AN INFECTIOUS INTEREST IN THE CORONAVIRUS

Viola Priesemann's life has changed a great deal since the corona epidemic first started in Germany: Priesemann, the head of a research group at the Max Planck Institute for Dynamics and Self-Organization, is now investigating not only information processing in the brain, but also how the SARS-CoV-2 virus spreads. And ever since, her daily routine has included consultations with policymakers, giving interviews, and appearing on TV.

TEXT: UTA DEFFKE

It was past 11 p.m. on an evening in late March 2020 when Viola Priesemann sat back down at the computer in her home office in Goettingen. Her usual tasks as a physicist – developing new models, performing calculations, and fine-tuning new academic papers – were not on her mind. She was focused on a completely different matter: drafting a position paper for policymakers written from the point of view of a scientist. The COVID-19 pandemic, just a few weeks old at the time, was gripping the world's attention. Germany had also just gone into lockdown: events were prohibited, daycare centers, schools and universities were closed, as were most stores, restaurants and cultural institutions. Social distancing was the order of the day. Even the streets of the big cities were filled with an eerie stillness.

But Viola Priesemann's mind was racing. The head of the Max Planck Research Group "Theory of Neural Systems" at the Max Planck Institute for Dynamics and Self-Organization in Goettingen had only begun analyzing the spread of the virus and the effectiveness of the countermeasures in the past few weeks. But the physicist already recognized one fact: the pandemic can only be controlled over the long term by keeping case numbers low. It's the only way to avoid excessive collateral damage to public health, society and the economy. A lockdown, she realized, would have to reduce case numbers to the point where health departments can reliably detect and isolate a sufficient percentage of cases by means of consistent testing and tracking. If this can be achieved, restrictions could be relaxed again. Any local flare-ups could then be quickly identified and easily contained with short, but tough, measures.

That was the conclusion Priesemann arrived at based on her calculations of several alternative scenarios. And that's what she wrote in the draft of her statement. "I suddenly recognized that my working group had expertise that was important to society, but it was not yet known to others. That's a really strange feeling." She was certain even then that we were going to be dealing with the pandemic for many months to come. Her assessment of the benefits of the shortest possible hard lockdown was shared by colleagues in the fields of psychology, social sciences, and economics. She shared and discussed her findings with them. Because one thing was clear to her: her own epidemiological findings on the spread of the pandemic were only one perspective on how the disease would develop. She was particularly impressed by an article in *The Economist* on the "90 percent economy", which argued that a short, sharp restriction would be less damaging to the economy than repeated curtailments over months or years. Priesemann coordi-

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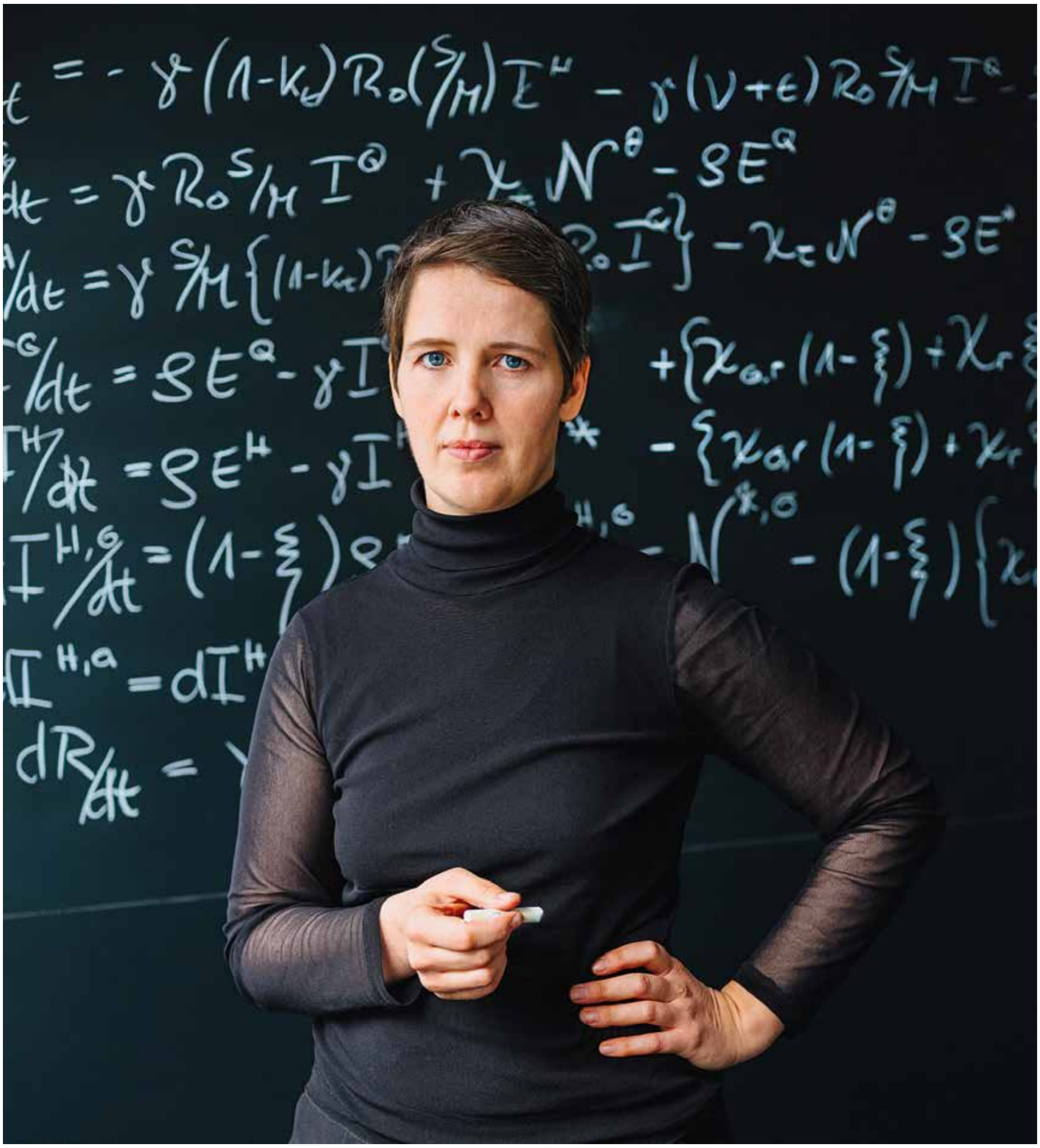
VISIT TO

VIOLA PRIESEMANN

PHOTO: JULIA STEINIGEWEG



Theorist of the epidemic: Viola Priesemann develops mathematical models of information processing in the brain. She employs similar methods to predict the spread of the coronavirus.

PHOTO: JULIA STEINIGEWEG

A rare chance to find some balance: when she can make the time, Viola Priesemann likes to go horse riding. Right now, however, she has little opportunity to do so.

nated her draft with colleagues at the other major German research institutions. "It was important and reassuring that we all came to the same conclusions, each with our own specific approaches," she says, looking back. A first version of the position paper quickly entered the political realm. Nonetheless, the message that sprang from the research institutions largely went unheeded in the "orgy of discussions on opening back up," as Chancellor Merkel is said to have called the ongoing debates in the German states. When the paper officially appeared on April 28th, an end to the lockdown had already been decided. But a second wave was on its way, at the latest in the fall; of that the researchers were certain.

Over the summer, a modicum of calm returned – at least in hospitals and health departments. Viola Priesemann continued to work flat out, both on the COVID-19 pandemic and on her other scientific pursuits. Her main area of research, after all, is the theory of information processing in the brain. To understand her sudden involvement in research into COVID-19, you need to trace her career back a few steps.

For many years, it was far from clear whether Priesemann would follow a scientific career path or not. With a grandfather who was a classical philologist and pedagogue, as well as vice president of the University of Kiel, her social background certainly placed a high value on education. But for a long time it never occurred to Viola that women could also become researchers, inventors, or even professors. For example, she remembers a schoolfriend's father telling her about his work in speech recognition, the technology involved in translating spoken words into written text: "Right now, the methods known as 'deep learning' are revolutionizing speech recognition, but even back then, I thought it was pretty cool. But at the same time, I was subconsciously aware that this was not anything that I would ever work on." Because it's just not something that women do. Studying was still the order of the day though – in Darmstadt. Physics appealed to her, because she had always felt an urge to understand the world. "Looking back at it now, physics was the perfect foundation for what I now enjoy doing," she says. The theory of complex systems fascinates her the most. How do swarms develop? Why do zebras have stripes? How do natural structures form? The underlying premise is discovering how numerous individual entities are transformed into a single large one that has its own unique properties. In her fifth semester, Priesemann happened to notice a new sign on an office door: Prof. Barbara Drossel. "That's when it hit me for the first time – wow, a woman can become a professor too. In theory, so could I."

As it turned out, she called her career goals into question once again during her Erasmus study year. A passionate rider from childhood ("Some people just seem to have a horse gene."), she headed off to Lisbon. It's a part of the world with a great tradition in classical dressage. Priesemann spent more time on horseback than in the lecture hall. But nonetheless, in the end, she made up her mind: her professional future was definitely going to be in physics.

She took great care in choosing the subject of her diploma thesis. It should, she felt, be something that was both complex and relevant to everyday life. And that's how she ended up working in the field of theoretical neuroscience with Wolf Singer, Director at the Max Planck Institute for Brain Research in Frankfurt/Main. After all, the brain is a complex system as well – perhaps the most complex one that we know of. And the fundamental principle underlying how we think and learn is the formation of new structures. Each of the 80 billion neurons interacts with thousands of other neurons by creating connections known as synapses. How these interactions lead to information processing – for instance, how information reaching the brain via the sensory organs is then combined with pre-existing information stored there – is something that Viola Priesemann is investigating using mathematical techniques. Another thing that attracted her to Wolf Singer's group at the time was its interdisciplinary perspective. Her work in the group would involve collaboration with physicists, psychologists, biologists, and philosophers. It was clear that the processes in the brain are self-organizing, since a network of that size and complexity could never be programmed.

"It's an incredibly dynamic time, especially for us scientists. Because new information is emerging every day."

Such self-organization is governed by local rules of learning, which determine the strength of individual synaptic connections. Insights into these processes help us, on the one hand, to better understand the biological brain, while on the other, they can help in optimizing artificial neural networks.

As she began delving into her diploma thesis, Viola Priesemann made an important discovery: if you want to get to grips with a system as complex and large as the brain, you'll inevitably need to limit yourself to examining its individual components. It had long been thought that the big picture could be extrapolated from such components, because the brain is a scale-independent system. Just like fractals, which are similar in appearance when you zoom in, it shouldn't matter whether you are observing such a system on a large or a small scale. However, on the basis of contradictory data, Priesemann discovered that unlike the system itself, the properties of a scale-independent system do not appear to be scale-independent when only a small subcomponent of that system is viewed. In other words, the properties of the subsystem can't simply be extrapolated to infer the properties of the system as a whole. This insight doesn't just apply to the brain; it's a general principle.

A discovery like that gave her self-confidence – and toughened her in scientific debate. After all, a young scientist – and a young female scientist to boot – isn't likely to endear herself by calling esta-

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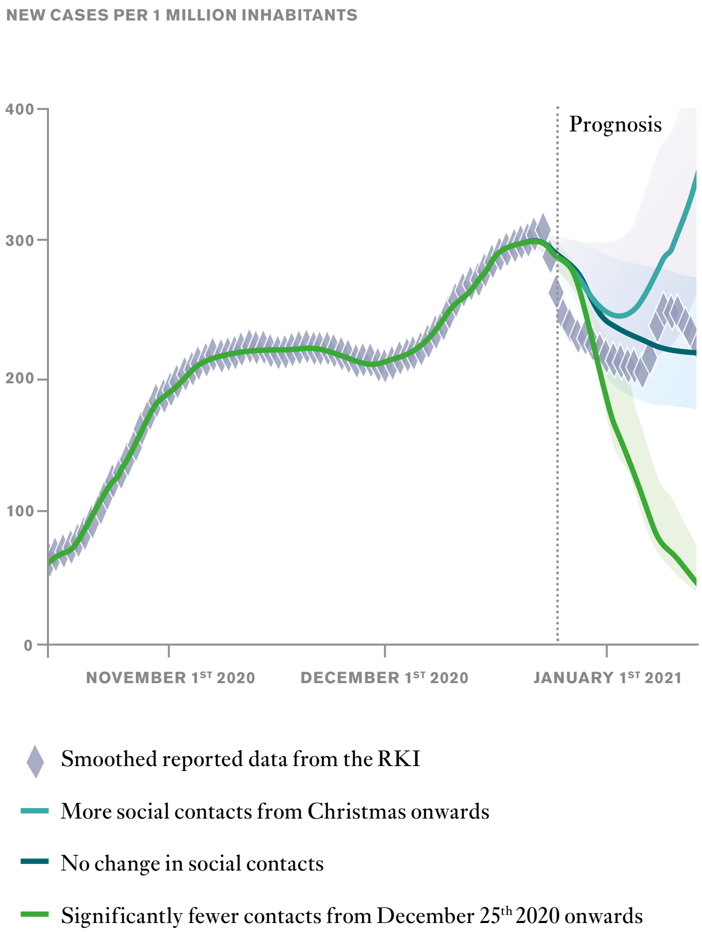

Scenarios of the epidemic: the model developed by Viola Priesemann's group makes it possible to track the numbers of new infections and forecast future developments based on various assumptions. The sharp reduction in cases over New Year is due to reduced testing during this period. The temporary increase in January is partly due to a return to normal testing operations and also to increased personal contacts during the Christmas holidays.

GRAPHIC: GCO BASED ON RESEARCH BY THE MPI FOR DYNAMICS AND SELF-ORGANIZATION

blished theories into question. But for Viola Priesemann, that insight was the foundation upon which her further research work was built. She asked herself: how could conclusions drawn from the sub-system nevertheless be applied to the entire system? She developed mathematical techniques to help her investigate.

Nonetheless, with a view toward broadening her expertise for the future, she sought a new subject for her doctoral thesis at the interface between theory and experiment. Priesemann's dissertation would lead her first to the École Normale Supérieure in Paris and then to Caltech in California to Gilles Laurent, who she later followed back to the Max Planck Institute for Brain Research when he became Director there. Above all, this meant years of hard work as an assistant setting up a laboratory. However, Priesemann has never shied away from technology and hands-on labor, even as a child when she once single-handedly repaired the family toaster because she was determined not to get a new one. She was working on more delicate objects in her lab: the brains of turtles – a good model system for studying the role of the outer corrugated structure of the brain known as the cortex, which plays an important role in vision and the processing of visual information. Her work confirmed a general but crucial insight into scientific research that she learned from her doctoral supervisor: "Making an observation that fits one's hypotheses is exciting. But then the real work begins. You have to scrutinize and check your results and be your own most critical reviewer."

In 2013, Priesemann returned to theoretical work – moving to the Max Planck Institute for Dynamics and Self-Organization in Goettingen. "I can perform experimental work. But I love to understand data and to develop theories to explain it." This she has done, first as a postdoc and then, soon after, as a Bernstein Fellow and Max Planck Research Group Leader. "This gave me independence, my own budget and, with an additional research grant, the ability to recruit my first students." She certainly has a gift for it. She learned from one of her mentors that working with people who stimulate you and are pleasant to be around is important. Her team has now expanded to around twenty researchers.

Among their most important findings is a learning rule for how neurons interconnect to form stable and effective networks that can process any and all types of information, and how they accomplish this by adjusting the strength of their connection. Connection strengths are not fixed, as was long assumed, but are adapted to the task at hand. Priesemann's team discovered this when they were working on the "Human Brain Project" with research colleagues from Heidelberg. They constructed artificial neurons from semiconductor materials and combined them to create relatively large networks that could autonomously learn using the applied rules.

When COVID-19 erupted in the spring of 2020, Viola Priesemann's own synapses immediately went into overdrive: "It was just such a good fit," she asserts. Brain research and the spread of a virus? In the brain, information propagates as one neuron activates its neighbors; similarly, corona virus infections spread from one person to the next. "In both cases, we can make inferences about the big picture (with a high level of uncertainty) by observing a small subset: drawing conclusions about how the activity of a few

PHOTO: JULIA STEINIGEWEG

Presenting her findings to other scientists is a regular part of the work of a research group leader. But Viola Priesemann also aims to disseminate her findings about the corona epidemic to politicians and the public – as a physicist, that is a new experience for her.

hundred neurons results in information processing in the brain and, in much the same way, about how a comparatively small number of known cases of COVID-19 cause the spread of the virus throughout the population." Fired up by this parallel and motivated by its relevance to society, Priesemann threw herself into the subject. She already had at her disposal a set of fundamental mathematical tools. These she developed further, adapting them to the new challenge. To quickly find out everything there was to know about viruses, she networked with experts: medical scientists, virologists, and epidemiologists. She also contacted psychologists, economists and social scientists – first experts in Goettingen and then all around the world – to attain a holistic view. "I'd always been interested in interdisciplinary discourse," says Priesemann, recalling the salons from her Frankfurt days, where people from all walks of cultural, political and business life could meet and engage in casual conversation. "Frankfurt at the time was the hotspot of the financial crisis. My partner and I discussed the crisis in all its dimensions with a large circle of friends from the worlds of philosophy, sociology, and economics, seeking to comprehend it." Living in the banking city of Frankfurt, the tensions and contrasts were palpable. After the pandemic, she hopes to revive such salons and discuss issues such as the concentration of power, self-organization, and social justice. Scientists have had a good understanding of how infectious diseases spread since the 1970s, but it was barely active as a field of research when she began exploring it. Nevertheless, Priesemann was able to introduce new ideas based on her mathematical methods from neuroscience, enabling her to model much more complex influences. "It's an incredibly dynamic time, especially for us scientists. New information is emerging every day – new figures and new publications. I have spoken with an incredible number of people, increased the size of my team, engaged in external press relations and written advisory reports. Sometimes I don't even know how I've managed it – Monday to Sunday from six in the morning until midnight," she says.

For Priesemann and everyone else, the corona crisis dominates our lives, with all its restrictions and insecurities. However, the virus isn't having a negative impact on her research activities – despite working from home and having a child in daycare

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since March. "Our work is purely theoretical. It requires, above all, the ability to think, free from distractions and with access to powerful computers – which we can fortunately operate from home." She can meet up with her team in two video chatrooms, which are accessible around the clock if needed. One is dedicated to research into the COVID-19 pandemic, the other to neuroscience issues. It's a system that works really well, she says. Everyone has been working fantastically together, scattered as they are across Hamburg, Leipzig, Hanover, Amsterdam, Lyon, and Granada. In the summer of 2020, small groups regularly met for extended walks around the grounds of the Institute, which is nestled in a beautiful wooded setting. The purpose of these meetings was to help develop a new project and to – literally – walk through the group's ideas at length.

One important finding from the fall of 2020 was that in addition to an R score above 1, another tipping point existed for the epidemic: the capacity of public health departments to trace cases. If this capacity proves insufficient, the virus spreads uncontrollably. "And then the longer we wait to initiate countermeasures, the harder it will become to contain high case numbers again." This is the message Viola Priesemann disseminated in talk shows, radio broadcasts, online media and newspapers throughout October 2020, and sometimes even on the front pages of those newspapers. Nonetheless, the second wave of the pandemic continued to spread. Researchers were alarmed, but policymakers dithered. It took until November 2nd for a "lockdown light" to be declared. Anne Will, the host of a German TV show, asked Priesemann whether she thought the measures that had been taken were sufficient. Priesemann measured her words: "We can succeed in lowering R from 1.4 to 0.7, but to achieve this, we need to employ every tool in our toolkit." And by "tool" she meant all possible measures to contain the epidemic. She's aware that science can only provide data and facts. Deliberating on those facts and making decisions is the task of politicians: "That's not a métier I would venture into." Four long weeks later, the politicians finally decided to tighten the lockdown. Way too late for a carefree Christmas.

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Does Viola Priesemann feel that politicians have adequately heeded her advice? One thing she's sure of is that the chancellor herself must have been quick to take note of her publications. That much was evident from Merkel's press conferences. Priesemann is less certain when it comes to the heads of Germany's federal states. In truth, Priesemann had been planning on scaling back her media activities in November – the time commitment was enormous, and she was also about to take the next steps in her scientific career. But as long as the corona pandemic is still rampant, and as long as new, politically relevant findings are still emerging, she's decided to stay involved.

For example, Priesemann is currently refining her corona model to take into account, among other things, the age structure of the population, its geographic distribution, and the uncertainties involved. Up to now, the calculations have been based on comparatively simple assumptions that the distribution of infected persons is homogeneous. An expansion of the model should help to more accurately estimate the number of undetected cases and the effectiveness of the measures taken. Priesemann is also expanding her perspective to take in all of Europe. She has coordinated a joint position paper, supported by over 300 colleagues from many countries, which was published in the British journal *The Lancet*. The paper calls for a reduction in the number of new infections to about seven per 100,000 people per week throughout Europe. Viruses are no respecter of borders, after all.

Now, at the beginning of 2021, it's impossible to predict when the next period of respite from the virus will be. Priesemann took a break over Christmas anyway, at least in her public capacity. She likes to spend her free time riding – a hobby, it turns out, that is shared by other female scientists. At a meeting with the president of the University of Frankfurt, she discovered that the president owns two horses. She also knows other top female scientists who ride: "Maybe it's a sport for strong women," Viola Priesemann says with a laugh. That bodes well for her next career leap.