



# Neural Data Science with **Python**

## L11: End-of-Course Projects - Selection and Realization

*Michael Graupner*

*SPPIN – Saint-Pères Institute for the Neurosciences*

*Université Paris Cité, CNRS*

# Aim of the End-of-Course project

- **Time for your emancipation** : realize a small-scale project using python on your *own* or in a *team of two*
- **Apply/solidify your knowledge** : use the knowledge/expertise acquired in course, extend it and apply it to a specific scientific project/question
- **Extend your understanding** : dive in-depth into a scientific topic and question

# Expected from you for the project work

- **Work independently** : after a kick-off meeting with the project organizer, you should strive to advance without further interaction (unless you are completely stuck)
- **Get involved in the project/question** : Use all available resources to learn about the underlying science, the scope of the question and how to implement the project realization.

# Tips for advancing the project

- **Set yourself small, achievable goals** : advance in small steps, go only further once you achieved your goal.
- **Start to work on the project as early as possible** : Learn about the project early and identify the challenges. Thinking about the project for a longer period of time will improve your result.
- **Spread your work on the project** : Committing small time periods here and there will avoid the deadline rush which is often not creative/productive.

# Tips for programming

- **Check at every step what you are doing** : look at results at each step and visualize: Does it make sense?
- **Validate your code if you have a reference or ground-truth** : use your code to run an example for which you know the outcome. Do you get the expected result?
- **Look back at the course material for help and example implementations** : the techniques used have been discussed in the course, this should be your first reference
- **Use the internet to get help** : Be precise in your question and key-words; common sites for useful help : *stackoverflow*, *askubuntu*, *github*, *ChatGPT*.

# Tips for the project jupyter-notebook

- evaluation will be based on the **jupyter-notebook** which you developed while working on the project
- the jupyter-notebook should be annotated (with explanations and comments also in the code) and contain the following

<b>Title</b>	Should be concise and precise	maximal 2 lines
<b>Abstract</b>	What did you do in a nutshell? Question – Method(s) – Results	1 paragraph
<b>Introduction</b>	What is the question?	2-3 paragraphs
<b>Annotate the python code</b>	Describe concisely what your aim to do with each code snippet	
<b>Results</b>	Explain, interpret your results; figures should have captions explaining them (labels too!)	
<b>Discussion</b>	What does it all mean?	2-3 paragraphs
<b>References</b>	Whose work did you refer to?	

# Tips on preparing the presentation

- Do not prepare slides ! the presentation and discussion will be solely based on the jupyter-notebook
- follow the logic :
  - Question – Method(s) – Results
- stick to the 10 min presentation duration (hard limit): requires training
- in case you worked as a team : present the project *together*
- do not go into the details of the python code, rather provide the general purpose

# Timeline of the project

- **Nov 29<sup>th</sup>, '24** (today) : introduction, presentation of possible projects
- **Dec 6<sup>th</sup>, '24** : final determination of who (teams) works on which project
- soon after **Dec 6<sup>th</sup>** : meet the tutor and get introduced to the project (you have to set up the meeting yourself)
- between **Dec 6<sup>th</sup>, '24** and **Jan 6<sup>th</sup> (23h59), '25** : work on the project, try to spread the work during that period (~2-3 full days of work are required)
- **Jan 6<sup>th</sup> (23h59), '25** : submit the project jupyter-notebook file
- **Jan 9<sup>th</sup>, '25, 9h00-15h00** : project presentation/discussion in front of a jury; each student/team of two has 10 min for presenting their project + 5 min of questions



# List of End-of-Year Project proposals

- 16 diverse projects are listed here :  
<https://github.com/mgraupe/NeuralDataSciPy2024/blob/main/EndOfYearProjects.md>
- go through the list and **pick out *three* proposals ranked by your order of preference** : **send** this list together with your team configuration to Michael **until Wednesday Dec 4<sup>th</sup>, noon**, Michael will get back to you with proposals of project attributions
- each project has contact person (Karine, Marcel, or Michael) with whom you should fix a kick-off meeting soon to get more details and information about the project
- own project ideas are possible and welcome but should be discussed with Michael Graupner beforehand

# The three project tutors



Karine Audouze, Université Paris Cité  
karine.audouze@u-paris.fr



Marcel Stimberg, Institute de la Vision  
marcel.stimberg@inserm.fr



Michael Graupner, Université Paris Cité  
michael.graupner@u-paris.fr

# The three jury members



Kirsten Petras, Université Paris Cité  
kirsten.petras@u-paris.fr



Marcel Stimberg, Institute de la Vision  
marcel.stimberg@inserm.fr



Michael Graupner, Université Paris Cité  
michael.graupner@u-paris.fr

# P#1: Testing classifier performance on hand-written digits

- *classification project* : train classifier to recognize hand-written digits

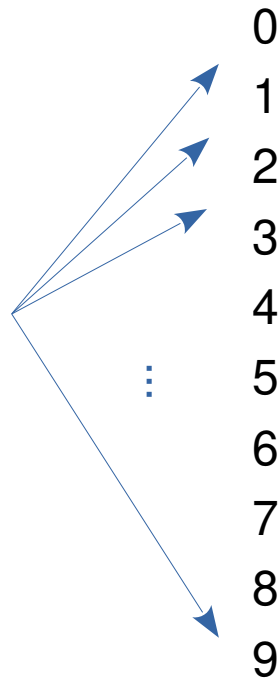
## MNIST handwritten digit database



[images 20x20 pixel]

classifier

1. train
2. test



# P#2: Exploring existence of clusters in hand-written digits

- *clustering project* : explore number of distinguishable clusters in hand-written digits

## MNIST handwritten digit database



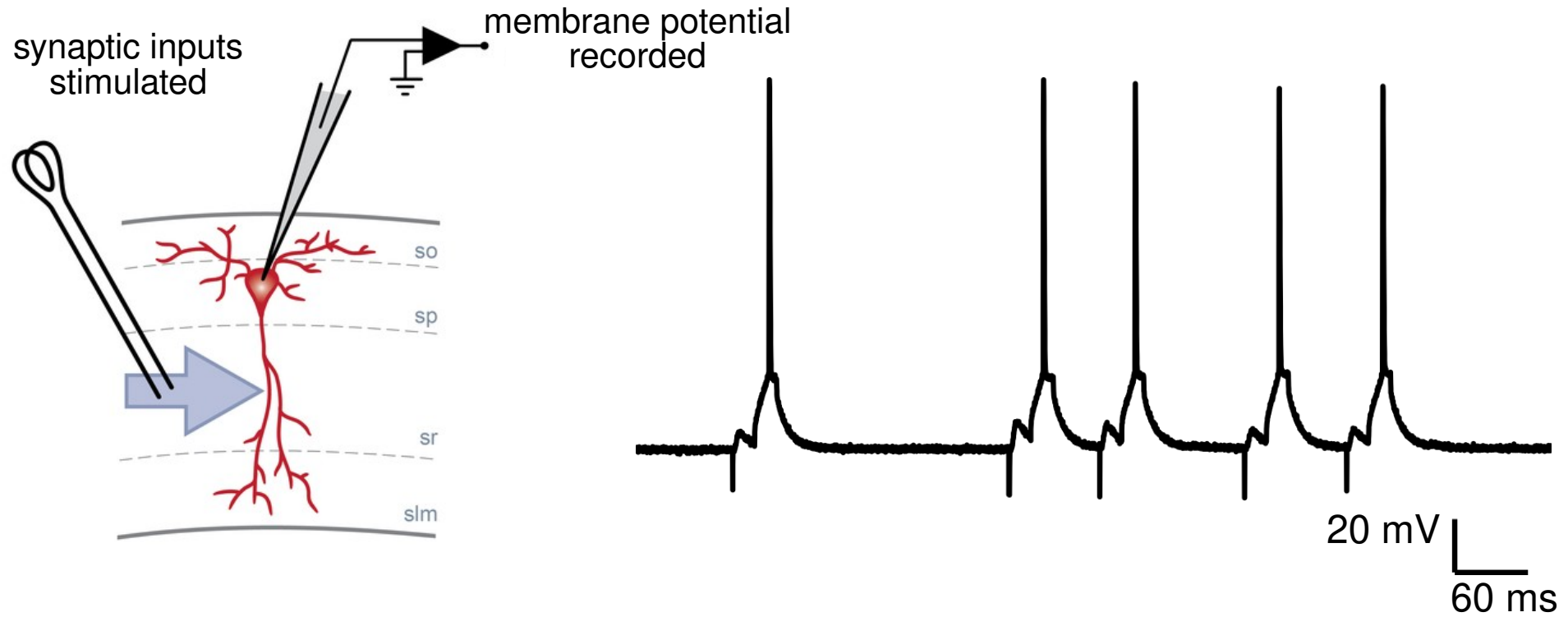
[images 28x28 pixel]

clustering  
algorithm

investigate  
existence  
and number of  
distinct clusters  
in the data-set

# P#3: Extracting and analyzing spike-times from membrane potential recording

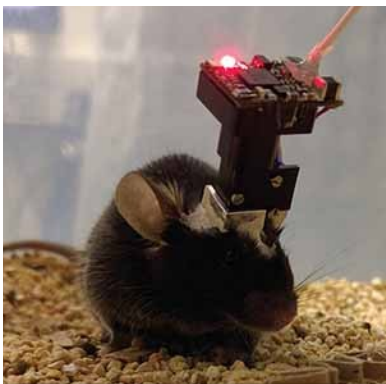
- *time-series analysis* : extract pre- and postsynaptic action potentials



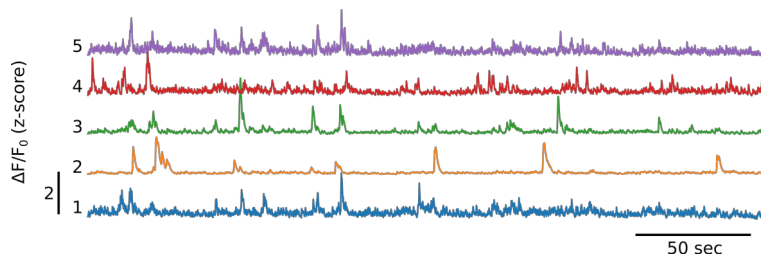
# P#4: Calculate head-direction tuning curves of presubicular neurons from calcium imaging

- *calcium imaging analysis* : compute the histogram and determine preferred head-direction

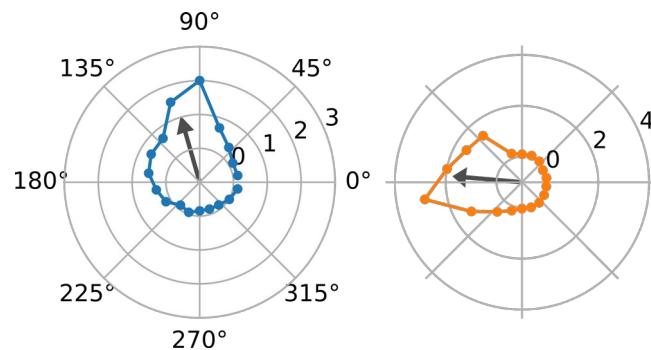
recordings with  
miniscope in  
presubiculum



calcium traces



head-direction  
tuning curves



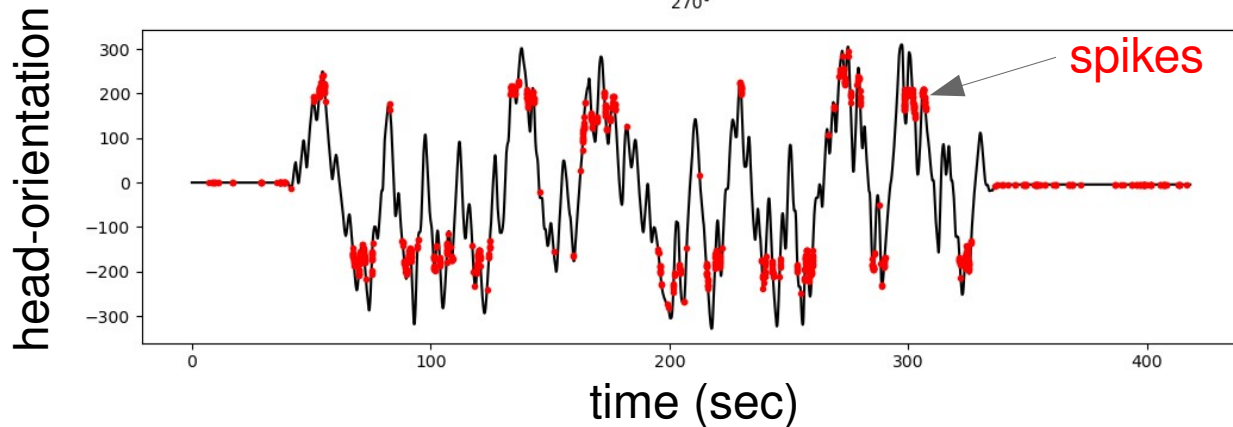
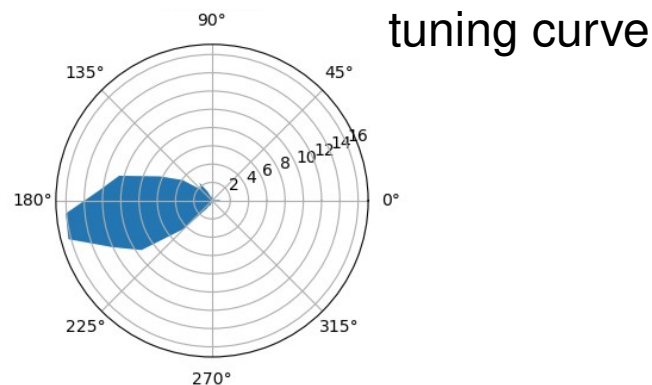
# P#5: Calculate head-direction tuning curves of presubicular neurons from electrophysiological recordings

- *spike train analysis* : calculate tuning curves, preferred direction, spiking statistics

neuropixel probe  
in presubiculum



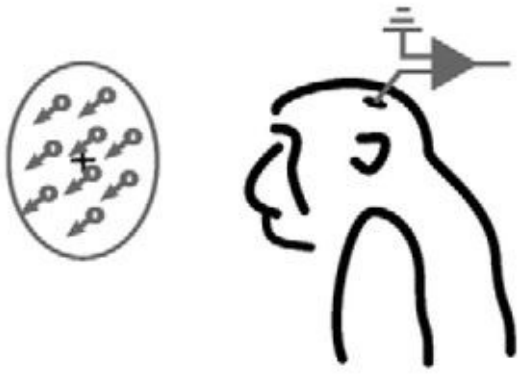
mouse is passively rotated



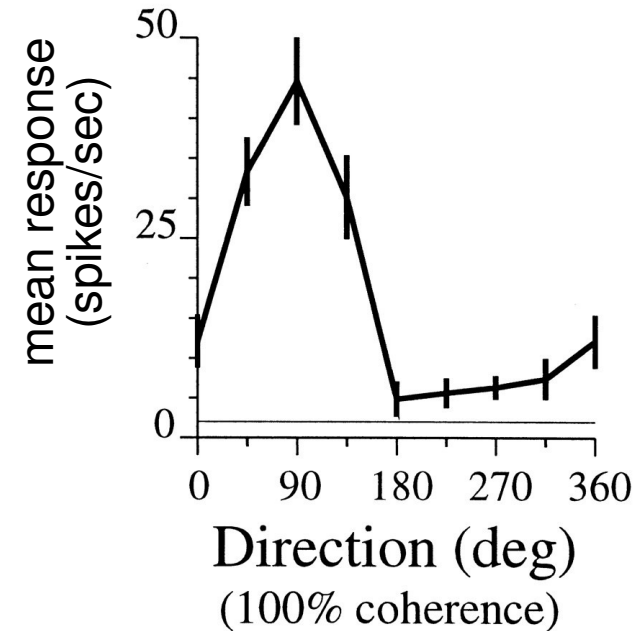
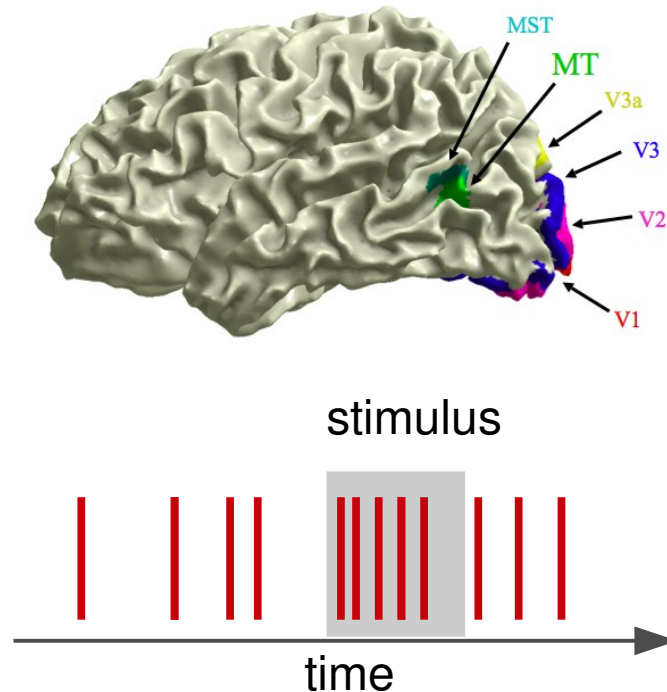


# P#6: Compute tuning curves of monkey visual cortex neurons

- *spike train analysis* : calculate tuning curves, PSTH, calculate spiking statistics

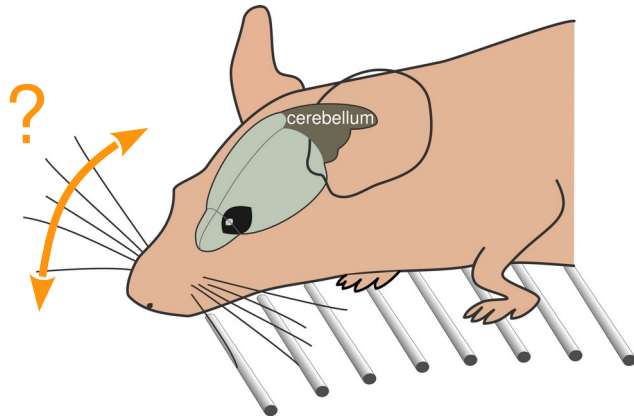


tetrode recording in  
visual area MT of awake  
fixating monkey



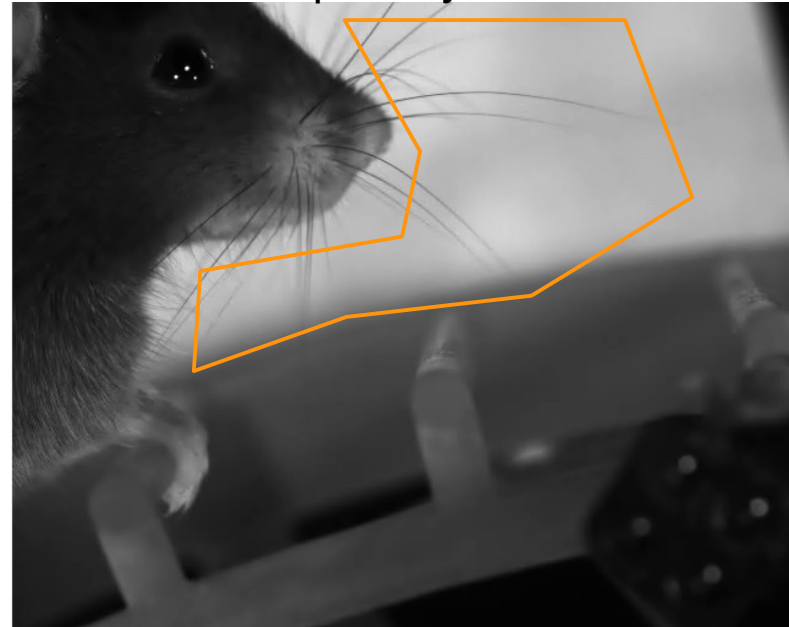
# P#7: Extract whisking activity from mouse video recordings

- video analysis : extract motion index of whisker activity



What is the dynamics of the whiskers during locomotion on the wheel ?

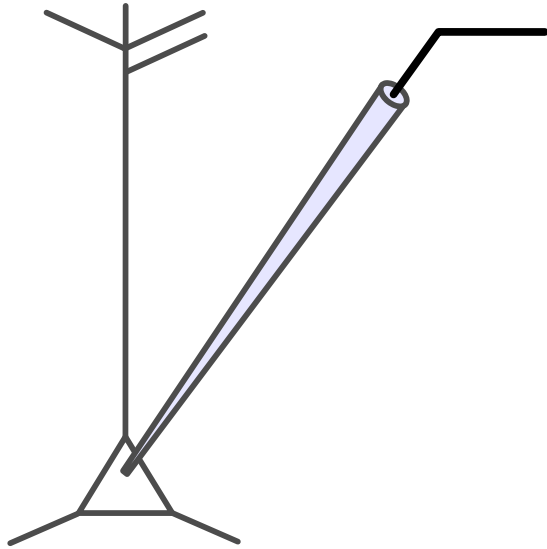
Define region of interest and quantify motion



# P#8: Adaptive Leaky Integrate-and-Fire (LIF) model

- *single neurons simulation in Brian* : analyze spike output patterns

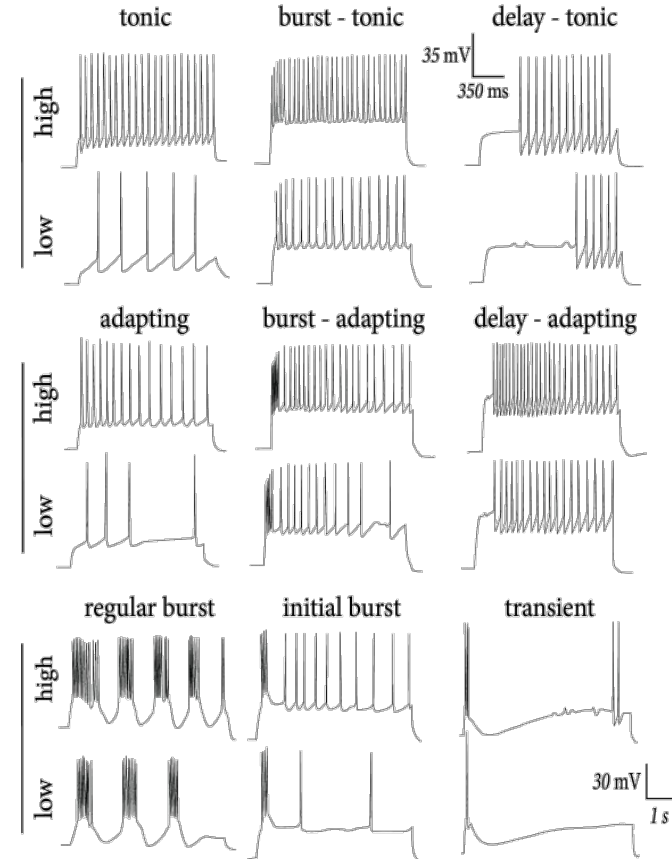
Single neuron model



Step current input

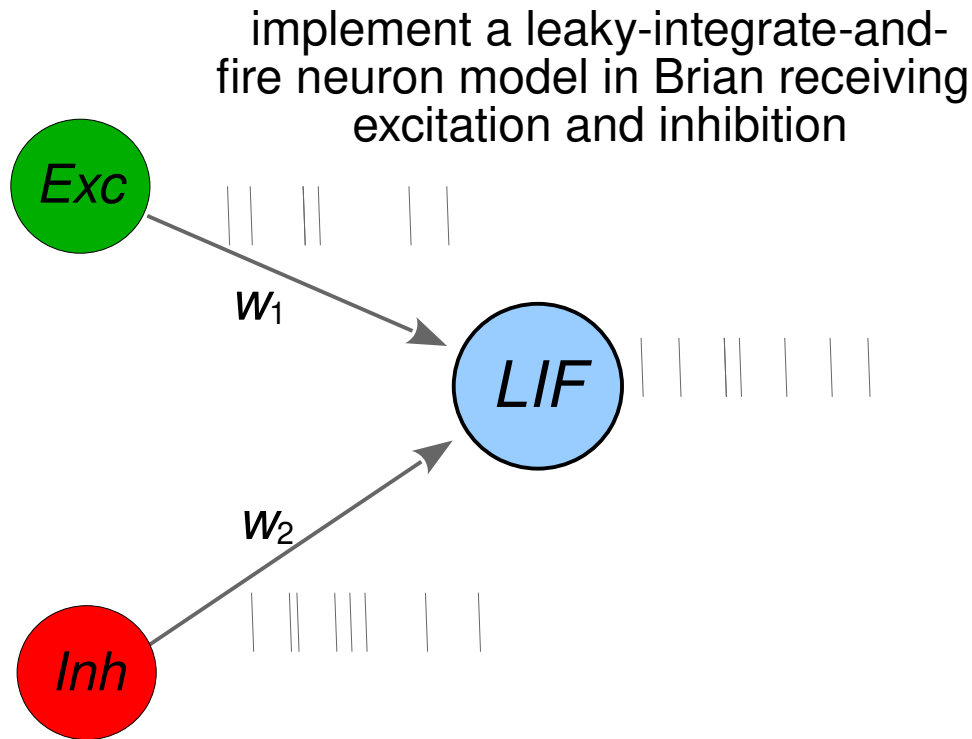


Diverse spike output patterns



# P#9: Interplay of excitation and inhibition

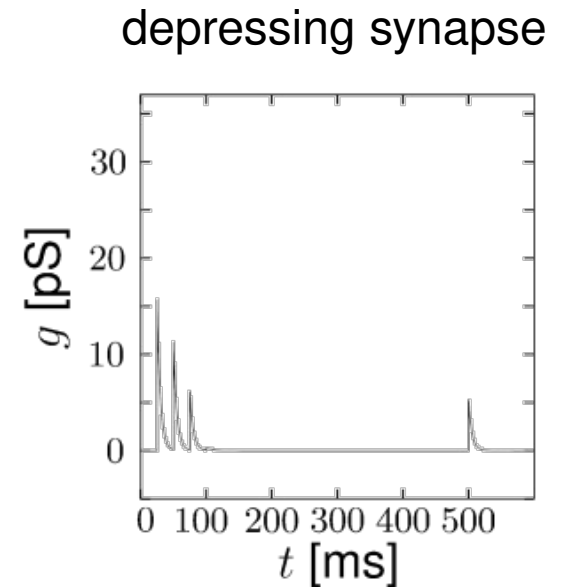
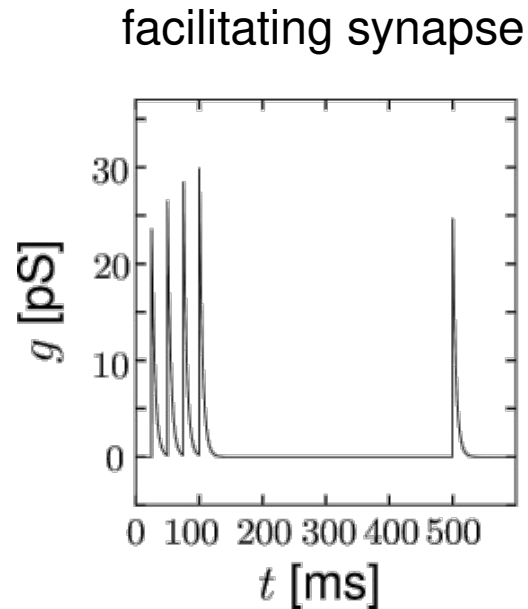
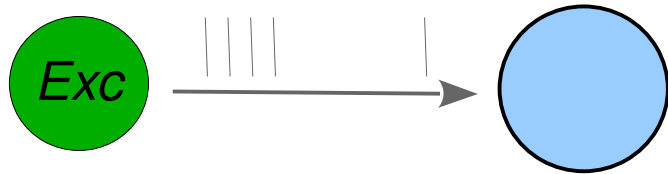
- *single neuron simulation in Brian* : analyze input and spike output of a single neuron



→ Explore how the excitatory and inhibitory synaptic inputs shape the spike output of the neuron

# P#10: Short-term synaptic plasticity

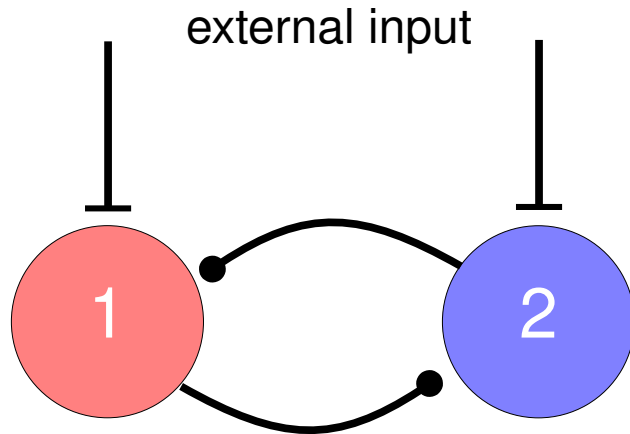
- *two neuron simulation in Brian : study synaptic transmission changes*



# P#11: Coupled oscillators

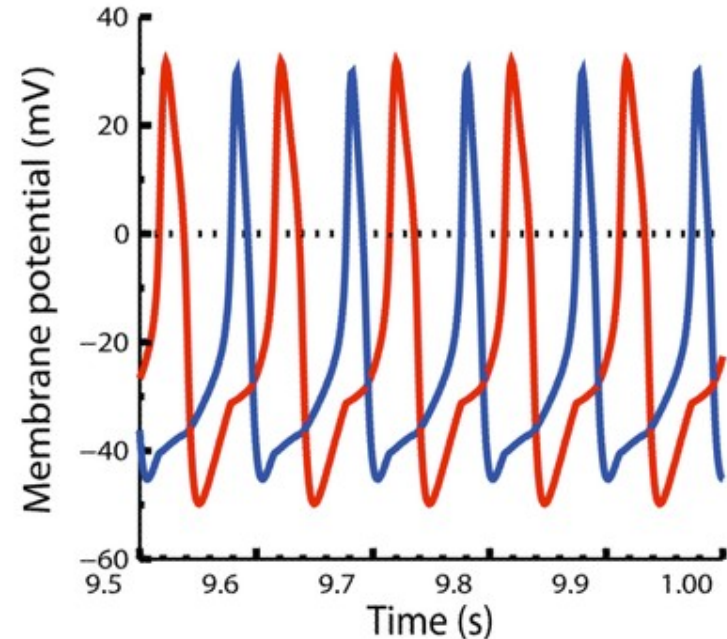
- *2-neuron network simulation* using Brian

implement network of 2 connected neurons  
and explore activity as function of  
synaptic connection



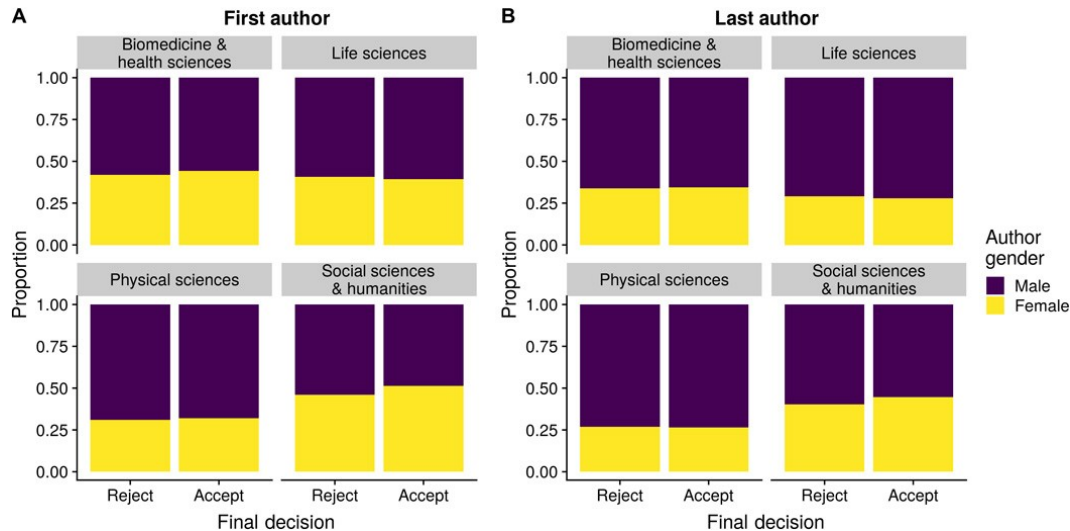
no connection, exc. synapses, inh. synapses

explore temporal relationship of  
the activity between  
both neurons



# P#12: Author position and gender bias

- *Bioinformatics* : literature search based project, query Pubmed

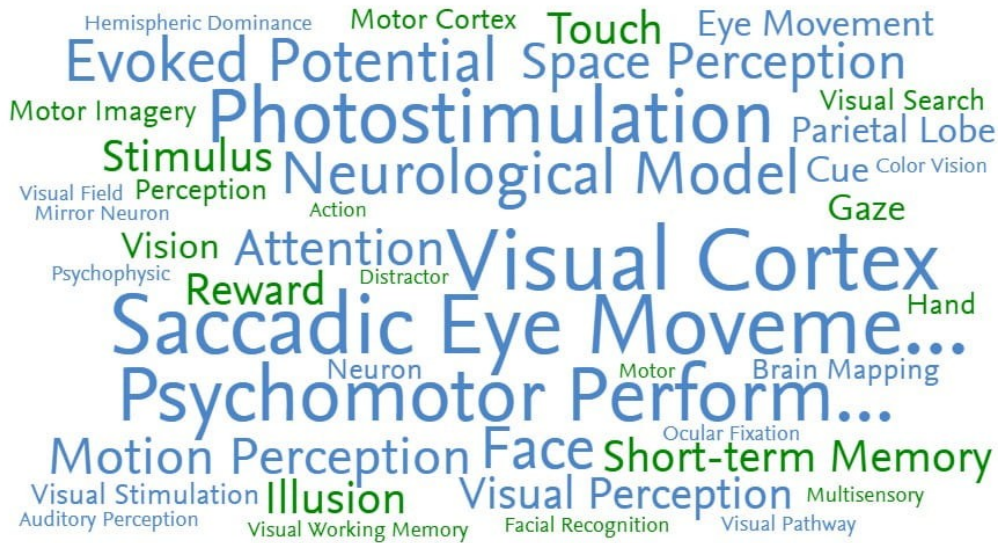


Study the gender ratio of first and last authors and how this ratio developed over the last 20 years.

[Squazzoni et al. Science 2021]

# P#13: Research trends in neuroscience

- *Bioinformatics* : literature search based project, query Pubmed



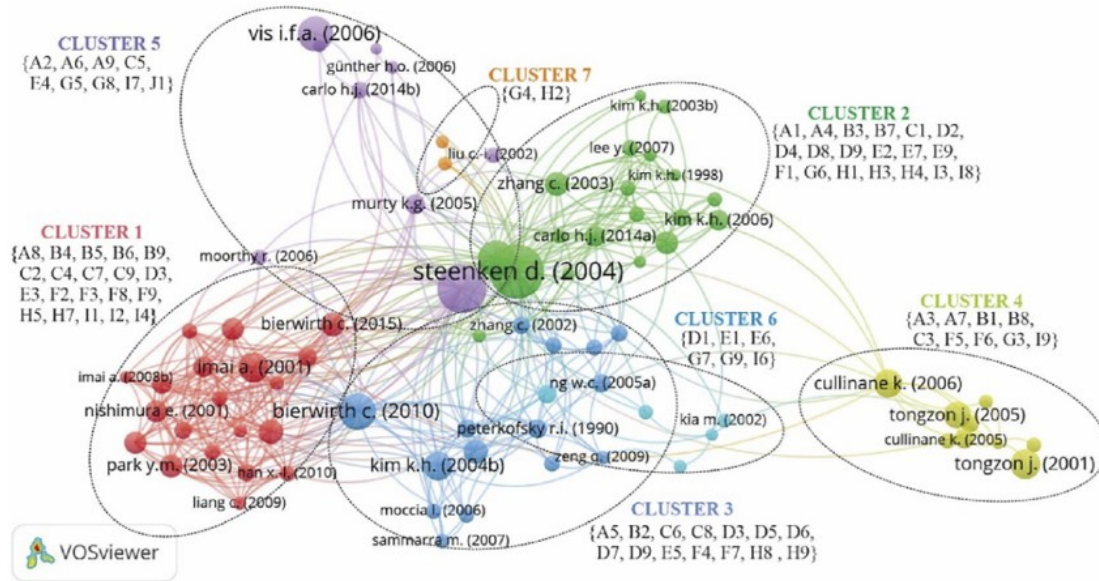
Explore patterns and extract research trends based on most common keywords in neuroscience publications (i.e. textual information based on the PubMed database)

Study how such trends changed over time



# P#14: Influential papers in neuroscience

- *Bioinformatics* : literature search based project, query Pubmed

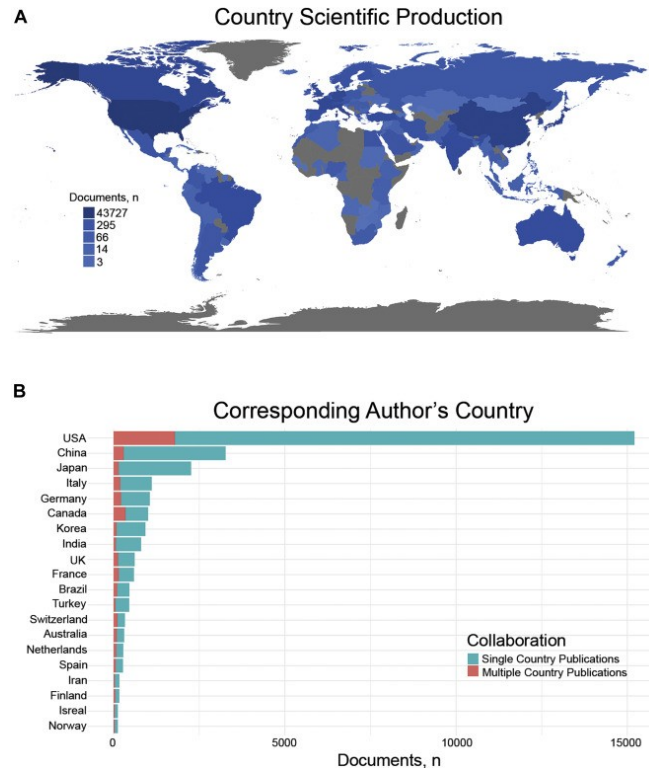


Identify influential papers in Neuroscience based on citation counts, i.e., which articles and topics received most citations

Compare the impact based on citations with the impact factors of the journals in which the articles are published

# P#15: Geographical Trends in Neuroscience Research

- *Bioinformatics* : literature search based project, query Pubmed



Investigate the geographical distribution of neuroscience research by analyzing author affiliations

Identify trends in publication output from different regions or countries, and study how the global research landscape has evolved over the last two decades