



# The electroencephalogram (4)

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# A plan for today

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- Finish skimming EEG analyses
- Introduce a set of tools and equipment that you may want to deal with
- ~~Start the course section on Electromyography~~
- Start a hands-on minicourse on signal processing
  - Frequency analysis
  - Filtering

# Time-frequency analysis

It's able to make the analysis of the spectrum of the signal in a time varying meter

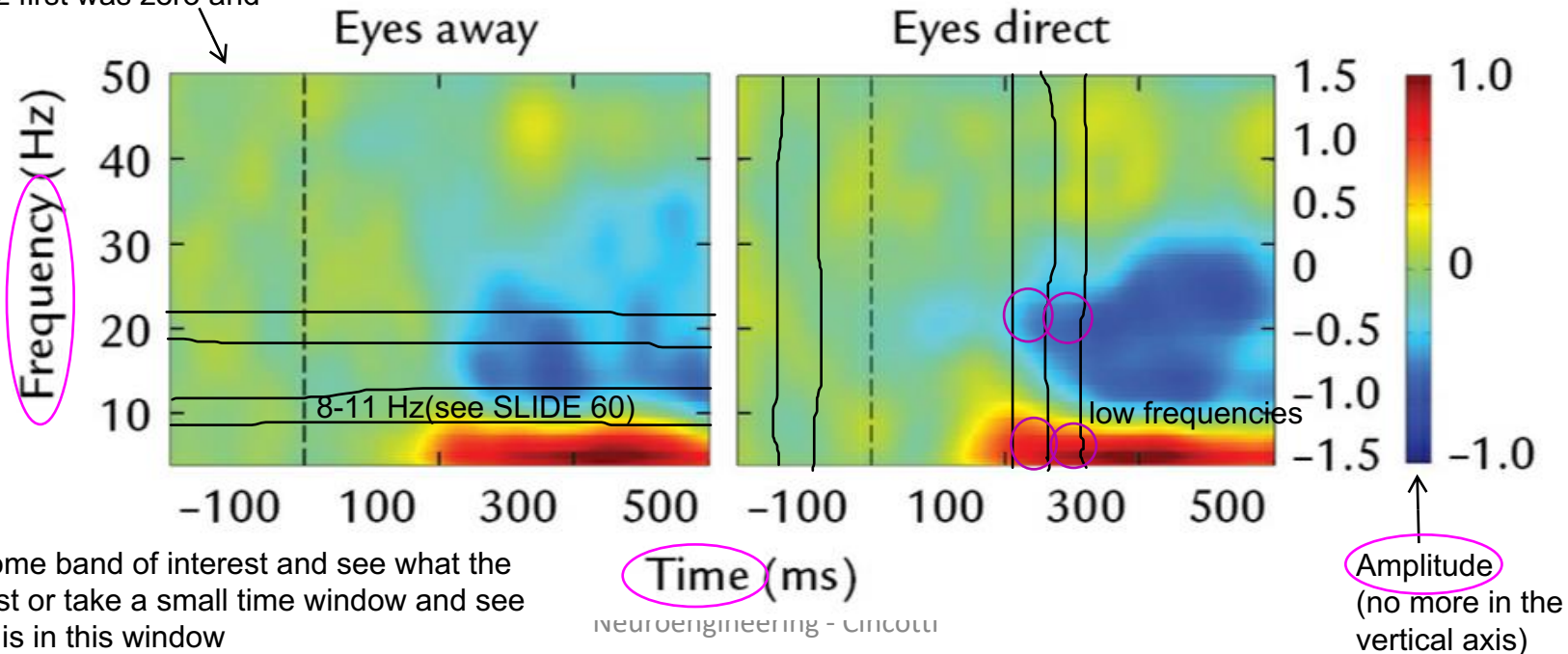
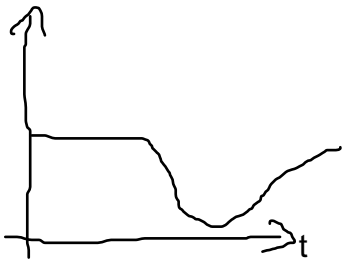
- Time–frequency analyses go one step further by computing and visualizing the spectral or amplitude content of the signal as a function of time simultaneously for all frequencies of interest.
- Fourier transforms, Hilbert transforms, and wavelet-based approaches can be used to calculate MEG/EEG signal power (amplitude)
- Using this procedure, features in MEG/EEG data can be visualized in both time and frequency.

Short time

the x axes(that previously was the amplitude), now is used for another domain(frequency)

In the range 8-11 Hz the frequency was first zero and then it increases(yellow), at 20Hz first was zero and then it decreases(blue)

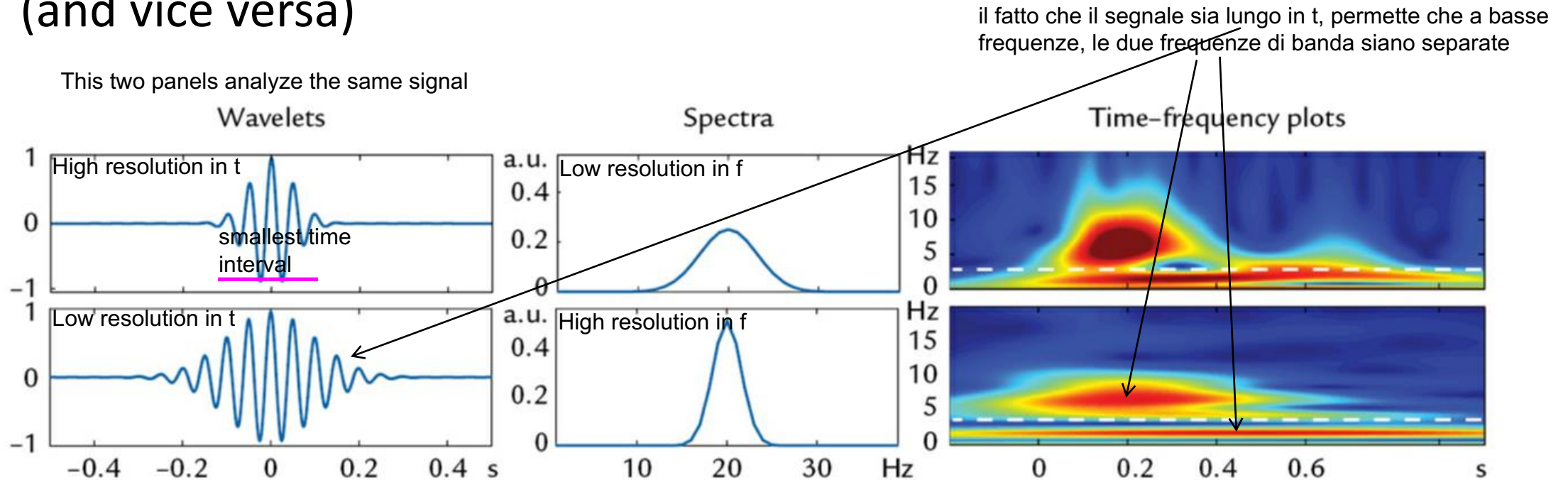
amplitude



For analyze that you can take some band of interest and see what the time course in this band of interest or take a small time window and see what the spectrum of the signal is in this window

# Time-frequency analysis – «indetermination principle»

- Improving time resolution worsens spectral resolution (and vice versa)



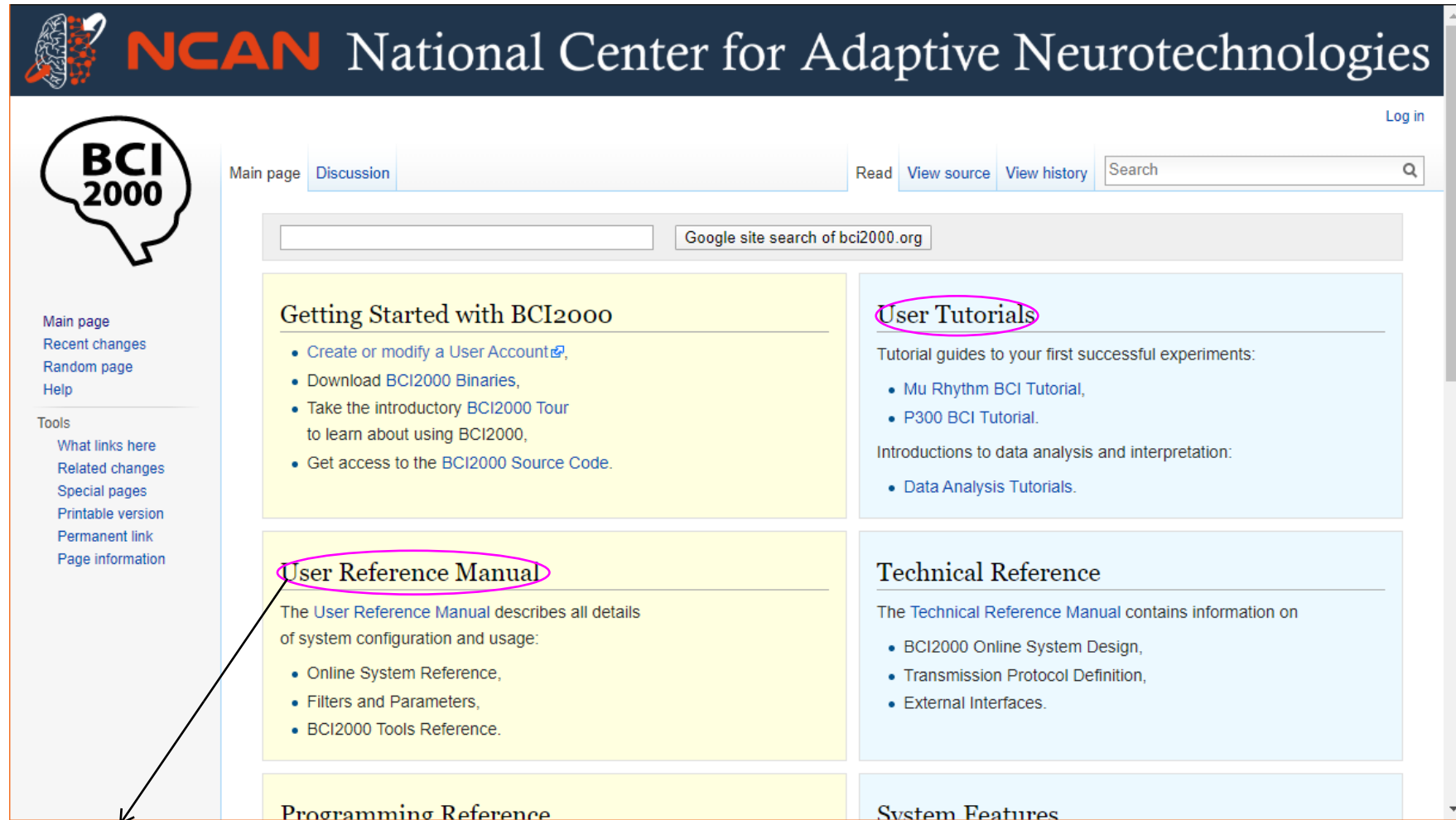
You can't have high time resolution and high frequency resolution at the same time (you can achieve tools but you will have a marginal improvement)

In the upper panel you will have a better resolution in the horizontal axis, in the lower panel you will have a better resolution in the vertical axis

# Further reading

- Ch 12. auditory responses, including steady-state
- Ch 13. visual responses, including steady-state
- Ch 14. somatosensory responses
- Ch 16. motor function
- Ch 17. change detection (CNV, MMN, P300, ErrN, ...)

Software tools



The screenshot shows the BCI2000 website homepage. At the top is a dark blue header with the NCAN logo (a brain with a red electrode) and the text "NCAN National Center for Adaptive Neurotechnologies". Below the header, on the left, is a sidebar with a "BCI 2000" logo in a speech bubble and a list of links: "Main page", "Recent changes", "Random page", "Help", "Tools", "What links here", "Related changes", "Special pages", "Printable version", "Permanent link", and "Page information". The main content area has a navigation bar with "Main page" (selected), "Discussion", "Read", "View source", and "View history". To the right of the navigation bar is a search box. Below the navigation bar is a "Google site search of bci2000.org" box. The main content area is divided into several sections: "Getting Started with BCI2000" (yellow background) with a list of links: "Create or modify a User Account", "Download BCI2000 Binaries", "Take the introductory BCI2000 Tour to learn about using BCI2000", and "Get access to the BCI2000 Source Code"; "User Reference Manual" (yellow background) with a description: "The User Reference Manual describes all details of system configuration and usage:" and a list of links: "Online System Reference", "Filters and Parameters", and "BCI2000 Tools Reference"; "User Tutorials" (light blue background) with a description: "Tutorial guides to your first successful experiments:" and a list of links: "Mu Rhythm BCI Tutorial", "P300 BCI Tutorial", and "Data Analysis Tutorials"; "Technical Reference" (light blue background) with a description: "The Technical Reference Manual contains information on" and a list of links: "BCI2000 Online System Design", "Transmission Protocol Definition", and "External Interfaces"; "Programming Reference" (yellow background); and "System Features" (light blue background). Annotations include a pink oval around "User Tutorials", a pink oval around "User Reference Manual", and a black arrow pointing from the "User Reference Manual" section to the "Tools" link in the sidebar.

NCAN National Center for Adaptive Neurotechnologies

Log in

Main page Discussion Read View source View history Search

Google site search of bci2000.org

**Getting Started with BCI2000**

- Create or modify a User Account
- Download BCI2000 Binaries,
- Take the introductory BCI2000 Tour to learn about using BCI2000,
- Get access to the BCI2000 Source Code.

**User Reference Manual**

The User Reference Manual describes all details of system configuration and usage:

- Online System Reference,
- Filters and Parameters,
- BCI2000 Tools Reference.

**User Tutorials**

Tutorial guides to your first successful experiments:

- Mu Rhythm BCI Tutorial,
- P300 BCI Tutorial.

Introductions to data analysis and interpretation:

- Data Analysis Tutorials.

**Technical Reference**

The Technical Reference Manual contains information on

- BCI2000 Online System Design,
- Transmission Protocol Definition,
- External Interfaces.

**Programming Reference**

**System Features**

For more advanced tools that are not in the "User Tutorials"

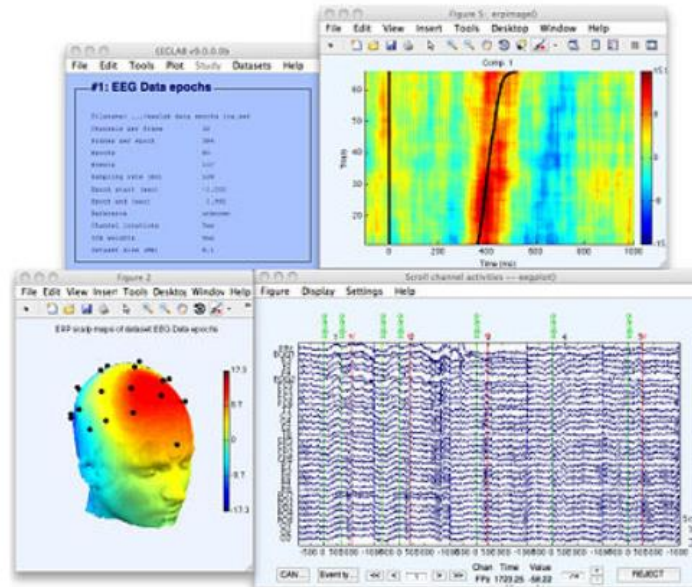
<https://www.bci2000.org>





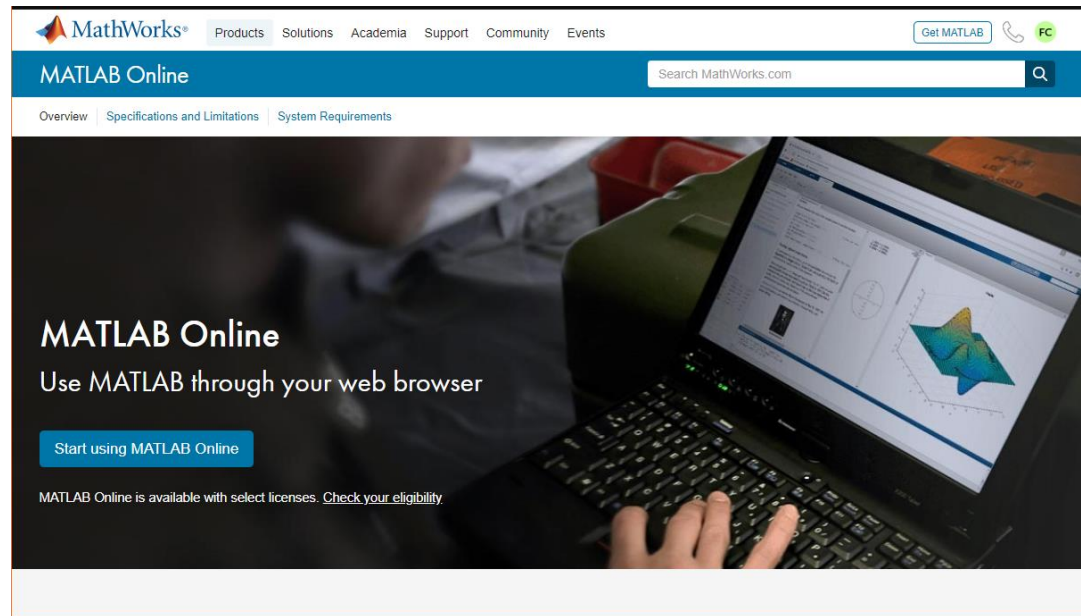
## What is EEGLAB?

EEGLAB is an interactive Matlab toolbox for processing continuous and event-related EEG, MEG and other electrophysiological data incorporating independent component analysis (ICA), time/frequency analysis, artifact rejection, event-related statistics, and several useful modes of visualization of the averaged and single-trial data. EEGLAB runs under Linux, Unix, Windows, and Mac OS X.




# Matlab

We will use it to learn very basic signal process



<https://www.mathworks.com/products/matlab-online.html>





**SAPIENZA**  
UNIVERSITÀ DI ROMA

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**CAMPUS**  
**Software**

Campus Uniroma1 RESTRICTED area  
Welcome febo cincotti, logged as: Personale  
your mail is: Febo.Cincotti@uniroma1.it  
your ip address is: 151.100.47.183  
logout >

### Software available for download

(Note: use Firefox if the ftp page is not visible or the ftp link is broken)

Software	Installation info	Download link
	info	SPSS
	Download SetiNIT file	SAS
	Download license.dat and activation key	Matlab
	Info on license server	Mathematica

<http://bit.ly/install-matlab-sapienza>

It is developed in Python

Magnetoenceelography  
(you do not mesure  
potencial but magnetic  
fields)


This is more strong  
for MEG and not so  
much for EEG

The screenshot displays the MNE Python software website. At the top, a dark navigation bar contains the MNE logo, links for 'Install', 'Overview', 'Tutorials', 'Examples', 'Glossary', 'API', and 'Contribute', and a version indicator 'v0.19.2'. A search bar is located on the right side of this bar. Below the navigation bar, the large 'MNE' logo is prominently displayed. To its right, the text 'Multi-core CPU & GPU.' is visible. Below the logo, the text 'MEG+ EEG ANALYSIS & VISUALIZATION' is shown, with 'MEG' circled in pink. To the right of this, the word 'Usability' is accompanied by an eye icon, and the phrase 'Clean scripting & visualization.' is below it. Further down, the word 'Flexibility' is accompanied by a list icon, and the phrase 'Broad data format & analysis support.' is below it. The main content area features a 'Data visualization.' section with the text 'Explore your data from multiple perspectives.' and a 'Check it out' button. Below this, a series of five circles indicates the current step in a sequence. At the bottom, three dark buttons are labeled 'Data I/O', 'Preprocessing', and 'Visualization'. On the left side of the 'Data visualization.' section, there is a small circular plot with a color scale and the text 'N<sub>ave</sub>=61' and 'fT/cm'.

<https://mne.tools/>

Freely available datasets

The database of EEG is not so large  
PhysioNet is a database for physiological signals including electro physiological signals

**PhysioNet** Find Share About News Account ▾ Search 

## Databases

- Clinical
- Waveform
  - Multiparameter
  - ECG
  - RR Interval
  - Other Cardio
  - Gait and Balance
  - Neuroelectric
  - Synthetic
- Image
- Miscellaneous

## Suggested Citation

If you use resources from PhysioNet in a publication, please credit the author(s) using the citation displayed at the top of the published content. Please also include the standard citation for PhysioNet:

Goldberger AL, Amaral LAN, Glass L, Hausdorff JM, Ivanov PCh, Mark RG, Mietus JE, Moody GB, Peng C-K, Stanley HE. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. *Circulation* **101**(23):e215-e220 [Circulation Electronic Pages; <http://circ.ahajournals.org>]

## Overview

This page displays a current search of our resources.

- Clinical Databases: Clinical measurements, imaging reports, and imaging reports
- Waveform Databases: Waveform data are organized according to the following categories:
  - Multi-Parameter: Blood pressure, respiration, heart rate, etc.

## Neuroelectric and Myoelectric Databases

- [Class 2] [CHB-MIT Scalp EEG Database](#): EEG recordings of 22 pediatric subjects with intractable seizures, monitored for up to several days following withdrawal of anti-seizure medication to characterize their seizures and assess their candidacy for surgical intervention. In all, the onsets and ends of 182 seizures are annotated.
- [Class 2] [EEG During Mental Arithmetic Tasks](#): The database contains EEG recordings of subjects before and during the performance of mental arithmetic tasks.
- [Class 2] [EEG Motor Movement/Imagery Dataset](#): One- and two-minute recordings of 109 volunteers performing a series of motor/imagery tasks. Each record contains 64 channels of EEG recorded using the BCI2000 system, and a set of task annotations.
- [Class 2] [EEG Signals from an RSVP Task](#): This project contains EEG data from 11 healthy participants upon rapid presentation of images through the Rapid Serial Visual Presentation (RSVP) protocol at speeds of 5, 6, and 10 Hz.
- [Class 2] [Effect of Deep Brain Stimulation on Parkinsonian Tremor](#): Rest tremor velocity in the index finger of 16 subjects with Parkinson's disease, who receive chronic high frequency electrical deep brain stimulation.
- [Class 2] [ERP-based Brain-Computer Interface recordings](#): Annotated 64-channel EEGs with 4-channel EOGs sampled at 2048 Hz from 10 subjects; 20 short records for each subject, generated while focusing on specified target characters displayed by a traditional matrix keypad. This dataset was generated as part of a

<https://physionet.org/about/database/#neuro>

## BCI Competitions



Here there are various type of stimulation or spontaneous activity

- [BCI Competition I](#)
- [BCI Competition II](#) (also called BCI Competition 2003)
- [BCI Competition III](#) → Have been used by various paper to test a signal
- [BCI Competition IV](#) → processing tool change so a classification tool change

## References

Please help us to make the list of references complete and keep it up to date by reporting unlisted papers to [benjamin.blankertz@tu-berlin.de](mailto:benjamin.blankertz@tu-berlin.de), preferably PubMed ID (PMID) or in BibTex format.

- B. Blankertz, K.R. Müller, D.J. Krusienski, G. Schalk, J.R. Wolpaw, A. Schlögl, G. Pfurtscheller, J.d.e.I. R. Millon, M. Schröder, and N. Birbaumer. The BCI competition. III: Validating alternative approaches to actual BCI problems. *IEEE Trans Neural Syst Rehabil Eng*, 14:153-159, Jun 2006. [\[pdf\]](#)
- B. Blankertz, K.R. Müller, G. Curio, T.M. Vaughan, G. Schalk, J.R. Wolpaw, A. Schlögl, C. Neuper, G. Pfurtscheller, T. Hinterberger, M. Schröder, and N. Birbaumer. The BCI Competition 2003: progress and perspectives in detection and discrimination of EEG single trials. *IEEE Trans Biomed Eng*, 51:1044-1051, Jun 2004. [\[pdf\]](#)
- P. Sajda, A. Gerson, K.R. Müller, B. Blankertz, and L. Parra. A data analysis competition to evaluate machine learning algorithms for use in brain-computer interfaces. *IEEE Trans Neural Syst Rehabil Eng*, 11:184-185, Jun 2003. [\[pdf\]](#)

3 references, last updated Tue, Jun 24 18:03:58 2008

<https://www.bbci.de/competition/>

Questa è la slide più bella

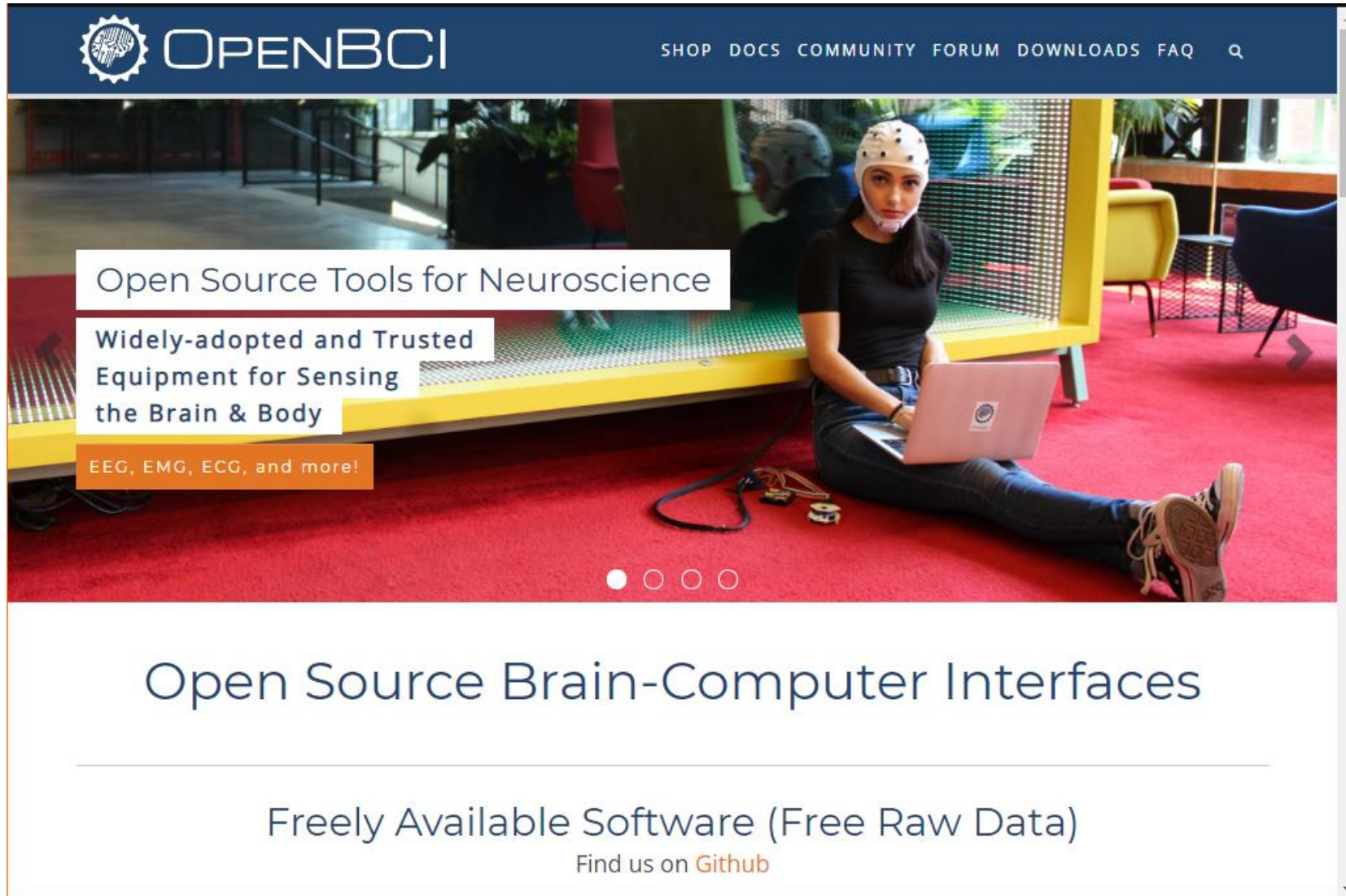
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- Many more ...



# Devices



The image shows the OpenBCI website banner. At the top is a dark blue header with the OpenBCI logo (a gear with a brain inside) and the text "OPENBCI". To the right of the logo are navigation links: "SHOP", "DOCS", "COMMUNITY", "FORUM", "DOWNLOADS", "FAQ", and a search icon. Below the header is a large photograph of a woman sitting on a red carpet, wearing a white EEG cap and using a laptop. Overlaid on the left side of the photo are three text boxes: "Open Source Tools for Neuroscience", "Widely-adopted and Trusted Equipment for Sensing the Brain & Body", and "EEG, EMG, ECG, and more!". Below the photo is a white section with the heading "Open Source Brain-Computer Interfaces", followed by the text "Freely Available Software (Free Raw Data)" and "Find us on Github".

OPENBCI

SHOP DOCS COMMUNITY FORUM DOWNLOADS FAQ

Open Source Tools for Neuroscience

Widely-adopted and Trusted Equipment for Sensing the Brain & Body

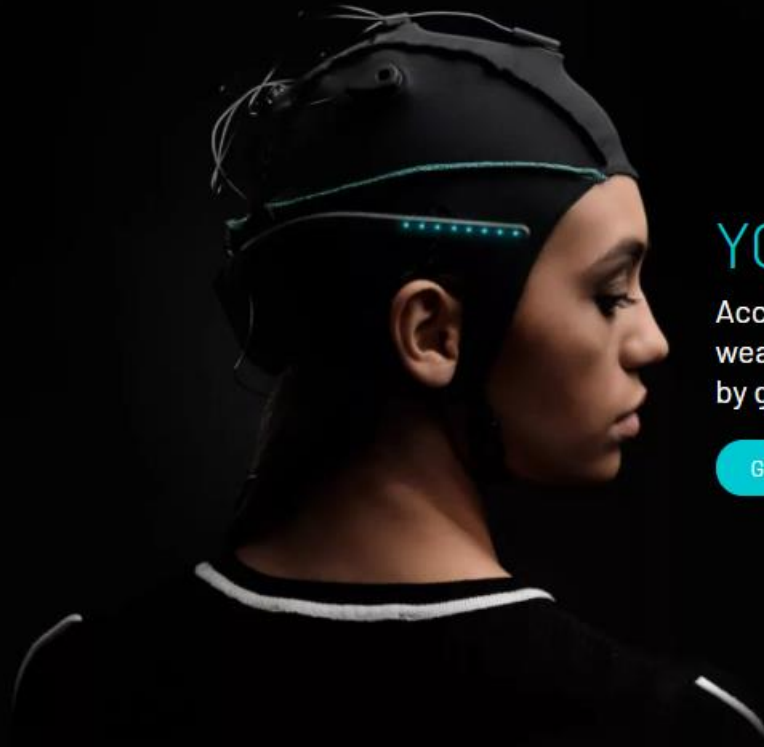
EEG, EMG, ECG, and more!

# Open Source Brain-Computer Interfaces

Freely Available Software (Free Raw Data)

Find us on [Github](#)

<https://openbci.com/>

[About](#)[Products](#)[Your Unicorn](#)[Ressources](#)[Shop](#)[Log in](#)

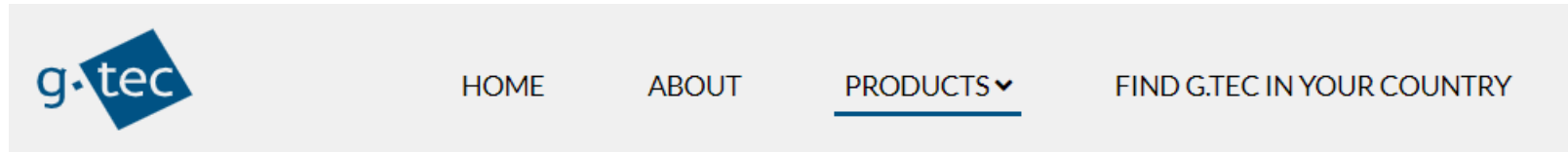
## YOU CAN THINK NOW.

Access your brain with Unicorn Hybrid Black. Your wearable, high-quality EEG headset by g.tec neurotechnology GmbH, Austria.

[GET YOURS](#)

<https://www.unicorn-bi.com/>

It is usefull for projects but is so expensive  
They have it at the hospital

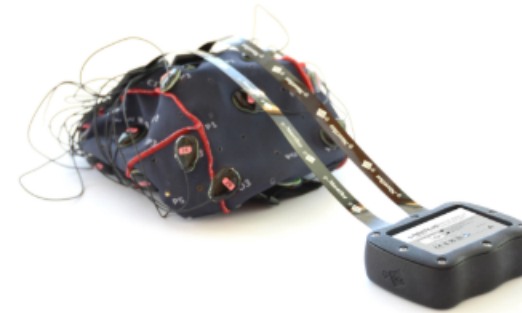


Products / g.NAUTILUS RESEARCH

32 channel

# g.NAUTILUS RESEARCH



WEARABLE EEG HEADSET



\$\$\$

<https://www.gtec.at/product/gnautilus-research/>


It have 14 channels and works wetting the electrodes  
It is cheap but it is not so satisfying

EMOTIV **GET STARTED** SOLUTIONS ▾ PRODUCTS ▾ THE SCIENCE ▾ DEVELOPERS RESOURCES ▾ STORE ▾ LOGIN CART / \$0.00  




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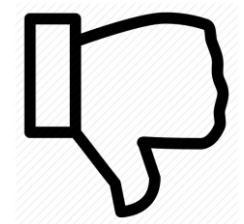
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