Math and Matlab for Neuroscientists
(mini-course, RSS 2017)

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Purpose

The purpose of this course is to introduce you to advanced neural time series (LFP/EEG/MEG) analyses. If you want to analyze your neuroscience data completely on your own, this course will certainly help get you started. It will also provide a firm basis for using analysis toolboxes such as eeglab or fieldtrip, although you will not learn how to use those toolboxes in this course.

Organization

There will be 15 sessions (3x a day, 5 days), each lasting 120 minutes (with break). Each class is a mixture of lecture and hands-on work. Optional homeworks are assigned daily. Solutions will be emailed the following day.

Lectures cover the mathematical and theoretical bases behind data processing and analyses. "Hands-on" means you will work with real EEG data in Matlab, programming and applying the material covered in the lecture. Working in groups is encouraged.

What to bring to class?

Bring paper and a pen/pencil. You will need to take notes, write down equations, and draw diagrams, and paper is better than computer. **Lecture slides will not be made available!**

You should bring your own laptop with Matlab and the EEGLAB toolbox. Matlab scripts and sample data will be posted on the web (mikexcohen.com/rss). Even if you have your own data, you should use the course data for assignments. You can work on your own data in parallel.

What do I need to know before class?

Nothing about EEG data analyses. However, you will need some Matlab background. There are many introduction-to-matlab tutorials on the web. That said, the more you know about neuroscience data analysis and Matlab programming, the more you will get from the course.

The trinity of EEG data analysis equations

There are three equations that you must learn by heart in this class. These form the mathematical bases of most advanced EEG data analyses. The more familiar you are with these equations, the easier it will be to learn EEG data analyses. ***You must memorize these formulas and you will be expected to recall them from memory during class!***

Sine wave: $A\sin(2\pi ft+\theta)$

"Aey sine two pie eff tee plus theta"

Euler's formula: $Me^{ik}=M(\cos(k)+i\sin(k))$

"Em ee to the eye kay equals em cosine kay plus eye sine kay"

Gaussian: $e^{-t^2/2s^2}$

"ee to the minus tee squared over two ess squared"

MMN course schedule

Dates: 14-18 August
Lecture 0: 9:00 to 9:30 [note: this is an optional Q&A session]
Lecture 1: 9:30 to 12:00
Lecture 2: 13:30 to 15:00
Lecture 3: 15:30 to 17:30

Location: Erasmus E 2.50

n.b. this schedule is subject to minor adjustments!

Monday
Lecture 1: [***note: starts at 11.00!***] Introduction to EEG/LFP analyses
Lecture 2: Sine waves and dot products
Lecture 3: Complex numbers, Euler's formula

Tuesday
Lecture 1: Fourier transform
Lecture 2: More on the Fourier transform (frequency resolution, zero-padding, etc.)
Lecture 3: Complex Morlet wavelets, convolution theorem

Wednesday
Lecture 1: Getting power and phase results from wavelet convolution
Lecture 2: Parameters and their effects on TF results. Baseline normalization.
Lecture 3: Other time-frequency methods: filter-Hilbert, STFFT, multitaper

Thursday
Lecture 1: Introduction to linear algebra (vectors, matrices, rank)
Lecture 2: Matrix analysis (least-squares, eigendecomposition)
Lecture 3: Source separation and spatial filtering via generalized eigendecomposition

Friday
Lecture 1: Introduction to connectivity
Lecture 2: Statistics: permutation testing and multiple comparisons
Lecture 3: Statistics: group-level analyses [***note: this class might be cut short depending on time***]