Q&A NeuroEngineering [L.Astolfi]

(2020-2021)

2.1 - The Neural cell

What are the 3 main functions of the neural cell?

1. Collection of information from multiple sources (other neural cells/receptors)

2. Integration (in time and space) of incoming information to provide a binary decision

3. Generation and propagation of a bit of information up to target cells (other neural cells, muscle cells)

What are the four main ion families having a role in the neuron functioning?

The main ions families are: $Na+, K+, Cl-, Ca++$

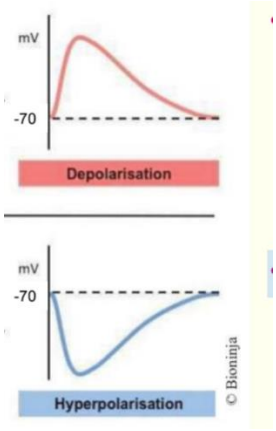
How is the resting membrane potential determined? What valuedoes it assume?

It is due to the different ion concentrations on the two ends of the membrane, at rest it's around -70 mV.

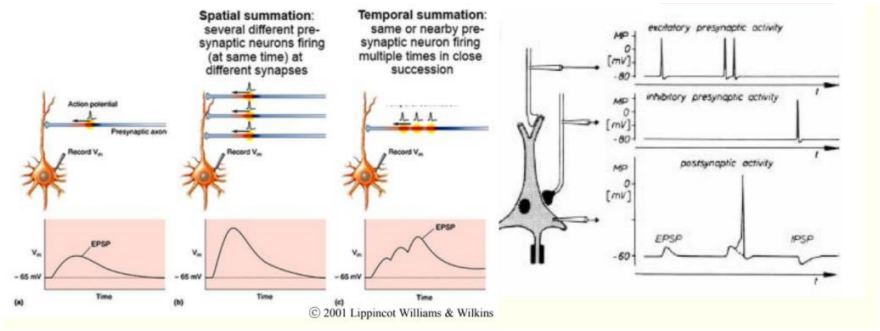
How is the membrane potential modified by an excitatory synapse? And by an inhibitory one?

•Excitatory Post-Synaptic Potential (EPSP) → depolarization

•Inhibitory Post- Synaptic Potential (IPSP) → hyperpolarization



What's the difference between temporal and spatial summation? Can they occur simultaneously?

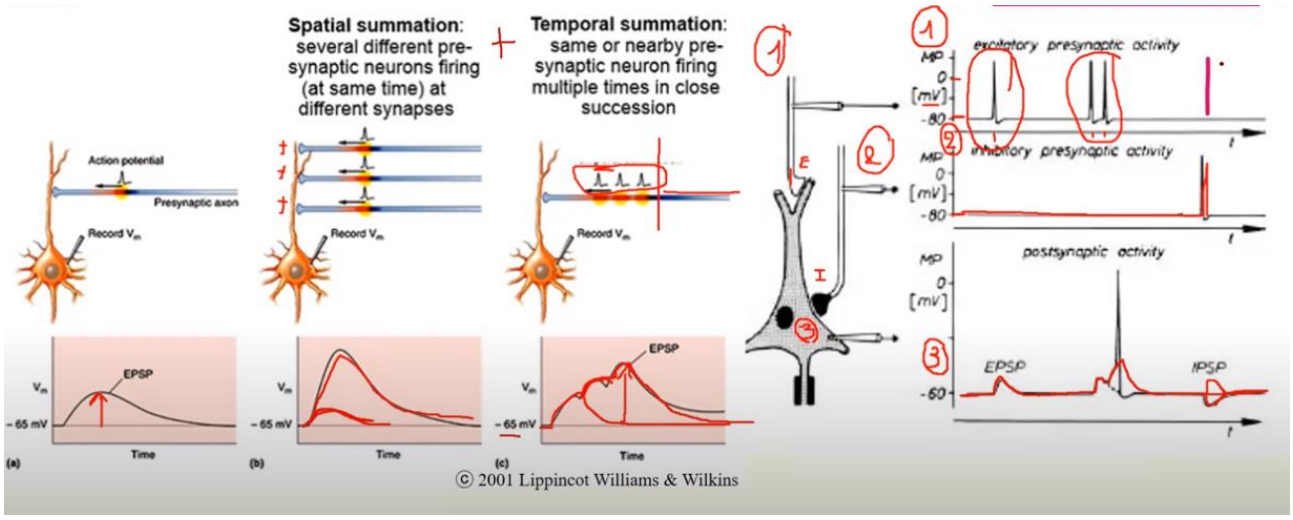


Yes they can occour simultaneously.

Why is a depolarizing post-synaptic potential called "excitatory"?

Because the depolarization causes a flow of positive ions (excitatory post sinaptic current), this creates the generation of an action potential. In neuroscience, an excitatory postsynaptic potential (EPSP) is a postsynaptic potential that makes the postsynaptic neuron more likely to fire an action potential. This temporary depolarization of postsynaptic membrane potential, caused by the flow of positively charged ions into the postsynaptic cell, is a result of opening ligand-gated ion channels. The flow of ions that causes an EPSP is an excitatory postsynaptic current (EPSC).

What is the use of an inhibitory PSP?



2.2 - The Neural cell

Do we need to measure the amplitude and duration of an action potential each time it occurs to understand the cell behavior?

No we don't. There is no relevant information in amplitude and duration of action potentials because they are, more or less, always the same. A relevant feature could be the frequency for example.

Which parameter of the spike train in output to a neuronal cell is the most informative?

The temporal distance between spikes.

What will the frequency of the spikes influence?

The temporal summation of the PSPs

The absolute refractory period is due:

To the voltage-gated $Na+$ channel

The saltatory (myelinated) conduction is faster than the continuous one

True

A hyperpolarization of 10 mV with respect to the resting potential causes the generation of an action potential

False

A depolarization of 20 mV causes a stronger action potential than a depolarization of 10 mV

False

3 - Principles of Neuroanatomy and Brain organization

At what temporal scale does the brain operate?

It works in a temporal scale of milliseconds.

At which different spatial scales may we look at its functioning?

Spatial scale of *um* (soma; membrane thickness: nm)

Put the following levels of cortical organization in a hierarchical order

(from the smaller to the larger):

A. Brodmann areas
D, B, E, A, C (forse)

B. Cortical columns

C. Brain lobes

D. Cortical layers

E. Brain circuits

Indicate which of the brain lobes houses the visual function:

A. Frontal

B. Temporal

C. Parietal

D. Occipital

D. Occipital

For each of the following brain areas, indicate if they are cortical or subcortical:

A. Thalamus	Subcortical
B. Primary motor area	Cortical
C. Cerebellum	Subcortical
D. Broca (language) area	Cortical
E. Brainstem	Subcortical

Does the short-term synaptic plasticity involve:

A. A structural change in the post-synaptic membrane

B. An increased number of membrane receptors

C. The amount of neurotransmitter released in the synaptic cleft

D. An irreversible change in the synaptic structure

C

List the four main neuronal mechanisms behind brain plasticity

1. Increasing of neurotransmitters

2. Increasing of receptors
3. Axonal sprouting
4. Axonal Regeneration

4 - Electrical Correlates of the Brain Activity

Put the following levels of brain electrical correlates in sequence according to their increasing spatial resolution (from the less to the more detailed):

A. ECoG: Elettrocorticography

B. LFP: Local field potentials

C. IP: Intracellular Potentials

D. S-EEG: Stereo-electroencephalography

E. EEG: Electroencephalography

F. EP: Extracellular Potentials

EADBFC

To record in vitro measures of the membrane potential over the dendrites of a neural cell, you can use:

Intracellular measures

Indicate which of the following factors affect the amplitude of EEG signals (multiple answers):

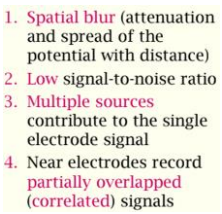
- Synchronicity of the neural activity
- Neurons' orientation

Which electrical variation of the membrane potential mainly contributes to EEG?

The post-synaptic potentials

Which regions of the brain mainly contribute to scalp EEG? Why?

List at least 4 limitations of scalp EEG recordings

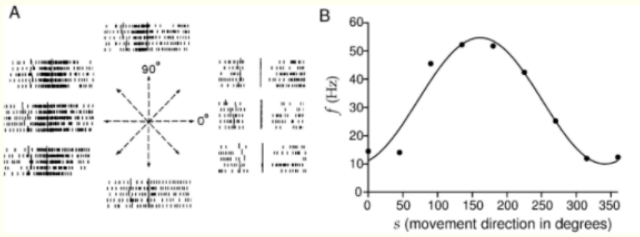


List at least 5 advantages of scalp EEG recordings

1. Noninvasive
2. Easy to use
3. Portable
4. Inexpensive
5. Covers the entire cortical surface
6. Excellent temporal resolution

5.1 - Neural Encoding

Given the following tuning curve:



- The neural response for a movement direction of 90 degrees is greater than for 180 degrees (T/F)
- I will build a different tuning curve for each trial (T/F)
- When the movement direction is 250 degrees I can expect a firing rate around 30 Hz (T/F)
- If the measured firing rate is 55Hz, I can «guess» which was the movement direction that produced that response (T/F)

1) F (90° about 40Hz, 180 about 55Hz)
2) F (you have to do the average)
3) T
4) T

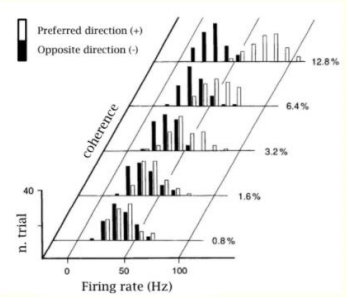
5.2 - The Poisson Spike Generator

1. When the occurrence of each spike is independent from the others, the firing rate r *is* sufficient to compute the probabilities for all possible action potential sequences (T/F)
2. In a Poisson process, when r increases, higher values of n are *more* likely (T/F)
3. Long inter-spike intervals (*isi*) have a probability that falls with their duration according to the exponential law (T/F)
4. The differences between the distribution of *isi* in real data and in simulated data produced by a Poisson generator are due to the refractory periods (T/F)

1) T $P_T[n] = \frac{(rT)^n}{n!} e^{(-rT)}$
2) T [$rT = n$]
3) T [$e^{(-r\tau)}$]
4) T

6.1 – Neural Decoding

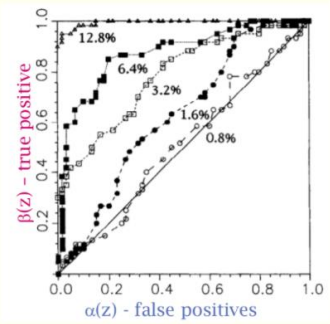
1. Given the distribution of firing rates in the figure:
   - A. The discriminability d' is higher when the coherence is =1.6 than =6.4 (T/F)
   - B. There is an optimal value of z that can be used for all coherence levels (T/F)
   - C. r_+ distribution is more affected by the coherence level than r. (T/F)



1) F $\quad d' = \frac{<r^+> - <r^->}{\sigma_r}$
2) F
3) T (I Bianchi ovvero i + si spostano all'aumentare della coherence)

6.2 – Neural Decoding

2. Given the ROC curves in the figure:
   - A. The related AUC is between [0,1] (T/F)
   - B. The classification performances do not depend on z (T/F)
   - C. The classification performances depend on the experimental conditions (T/F)
   - D. The ideal curve is the one closer to the diagonal (T/F)



1) F [between 0.5, 1. Worst case scenario in binary condition is random]
2) F
3) T [The experimental conditions are the lines that cross the figure]
4) F [farther to the diagonal]

7 - Brain Networks

1. Explain the difference between univariate and multivariate analysis of the brain
2. Explain the difference between anatomical, functional and effective connectivity
3. If $C_{xy}(f)$ is the ordinary coherence between x and y, indicate, for each of the following sentences, if they are true or false:
   a) C_{xy} is a function of frequency
   b) $C_{xy} \in [0, 1]$
   c) $C_{xy}=C_{yx}$
   d) C_{xy} can be computed also if the Fourier transform of x and y does not exist
4. Describe at least 2 advantages and 2 limitations of the ordinary coherence
5. Make an example of the problem of the common source

1) When each signal is independent from other (**Univariate Analysis**). In complex systems it is necessary to analyse the signals **and** their **interdependency** (**Multivariate Analysis**).

2)

Anatomical, physical or structural connections linking sets of neurons or neuronal elements. Relatively **stable** and **shorter time scales**, thus, during a recording session of a couple of hours we do not expect changes. Anatomical connectivity is at the basis of functional/effective connectivity, but **cannot explain it**.

Functional, it is essentially a description of what is happening in the brain in terms of similarity between the activity in different regions. Usually it is based on **correlation**, **coherence**, and **transfer entropy**.

Effective, it refers explicitly to the **influence** that one neural system exerts over another, either at a synaptic or population level. It corresponds to **parameters of a model** that tries to **explain observed dependencies**. Based on concept of **causality**.

3) T T T T

4) Limitations: cannot measures causality; no information about direction of the interaction.

Advantages: It is symmetrical; It measures synchronicity.

5) As the land increases, the number of babies and storks increases.

8 - Brain Networks

1. Testing causality as temporal precedence is more practical than testing the physical influence (T/F)
2. The difference between the Wiener's and Granger's definitions of causality in the statistical sense is in the definition of a model to be used for the prediction (T/F)
3. Given two time series x and y:
   a) $G_{x\to y}$ is always equal to $G_{y\to x}$ (T/F)
   b) $G_{x\to y} \in [-\infty, \infty]$ (T/F)
   c) A negative value of $G_{x\to y}$ means an inverse precedence between the two time series (T/F)
4. List two advantages and two limitations of the Granger test

1) T

2) T

3) **F** because → $G_{\{y\to x\}} \neq G_{\{x\to y\}}$

F because → $G_{\{y\to x\}} \in [0, \infty]$

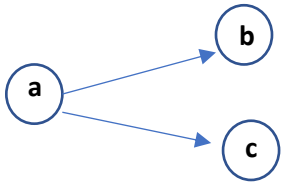
F because → $G_{\{y\to x\}} = \ln(\frac{V_{x|x}}{V_{x|x,y}})$

4) Advantages: [1] **Directionality** $G_{\{y\to x\}} \neq G_{\{x\to y\}}$. [2] **Statistical** meaning

- Limitations: [1] Defined in **time domain,** we have lost the frequency information. [2] **True causality** can **only** be assessed if the set of two time series contains **all possible relevant information and sources** of activities for the problem.

1. Show an example of network for which a pairwise approach is less accurate than a multivariate one
2. Given the PDC estimator:
   a) $PDC_{i\to j}(f)$ is always equal to $PDC_{j\to i}(f)$ (T/F)
   b) The normalized PDC $\in[-\infty, \infty]$ (T/F)
   c) PDC can always avoid the problem of the "hidden source" (T/F)
3. List two advantages and a limitation of the pairwise and of the multivariate approach

1)



2) **F** because → The value of PDC_{ij} at a certain frequency f_0 represents the existence of a causality link **directed from j to i.** $\pi_{ij}(f) \neq \pi_{ji}(f)$

F because → [0,1]

F because otherwise you should know all the sources

3)

Multivariate approach:
- Advantages:
  - Better estimation performances
  - Allows for inserting all data sources in the model
- Limitations:
  - Limitation in the number of channels/signal that can be modeled → more data required

Bivariate approach:
- Advantages:
  - No limit to the number of signals
  - To be used when short data segments are available
- Limitations:
  - Reduced accuracy

9 - Graph theory X

10 - Graph theory X