Computational Neuroscience: Neuronal Dynamics of Cognition

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

A: ASSOCIATIVE MEMORY in a Network of Neurons

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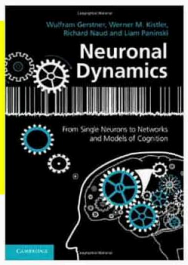
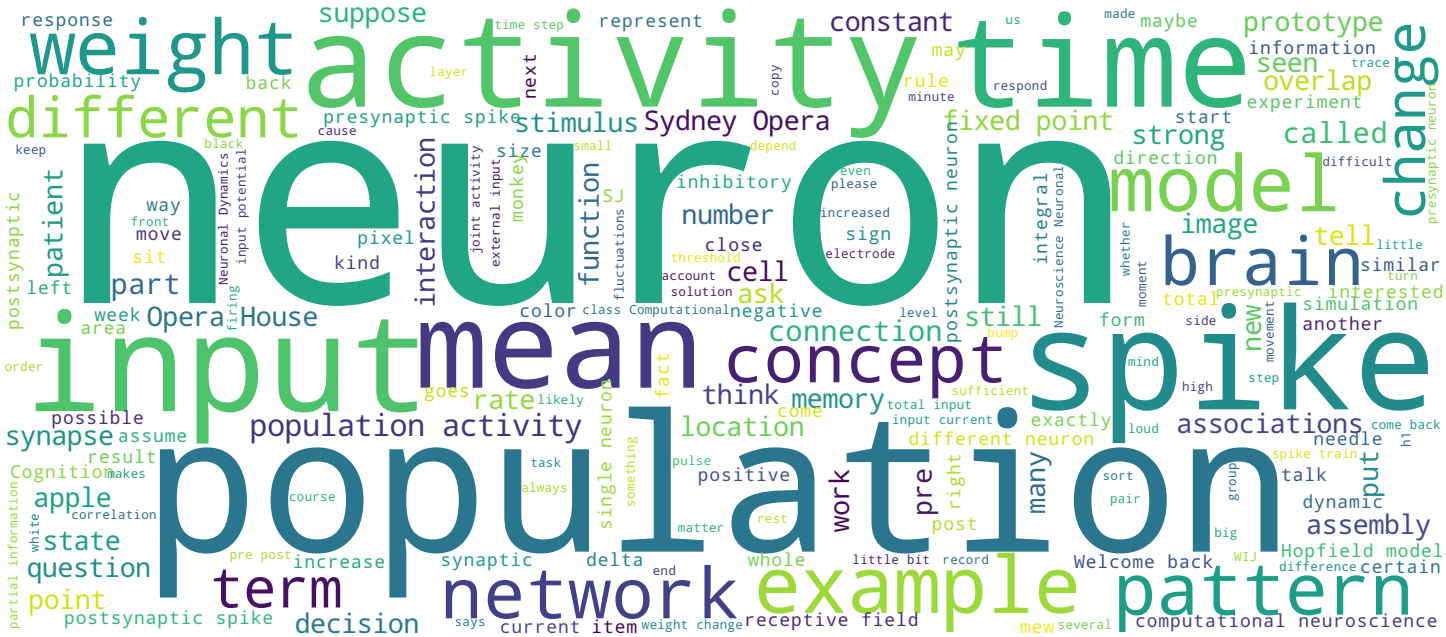
Reading for this week:
NEURONAL DYNAMICS
- Ch. 17.1 - 17.2.4

Cambridge Univ. Press





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Video

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5. Learning of Associations

Where do the connections come from?

Hebbian Learning

When an axon of cell **j** repeatedly or persistently takes part in firing cell **i**, then j's efficiency as one of the cells firing i is increased

Hebb, 1949

- local rule
- simultaneously active (correlations)

So welcome back to the class on computational neuroscience. We are looking this week at associative memory in a network of neurons. And I would like to come back to the question of how do we set the weights? For the physical systems like my data materials I said clearly, I think that its nature who has decided on the value of the interaction weights. But for the Hopfield model, it's basically us, I decided what to put there I made a proposition what to put there. But the question arises, where do the connections really come from? This specific formulation goes back to Donald Hebb in 1949. But the concept can be traced back to earlier philosophical ideas, starting probability with our stateless. So, basically, this would say, if you have a neuron j and if this neuron j is connected to another neuron I then the connection between j and i can change and you can change based on the joint activity. If the neuron j which is also called the presynaptic neuron, because it sits before the synapse repeatedly or persistently takes part in firing cell I, which is called the postsynaptic neuron, because it's after the synapse, then the efficiency of j driving i is increased, which means the weight is increased.

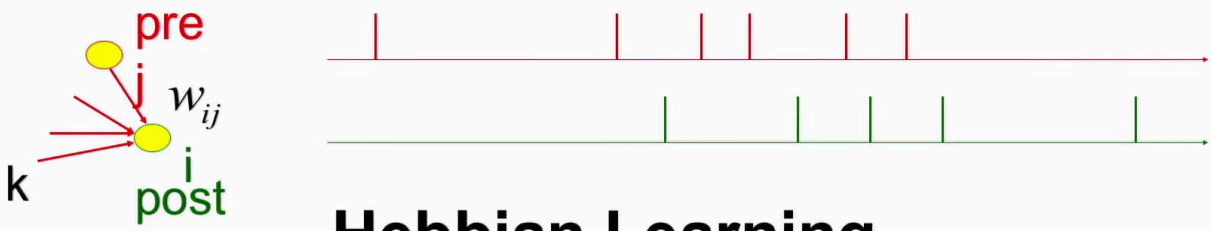
Notes

Summary

0m 01s

5. Learning of Associations

Where do the connections come from?



Hebbian Learning

When an axon of cell **j** repeatedly or persistently takes part in firing cell **i**, then j's efficiency as one of the cells firing i is increased

Hebb, 1949

- local rule
- simultaneously active (correlations)

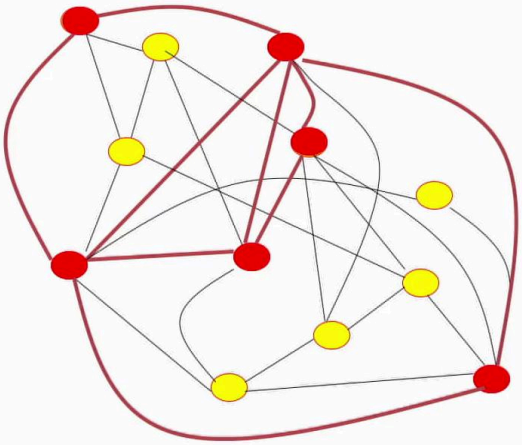
Now, this is a local rule, because, for this connection, I only use information from those two neurons but not information from other neurons K. And somehow, it says that you need joint activity of the two neurons to need simultaneously active neurons, it picks up the correlations if neurons fire together than they wired together. That's the basic idea.

Notes

Summary

1m 27s

5. Hebbian Learning of Associations



item memorized

So hip had a slightly different example when he explained this. But what he had in mind was more or less this, suppose you go on the travel, you're going to a foreign country tree, and you see a really exotic fruit. Now, these fruit has a certain shape you activated some set of neurons in the sensory areas, it has a certain color, it has your bite in it, it has a certain taste, you can smell it, it has a certain order so different neurons in different areas of the brain will become active based on this stimulation by an apple. And now suppose we have this rule of the hip. So now we have active neurons, so read neurons, and these neurons because the active, they fire together, and that means they make stronger connections, the connections are stronger. And this is what makes me say, this item, this concept of an apple is now memorized. And how can I test that it's memorized?

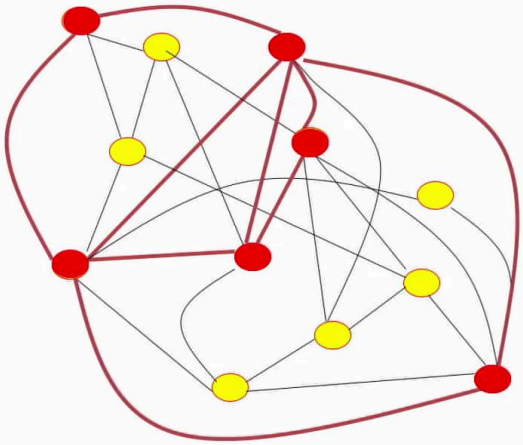
Notes

Summary

1m 49s

5. Hebbian Learning: Associative Recall

Recall:
Partial info



item recalled

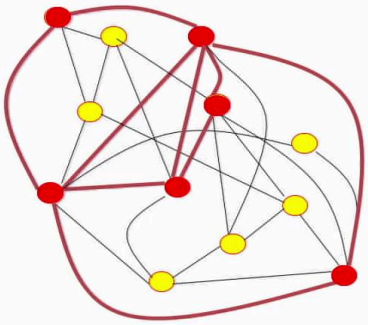
I, suppose you come back from your trip, and you have taken a photograph of the apple, and the photograph might even be in black and white and it might be incomplete. So you only see part of the image. But now, this part of the image that you see is sufficient to stimulate the rest of the image. Once you have the image, it's sufficient to make you recall, yeah, it tasted like this, it smelled like this. So the whole concept of an apple is recalled by partial information. Until so that's the essence of this associative recall that we are trying to explain in the model, such as the Hopfield model. So despite of the partial information, you can retrieve the full information, the picture of the apple, the smell of an apple the order of an apple.

Notes

Summary

2m 48s

5. Learned concepts



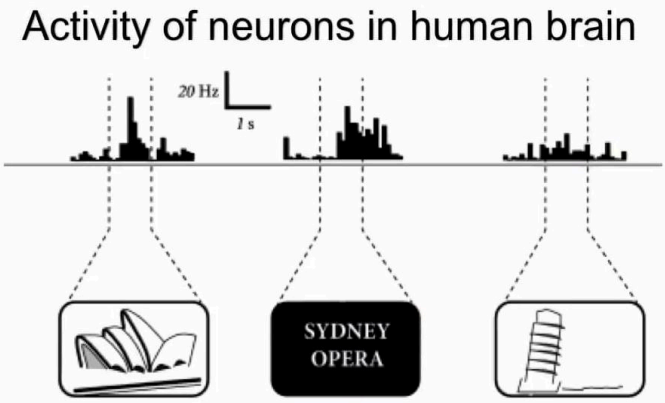


Image: Neuronal Dynamics, Gerstner et al., Cambridge Univ. Press (2014), Adapted from ***Quiroga et al. (2005),*** *Nature 435:1102-1107*

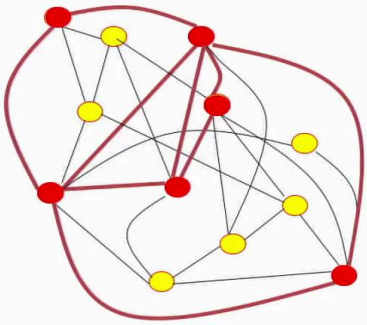
These strong connections connected neurons that represent the concept of an apple in their connections; they also called an assembly and assembly that represent the apple concept. Now the question is whether this is true. Of course, you don't want to make experiments with humans, but they are special cases that human sufferings from a strong form of epilepsy. And these patients do not respond to pharmacological treatment. So surgery is undertaking before you do the surgery, you make sure that it's not affecting an important part of the brains, therefore, you stick a needle an electrode, and you can record from one or several neurons. And before you do the recordings, you can talk with a patient and ask him what they're interested in. Okay, maybe they are interested in opera. And they have been in Sydney Opera how they really like and it may also have been in pizza, they have seen certain Films, like movies. So we know something about the patients, and it doesn't hurt to have these electrodes in your brain, humans are awake, you can actually ask them what they have, how they feel, you can ask them, you can present them, you can discuss with them, you can present images, and ask them what they think about it.

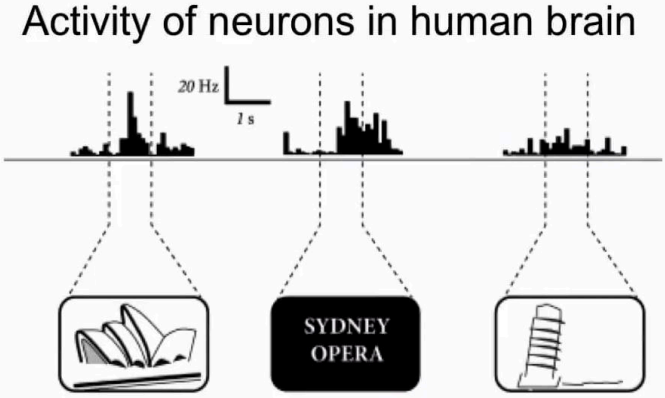
Notes

Summary

3m 38s

5. Learned concepts





assembly of neurons

Image: Neuronal Dynamics, Gerstner et al., Cambridge Univ. Press (2014), Adapted from ***Quiroga et al. (2005),*** *Nature 435:1102-1107*

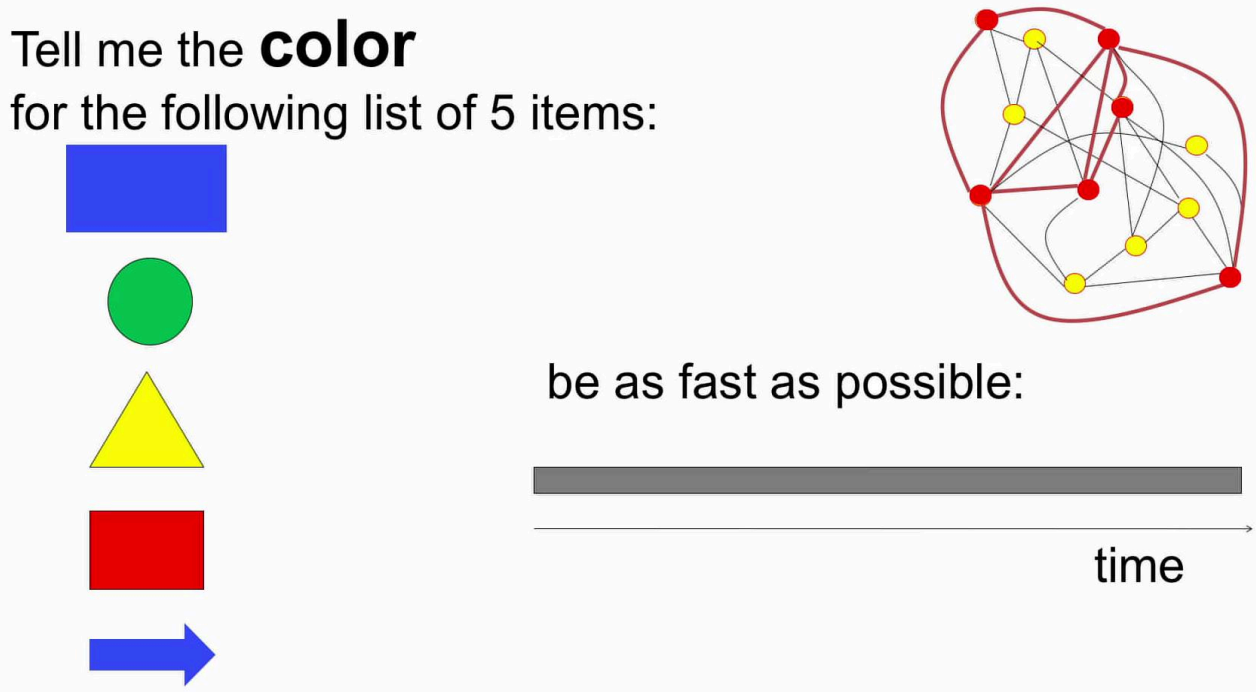
And so this patient here had a neuron somewhere in the brain. And this neuron always responded to the Sydney Opera House. Now, this is not a sensory stimulation, because this could be different views of the City Opera House taking on the different elimination conditions, but also just divert Sydney Opera would re-stimulate the same neuron. And this neuron is not stimulated by pizza tower so the likelihood that you would find one single neuron and that represents the Sydney Opera House if this is the only neuron to do so would be extremely low. So the fact to define such a neuron at all is an indication that there is this kind of happy and assembly and assembly of neurons that we represent together, the concept of Sydney Opera House, the concept, not just the visual stimulation, but the concept that brings together the name, the form of the Opera House, and maybe memories of operas that the patient has seen in Opera House.

Notes

Summary

4m 58s

5. Associative Recall



Now let's look at other forms of memory. Let's look at associative recall. And I would like to first tell you the shape of these objects to rectangle, it's a circle, it's a triangle, it's a rectangle again, and it's an arrow, I would like you to tell and you can just say it out loud or mumbling in front of you just tell the color of these objects and try to be as fast as possible. Okay, it's an easy task.

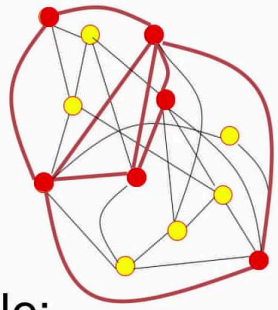
Notes

Summary

6m 01s

5. Associative Recall

Tell me the **color**
for the following list of 5 items:



be as fast as possible:

time

Now, let's redo this again, and tell me the color of the falling five items.

Notes

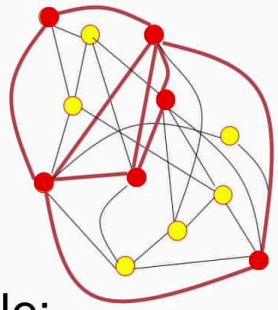
Summary

6m 29s

5. Associative Recall

Tell me the **color**
for the following list of 5 items:

Red
Blue
Yellow
Green
Red



be as fast as possible:

time

Stroop effect:

Slow response: hard to work
Against natural associations

Okay, so most likely have seen that it's more difficult, it's more difficult because you have to work against the natural associations. And this is called the Stroop effect. The point is that associations can be very strong. And these associations can go between different aspects of the same concept.

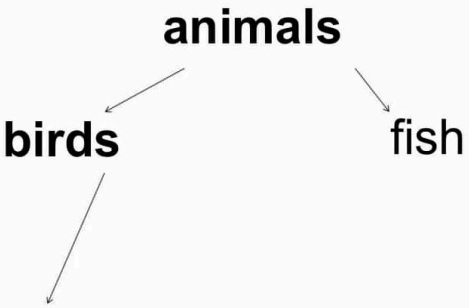
Notes

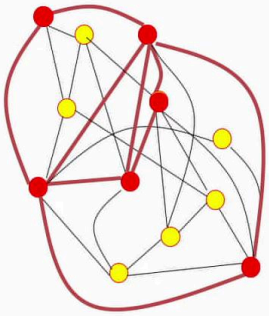
Summary

6m 35s

5. Associative Recall

Hierarchical organization of Associative memory





There are also associations that go across the levels. For example, animals can associate birds or fish.

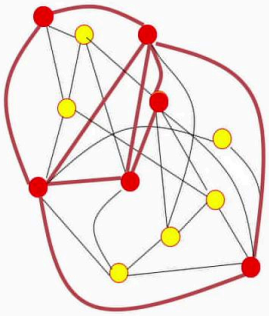
Notes

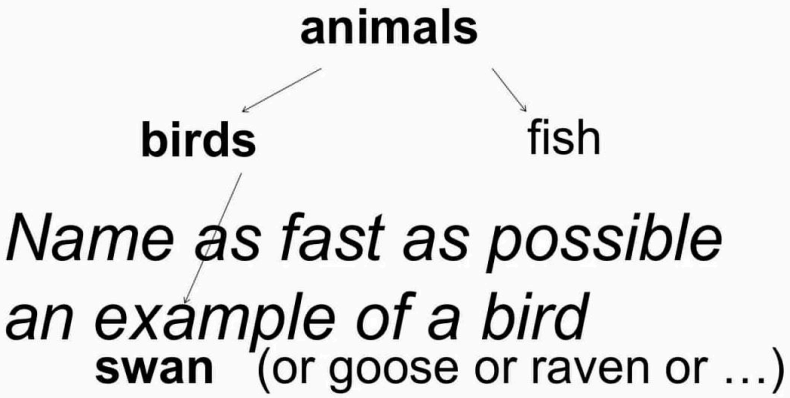
Summary

6m 56s

5. Associative Recall

Hierarchical organization of
Associative memory





Name as fast as possible
an example of a bird
swan (or goose or raven or …)

Write down first letter: *s* for *swan* or *r* for *raven* …

If you think of birds, you may think of a specific example of a bird and say, it's a Swan or Goose or Raven or whatever you like. Unknown Speaker 7:13 Okay. Now, again, I would like you to speak out loud what you think first, or you write down the first letter on a piece of paper. But if you're alone in a room just speak out loud. What do you think?

Notes

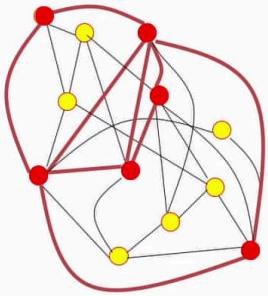
Summary

7m 04s

5. Associative Recall

name as fast as possible
an example of a

tool



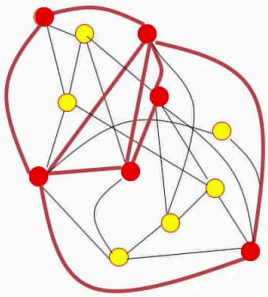
Well, first, and here is what I want you to do.

Notes

Summary

7m 24s

5. Associative Recall



name as fast as possible
an example of a

tool	hammer
color	red
fruit	Apple
music instrument	violin

I want you to give me as fast as possible, an example of a tool, an example of color, an example of fruit, and an example of a musical instrument. And most likely, three of the four items that came in your into your mind are correct, hammer, red, apple, maybe not the violin. This is sort of not undertaking example.

Notes

Summary

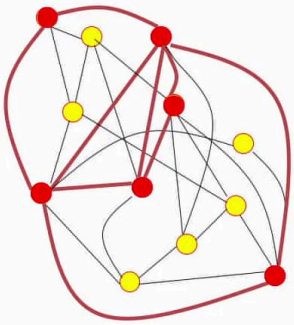
7m 33s

5. Associative Recall

Associative memory

animals

birds fish



- Associations can be very strong!
- It is hard to go against natural associations!
- Different aspects of a ‘concept’ are bound together!
- Assocations have been learned!

So associations can be strong. The associations can go across different hierarchies. They can go, they can link different aspects of a concept, and it's hard to go against natural associations. And these associations are obviously not preprogrammed at birth in your brain. But these associations have been learned. And happy learning is one of the possibilities.

Notes

Summary

7m 53s

Quiz 3: Assocations

The Stroop effect implies that you are faster,
if the color does not match the meaning of the color-word
[ ] Yes
[ ] No

Hebbian learning strengthens links between neurons that
[ ] are simultaneously active
[ ] belong to the same ‘concept’ (assembly)

So please take a minute to answer the quiz.

Notes

Summary

8m 20s