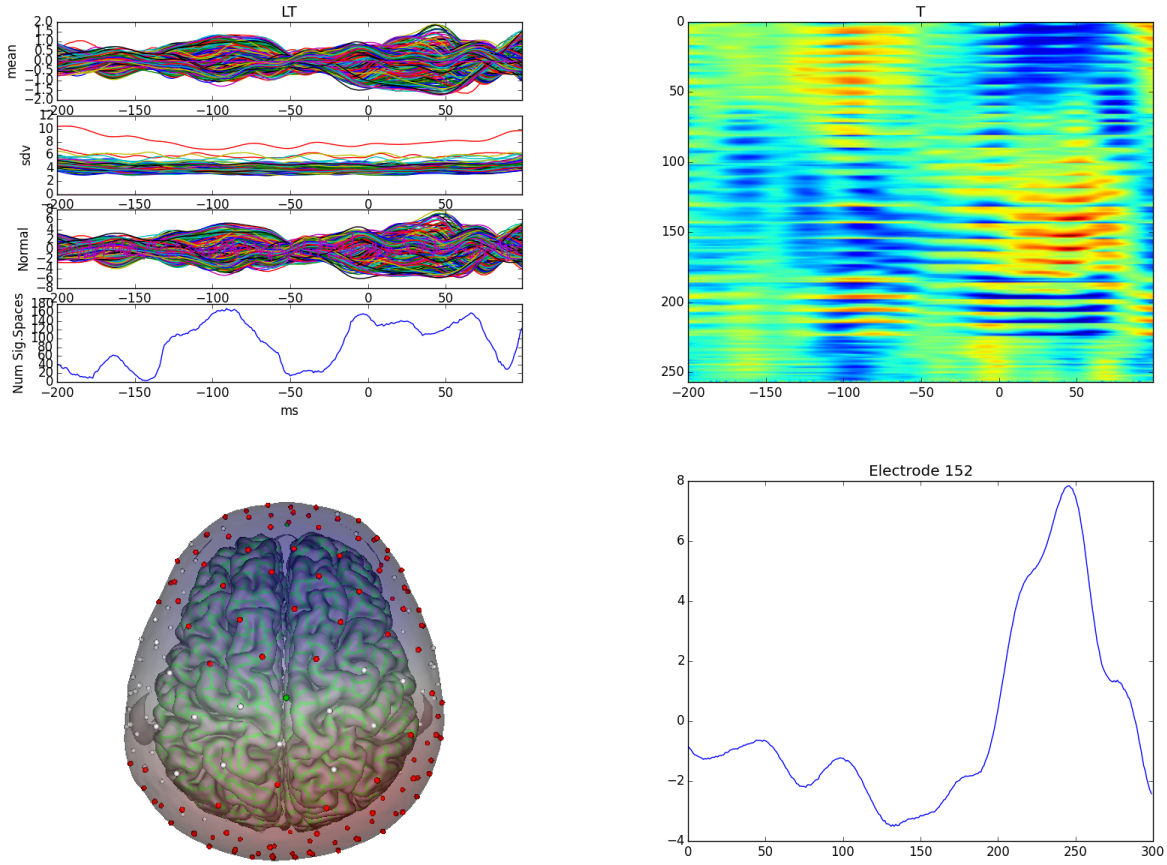

Figure 3: One Sample T test: (a) mean of single trials; (b) standard deviation; (c) mean/sd (d) number of significant spaces over time (e) image plot of Statistics values (T) which are normalized (f) Significant electrodes at time 45 ms (g) statistics at electrode 152 over time

3 Parametric test

Parametric test performs both one sample t-test, two sample t-test and anova.

$$\Phi = KS + \varepsilon, \tag{1}$$

Φ is the observed scalp eeg data. K is the lead field matrix, S is the source to be estimated, ε is the noise. The data size of scalp mff is $I \times T \times J$, where I is the number of channels, T is the number of samples and J is the number of trials. If there are two categories, say R and L, $J_R + J_L = J$.

3.1 One sample t-test

Consider the each trial as observed data. We have $I \times T$ tests.

$$H_0 : \Phi_{it} = 0, \text{ for } i = 1, \ldots, I \text{ and } t = 1, \ldots, T \tag{2}$$

$\bar{\Phi}_{it\bullet}$ is the average over trials and σ_Φ is the sample standard deviation over trials for each i and t. Then T-statistic at i and t is

$$T_{it} = \frac{\bar{\Phi}_{it\bullet} - 0}{\sigma_\Phi / \sqrt{J}}, \text{ with d.f.} = J - 1 \tag{3}$$

Table 1: ANOVA

Source of Variance	SS	df	MS	F	p-val
Between Groups	$\sum_{i=1}^{k} n_i(\bar{x}_i - \bar{x}_\bullet)^2$	$k-1$	$\frac{\sum_{i=1}^{k} n_i(\bar{x}_i - \bar{x}_\bullet)^2}{(k-1)}$	$\frac{MS_B}{MS_W}$	$F_{(k-1,n-k)}$
Within Groups	$\sum_{i=1}^{k}\sum_{j=1}^{n_i}(x_{ij} - \bar{x}_i)^2$	$n-k$	$\frac{\sum_{i=1}^{k}\sum_{j=1}^{n_i}(x_{ij} - \bar{x}_i)^2}{(n-k)}$		
Total	$\sum_{i=1}^{k}\sum_{j=1}^{n_i}(x_{ij} - \bar{x}_\bullet)^2$	$n-1$			

Suppose the significant level is α (typically 0.05). The p-values is $P(t_{(J-1)} > T_{it})$. If p-value $< \alpha$, the H_0 is rejected, i.e. $\Phi \neq 0$ at i and t. Since we have multiple comparison problems(MCP), we need to correct the significant level to control the familywise error rate(FWER). For correcting MCP, use the most conservative method, Bonferroni corrections, which assume all tests are independent hence the corrected significant level is $\alpha/(I \times T)$. We can consider MANOVA(Multivatiate ANalysis Of VAriance).

3.2 Two sample t-test

We would like to test that two categories (R and L) are different or not.

$$H_0 : R_{it} = L_{it}, \text{ for } i = 1, \ldots, I \text{ and } t = 1, \ldots, T \tag{4}$$

$\bar{R}_{it\bullet}$ is the average over trials and σ_R is the sample standard deviation over trials of category R, $\bar{L}_{it\bullet}$ is the average over trials and σ_L is the sample standard deviation over trials of category L for each i and t. Then unequal sample sizes but equal variance T-statistic at i and t with d.f.$= J_R + J_L - 2$ is

$$T_{it} = \frac{\bar{R}_{it\bullet} - \bar{L}_{it\bullet}}{\sigma_{RL}\sqrt{1/J_R + 1/J_L}}, \text{ where } \sigma_{RL} = \sqrt{\frac{(J_R-1)\sigma_R^2 + (J_L-1)\sigma_L^2}{J_R + J_L - 2}} \tag{5}$$

The p-values is $P(t_{(J_R+J_L-2)} > T_{it})$. If p-value $< \alpha$, the H_0 is rejected, i.e. $R_{it} \neq L_{it}$ at i and t. Two categories are significantly different at i and t.

3.3 ANOVA

We would like to test that two or more categories are different or not. Suppose there are k levels in group (category) and n samples. $H_0 : x_1 = x_2 = \cdots = x_k$ and H_A : at least one mean is not statistically equal. We reject the null hypothesis H_0 if only one mean is not equal.

4 Nonparametric test

Nonparametric test only performs two sample t-test. The method is in (2), (3) (1), (4).

1. Collect the trials of two experimental conditionals in a single set.
2. Randomly draw as many trials from this combined data set as there were trials in category 1 and place those trials into subset 1. Place remaining trials in subset 2. The result of this procedures is called a random partition.
3. Calculate the test statistic on this random partition.
4. Repeat step 2 and 3 a large number of times and construct the distribution(histogram) of the test statistics.
5. Compare the test statistics from the observed data to the distribution form step 4. calculate the proportion of random partitions that resulted in a larger test statistics than the test statistics from observed data. The proportion is called the p-value.

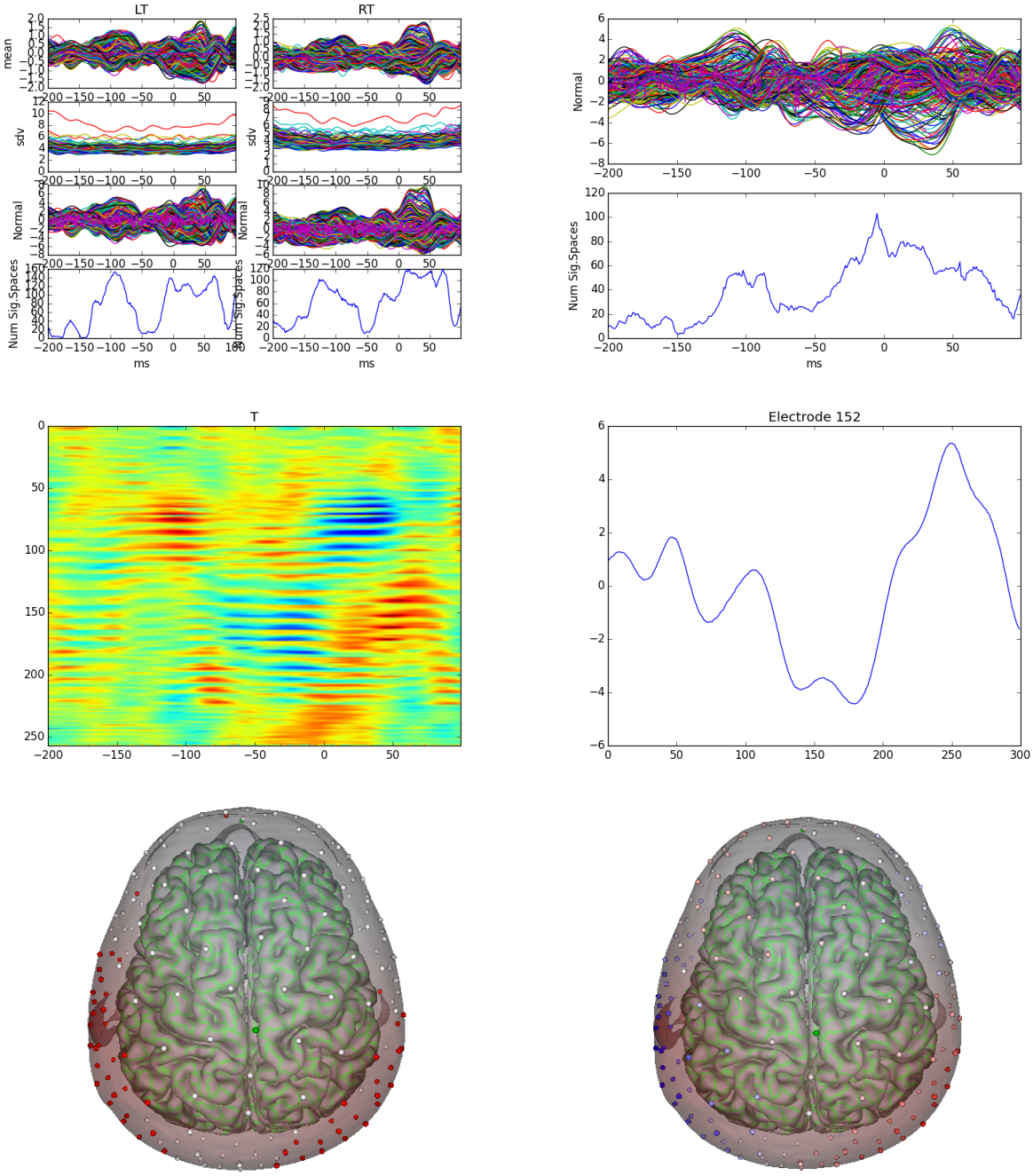

Figure 4: Two Sample T test: (a) mean of single trials; standard deviation; mean/sd; number of significant spaces over time (b) t-statistics and number of significants over time (c) image plot of Statistics values (T) which are normalized (d) statistics at electrode 152 over time (e) Significant electrodes at time 45 ms (f) statistics at time 45 ms

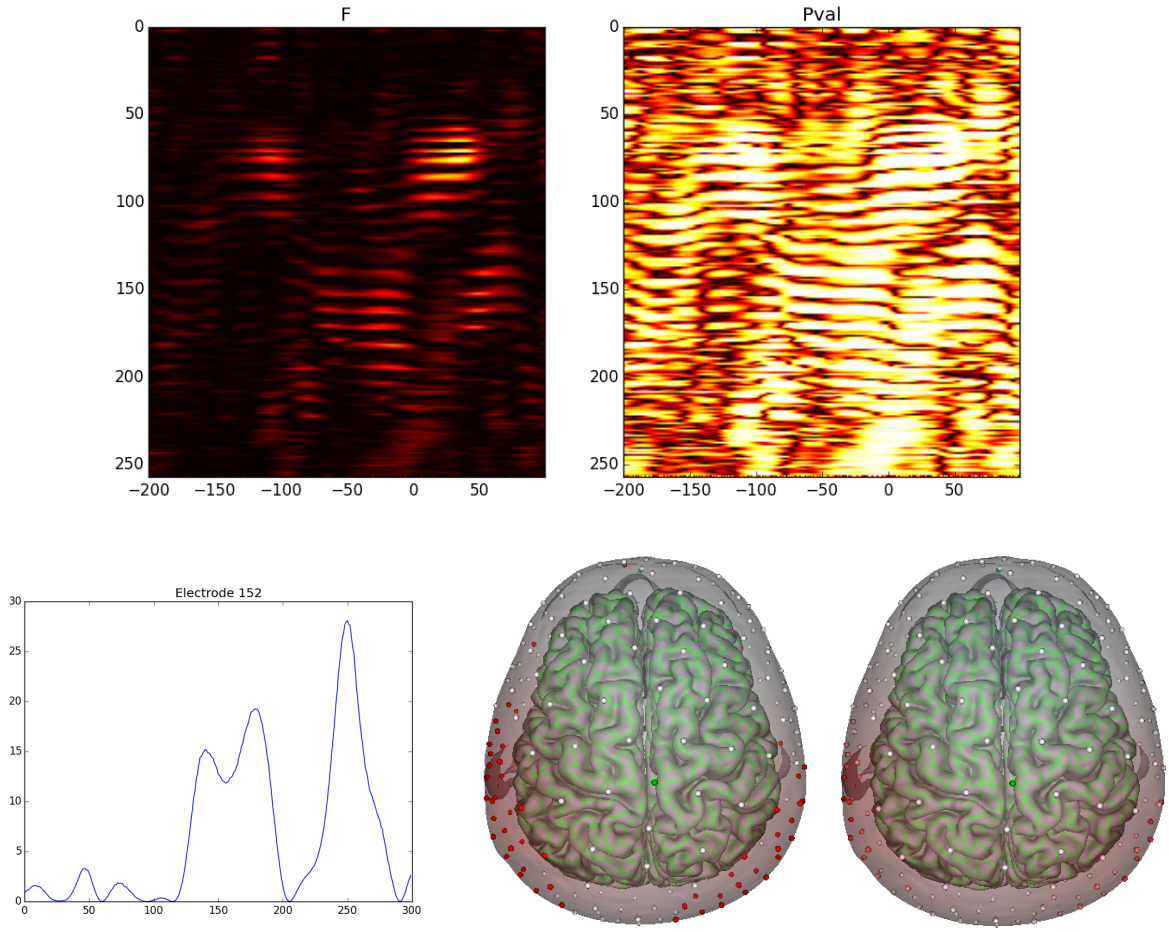

Figure 5: ANOVA: (a) F statistics (b) p-value (c) statistics at electrode 152 over time (d) Significant electrodes at time 45 ms (e) F statistics at time 45 ms

6. If the p-value is smaller than the critical α-level (typically 0.05) then conclude the data in two experimental categories are significantly different.

References

[1] Eric Maris and Robert Oostenveld. Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods*, 164:177–190, 2007.

[2] T.E. Nichols and A.P. Holmes. Nonparametric permutation tests for functional neuroimaging: a primer with examples. *Human Brain Mapping*, 15:1–25, 2002.

[3] D. Pantazis, T.E. Nichols, S. Baillet, and R.M. Leahy. A comparison of random field theory and permutation methods for the statistical analysis of MEG data. *NeuroImage*, 25:383–94, 2005.

[4] Jasmine Song, Phan Luu, and Don M Tucker. Nonparametric Statistical Analysis for EEG Source Localization. In *OHBM Hamburg*, 2014.