Origins: Exploring the Journey of Discovery

Konrad Kording uses the power of Big Data and interdisciplinary research to reveal how the brain processes information

Konrad Kording is chipping away at your head.

He wants a breakthrough in inner space, and he's using Big Data to explore a very small place: the vast-yet-tiny network of some 80 billion neurons in the average human brain. His efforts aim at revealing new insights into how the nervous system processes information.

A physicist by training, Kording is also a data science expert with a passion for harnessing data analytics and cross-disciplinary inquiry in his Bayesian Behavior Lab, home to an array of researchers with interests in biology, applied and theoretical mathematics, cognitive science, metascience, and more. Kording wants to push the boundaries of neurological research and spur innovation that can result in numerous benefits — including in settings such as the Rehabilitation Institute of Chicago (RIC), where he is a research scientist in addition to his role at Northwestern in physiology and physical medicine and rehabilitation.

Kording's lab pursues a variety of inquiries, yet mostly with a focus on data analysis and Bayesian methods. (Bayesian logic seeks probabilistic inferences using prior knowledge to predict future occurrences.) The team studies how people move and how those movements are affected by environmental uncertainty. They also build computational models to calculate how people could move better, or could learn to move optimally.

One of the most daunting research challenges Kording and his colleagues tackle through Bayesian algorithms is recording the electrical transmission of neurons, a key to unlocking the secrets of consciousness. The scientists can and do make such measurements, but making them at sufficiently large scale is another matter. President Obama's BRAIN Initiative has geared up to develop the technical capabilities to record a million neurons simultaneously. A related DARPA-run program is even more ambitious: it's looking to create a miniaturized wireless tool to stimulate 100,000 or more neurons. If successful, the outcomes could hold promise for revolutionary interfaces to aid people who are paralyzed.

Getting there won't be easy, and some researchers consider the attempt a "moon shot," but a worthy one. After all, says Kording, millions of neurons are involved in movement across many different areas of the brain.

Kording was born in a suburb of Darmstadt, Germany, in a family that prized learning: his father is a university professor, his mother a teacher, and his brother an astrophysicist. Kording's spouse, Ioana Marinescu, is an economist at the Harris School of Public Policy and a member of the National Bureau of Economic Research. Kording earned his doctorate in physics in 2001 from the Federal Institute of Technology in Zurich and joined Northwestern in 2008. Since 2014, he has served as research scientist at RIC and also has a courtesy appointment in Northwestern's biomedical engineering department. *Research News* connected with Kording to learn more about his background and work.

What is one of your memorable moments of childhood discovery?

One of my favorite experiences was participating in the German science competition "Jugend Forscht," a national event with multiple rounds. It's pretty popular in Germany and hosted by Bitburger beer. Our project simulated the growth of trees. Today, I still simulate biological systems. Looking back, I always wanted to be a scientist.

Who were early role models who helped shape your career path?

Horace Barlow was my first big hero. He's a British neuroscientist who had a deep way of thinking about brains. Barlow argued that you could not understand parts of the brain until you understand what they are for. He said: "The bird's wing accelerates downward the air flowing past it, producing an upward force sustaining the weight of the bird. What would be an alternative description of a [sensory neuron]?"

Did you ever meet Barlow?

Yes, and there is a fun story behind that. I was going to a conference on using natural visual stimuli in the US as a young PhD student. I knew the work of Bruno Olshausen, who was one of my other heroes. He had just discovered a very simple theory that describes much of the visual system. So I emailed Bruno to see if I could visit his lab. Not only could I visit, but I could stay at his place. I was converted to Bayesianism during that visit. While I was there, Horace Barlow visited and he and Bruno conducted a joint and extremely clever vision experiment.

Your research takes on two of the most complex scientific challenges: understanding the brain and understanding Big Data. What led you down this daunting path?

I guess as a physicist I cannot resist the urge of models. As an empirically minded person I cannot resist the urge of data. I always found complex systems interesting. Data only leads to insight if we have models. In fact, data itself is not even usually interesting to the human mind. The problem about modeling the brain is that it consists of many pieces, each of which may have different rules, and all useless without the others. This is very difficult. In fact, a recent paper of ours that showed that with our techniques it would even be hard to understand a microprocessor (on BioRxiv). This paper became very popular for demonstrating this.

What's been a "eureka!" moment for you professionally?

Eureka moments are not real in science. Only in movies do scientists have eureka moments; I have never witnessed one in science. We are all just getting by with a very fuzzy understanding that crystallizes extremely slowly.

Fair point. Then, in studying neurons — at both an individual and aggregate level — what's been most surprising?

I think that the fact that the brain is very good at subconscious statistics is probably the most interesting finding.

Your investigations include a focus on how the nervous system handles uncertainty effectively. Can you share a basic insight into this point?

Whatever we learn about the world is noisy. And incomplete. Of all the things in the universe we thus noisily observe just a tiny bit. And yet, we have this model about how the world works. That is an amazing statistical problem. It was beautifully set up by people like Plato and Helmholtz. Now we are in the position where we can mathematically formulate and empirically test such ideas.

Your research has used mobile phones and gaming technology to help patients in rehabilitation.

We all carry phones these days. So why not use them to diagnose diseases? It is a difficult machine learning problem, but that is what we do. And games — the biggest thing in rehabilitation is putting in time. Games are addictive. They make it easy to put in time, which is the one thing we know to actually be effective.

What is the biggest challenge for you in designing experiments? Recording all the neurons in a mouse is a lofty goal.

Yes. I wrote a number of papers trying to estimate how difficult. In fact, we are not even close to fully recording the entire mouse brain! The current record is at a few hundred or maybe thousand neurons. The mouse has 10^8 neurons. I figure out the physics and then I talk good experimentalists into doing great experiments.

That helps explain why your lab is so interdisciplinary. How does this contribute to your research success and how do you manage these relationships?

I mostly know data science. The only reason why I can be successful is the broad range of collaborations I have. It is crucial for us to understand our individual areas of expertise, and to know what our colleagues know. It is also important to estimate what is known by no one. One needs to handle the fact that collaborators can be wrong, but they may be wrong in an irrelevant way, which obviates the need to correct them. Also, taking the collaborators' questions as real and important, even if they seem meaningless, is another key for successful engagement. Their questions are framed based upon their own domain field, which has a reason to care about a particular inquiry even if another field might not yet understand that inquiry. The hope is these relationships prove reciprocal.

What would most surprise a layperson about your research?

Understanding the brain is crazy difficult. Almost anything you read in the news about neuroscience is hyped over the top and does not actually survive critical thought. Models and data analysis approaches, as well as experiments, in neuroscience are getting so complicated that no one person has a good understanding anymore. The only way forward is enhanced specialization, and this is largely blocked by traditional ways of doing science. The classical model is that one alpha male experimentalist comes up with the idea, develops the methods, leads the experiment, and hires someone to do the data analysis. I think in the future this process may be divided into many pieces in different groups. It is hard to acknowledge that we are all clueless about most things and actually rely on other scientists.