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Abigail Morrison – How does the brain learn?

The brain contains billions of synapses. Although at first sight it might appear to be an electrical chaos, the brain nevertheless contains clear structures and patterns. But how are these patterns generated? How do they change under the influence of experience? The physicist and neuroscientist Prof. Dr. Abigail Morrison from the Bernstein Center for Computational Neuroscience (BCCN) in Freiburg has always been interested in theoretical questions relating to thinking and remembering. She now works on the development of computer models of different brain areas. Is it possible to untangle the complexities of neural networks in the brain using mathematics and informatics?


Prof. Dr. Abigail Morrison (© private)

Abigail Morrison was born in Oxford in 1976 and began studying physics and philosophy at King's College in London in 1995. She wanted to focus on a natural science and found physics to be the most fundamental of all. As she was interested in the origin of thinking and did not want to restrict her studies to calculations, she also opted to study philosophy. She transferred to the University of Göttingen after two years because she felt that British university courses were too regimented. In Germany, students were free to choose to study whatever they wanted if they felt capable of following their chosen subject. "For example, what we learned about quantum mechanics in one semester in London was covered in just four weeks in Göttingen," said Prof. Dr. Abigail Morrison, junior professor at the Bernstein Center for Computational Neuroscience (BCCN) at the University of Freiburg, speaking in perfect German. But she did not have intends to stay in Göttingen for long either. After three years, she moved on to Edinburgh (Scotland) to study artificial intelligence and she received her master's degree from Edinburgh University in 2001.

Modelling parts of the brain

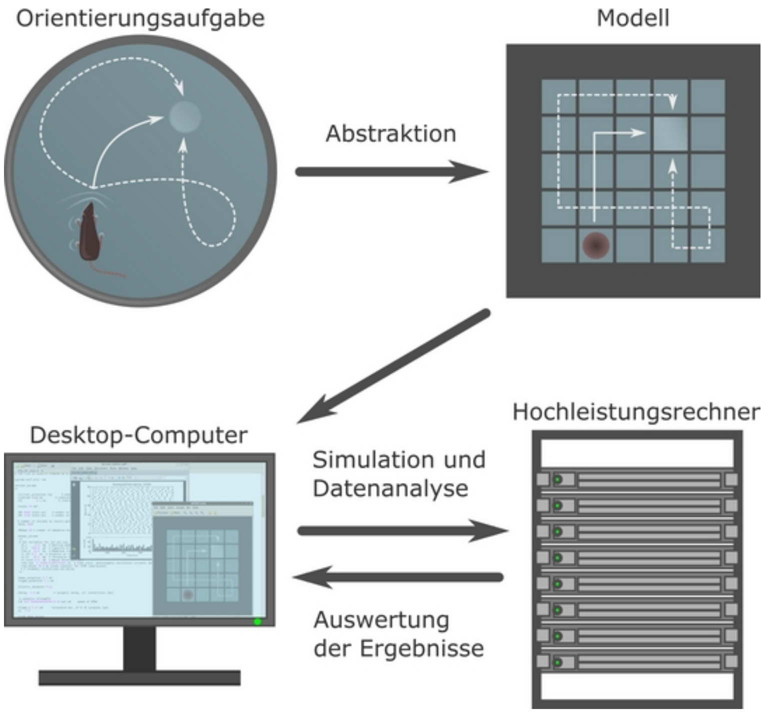
She then returned to Göttingen to work at the Max Planck Institute for Dynamics and Self-Organisation and do her doctoral thesis under the supervision of Markus Diesmann, who continues to be one of her major research partners. Diesmann introduced her to the simulation software NEST, which he and one of his colleagues had developed. Abigail Morrison took the software and used it to test whether large neural networks behaved in the same way as real-brain networks when the synapses reacted plastically, i.e. when the contacts between neurons became tighter through frequent usage, or weaker through less frequent usage. The basic question she wanted to clarify was: how does the brain learn? NEST has since become the most widely used software for the simulation of large neural networks. Morrison is one of the key developers of the NEST software and is a member of the NEST initiative's steering committee (www.nest-initiative.org) that monitors the development of the software that is continuously being optimised and expanded by different scientists.

“If you look at what I am doing now, my original choice to study physics and philosophy was actually a good one,” said Morrison who completed her doctoral thesis in Freiburg in 2006. She spent another year as postdoctoral researcher in Freiburg before moving on to Japan where she spent three years at the RIKEN Brain Science Institute in WAKO where Diesmann had established a new research group. At the end of 2009, she was offered a junior professorship at BCCN and returned to Freiburg.

Relation to reality

Morrison uses computers to simulate neural networks involving around 100,000 cells, in an attempt to model the human brain. However, since it is still not known how the gigantic chaos of cells and synapses in the human brain learns and thinks, Morrison always proposes a hypothesis first. In concrete terms this means: “For example, I think about how a network learns a certain task,” said Morrison. “Then I model this task using the simulation software to find out whether the network can actually learn this particular task.” How should the individual cells be connected with each other? Which activities enable the circuits to consolidate and which cause them to weaken?

Even if the computer model works, this does not necessarily mean that Morrison has discovered something about the real brain. The theoretical system modelled by the computer needs to prove its worth compared with empirical findings. One of Morrison’s projects with her research partners dealt with a network that was able to learn to spatially orient itself. This has an equivalent in the real world. Imagine putting a mouse into a tank of water. A platform that the mouse can step on to is just below the surface of the water where the mouse cannot see it. After a few attempts, the mouse will work out where the platform is and will then be able to find it quite quickly when it needs to. “We have implemented a more abstract version of this learning algorithm into our network,” said Morrison who found that the properties of the individual neurons of the network corresponded neatly with the properties of real neurons characterised in a number of empirical projects.



Approach used to simulate a neural network that is able to learn a spatial orientation task. (© Prof. Dr. Abigail Morrison)

Morrison’s work as scientist

“In principle, we always have two ways of dealing with a research project,” said Morrison. “I am particularly interested in top-down approaches, i.e. formulating hypotheses on the function of a network, then looking at the consequences on the next (lower) level which consists of individual neurons and synapses.” However, the risk of taking this approach is that a system is being looked at without any relation to the underlying biology. The biological relationship needs to be investigated in a second approach that also takes empirical data into account. The other approach, i.e. the bottom-up approach, is the one Markus Diesmann prefers to use. His main interest is the dynamics of individual cells and networks and he uses the information about the dynamics to deduce their function. “This is why Markus and I complement each other so perfectly,” said Morrison.

As to whether she plans to return to Great Britain some time in the future, Morrison said: “There are a few things that I miss,” said Morrison with a smile. “For example, mature Cheddar cheese. I think that this British cheese is sadly underestimated by many people around the world.” However, at present, she has no plans to return to Britain; she likes her work at the BCCN and as a scientist in general, not least because there is a good work-life balance. She has two daughters and enjoys the freedom of being able to work from home occasionally. The one thing she finds difficult to combine with family life is the many conferences and meetings abroad, particularly so because her youngest daughter is only eight months old. “I often think hard about whether a conference is so important that I really need to attend, and it is not always easy to decide,” said Morrison who uses modern computing to the full, for example by taking part in online meetings from her home or office computer. Morrison concluded: “In future we hope that the brain will teach us things that will be useful for developing new computers.”

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A contribution from:

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