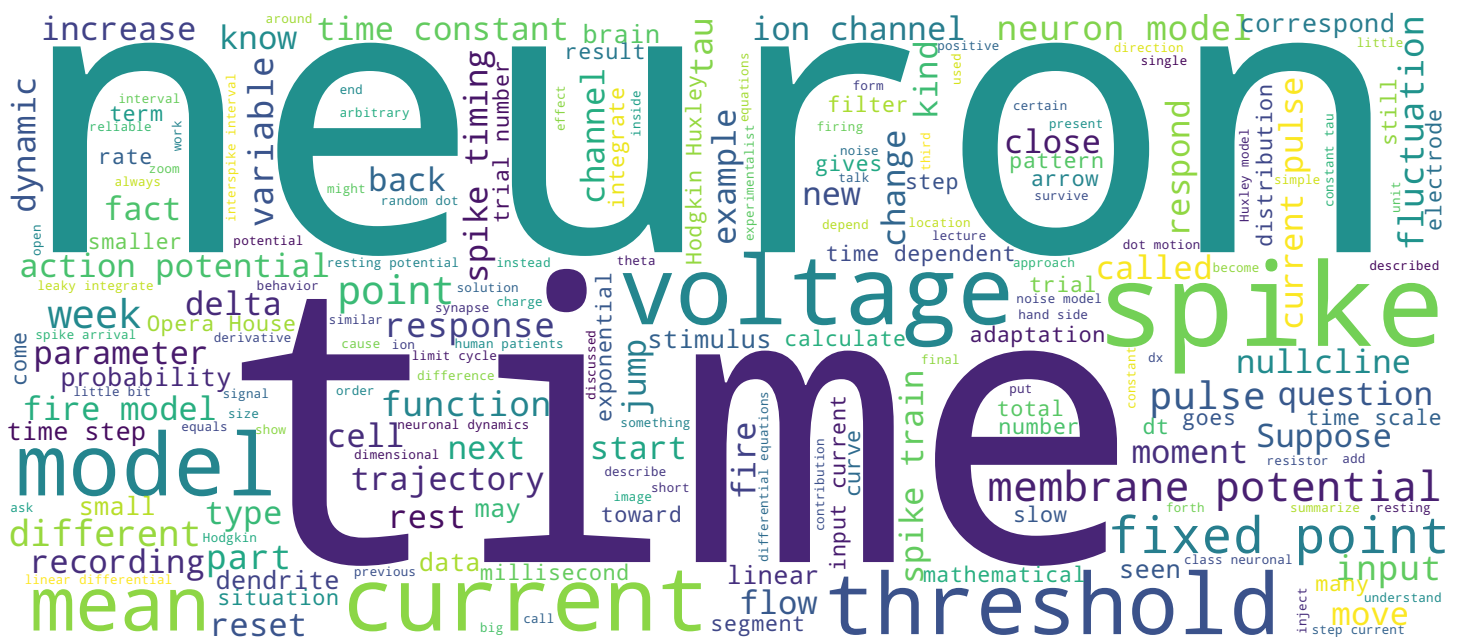


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EPFL, Lausanne, Switzerland

- subthreshold and superthreshold



EPFL



Week 5 – part 1 :Variability



5.1 Variability of spike trains

- experiments

5.2 Sources of Variability?

- Is variability equal to noise?

5.3 Three definitions of Rate code

- Poisson Model

5.4 Stochastic spike arrival

- Membrane potential fluctuations

5.5. Stochastic spike firing

- subthreshold and superthreshold

Welcome to week five of the class neuronal dynamics. In the previous four weeks, we have looked at neuron models. And all these neuron models were deterministic. There was no notion of noise. Now, in the brain, if experimentalists do recordings, they find a lot of fluctuations. One of the questions were are going to ask-- where do these fluctuations come from? Are these fluctuations noise?

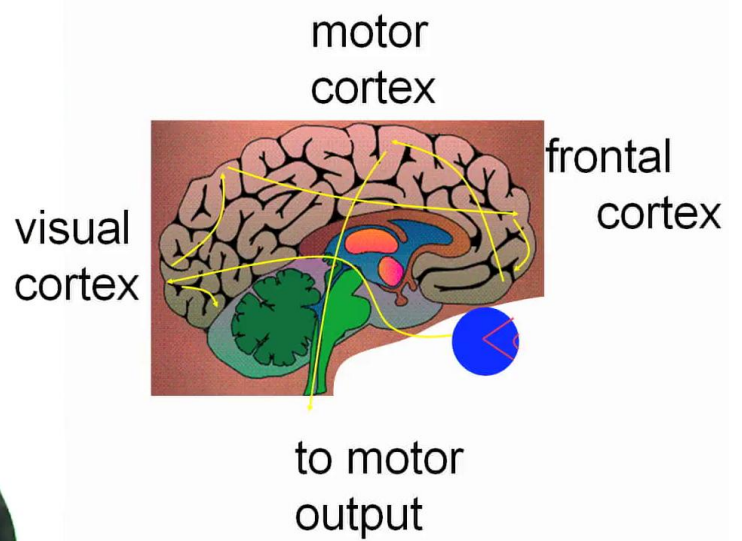
Notes

Summary



0m 04s

Neuronal Dynamics – 5.1. Variability



Now, let's for a moment go back to the full brain-- not an isolated neuron, but a full brain with all its different areas of brain involved in processing of information arising from external stimuli.

Notes

Summary

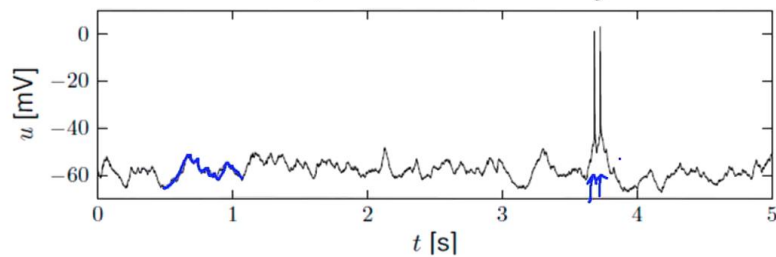


0m 34s

Neuronal Dynamics – 5.1 Variability *in vivo*

Spontaneous activity *in vivo*

awake mouse, cortex, freely whisking,



Crochet et al., 2011

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So here is a recording from a mouse-- a mouse that's awake sitting in the cage and whisking from time to time. And what we see in this recording is that the membrane potential exhibits strong fluctuations, as we have already discussed in week one. From time to time, there are action potentials.

Notes

Summary



0m 48s

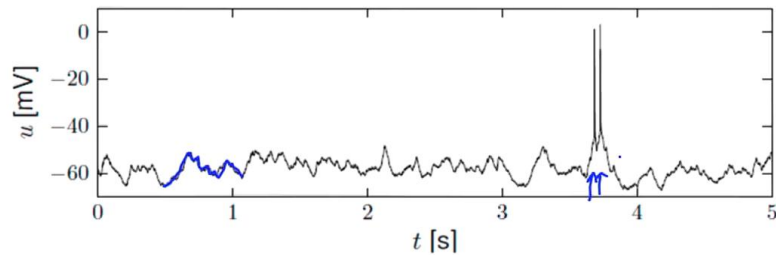
Neuronal Dynamics – 5.1 Variability in vivo

Spontaneous activity *in vivo*

Variability

- of membrane potential?
- of spike timing?

awake mouse, cortex, freely whisking,



Crochet et al., 2011

And one of the questions is is the timing of these action potentials also fluctuating? Is this variable? Another question is, where do these fluctuations of the membrane potential come from?

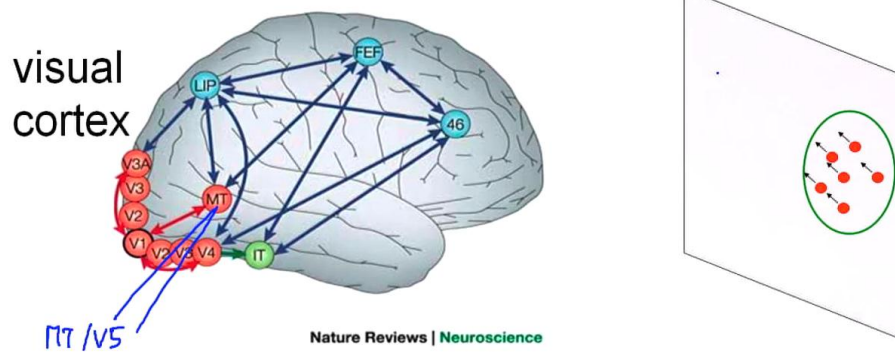
Notes

Summary

1m 15s



Detour: Receptive fields in V5/MT



cells in visual cortex MT/V5
respond to motion stimuli

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Regarding spike timing, let's look at monkey data. The visual cortex is organized in different areas. And one of the areas is called MT, or V5--area 5 of the visual cortex. Neurons in that area respond strongly to movement stimuli. So if you present a thought pattern on the screen and the pattern of thoughts is moving, then neurons in MT will respond to this pattern.

Notes

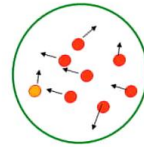
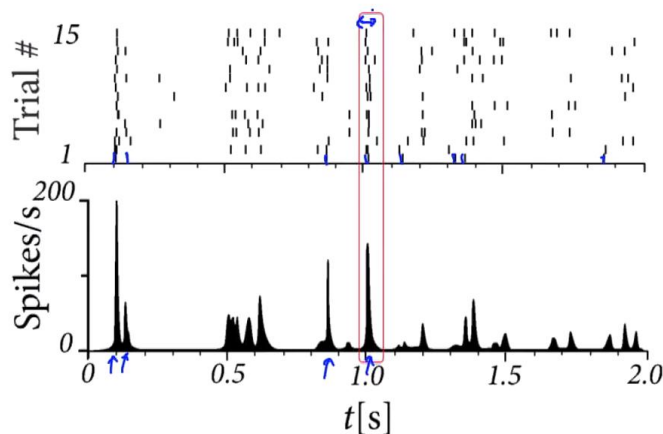
Summary



1m 28s

Neuronal Dynamics – 5.1 Variability in vivo

15 repetitions of the same random dot motion pattern



*adapted from Bair and Koch 1996;
data from Newsome 1989*

Now, instead of presenting just a coherently moving object, one can think of presenting random dot motion. So there's a random configuration of dots. They move in some directions. And if the very same random dot motion pattern is repeated several times. And you see in the first trial, spikes arrive here and there and there and there and there and there and there and there. Now, the same pattern is repeated a second time. Spike timing is different. Spike timing is different at every different trial. If you average over several trials, then you find that a lot of activity occurs here and again here. But then there is a pause and there is more activity coming here and there. So on a time scale of one segment, timing looks fairly reliable. This neuron emits spikes reliably in response to such a random dot motion. However, if you zoom in on the time scale of milliseconds, then we see that there are a lot of fluctuations of spike timing between one trial and the next. Now, this is monkey data.

Notes

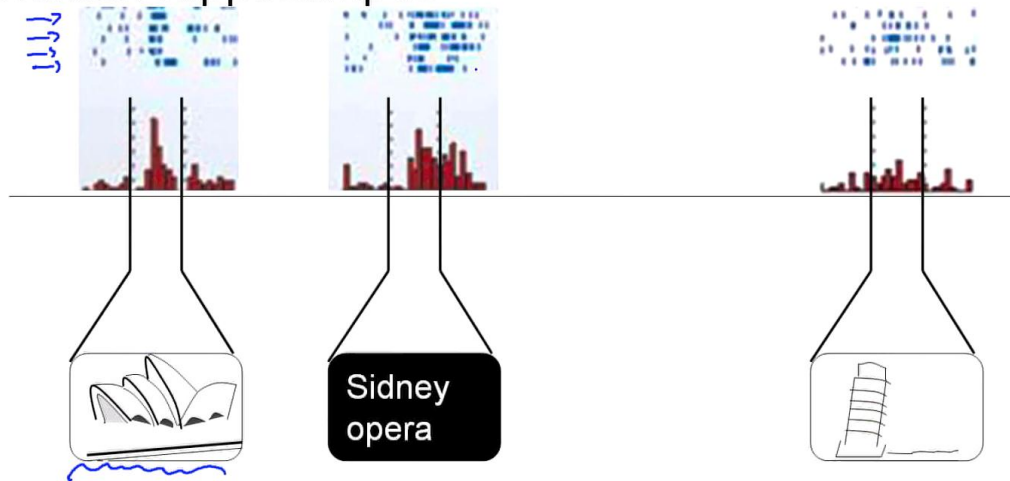
Summary



2m 06s

Neuronal Dynamics – 5.1 Variability in vivo

Human Hippocampus



Quiroga, Reddy, Kreiman, Koch, and Fried (2005). *Nature*, 435:1102-1107.

⌂ / ☰ ➡

There's also data from humans-- human patients who suffer from a severe form of epilepsy, a form of epilepsy that cannot be treated by pharmacological means. Then these human patients often have to undergo a surgical treatment. Now, before the operation, an electrode is implanted in the brain. And the electrode stays there for several days while humans are awake. You can talk with the human patients. You can present pictures. And so this is recordings from an electrode. And we find that neurons close to this electrode respond strongly to images of, say, the Sydney Opera House. And the same neurons respond in trial number one, in trial number two, in trial number three, in trial number four, and so forth. And if you average across different trials, you see a strong peak in the number of spikes during the presentation of the image. The same neurons also respond if you just present the name "Sydney Opera House." And in fact, they continue to respond, indicating memory. "Opera House" evokes some memory. Neurons, or this one neuron sitting close to the electrode, responds for a prolonged time. However, between individual trials, timing of spikes does not look reliable.

Notes

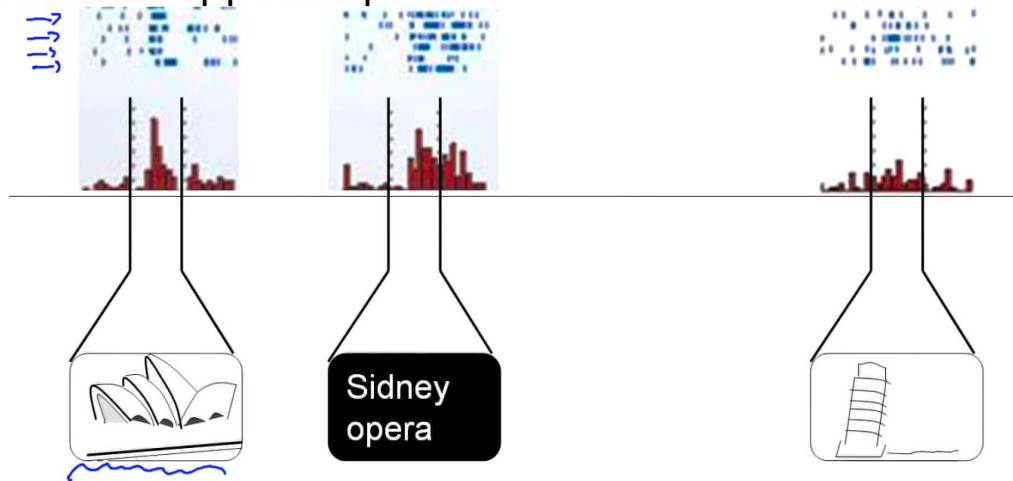
Summary



3m 25s

Neuronal Dynamics – 5.1 Variability in vivo

Human Hippocampus



Quiroga, Reddy, Kreiman, Koch, and Fried (2005). *Nature*, 435:1102-1107.

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Now, while this neurons response to "Opera House," it does not respond to the Pisa Tower, but there is always some spontaneous activity going on which is not repeatable between one trial and the next. So this is data in vivo.

Notes

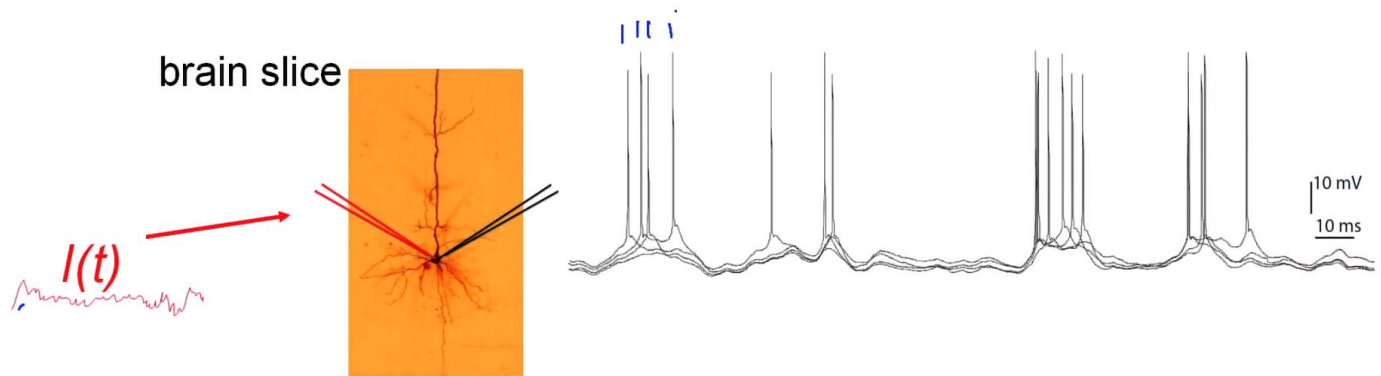
Summary



5m 07s

Neuronal Dynamics – 5.1 Variability in vitro

4 repetitions of the same time-dependent stimulus,



⌂ / □ ➡

In brain slices of mouse cortex or rat cortex, you can isolate a neuron and inject a specific time-dependent current into the neuron while recording, say, with a second electrode, the membrane potential. Now, if the very same fluctuating input current is injected several times, then you see that the neuron responds, but it responds each time at a slightly different moment. In other words, spike timing is not reliable.

Notes

Summary



5m 25s

Neuronal Dynamics – 5.1 Variability



Fluctuations

- of membrane potential
- of spike times

fluctuations=noise?

relevance for coding?

source of fluctuations?

model of fluctuations?

So spike timing is not reliable. The neuron models we have discussed in the first two weeks were deterministic models. If you repeat the same stimulus, they respond the same. In the brain, we find fluctuations--fluctuating membrane potentials, fluctuating spike times. So the question arises, well, what's the meaning of these spikes? What does that mean for information transmission? How can neuron encode information in the presence of these fluctuations? Are these fluctuations noise? Can we model these fluctuations? Now, these are the questions that we will address in the next few lectures. Please stay with us.

Notes

Summary



6m 03s