

Adaptive Mixture ICA (AMICA): Theory & Practicum

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Outline

Rationale
& Theory

- Why AMICA?
 - 1st reason: improve IC decomposition
 - 2nd reason: model EEG non-stationarity
- What is AMICA?
 - Model, learning, and parameters
- 3 sample results:
 - Sleep dynamics, drowsiness fluctuation, guided meditation
- How to run AMICA
 - EEGLAB GUI & MATLAB script
 - via Neuroscience Gateway (NSG)
- How to analyze AMICA results
 - Post-utility plugin

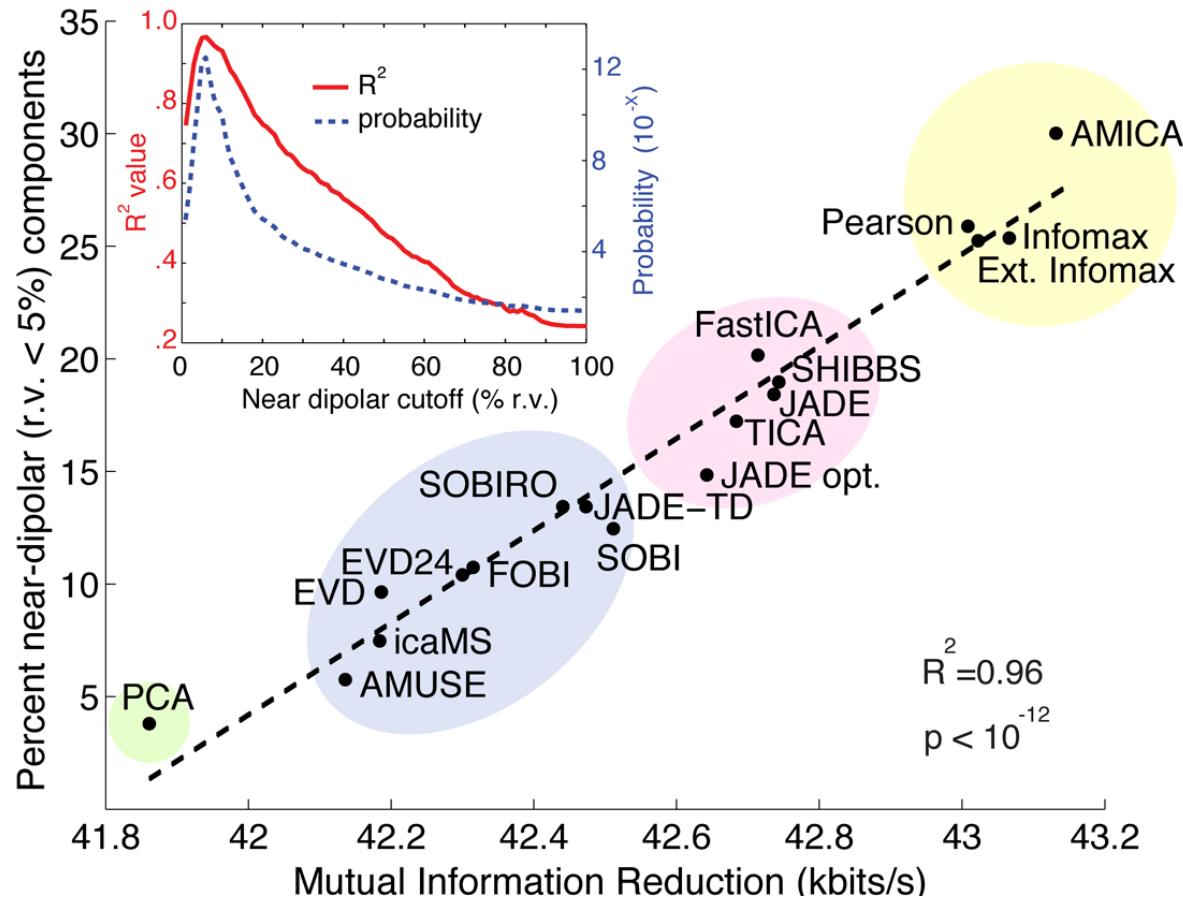
Practicum



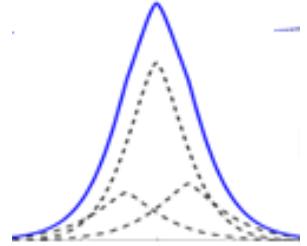
Why AMICA? 1st reason – improve IC decomposition



Jason Palmer

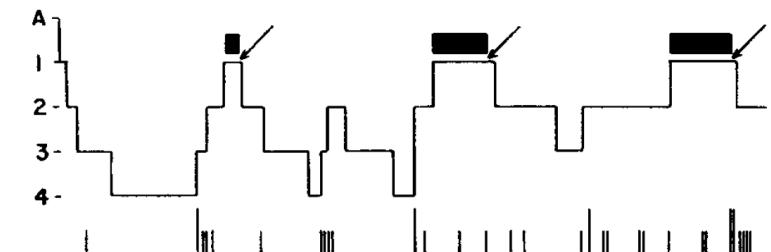
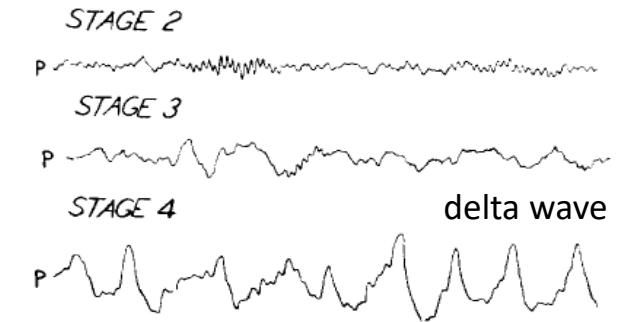
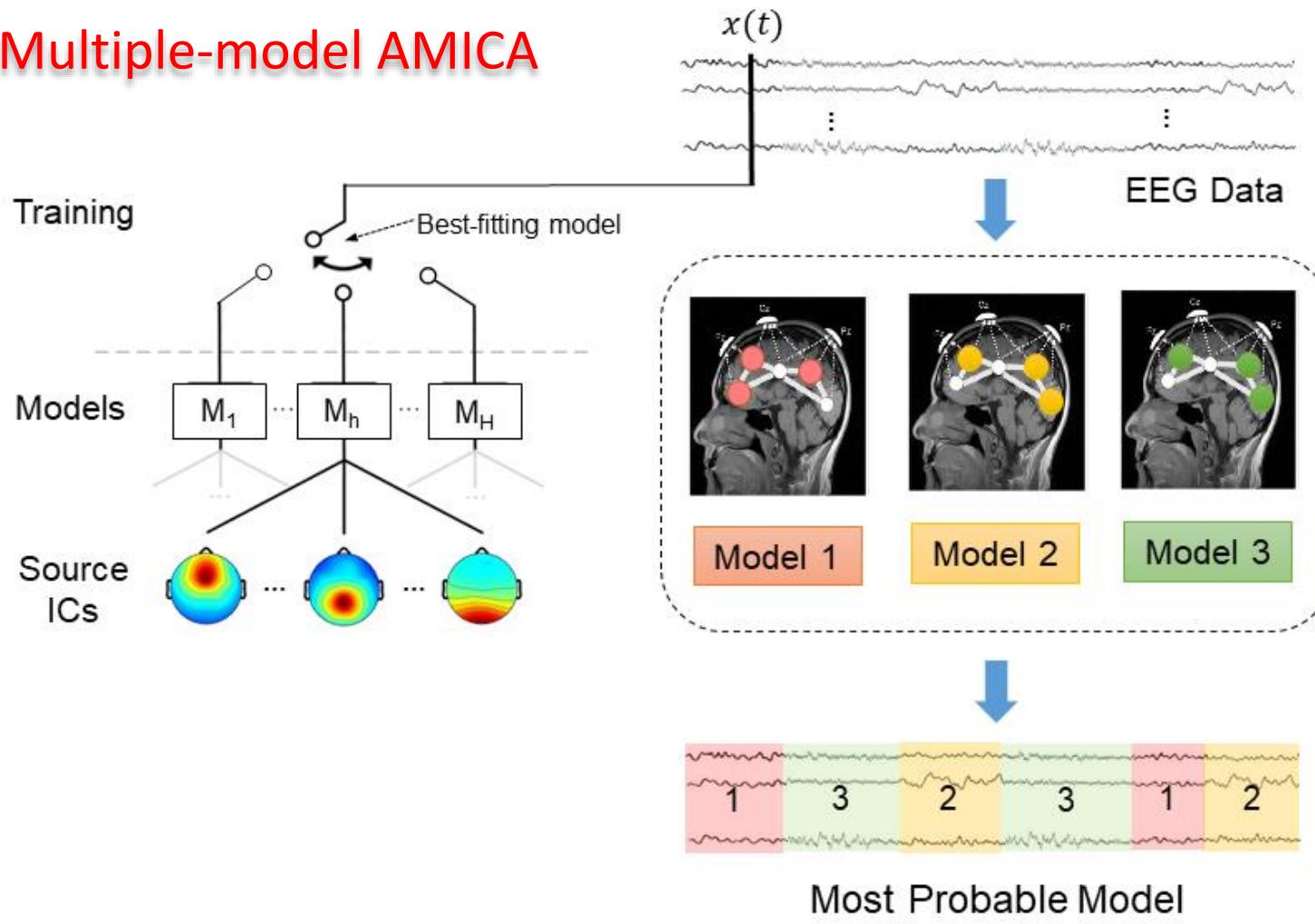


- More parameters:
Mixture source model
- Yet feasible to learn...
 - Convergence:
2-order Newton > 1-order gradient
- Computation time:
Parallel computing (pre-compiled)



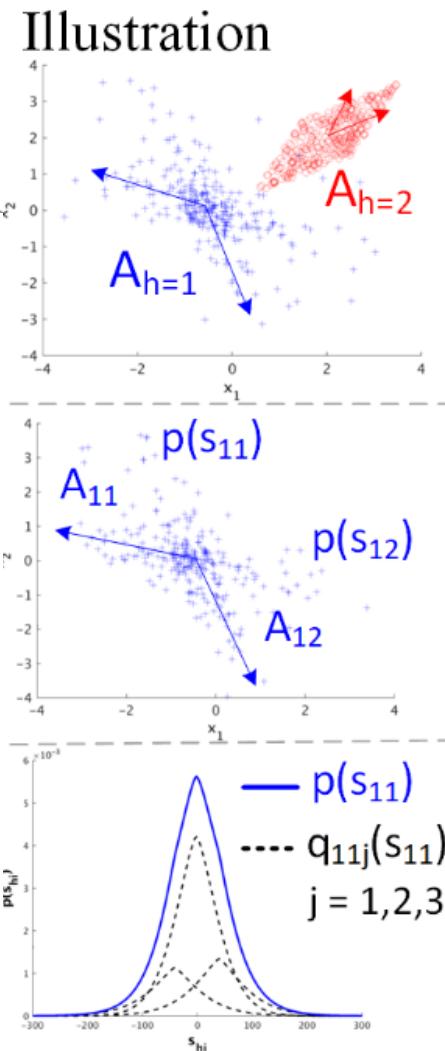
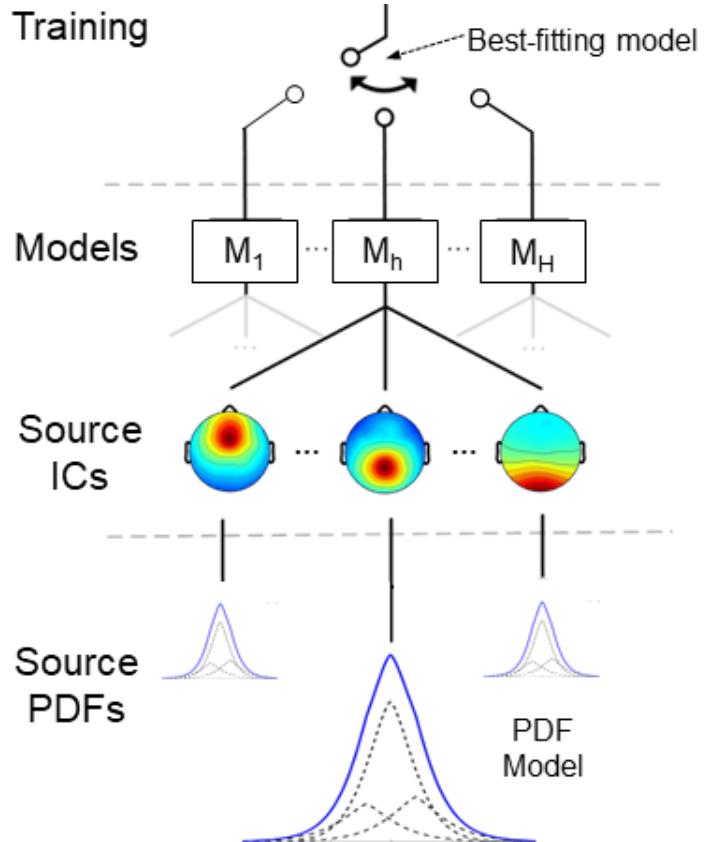
Why AMICA? 2nd reason – model EEG non-stationarity

Multiple-model AMICA



Hsu & Jung, *J. of Neural Eng.*, 2017
Hsu et al., *NeuroImage*, 2018

What is AMICA?



Models

$$\mathbf{x}(t) = \mathbf{x}_h(t)$$

$$\mathbf{x}_h(t) = \mathbf{A}_h \mathbf{s}_h(t) + \mathbf{c}_h$$

$$q(s; \rho, \mu, \beta) = \frac{\rho}{2\beta \cdot \Gamma(1/\rho)} \exp\left(-\left|\frac{s - \mu}{\beta}\right|^\rho\right)$$

Hsu et al., *NeuroImage*, 2018



What is AMICA?

- Likelihood function:

$$p(\mathbf{X}|\Theta) = \prod_{t=1}^T \sum_{h=1}^H p(\mathbf{x}(t)|C_h, \theta_h) \cdot p(C_h)$$

Mixture ICA

$$p(\mathbf{x}(t)|C_h, \theta_h) = \left| \det \mathbf{W}_h \right| \cdot \prod_{i=1}^N p(s_{hi}(t))$$

Independent components

$$p(s_{hi}(t)) = \sum_{j=1}^M \alpha_{hij} \cdot q(s_{hi}(t); \rho_{hij}, \mu_{hij}, \beta_{hij})$$

Mixture source PDF

- User-defined parameter: H
- Optimization:
 - EM algorithm
 - Gradient → Newton

Palmer et al., ICASSP, 2008



What is AMICA?

- Output parameters:

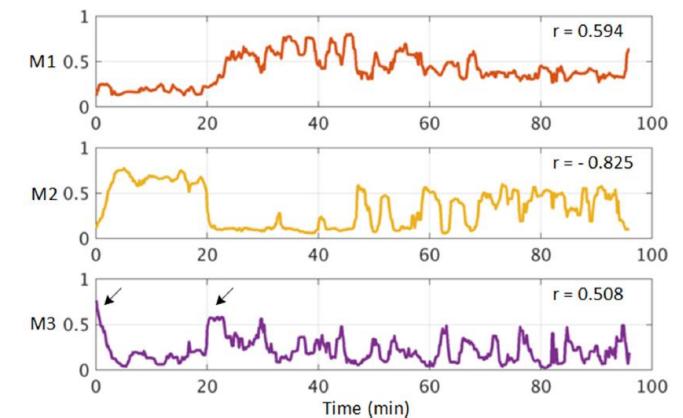
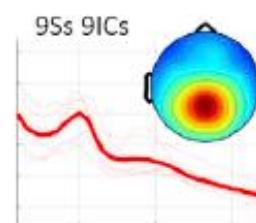
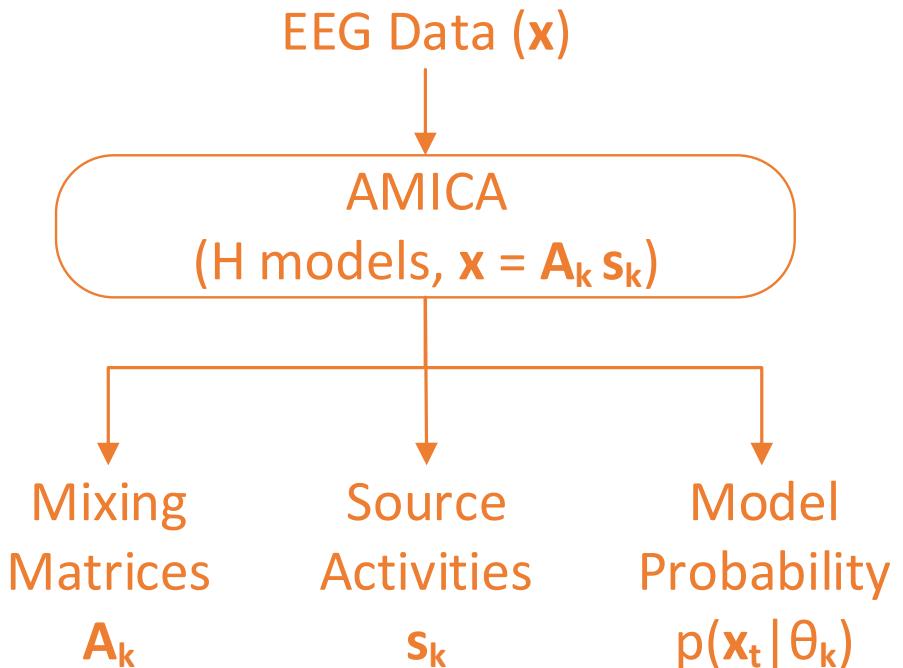
$$\Theta = \{\mathbf{W}_h, \mathbf{c}_h, \gamma_h, \alpha_{hij}, \beta_{hij}, \rho_{hij}, \mu_{hij}\}$$

$$p(C_h) = \gamma_h$$

- Model probability:

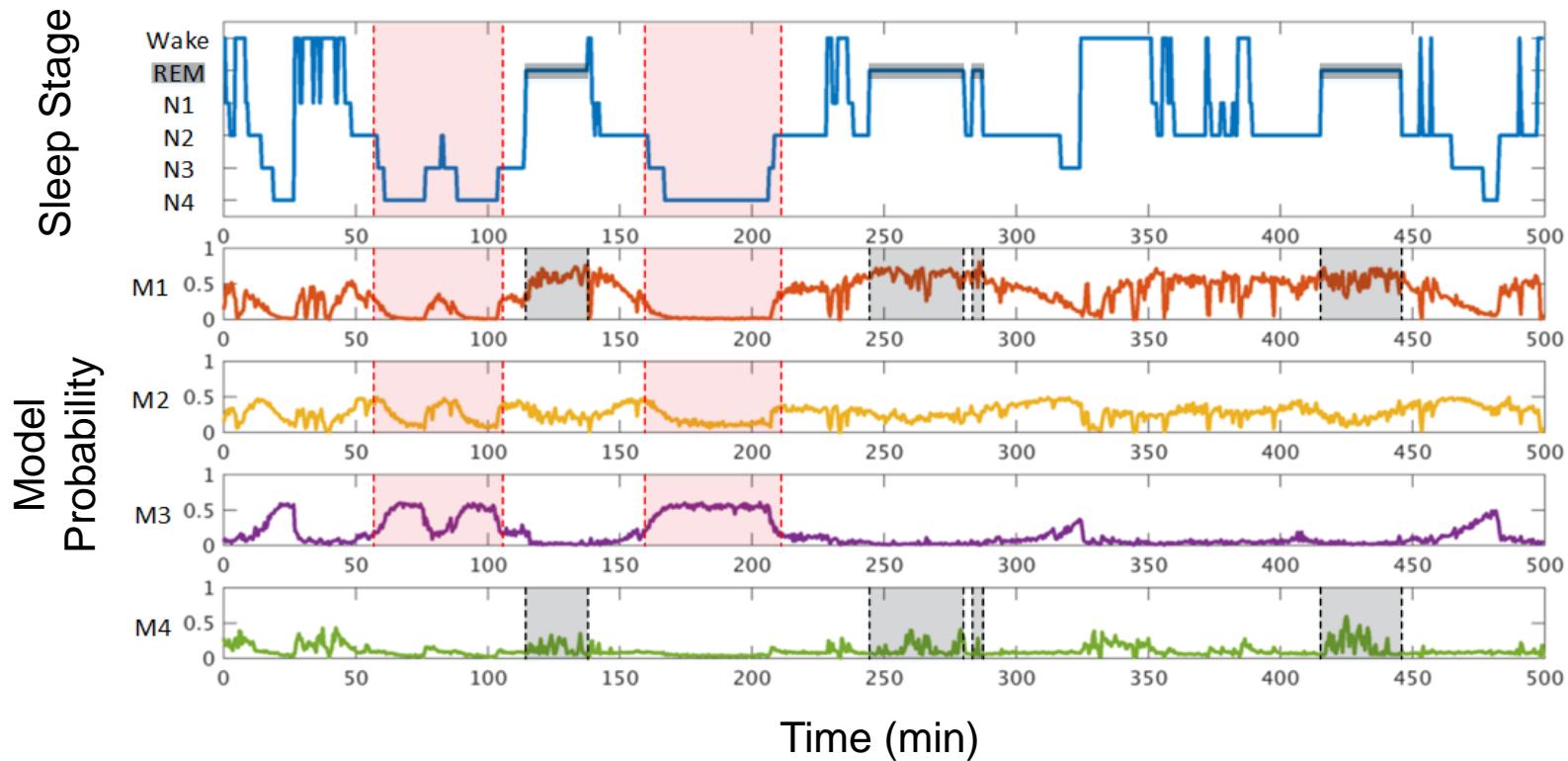
$$p(h(t)) = L_{h(t)} / \sum_{h=1}^H L_{h(t)}$$

$$L_{h(t)} = p(C_h) \cdot \left| \det \mathbf{W}_h \right| \cdot \prod_{i=1}^N \sum_{j=1}^M \alpha_{hij} \cdot q(s_{hi}(t); \rho_{hij}, \mu_{hij}, \beta_{hij})$$



Sample result #1 - modeling sleep dynamics

CAP Sleep Database: 6-13 ch, 6-10 hr EEG



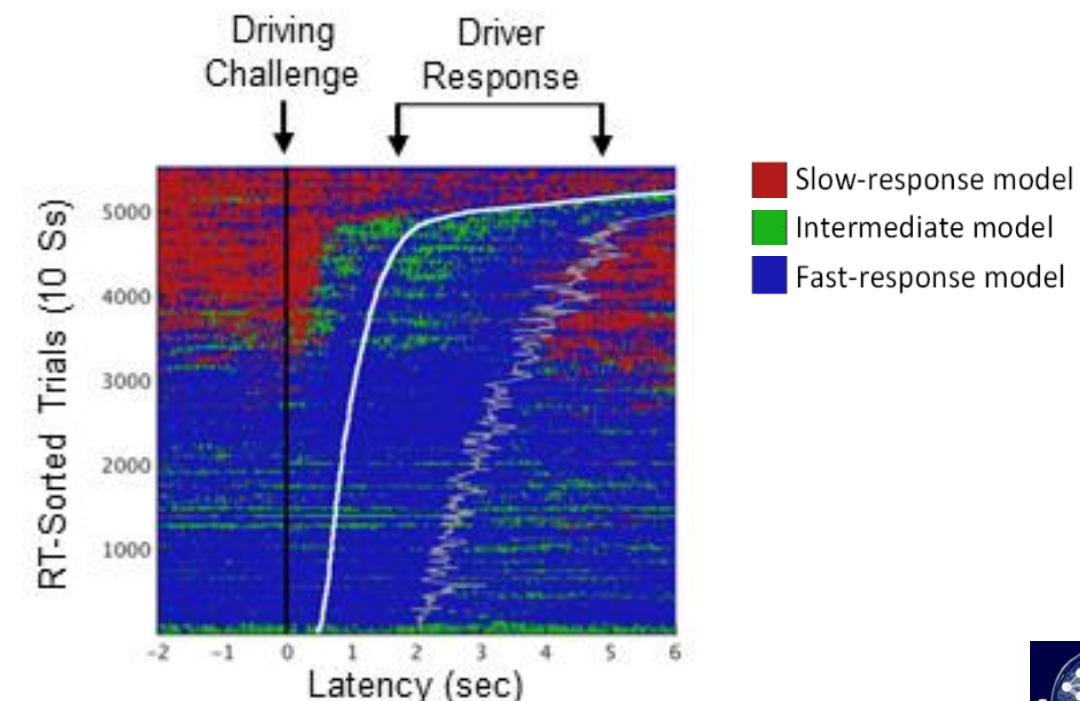
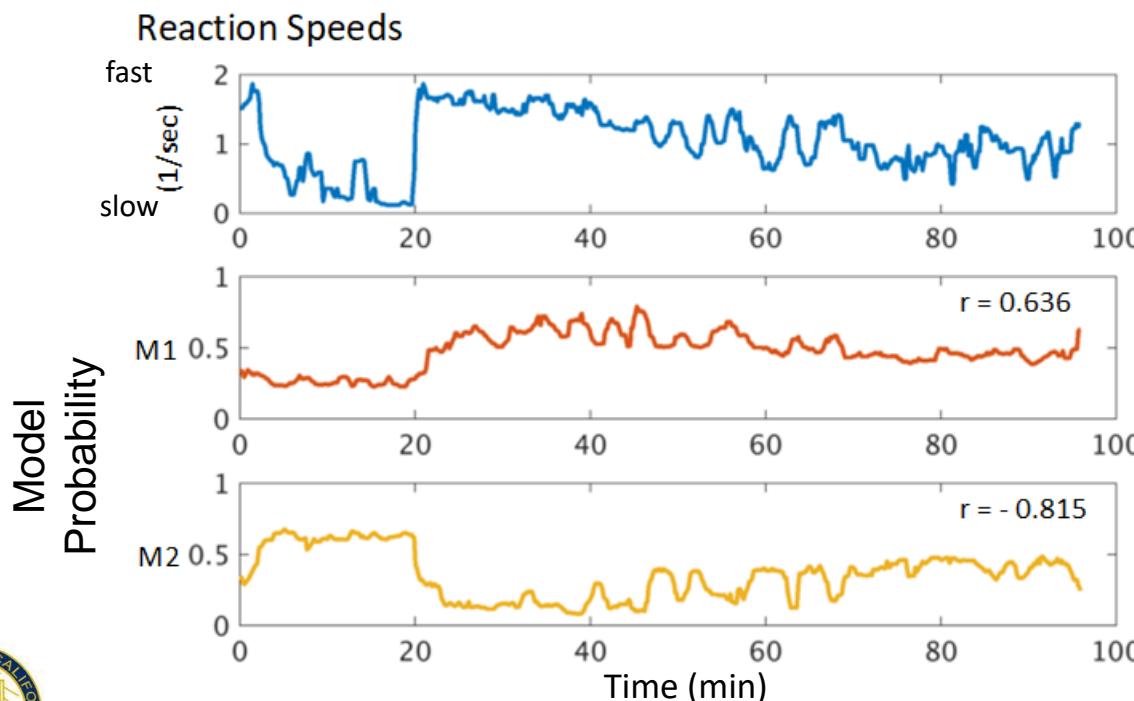
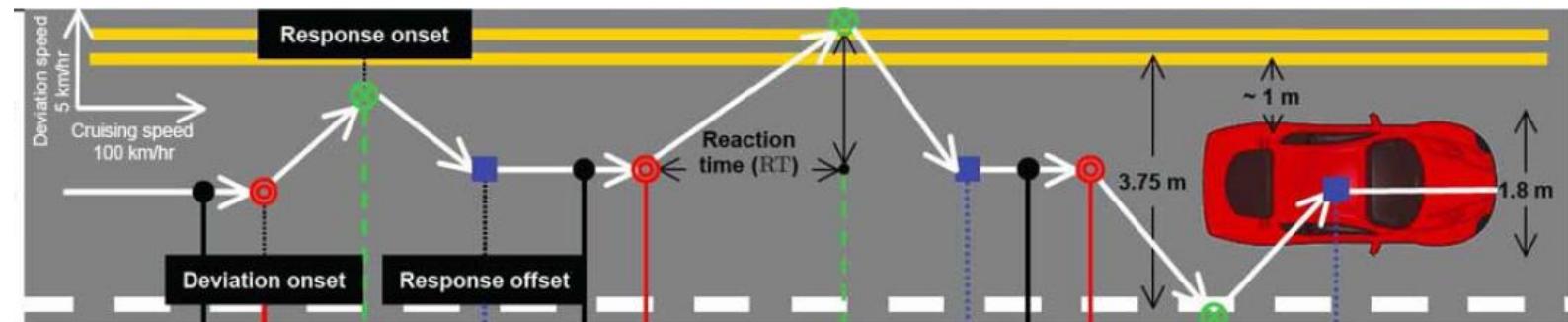
6-sleep stage classification accuracy: 75%

Hsu et al., *NeuroImage*, 2018



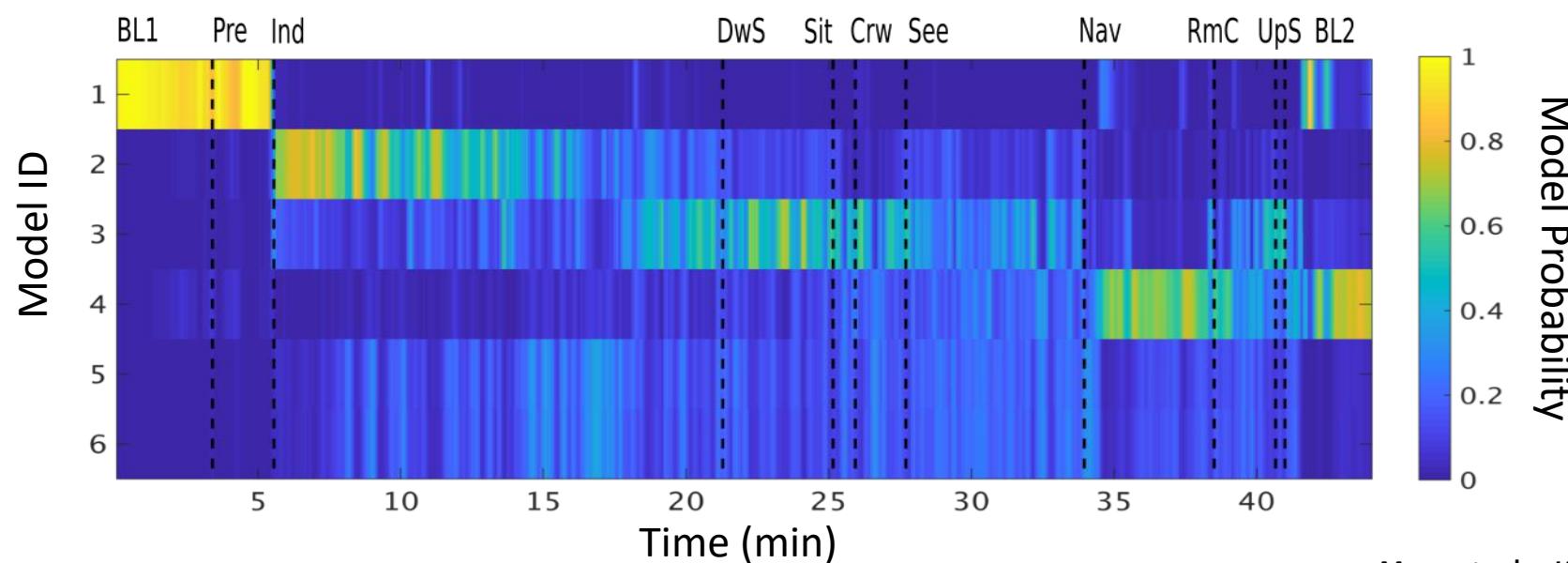
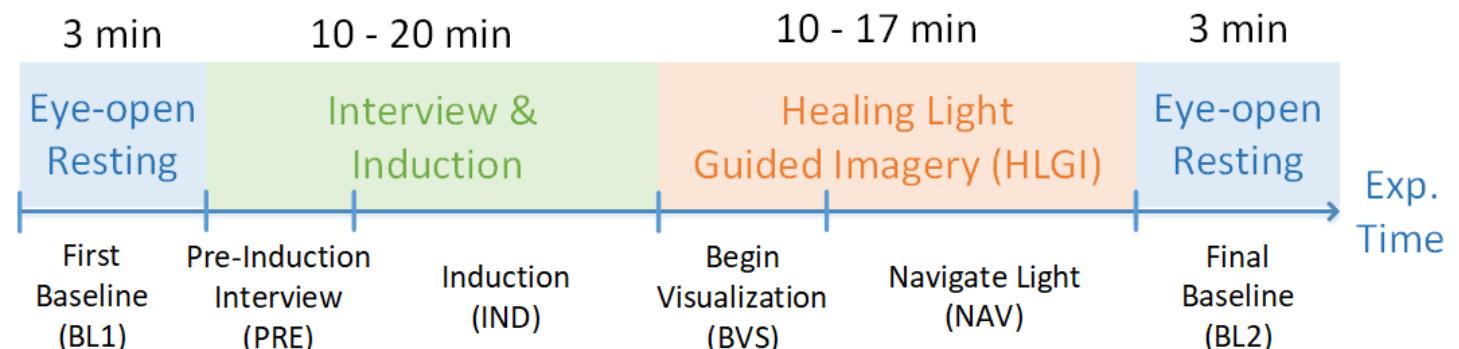
Sample result #2 – tracking drowsiness fluctuation

Sustained attention task:
30 ch, ~40 min EEG



Sample result #3 – brain state changes in meditation

Guided meditation:
66 ch, ~45 min EEG



Hsu et al., IEEE BioCAS, 2018



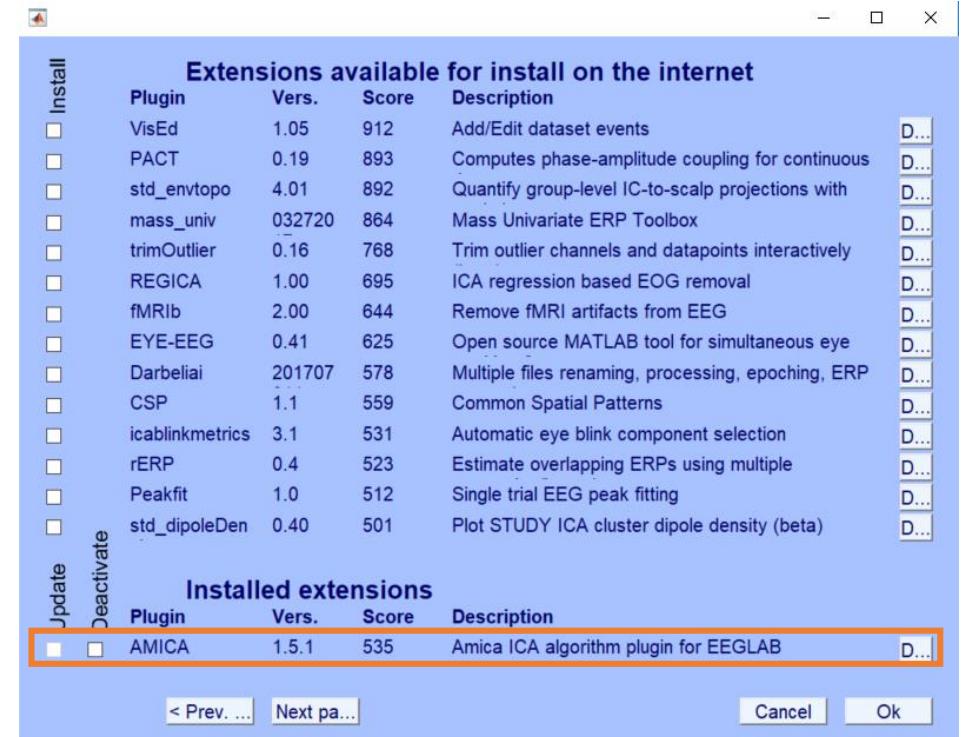
How to run AMICA?

EEGLAB GUI & MATLAB script



Download AMICA code / plugin

- Option 1: EEGLAB plugin
 - EEGLAB → File → Manage EEGLAB extensions → Data processing extensions → AMICA
 - Or through EEGLAB extensions and plugins webpage:
https://sccn.ucsd.edu/wiki/EEGLAB_Extensions_and_plug-ins
 - Current version (Oct. 2018) : amica1.5.1
- Option 2: Jason's webpage
 - https://sccn.ucsd.edu/~jason/amica_web.html
- Note: following sources may not be up-to-date
 - On Github: <https://github.com/japalmer29/amica>
 - Old wiki page: https://sccn.ucsd.edu/wiki/Amica_Download



AMICA - Adaptive Mixture ICA
(c) Jason Palmer, University of California San Diego, 2015.

What is Amica?
Amica is a binary program (for Linux, Mac, and Windows) that performs an independent component analysis (ICA) decomposition on input data, potentially with multiple ICA models. It can be run standalone, or from Matlab. Key features of Amica include:

- 1 Adaptive Source Densities – the source density models are adapted using a mixture of Generalized Gaussian density model, resulting in extremely good fit between the density model and the actual density of the source being estimated
- 2 Multiple models – Amica allows multiple ICA models to be learned simultaneously, automatically segmenting the data into regions of local stationarity, and returning a set of components for each model. Amica can also be set to share components between models to increase estimation efficiency
- 3 Likelihood – posterior likelihood of each model for given and new data is available, allowing rejection of unlikely data, as well as classification of new data
- 4 Parallel implementation – the programs can use multiple cores in a single workstation (using portable OpenMPI code), as well as multiple nodes in a cluster (using portable MPI code). All binaries allow multi-core (SMP) execution. Only the Linux version currently supports clusters (use the freely available Rocks + Sun Grid Engine).

Download Amica

EEGLAB plugin zip file:
- [amica1.5.zip](#)

Matlab files:
- [amica.m](#)
- [amica.m](#)
- [runamica.m](#)
- [loadamica1.m](#)
- [err_loadamica.m](#)

To use as an eeeglab plugin, create a directory under eeeglab-plugins.../eeeglab-plugins/amica1.5, and download the .m files and the appropriate binary file below into that directory. Then run eeeglab, and "Run Amica" should appear under tools.

Binary files:
- [amica15mkl.exe](#) (Windows 7 10 64-bit binary)
---- Install MPICH2 (apparently the latest mpich2 version may cause problems so please try installing older version using msi installer here: <http://www.mpich.org/static/downloads/1.4/>)
---- [mpich2.dll](#) (Windows DLL save in directory with binary)
---- [amica15mkl.dll](#) (Windows DLL save in directory with binary)
- [amica15mac](#) (Mac OS X 64-bit binary)
- [amica15ub](#) (Ubuntu 12.04 LTS 64-bit binary)
- [amica15c](#) (Compiled under Fedora Linux)

On Mac, you should also change the permissions of the binary file amica15mac to executable. Run "Terminal" from the Go->Utilities menu, then at the prompt run



Setup AMICA on your workstation / laptop

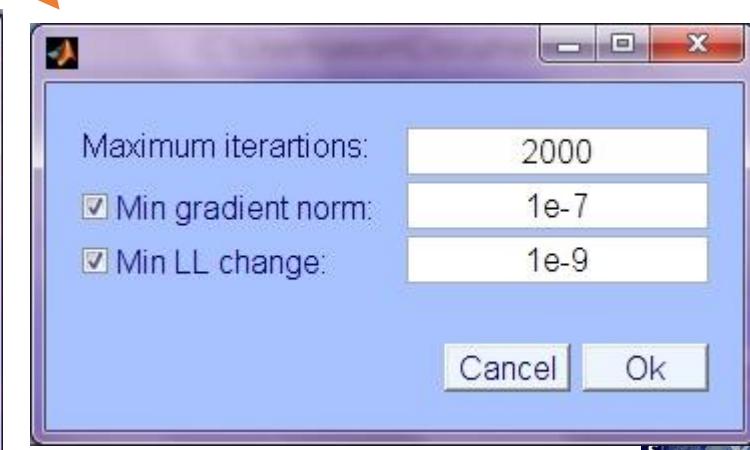
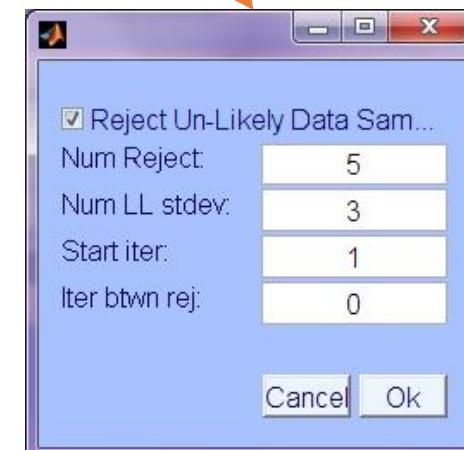
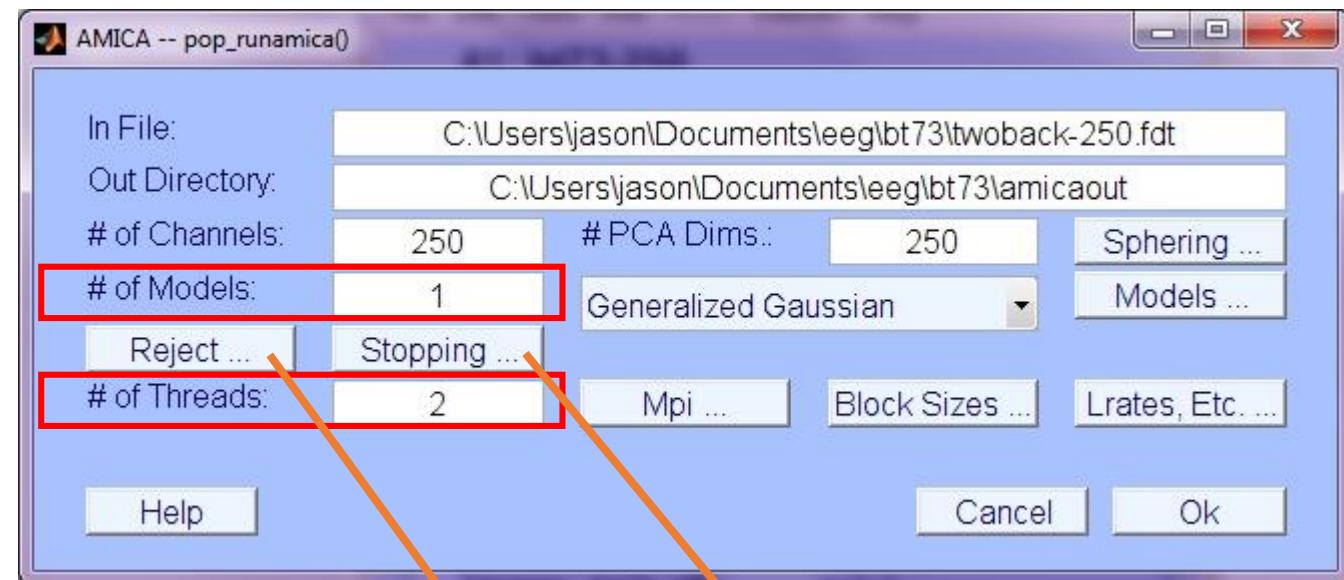
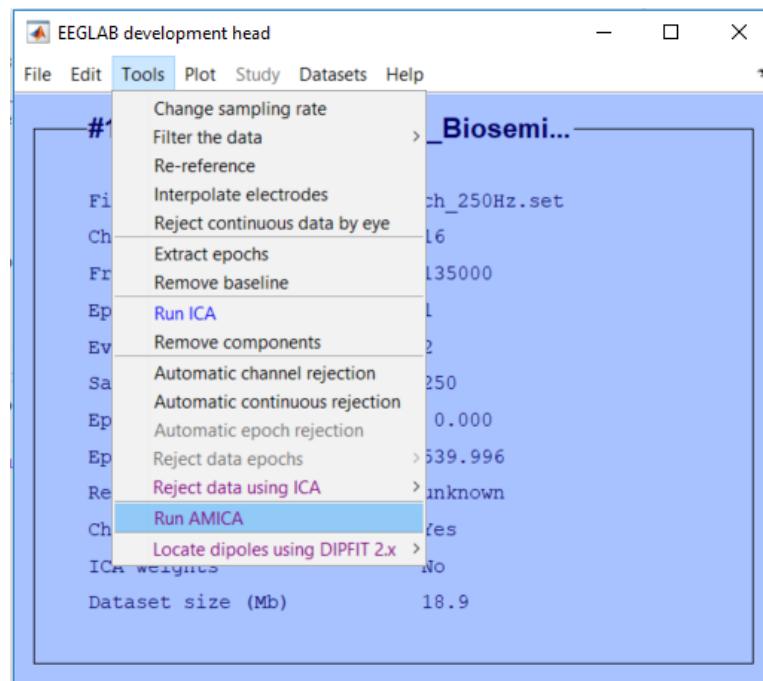
- Follow the instruction on https://sccn.ucsd.edu/~jason/amica_web.html
- The amica1.5.1 package (not amica1.5) contains all of the compiled bin file for different OS.
- Windows users:
 - Install MPICH2 (32-bit: [mpich2-1.4-win-ia32](#) or 64-bit: [mpich2-1.4-win-x86-64](#)), which is included in the amica1.5.1 package. Otherwise download it from <http://www.mpich.org/static/downloads/1.4/>
- Mac users:
 - Change the permissions of the binary file amica15mac to executable.
 - Run "Terminal" from the Go->Utilities menu, then at the prompt run:
*cd <put your eeglab path here>/eeglab/plugins/amica1.5
chmod 777 amica15mac*
- Linux users:
 - Plug-and-play! May need to recompile if runs with multiple nodes or threads.



Method 1: run AMICA via EEGLAB GUI

- Amica EEGLAB GUI Help:

https://sccn.ucsd.edu/~jason/amica_help.html



Method 2: run AMICA via MATLAB script

- Sample script

```
% add eeglab to path
EEG = pop_loadset('test_data.set');

% define parameters
numprocs = 1;          % # of nodes
max_threads = 1;        % # of threads
num_models = 1;          % # of models of mixture ICA
max_iter = 1000;         % max number of learning steps

% run amica
outdir = [ pwd filesep 'amicaouttmp' filesep ];

[weights,sphere,mods] = runamical5(EEG.data, 'num_models',num_models, 'outdir',outdir, ...
    'numprocs', numprocs, 'max_threads', max_threads, 'max_iter',max_iter);

% type "help runamical5()" for a full list and explanation of the parameters
```



How to run AMICA? via Neuroscience Gateway (NSG)



Step 1: prepare data package

(1)

```
%% test_script_amica_nsg.m

% add eeglab to path
eeglab; close;

% load dataset
filepath = [ pwd filesep ];
filename = 'test_data.set';
EEG = pop_loadset(filename, filepath);

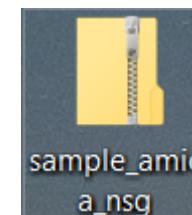
% define parameters
numprocs = 1; % # of nodes
max_threads = 24; % # of threads
num_models = 1; % # of models of mixture ICA
max_iter = 1000; % max number of learning steps

% run amica on NSG
outdir = [ pwd filesep 'amicaouttmp' filesep ];
runamical5_nsg(EEG.data, 'num_models', num_models, 'outdir', outdir, ...
    'numprocs', numprocs, 'max_threads', max_threads, 'max_iter', max_iter);
```

(2)

	>	sample_amica_nsg
	test_script_amica_nsg	MATLAB Code
	test_data.set	SET File
	test_data.fdt	FDT File

(3) Create .zip file



Step 2: upload data package

The screenshot shows the NeuroScience Gateway (NSG) interface. At the top, there is a navigation bar with links for NSG, Home, Toolkit, My Profile, Help, and How to Cite Us. The main content area has a sidebar titled "Folders" containing a list of items under "AMICA testing": "Data (4)" and "Tasks (4)". A red box highlights this folder. Below the sidebar, a message says "Welcome shhsu to the NeuroScience Gateway - NSG". There is a "Create New Folder" button. Under "Current Folder Details", the "Label" is set to "AMICA testing" and the "Description" is "Testing AMICA on NSG for EEGLAB users". At the bottom are buttons for "Create Subfolder", "Edit Folder", and "Delete Folder".

Upload the .zip folder!

The screenshot shows the "Use Data" page. At the top, there is a "Upload Data" button with an arrow pointing to it from the text above. Below it is a dropdown menu set to "20 records on each page" and a "Page 1 of 1" indicator. The main area is a table titled "Use Data" with columns: Select all, User Data ID, Label, Bytes, Data Format, and Date Created. The table lists four entries:

Select all	User Data ID	Label	Bytes	Data Format	Date Created
<input type="checkbox"/>	34445	sample_amica_nsg	17011906	Unknown	11/7/18, 11:43
<input type="checkbox"/>	34446	sample_amica_nsg_v1	17011907	Unknown	11/7/18, 11:59
<input type="checkbox"/>	34447	sample_amica_nsg_v2	19336678	Unknown	11/7/18, 12:00
<input type="checkbox"/>	34449	sample_amica_nsg_v3	17011962	Unknown	11/7/18, 18:14

Below the table are buttons for "Move" (with a dropdown menu "selected to AMICA testing" and a "GO" button), "Delete Selected", and other navigation controls.



Task Summary Select Data Select Tool Set Parameters

You may edit your task using the tabs above.
Current CPU Hr Usage: 0 [Explain this?](#)

Description Description

Input Select Input Data → **Select the .zip file**

Tool Select Tool → **Select “EEGLAB on Comet”**

Input Parameters Set Parameters

Save Task **Save and Run Task** **Discard Task**

Step 3: create and run task

EEGLAB on Comet: Running EEGLAB models using MATLAB ([Scott Makeig](#))

Simple Parameters

Maximum Hours to Run (click here for help setting this correctly) * Max 48 hr

Enter Main Input Matlab Filename (click here for help setting this correctly) *

Enter sub-directory name (OPTIONAL - click here for help setting this correctly)

Enter name for the compressed output file created by the NSG job (OPTIONAL - click here for help setting this correctly)

**Run this .m file
(`test_script_amica_nsg.m`)**

**Output .tar.gz file
in a .zip folder**



Step 4: output files

Cipres_Data.zip\output.tar.gz\

Name	Size	Packed Size
sample_amica_nsg	18 672 343	18 673 664
scheduler_stderr.txt	317	512
scheduler_stdout.txt	304	512
stderr.txt	0	0
stdout.txt	1 717	2 048

Name	Size	Packed Size
amicaouttmp	2 304 060	2 307 072
test_data.fdt	8 640 000	8 640 000
test_data.set	10 001 176	10 001 408
test_script_amica...	605	1 024

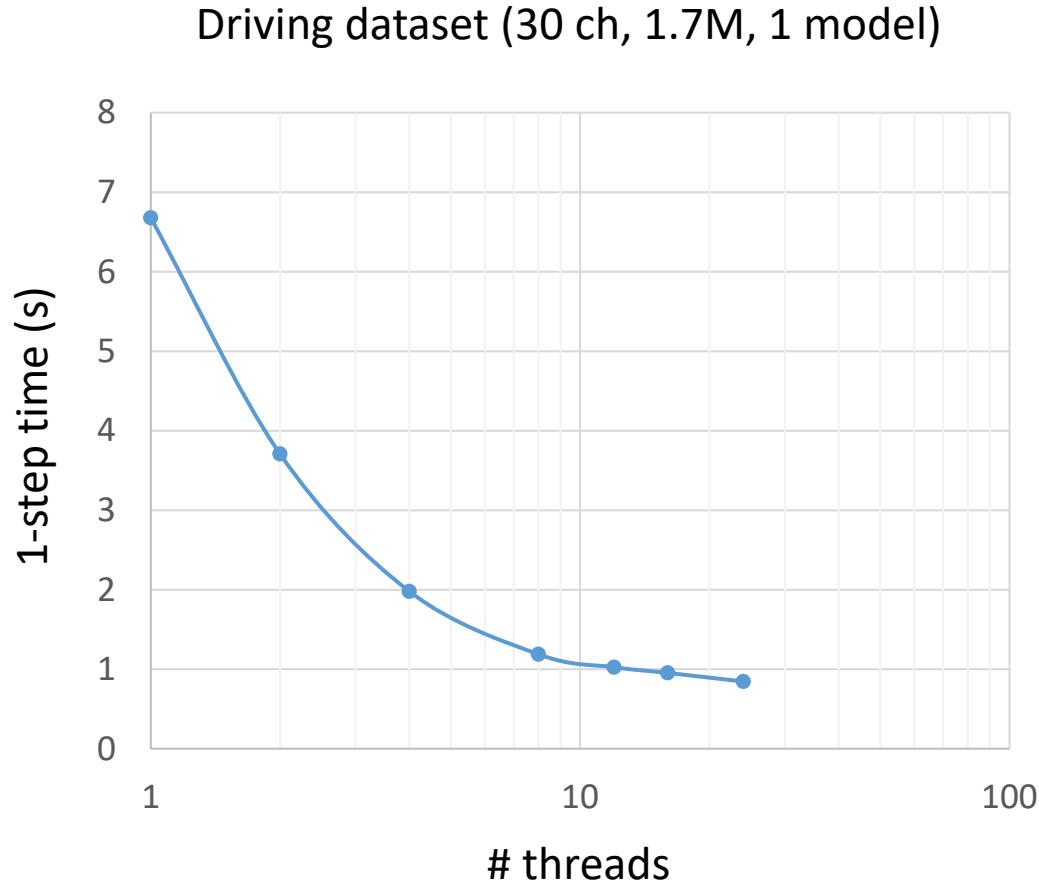
Name	Size	Packed Size
A	2 048	2 048
alpha	384	512
c	128	512
comp_list	128	512
gm	8	512
input.param	1 337	1 536
LL	16 000	16 384
LLt	2 160 000	2 160 128
mean	128	512
mu	384	512
out.txt	252 630	252 928
rho	384	512
S	2 048	2 048
sbeta	384	512
W	2 048	2 048

Load output for analysis!

→ loadmodout15()



Runtime Analysis



Multiple nodes capability coming soon!

Rule of thumb:

$$\text{Runtime} \propto (\# \text{ par}) \cdot T \propto (N^2 \cdot M) \cdot T$$

Dataset	Sim	Driving	Sleep	Memorize
# CH (N)	16	30	13	71
# Samples (T)	135K	1.7M	17M	320K
# models (M)	1	3	8	1
1-step time	0.03 s	2.87 s	56.77 s	0.35 s
*2000-step time	1.0 m	95.7 m = 1.6 h	1890 m = 31.5 h	11.7 m

On Comet, SDSC:

1 node, 24 threads, Intel Xeon E5-2680v3, 2.5 GHz



How to analyze AMICA output?



Sample script for analysis

```
% load EEG data and AMICA results
EEG = pop_loadset('test_data.set');
outdir = [ pwd filesep 'amicaouttmp' ];
modout = loadmodout15(outdir);

% load individual ICA model into EEG structure
model_index = 1
EEG.icawinv = modout.A(:,:,model_index);
EEG.icaweights = modout.W(:,:,model_index);
EEG.icasphere = modout.S;
EEG = eeg_checkset(EEG);
pop_topoplot(EEG,0);    % plot IC scalp maps of ICA model #1

% compute model probability
model_prob = 10 .^ modout.v;    % modout.v (#models x #samples)
figure, imagesc(model_prob(:,1:10*EEG.srate)); % model probability changes in first 10s
```



EEGLAB Plugin – postAmicaUtility 2.00



Makoto Miyakoshi Ozgur Balkan

Install

Extensions available for install on the internet

Plugin	Vers.	Score	Description
pvaftopo	0.10	451	Plot topography of percent variance accounted for
bioelectromag	1.01	389	Uses Bioelectromagnetism toolbox for ERP peak
std_ErpCalc	0.11	366	[DEPRECATED] Use std_erpStudio.
BERGEN	131130	356	Remove fMRI artifacts from EEG
LR	1.2	353	Linear Discrimination
std_infocluster	1.1	351	Statistics and contribution of ICs to clusters
postAmicaUtili	2.00	331	Calculates AMICA model probability and mutual
fitTwoDipoles	0.01	329	Search and fit bilateral dipoles wherever
GEVD	1.00	326	Generalized Eigenvalue Decomposition (GEVD)
erppeakinterv	1.0	291	Extract the mean amplitude surrounding the peak
ARfitStudio	0.40	284	Cleans event-related transient artifacts using ARfit
Viewprops	1.5.3	274	Channel and IC properties viewer
eegplot_w	1.1.4	266	Scroll using mouse wheel in wide-screen
CIAC	1.00	261	Cochlear Implant Artifact Correction
FAA	1.0	261	Frontal alpha asymmetry index computation

< Prev. pag... Next pag... Cancel Ok

EEGLAB development head

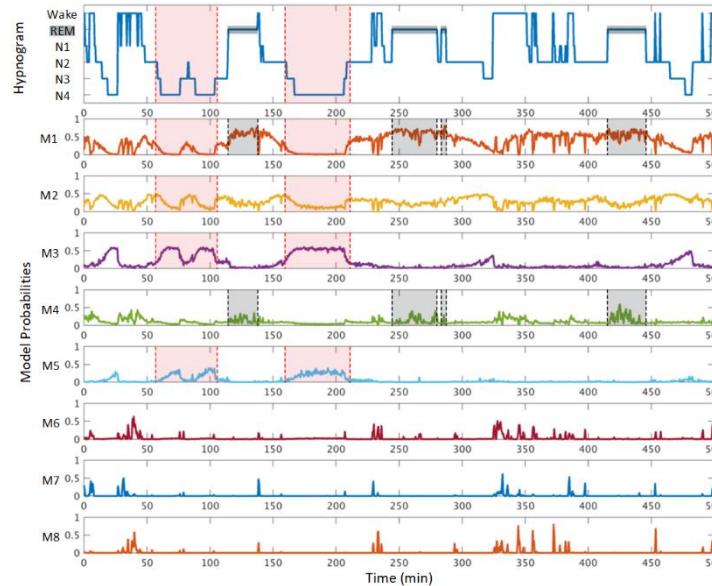
File Edit Tools Plot Study Datasets Help

#1 Change sampling rate
Filter the data
Re-reference
Interpolate electrodes
Reject continuous data by eye
Extract epochs
Remove baseline
Run ICA
Remove components
Automatic channel rejection
Automatic continuous rejection
Automatic epoch rejection
Reject data epochs
Reject data using ICA
Run AMICA
Locate dipoles using DIPFIT 2.x
post AMICA utility
Dataset size (MB) 18.9

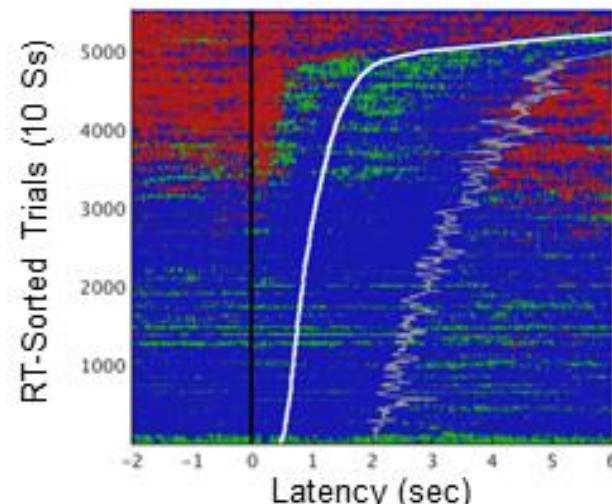
Biosemi...
ch_250Hz.set
L6
L35000
Load AMICA components
Change current ICA weights (beta)
Smooth model probabilities
Plot pairwise mutual information (Infomax compatible)
Plot Model Probability time series
[For epoched] Plot event-related dominant model image
Plot PDF of Gaussian mixtures for each IC
Scroll channel data with AMICA model (beta)
Scroll IC activation with AMICA model (beta)
[For continuous] Select data using a dominant model

- Load AMICA components
- Change current ICA weights (beta)
- Smooth model probabilities
- Plot pairwise mutual information (Infomax compatible)
- Plot Model Probability time series
- [For epoched] Plot event-related dominant model image
- Plot PDF of Gaussian mixtures for each IC
- Scroll channel data with AMICA model (beta)
- Scroll IC activation with AMICA model (beta)
- [For continuous] Select data using a dominant model

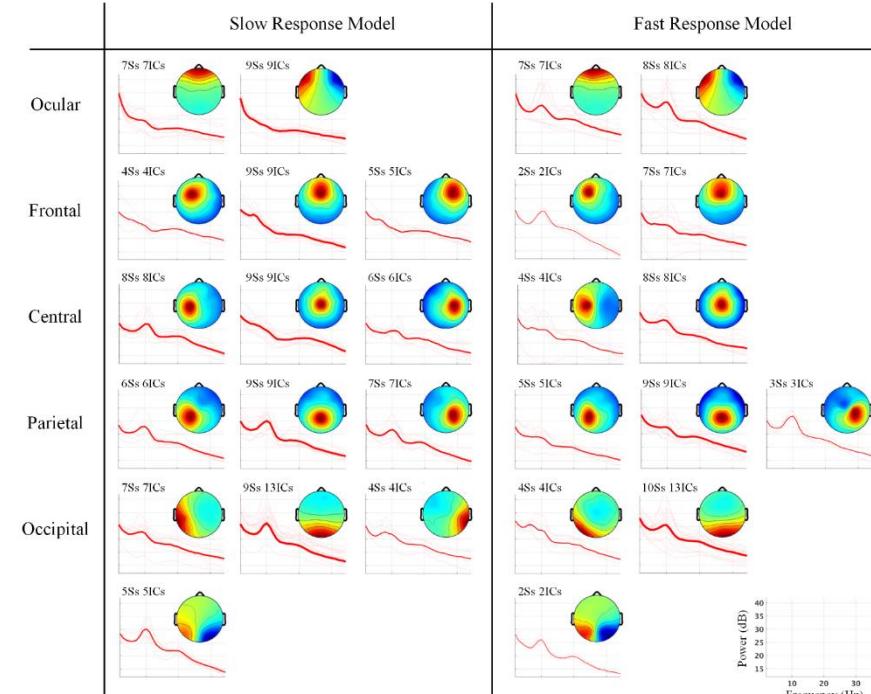
Model Probability time series



Event-related dominant model image



ICA weights and source power spectra



Pairwise mutual information

Day 1: Track A

4:20 PM -- A4: Mutual information reduction (MIR) and IC dependent subspaces – Scott Makeig & Makoto Miyakoshi

Conclusions – theory & applications

Properties / Models	(Infomax) ICA	AMICA	AMICA compared to ICA
Model of source PDF	Pre-defined	Learned by model fitting $p(s) = GG_1(s) + GG_2(s) + \dots$	Better IC decomposition
Model of mixing matrix	# sources \leq # channels (complete)	# sources \geq # channels (overcomplete)	Applicable to low-density EEG data
Spatial stationarity of sources	1-mixing model (Fixed sources)	N-mixing model (Emerging / disappearing sources)	Modeling nonstationary EEG data, indicating brain-state changes
Sensitivity to artifacts	X	Low-likelihood data rejection	Dealing with transient large-amplitude artifact

Multiple-model AMICA → Sleep dynamics, drowsiness fluctuation, guided meditation, (emotions), and more!



Conclusions – practicum & resources

- Two plugins: **amica1.5.1** & **postAmicaUtility 2.0**
 - Download at: https://sccn.ucsd.edu/wiki/EEGLAB_Extensions_and_plug-ins
- Computing resources: via Neuroscience Portal (NSG)
- Tutorials:
 - Installation: https://sccn.ucsd.edu/~jason/amica_web.html
 - GUI: https://sccn.ucsd.edu/~jason/amica_help.html
- References:
 - **[Algorithm]:** Palmer, J.A., Makeig, S., Kreutz-Delgado, K., Rao, B.D., 2008. Newton method for the ica mixture model. IEEE International Conference on Acoustics, Speech and Signal Processing, ICASSP, pp. 1805–1808.
 - **[Application]:** Hsu, S.H., Pion-Tonachini, L., Palmer, J., Miyakoshi, M., Makeig, S. and Jung, T.P., 2018. Modeling brain dynamic state changes with adaptive mixture independent component analysis. *NeuroImage*, 183, pp.47-61.



