Domande Astolfi

Veronica Romano 1580844

June 6, 2020

2.1-2.2 THE NEURAL CELL

1

What are the 3 main functions of the neural cell?

The neural cell has 3 main function. The first is to **COLLECT** info that arrive continuously (each ms) from the other cells. The info are collected by the dendrites, which are protuberances of the neuron. The second function is to **INTEGRATE** this collected info. It means that the info should be summarized temporarly and spatially to provide a **BINARRY DECISION**. This binary decision is the result of integration. Binary means that it should be 1 or 0. It's zero if the decision of the cell is that of not producing a signal to send to the other cells. 1 means that the signal will be produced and will be send. The last function is the **GENERATION AND PROPAGATION** of the response that is a bit of info to reach the final cell that should be another neural cell or a muscle cell.

2

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

The main families are Na+, K+, Cl-, Ca++.

3

How is the resting membrane potential determined? What value does it assume?

The citoplasm intern to the cell and the fluid external to the cell are different potencial charged, so there is a difference of potencial in and out the cell; this because, at rest, the intern of the cell has prevalence of negative ions and there are also proteins that are negative, with respect to the external that has prevalence of positive ions, infact if we put a device in the membrane and we measure the potencial in the cell, this is of -70mV that is the resting potential.

4

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

if the synaptic is exitatory, during the passage of info from the presynaptic cell to the post synaptic cell, there is a passage of a Na+ ion. It means that the potencial in the post synaptic cell became less negative and so the results is that there is a depolarization. While in the hinibitory synapses there is a passage of a Cl- ion that makes the potential in the postsynaptic cell more negative, so we will have a hyperpolarization.

5

Whats the difference between temporal and spatial summation? Can they occur simultaneously?

When an action potencial is sent from the presynaptic cell to the postsynaptic, what happens is that if the synaptic is excitatory, there is a depolarization starting from the resting potential when the spike arrives, and then there is a repolarization to the resting potential. This is the case of one single spike. However the cell receives many section potencial from different other cell at the same time, but also from the same cell one after another. In the first case the cell make a spatial summation, so the total potential is given by the sum of the all single spike potential. So starting from the resting potencial there will be a depolarization (equal to the sum of all spikes) and then a repolarization to the resting potential. The second case is that of temporal summation. The spikes arrive one after another. So when the first spike arrives the cell behaves in the same way of one single spike, however when begin the repolarization of the potential, the second spike arrives and there is another depolarization, and so on. Finally the cell turn back to the resting potential. If the synapses are inhibitory, the mechanism is the same, but starting from the resting potencial there is first an hyperpolarization and then the depolarization to turn back to the resting potencial. The cell receives these spikes continuously and contemporarly, but the cell makes first the temporal summation of this pulses and then the spacial summation to reach a non binary signal.

6

Why is a depolarizing post-synaptic potential called excitatory?

it is called excitatory because the post synaptic cell receives a positive ions. An excitatory post-synaptic potential increases the probability that a neuron will fire since (it is depolarizing) or in other words it lets that positive ions flows into the cell.

7

What is the use of an inhibitory PSP?

They tend to keep the membrane potential of thepost-synaptic neuron below threshold for firing an action potential. It increases also the flexibility of the system to make in the way that all the neurons fire not at the same time.

8

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

No because, we don't care the shape of the action potential or the duration but only at which temporal distance the spikes occur. Moreover because it is all-or-none, we are interested only in the fact that it overcome a threshold or not.

9

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

- A. The amplitude of the spikes
- B. The spatial position in which the spikes are generated
- C. The temporal distance between spikes X

10

What will the frequency of the spikes influence:

- A. The temporal summation of the PSPs X
- B. The spatial summation of the PSPs
- C. The amplitude of the resulting action potential in the post-synaptic cell

3 PRINCIPLES OF NEUROANATOMY AND BRAIN ORGANIZATION

1

At what temporal scale does the brain operate?

the brain operates at temporal scale of milliseconds. However this time can be increased by the use of alcoll and drugs, but it can pass from ms to few more ms, but not an another temporal scale.

2

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

At scale of nanometer we can observe the membrane of the cell, at scale of micrometer we can observe the soma, and the organization of the neuron in 6 vertical layers, and the organization in columns where the neuron performs the same function and respond in the same way at the same stimuli. At level of centimeters we can observe the Broadmann areas which perform several task. More regions can perform the same function. At the level of cm we can also observe the general functioning of the brain circuits and how the parts of it cooperates.

3

Put the following levels of cortical organization in a hierarchical order (from the smaller to the larger):

- A. Brodmann areas 3
- B. Cortical columns 2
- C. Brain lobes 4
- D. Cortical layers 1
- E. Brain circuits 5

4

Indicate which of the brain lobes houses the visual function:

- A. Frontal
- B. Temporal
- C. Parietal
- D. Occipital X

5

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

6

Does the short-term synaptic plasticity involve:

- A. A structural change in the post-synaptic membrane LONG-TERM
- B. An increased number of membrane receptors LONG-TERM
- C. The amount of neurotransmitter released in the synaptic cleft X SHORT-TERM
- D. An irreversible change in the synaptic structure NOT TRUE

7

List the four main neuronal mechanisms behind brain plasticity

The first SYNAPTIC PLASTICITY. When we learn there in an incremental of the neurotransmitter between the presynaptic and the postsinaptic cell. If we make something for several ours, the amount of neurotransmitter increases. The second is the AXONAL SPROUTING (OR PRUNING) that consists in the formation of new synapses. The third is the AXONAL REGENERATION. This is typical in the prenatal period and in critical situation but less in adult age. Finally there is the UNMASKING OF LATENT SYNAPTIC CONNECTIONS. The synapses are not used until they are need because of a lesion.

4 ELECTRICAL CORRELATES OF THE BRAIN ACTIVITY

1

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 2
- B. LFP: Local field potentials 4
- C. IP: Intracellular Potentials 6
- D. S-EEG: Stereo-electroencephalography 3
- E. EEG: Electroencephalography 1
- F. EP: Extracellular Potentials 5

2

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

- A. Intracellular measures X
- B. Extracellular measures

3

Describe which part of the pyramidal neuron acts as a current dipole and how

The part is the dendrite (or apical dendrite) because it is like a dipole with one charge here at distance d from the other which is the basal dendrite (but we

can consider also the soma) of the cell. When the post-synaptic neuron receives an excitatory signal from an active axon terminal, positive ions flows in the dendrite. So the intracellular space becomes more positive making the extracellular space relatively more negative at the reception site. The extracellular space at the basal dendrite, above the soma, is now more positive, so it makes the intracellular space more negative. Now in the apical dendrite we have a positive charges and in the basal dendrite or in the soma the negative ones. It means that a current from + (source) to -(sink) will be generated, creating an intracellular current, and the charges in the extracellular space create an extracellular current that has opposite direction with respect to the intracellular current. For an hinibitory cell is the same, but the polarity of the dipole is reversed.

4

For each of the following factors, indicate if they affect or not the amplitude of EEG signals:

- A. Open/closed field X
- B. Neurons orientation X
- C. Synchronicity of the neural activity X
- D. Distance between the neurons and the electrodes X

5

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

- A. The action potential
- B. The spike train
- C. The resting membrane potential
- D. The post-synaptic potentials X

6

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

The part is the cortex because pyramidal neurons produce an open field and in particular neurons that are on the gyri produce most of the EEG signal with respect to neurons that are in the sulci. All the neurons are oriented **normally** to the cortical surface, so the signal is propagated on the surface. But since the neurons can be seen as dipole and the produce current, this current is more captured in the gyri. While in the sulci it is attenuated, because we have, in a double layer of the cortical surface; in this case on each layer we have a current that has the same intensity and direction but opposite verse. It means that in the sulci the current eliminate each other, so the signal in this part will not

be recorded from the EEG. Moreover the neurons are organized in palisades, or more specifically they are **parallel each other**, it means that the resulting signal of each neuron is summed up to that of the other neurons. The last reason is the **longitudinal shape** of the pyramidal neurons, so the signal generated flows towards the cortical surface.

7

List at least 4 limitations of scalp EEG recordings

- **Low SNR**
- **Reference choice**
- **Spatial blur**, i.e. attenuation and spread of the potential with distance
- **Multiple sources** contribute to the single electrode signal
- Near electrodes record **partially overlapped (correlated)** signals

8

List at least 5 advantages of scalp EEG recordings

- **Non invasive**
- **Easy to use** for practical applications and researches
- **Portable** wherever we want
- **Inexpensive** its cost is only of few thousand of euro
- **Covers the entire cortical surface**
- **Excellent temporal resolution** because the propagation is instantaneous
- It can be used more easily incorporated for simultaneous use with functional magnetic resonance imaging (fMRI), transcranial magnetic stimulation and transcranial direct current stimulation.

5.1 NEURAL ENCODING

1

Is the neural response for a movement direction of 90 degrees greater than for 180 degrees?

No, the neural response is maximum at 180 degrees.

Will I build a different tuning curve for each trial?

No because we used the average firing rate, so for each group of trials we consider an average value of it.

Which firing rate can I expect when the movement direction is 250 degrees?

I expect that the firing rate will be the average between the maximum and the minimum firing rate. (circa 35 Hz)

If the measured firing rate is 55Hz, can I guess which was the movement direction that produced that response?

If I put on the y axis at the value of 55 Hz (we have the r_max around 55 Hz, on the top of the curve), this point correspond to the firing rate of an angle of 160 degrees. From this result I can suppose that the direction of the movement will be on the left.

5.2 NEURAL ENCODING

1

When the occurrence of each spike is independent from the others, is the firing rate r sufficient to compute the probabilities for all possible action potential sequences?

Yes, in this case is possible. In fact for the Poisson process we consider that for homogeneous type r is constant (this is the type we consider), while for the inhomogeneous type we consider r(t) dependent from time.

2

In a Poisson process, when r increases, higher values of n are more or less likely?

When r increases higher values of n are more likely, because we have the maximum probability when rT=n, so if we consider the same T, if r increases, increases also the probability of n spikes in that interval.

3

Long inter-spike intervals (isi) have a probability that falls with their duration according to which mathematical law?

According to the exponential function because the probability of inter-spike interval (ISI) is given by $e^{(-r\tau)} * r\triangle t$. So if r is fixed and $\tau > \triangle t$, the exponential function changes when τ changes. In particular, when τ increases (where τ is the interval between 1 spike and the following one; so it is the time in which we have zero spike), the value of $e^{(-r\tau)}$ decreases.

4

What are the differences between the distribution of isi in real data and in simulated data produced by a Poisson generator? How can we reduce them?

In the real date, for small values of inter-spike interval, we can note that the probability of having a spike is very very small and in the at 1 ms is even zero. While in the spike generator date, we have a different result. For small values of inter-spike interval, the probability of having a spike is maximum. This is not a good result, but the problem is due to the presence of the refractory period. If we think about an action potential, after that the Na+ voltage gated channel is open (30mV), it pass in a condition of inactivity for about 1 ms (ABSOLUTE REFRACTORY PERIOD). During this time no action potential can be generated, so the probability of having another action potential or spike is zero. However in this time, the K+ channel open. After the absolute refractory period, starts the RELATIVE REFRACTORY PERIOD that has a duration of about 2 ms. In this time the K+ voltage-gated channel, close, after reaching the potential of -80 mV, as consequence of the hyperpolarization, and turn back to the resting potential. In the relative refractory period the probability that a spike is fired is very very low, because for to be generated it requires a strong depolarization. So turning back to the data recorded, we can see that in the previous milliseconds the probability is very low, and as I said before in 1 ms is zero. To having the same condition in the Poisson generator we need to impose some hard constraints, such as that below 1 ms, the probability should be zero, and for the next 2-3 milliseconds the probability should be low. By imposing these, the new Poisson generator gives a result similar to the real data. This because for very low values of the number of spike the exponential distribution don't work very well.

6 NEURAL DECODING

1

Explain why we perform the neural decoding (two reasons)

We perform the neural decoding because starting from the train of action potential generated with a specific firing rate r, we can find the property of the stimulus s that has generated it. The aim was to identify the stimulus that induced the neuronal spike train response; and the other is that the decoding permits to interface an external device with the brain.

2

Given the distribution of firing rates in the figure:

- A. Is the discriminability d higher when the coherence=1.6 or =6.4?

The discriminability is given by $\frac{d'=<r>_+-<r>_-}{\sigma_r}$, where $< r >_-$ is the average firing rate (it's the mean) for the opposite direction(-) distribution and $< r >_+$ is the average firing rate (it's the mean) for the preferred direction(+) distribution, and $\sigma_r$is the square root of the variance that is equal in the 2 gaussians. So at coherence level of 1.6 $< r >_+><$ $r >_-$ but they are near, while at 6.4 they are more far, so the numerator of d' is more distant to zero, and by considering that the variance is the same, d' is higher at 6.4 .

- B. Is there any optimal value of z that can be used for all coherence levels?

  Non esiste un valore di z che vada bene per tutti i livelli di coerenza, perch dipende da come sono le due distribuzioni da separare. Ad esempio, per una coerenza del 12.8%, una z pari a 50 Hz potrebbe andar bene, mentre per valori di coerenza pi bassi probabilmente ci sposteremo verso valori di z minori, che si collocano circa a met tra le due distribuzioni. L'idea scegliere una z che separi il meglio possibile le due curve. Il caso limite quello in cui il livello di coerenza molto basso: in questo caso, qualunque z separa male le due distribuzioni, perch sono sovrapposte. Questo ce lo confermano le curve ROC (slide 12) in cui la curva relativa ad una coerenza pari a 0.8% corre lungo la diagonale, che equivale alla probabilit del 50% di sbagliare, quindi pari al caso (lancio della monetina).

- C. Which of the two distributions (r+ or r-) is affected by the coherence level?

  The distribution that changes is the white (r+). As coherence increases, we can note that the white distribution shift towards right, while the black (r-) is always in the same place.

3

Given the ROC curves in the figure, indicate if the following statements are true or false:

- A. The related AUC is between [0,1] F
- B. The classification performances do not depend on z F
- C. The classification performances depend on the experimental conditions T

  [le condizioni sperimentali indicano il modo in cui si somministra lo stimolo al soggetto. Quindi, in questo caso, il livello di coerenza. C' una curva diversa per ogni livello di coerenza, e ogni curva associata a una diversa AUC, quindi a diverse performance. Perci la risposta VERO. Oltre che dall'osservazione delle curve, pu arrivare alla stessa conclusione ragionando cos: se io somministro uno stimolo molto rumoroso, sar pi difficile discriminare la risposta neuronale rispetto al caso in cui lo stimolo forte e chiaro]

- D. The ideal curve is the one closer to the diagonal F

7 BRAIN NETWORKS I - CORRELATION AND ORDINARY COHERENCE

1

Explain the difference between anatomical and functional/effective connectivity

For the anatomical connectivity there is a physical link between the 2 parts that are connected, for instance this can be an axon of fiber. While in the case of functional connectivity, we have always the physical link, but it can be used or not and at different levels. They are different also in the time scale, in fact at longer time scale (hours to days) the anatomical structure can be subjected to significant morphological changes and plasticity, but it is relatively stable at shorter time scales (seconds to minutes); while the functional connectivity is subject to changes at lower time scales (milliseconds).

2

Explain the difference between correlation and causation*
see also the next lecture

The correlation means that 2 events happen at the same time, while causation means that an even is the cause of another one, so a changing in an event caused a changing in the other one.

3

If C_{xy} 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 T
- B. $C_{xy} \in [0, 1]$ T
- C. $C_{xy} = C_{yx}$ T
- D. C_{xy} can be computed also if the Fourier transform of x and y does not exist T

4

Describe at least 2 advantages and 2 limitations of the ordinary coherence

ADVANTAGES:

- It's spectral

- It's normalized, so it's always between 0 and 1
- If $C_{xy}(F_0) = 0$ it means that $S_{xy} = S_{yx} = 0$, therefore there is no interaction between signal x and signal y at that frequency f_0. THEY ARE INDEPENDENT. If $C_{xy}(F_0) = 1$ it means that $S_{xy} * S_{yx} = S_{xx} * S_{yy}$, therefore all the power of x and y is shared between the two signal. THERE IS MAXIMAL CORRELATION between x and y.

LIMITATIONS

- we can't know the direction of the interaction
- It's bivariate
- it measures synchronicity but not causality

8 BRAIN NETWORKS II - GRANGER CAUSALITY

1

Explain why testing causality as temporal precedence is more practical than testing the physical influence

For testing the physical influence we need to change something in the brain activity, for instance through the use of current, and see what changes in another part of the brain, also far from we apply current. While for testing temporal causality we need just observe the brain because is based on the statistical properties of the signal.

2

Indicate whats the difference between the Wieners and Grangers definitions of causality in the statistical sense

Wiener definition said that: given 2 symultaneous measured signals, if one can predict the first signal better when we use also the past information from the second signal than using only the information of the first, then the second signal is causal to the first one. While Granger added the predictor (this is the main difference). It said that: an observed time series a(n) is said to Granger-cause another series b(n), if knowledge of a(n)'s past significantly improves prediction of b(n) by an autoregressive modelling. ed basata sulla autoregressive invece che sulla frquency-domain VEDI SLIDE8.

3

Given two time series x and y, indicate, for each of the following sentences, if they are true or false:

- A. $G_{x \to y}$ is always equal to $G_{y \to x}$ F

- B. $G_{x \to y} \in [-\infty, +\infty]$ F
- C. A negative value of to $G_{x \to y}$ means an inverse precedence between the two time series F

4

List two advantages and two limitations of the Granger test

ADVANTAGES:

- we can know the direction of the causality because $G_{x \to y} \neq G_{y \to x}$
- it has a statistical meaning

LIMITATIONS:

- it is defined in the time domain if the signal that we consider are stationary in a specific time window
- the true causality can be assessed if the set of two time series contains all the possible relevant informations and sources of activity, for the problem.

9 BRAIN NETWORKS III - PAIRWISE AND MULTIVARIATE

1

Show an example of network for which a pairwise approach is less accurate than a multivariate one

For instance when we have more than 2 channels, the mutivariate approach is better because it takes account of all signals and it considers all the informations about this at the same time. In this way we will have no spurious link in the graph. While for the pairwise approach, it takes account of only 2 signals at time, so it doesn't consider all the info, in fact we have the problem of the hidden sources, and in this case the graph will have some spurious links.

2

Given the PDC estimator, indicate, for each of the following sentences, if they are true or false:

- $PDC_{i \to j}$ is always equal to $PDC_{i \to j}$ F
- The normalized $PDC \in [-\infty, +\infty]$ F
- PDC can always avoid the problem of the "hidden source" F-¿perch comunque tocca considerare tutti i segnali per evitarlo

3

List two advantages and a limitation of the pairwise and of the multivariate approach

ADVANTAGES OF PAIRWISE:

- There isn't limit to the number of signals (we will consider always in pairs)
- It can be used when short data segments are available

ADVANTAGES OF MULTIVARIATE:

- Better estimation performances
- It allows to insert all data sources in the model.

LIMITATIONS OF THE PAIRWISE:

- Reduced accuracy

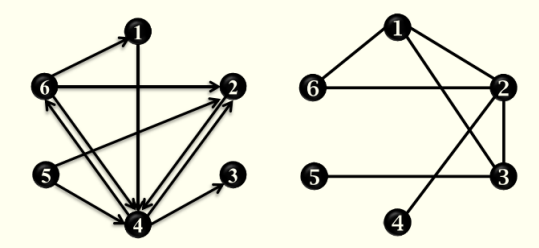
LIMITATIONS OF THE MULTIVARIATE:

- the number of channels that we can consider is always limited and more data are required

10 GRAPH THEORY AND NEUROSCIENCE

1

Given the following graphs:



2

Write down their adjacency matrices

3

Compute their densities

4

Compute their degrees

5

Write down their distance matrices

6

Compute their Global Efficiency