



FORSCHUNG FRANKFURT

Goethe University Science Magazine



In motion

2.2021

ANIMATED COMMUNICATION

New research programme looks at gestures and facial expressions

FILM IN MOTION

Mobile devices change production and viewing

THE UNMOVED MOVER

Accelerators send particles almost to the speed of light

CLOUDS AND THE CLIMATE

How ship emissions influence global warming

FATAL MOVE

Manipulative cancer cells overcome blood-brain barrier

KIDS' STUFF?

ADHD affects adults too



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MESSAGE FROM THE EDITORS

Dear reader,

Dynamics, according to the Metzler Lexicon of Philosophers, is the study of forces in relation to motion. How things change position as a result of external effects has occupied scholars since Plato and Aristotle. In the Renaissance, Kepler and Galileo described the movements of the planets, and Newton recognised the universal principle of gravity from a falling apple. The notion of dynamics has long entered our everyday language as well: we call lively pieces of music “dynamic” just as we do outgoing personalities and insurance policies with rising premiums.

Many research projects currently underway at Goethe University are concerned with movement, with various disciplines looking at its causes, nature and effects. Today, the physics of stars and planets can be explored in the laboratory, where tiny particles are accelerated to almost the speed of light in gigantic devices. Behind the technology for such appliances are physicists constantly engaged in transposing particle physicists’ most exotic requests into acceleration technologies (p. 21). Anyone looking inside the atomic structure of molecules, for example with a reaction microscope (p. 28), can observe something that vehemently contradicts our everyday experience: things that happen simultaneously although they are in fact mutually exclusive – welcome to the quantum world!

For the layperson, watching how animals move is easier to understand. While in the early days of behavioural research the focus was on the typical movements of individual species, which were also studied by filming them (p. 48), research interest today centres on the animal and its relationship to its environment. An example is mass animal migration in the Mongolian steppe (p. 7). This research is just as

important for nature conservation as for gauging the impacts of climate change. These are also at the core of studies on low clouds, whose contribution to global warming is influenced by emissions from commercial shipping (p. 12).

For many people, however, movement is associated with sport. A study on sports clubs has shown that sport can help people to integrate in a foreign country (p. 38). Muscle cramps soon put you out of action if they make every movement a misery – something being looked at in sports medicine research (p. 40). Although physical activity is generally good for us, ADHD patients tend to move about too much: the constant restlessness is not always something they grow out of but can instead cause problems in adulthood too (p. 35). And movement can even be fatal, for example when cancer cells cross the blood-brain barrier (p. 16).

Researchers at Goethe University are studying human movements from various perspectives: how gestures are part of our speech (p. 45) or how computers can be taught to recognise movements (p. 25). In media studies, experts are analysing how our YouTube, TikTok and Insta videos influence film production (p. 54).

Movement is keeping research at Goethe University in the fast lane, and – in this spirit – we hope that reading this magazine will set your ideas in motion too.

Anke Sauter and Markus Bernards
Forschung Frankfurt Editorial Team

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When Mongolian gazelles gather on green pastureland, some 100,000 animals can easily come together. Afterwards, they scatter in all directions. Animal ecologist Thomas Müller is investigating why that is.



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Self-learning programmes should help artificial intelligence systems to distinguish movements. For training, they use 100 million YouTube videos showing, for example, cooking instructions.



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With the COLTRIMS reaction microscope, phenomena from the quantum world can be observed in molecules: two movements that are in fact mutually exclusive – and whose waves nonetheless overlap.

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Over two years, researchers have studied how sports clubs can help with immigrant integration. Conclusion: voluntary work needs concrete support.



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To relieve professional athletes and other sufferers from annoying muscle cramps, sports physician Michael Behringer first triggers them artificially to raise the cramp threshold frequency for these painful contractions.



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FILM AND BEHAVIOUR

How do foxes behave in the wild? East Berlin ethologist Günter Tembrock (1918–2011) observed the animals in his study's four walls and produced valid results with the help of film.

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SPOTLIGHT

Thomas Wilhelm, professor of physics education research, designs ways to make movements clearer using stroboscopic images. To create such an image, a video is recorded, then the individual frames are superimposed. We added Thomas Wilhelm to our picture afterwards – in the original he appeared blurred because he had to move slightly to spin the bucket.

Speed and acceleration can be calculated from the bucket's position at different times. By the way, the bucket in the picture really does contain water – and not a drop was spilt!

www.thomas-wilhelm.net

Stroboscope picture: Thomas Wilhelm; Montage: Peter Kiefer

Physik



1
Max-von-Laue-Str.





MOTION WITH CONSEQUENCES



Animal migration in the “Serengeti of the East”

The extraordinary migratory behaviour of the Mongolian gazelle poses major challenges for nature conservation.

Over a million gazelles still live in Mongolia’s Eastern Steppe. Although they are mostly found in groups, individual animals seem to follow a chaotic pattern as they trek across the vast plains. Thomas Müller and his team are investigating why they do this. Within an interdisciplinary collaborative research project, they are also developing concepts to ensure that the “Serengeti of the East” survives the social and economic changes underway in Mongolia.

By Markus Bernards

It is the vastness of the Mongolia’s Eastern Steppe that visitors from other parts of the world find so fascinating about this landscape. The grass on the plateau stretches almost infinitely, with not a tree or shrub in sight; only seldom do hills give the terrain some shape. Wildlife researcher Thomas Müller remembers well how he felt when he first arrived there in 2004: “It’s like being on the open sea for the first time: a fascinating monotony, all around you can see as far as the horizon. And just like at sea, you’re at the mercy of the elements: the wind, the sun, the rain.”

In the distance, the colours change from a withered yellow-brown to a lush green, as the grass sprouts after the rain, to dark black when one of the frequent steppe fires has scorched the ground. The climate is predominantly continental: in the summer, temperatures can reach up to 35 °C, and in the winter icy snowstorms can blast – with temperatures as low as –40 °C.

There is scarcely a soul around. Of Mongolia’s three million inhabitants, half live in Ulaanbaatar, the capital city, and – with just two people per km² – Mongolia is the most thinly populated country in the world.

The rural population mostly makes its living as nomadic herders. They use the ubiquitous



Photo: IMAGO/Imaginechina-Tuchong

grass for their grazing livestock: mainly sheep and goats, but also cattle, horses and camels. The animals roam around freely: Mongolia is known as “the land without fences”. Thomas Müller was often a guest in the gers of the pastoral nomads and recounts: “When you wake up in the morning, go outside and look around, there’s not a single animal to be seen. One or two horses are tied up to the ger, the herders take them and ride off, and then they find their animals again. I don’t know how, but it works.”

Huge herds of gazelles graze the lush grass of the Eastern Mongolian steppe. Their migration is increasingly disrupted by railway fencing.

Grass is abundant in Mongolia's steppe and desert landscapes, and thus large herds of wild hoofed animals also live there: wild asses, Przewalski's horses and, most commonly, the Mongolian gazelle (*Procapra gutturosa*). These animals are 100 to 150 centimetres from nose to tail, a good metre tall and up to 45 kilograms in weight. They are fast, appear in groups of very few to several thousand animals and then disappear again, always on the lookout for fresh grass. Because rain, winter storms and wildfires are unpredictable and can rapidly disrupt food supply, mobility is everything for the animals and their herders: those quick on their feet – or hooves – can dodge winter storms and blazes.

Thomas Müller, professor for movement ecology, travelled to Mongolia to study the migratory behaviour of these gazelles, about which for a long time little was known. He had already been dealing with animal movements for many years and, for example, once used transmitters to track wolves in Poland – on a bicycle through dense forests.

The flat, treeless Eastern Mongolian steppe promised – with the help of modern technology –

to be a much easier research territory: by means of satellite pictures, it was easy to see where the grass was green and provided feed for the animals, and the researchers were able to catch them and tag them with GPS transmitters. Initially, the transmitters were battery-powered and detached themselves after a year, and the researchers could collect them. They now run on solar cells and deliver long-term data over many years.

Thomas Müller explains: "In the past, science assumed that the gazelles perhaps behave like North American caribou or the wildebeest in East Africa." Caribou gather in large groups to alternate between winter and summer pastures. Wildebeest trek through the Serengeti in gigantic herds in a kind of circular motion. In Mongolia, however, everything is different. "It was absolutely chaotic: the gazelles, all of which we had caught in the same place and tagged with transmitters, were found shortly afterwards scattered over a vast area. As if we had attached transmitters to deer in Frankfurt City Forest, and a few months later one turned up in Munich, one in Berlin and one in Paris. On a

ABOUT THOMAS MÜLLER



Photo on double page: Thomas Müller

Thomas Müller, born in 1974, studied biology in Marburg and earned his doctoral degree at the University of Maryland in the USA with a thesis on the nomadic movements of Eastern Mongolian gazelles and changes through human intervention in the landscape. He then worked in Frankfurt and Maryland as a postdoctoral researcher and as a research associate at the Smithsonian Conservation Biology Institute. In 2013, he returned to Frankfurt with a Robert Bosch Junior Professorship and has been Professor for Movement Ecology and Biodiversity Conservation at the Senckenberg Biodiversity and Climate Research Centre and Goethe University since 2018.

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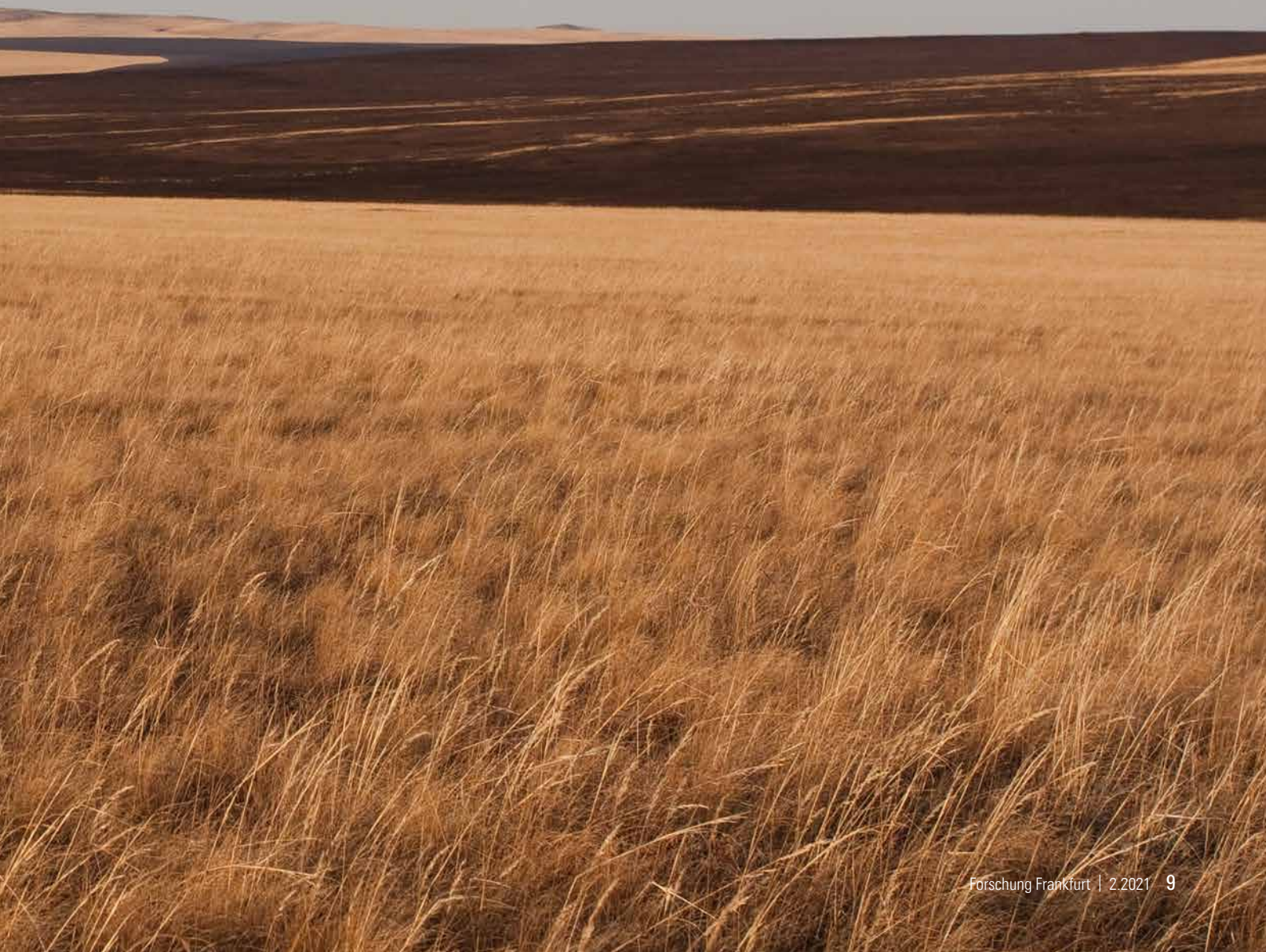
chart, the migration routes of these Mongolian gazelles form a pattern like spaghetti." Since the gazelles mostly appear in large groups, these groups evidently assemble in new constellations again and again, animals disperse and come together to form new groups. Müller calls this "fission-fusion dynamics". "For science, this is, of course, incredibly exciting: Why, in general, do they do this? After all, all gazelles are exposed to the same environmental conditions, but migrate in different directions and put a lot of effort into it."

To date, Müller, his team and his cooperation partners have not yet solved the riddle of this migration, which they call "nomadic". They have, however, formulated hypotheses on the basis of the extensive data collected so far: "We believe that it's a mixture of navigation and searching movements," Müller explains. "When we humans go to work in the morning, for example, we don't give it much thought. We find our way almost automatically and at most react to local events, such as stopping at a red light. If we've lost our key, whether we look in the bedroom first or start with the kitchen is not

so predictable. In the Eastern Mongolian steppe, fires, snowstorms and rainfall are unpredictable, and, as a consequence, the gazelles always find themselves searching aimlessly. This is certainly an aspect that explains why the animals all end up somewhere else. On the other hand, we also know that they can return to places they've been before, in some cases years earlier, meaning that they evidently also have an idea of where in the landscape they are."

However, the Eastern Mongolian steppe, the largest intact grassland in the temperate zone worldwide, is changing. Climate change is more apparent here than elsewhere, and there is more and more prospecting of Mongolia's rich mineral resources – in the steppe it is oil, among others. Tracks are now tarmac roads; new railway lines are being planned and built. When these railway lines are fenced off to protect grazing animals, they also form a barrier for migrating wild animals such as the gazelle. The construction of the Trans-Mongolian Railway, for example, which connects Ulaanbaatar with Beijing, is already disrupting the migrations of wild asses and gazelles.

The dry grass in the Eastern Mongolian steppe catches fire again and again, meaning that wild animals as well as herders with their grazing animals must be flexible when searching for pastureland.



www.morestep.org

The Mongolian-German project “Mobility at Risk: Sustaining the Mongolian Steppe Ecosystem” – is funded by Germany’s Federal Ministry of Education and Research.

The author

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(see page 27)

Will the huge herds of gazelles soon have disappeared? Steppe and gazelles are important in Mongolia. For the Mongolians, the steppe is not just grazing land, and the gazelles are not just occasional prey for hunters. Even for those people who have left the nomadic pastoral life behind them and now live in the towns and cities, the vast terrain with its animals is of cultural importance and creates identity. For this reason, several protection zones of up to 5,000 km² have been created to preserve the “Serengeti of the East”. The problem: the gazelles’ territorial claims are much larger. “We observed a gazelle over four and a half years that trekked about 18,000 kilometres during that time. A single gazelle can explore an area roughly the size of Hungary in the course of its life,” Müller says. “No protection zone can replicate that.”

That is why Thomas Müller and his team, together with partners, have launched a Mongolian-German research project for the sustainable development of the steppe ecosystem. Apart from movement ecologists from the

Senckenberg Biodiversity and Climate Research Centre and Goethe University, the “MORE STEP” project involves the Frankfurt Institute for Social-Ecological Research ISOE and many other German and Mongolian partners, including the National University of Mongolia, Hustai National Park and the Wildlife Conservation Society Mongolia. The aim is to find out how the steppe can be used sustainably without the ecosystem reaching a tipping point, that is, without wild animals disappearing, overuse of the land in some areas, for example through grazing, and an irretrievable loss of vegetation diversity in the steppe landscape. To achieve this, the needs of the developing Mongolian society ought to be aligned with those of nature as far as possible. “For example, it might be possible to dispense with fencing in railway lines, in some regions at least, if only few livestock are kept there,” says Müller. Another option might be to make the oil fields more passable, or perhaps trucks could travel in convoys so that herds of wild animals can cross the roads at certain

IN A NUTSHELL

- Huge herds of gazelles populate the Eastern Mongolian steppe, one of the last intact grasslands in the temperate zone.
- The animals roam across vast areas of roughly 100,000 km² – comparable to the size of Hungary – in the course of their lives. In the process, the animal herds form new groups again and again.
- Mongolian and German partners are developing concepts for the sustainable development of the steppe, since new, fenced-in railway lines and oil production are starting to severely restrict the animals’ migration routes.

Photo: Thomas Müller

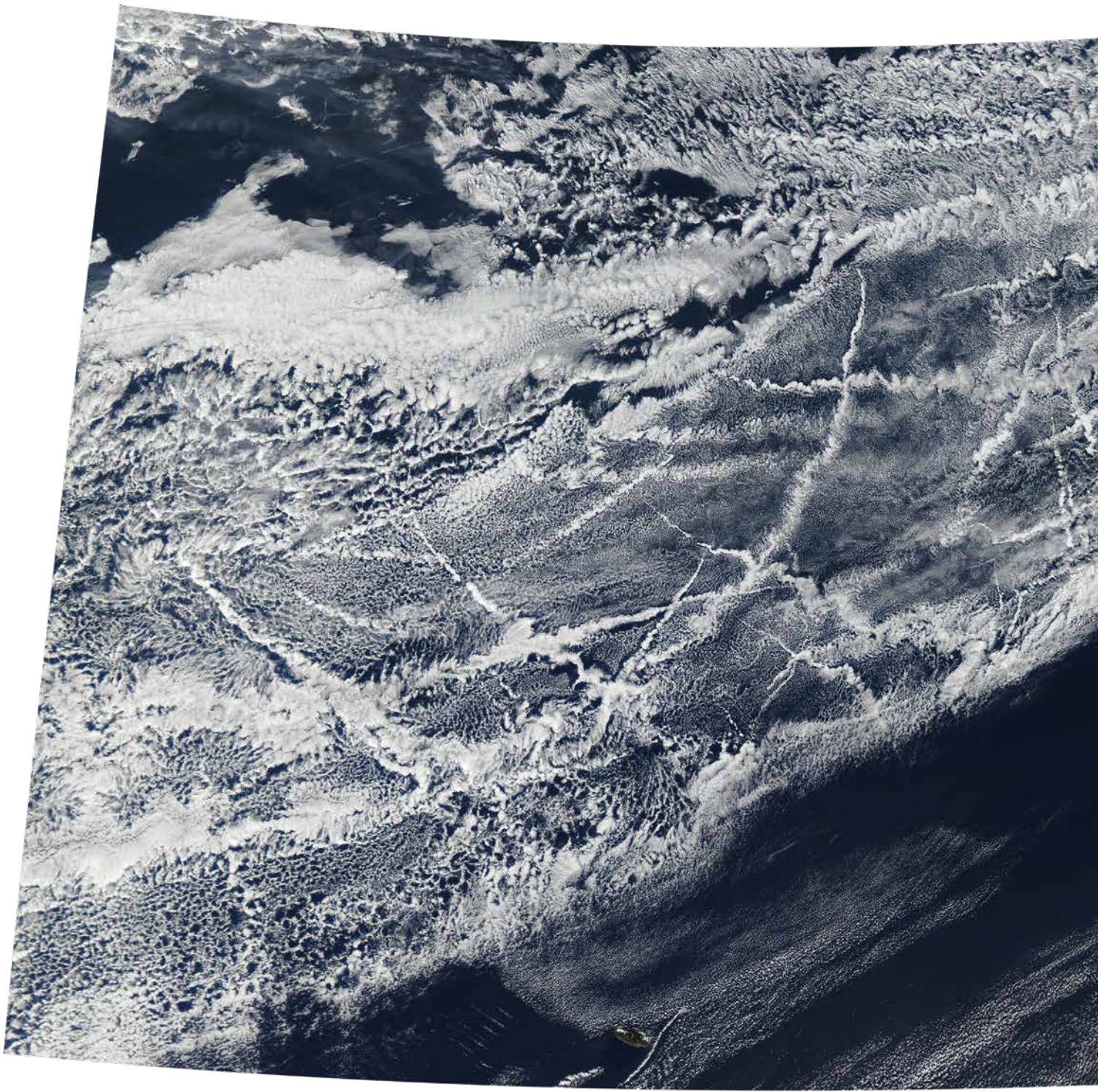


times. Here, MORE STEP is bringing together pastoral nomads, mining and oil companies as well as governmental and non-governmental organisations in the search for solutions.

Müller finds it conceivable that humanity could also exist without the huge herds of gazelles. The Mongolian people, however, would lose an important part of their culture. And when asked whether the herds of gazelles are worth protecting, he says: "I once stood on a hill in the steppe and around me were perhaps a hundred thousand of these animals, in several large groups. It was absolutely fascinating. The Mongolians there feel the same way. Anyone who has experienced that at some time in their life would answer the question of whether it's worth preserving quite simply with 'Yes'." ●

Mongolian gazelles and horses: wild and domestic animals have shared the same habitat in the Eastern Mongolian steppe for centuries – grass is abundant.





Ocean sunshade

How clouds influence climate change

By Andreas Lorenz-Meyer



Photo: Aqua-Modis/NASA Earth Observatory, 16.1.2018

As far as global warming is concerned, whether we are heading more towards +2 or rather +5 °C is decided to a quite significant extent over the oceans. It is there that vast layers of low, flat clouds shade the ocean surface below, cooling it down in the process. Will that be the case in future too?

To find out where our climate stands – just look up at the clouds! They play an important role in Earth’s radiation budget. On the one hand, clouds reflect short-wave solar radiation and send it back into space – the cooling effect also known as cloud albedo. On the other hand, they absorb long-wave thermal radiation emitted from Earth’s surface, preventing it from leaving the atmosphere – the warming effect.

Altogether, clouds currently have a global net radiative effect of -20 Wm^2 , meaning that their cooling effect is greater than their warming effect, and Earth is about five degrees cooler as a result. However, this initial value of minus 20 watts will not necessarily stay the same since clouds’ radiation properties change. One reason is cloud feedback, the direct response of clouds to human-induced global warming. The other reason is anthropogenic aerosols, that is, the minute suspended particles produced by waste gases that play a direct role in cloud formation.

Clouds influence climate change

How these two effects, which occur separately, have an impact is something that Anna Possner, physicist at the Institute for Atmospheric and Environmental Sciences, is investigating. For her, clouds are “the greatest source of physical uncertainty in climate change projections”. It is mostly down to them that we still do not know exactly what temperature increase we can expect at which CO_2 concentration. This has to do with the fact that clouds are complex structures, “the end products of many individual process chains within the atmosphere”. Radiation, dynamics, turbulence, surface fluxes of heat and moisture, microphysics and atmospheric chemistry – they all contribute to cloud formation. “They influence at what height clouds develop, how much radiation they reflect or absorb, whether they produce rain or snow, or simply evaporate. In each stage of the process, the uncertainties overlap – and that makes it difficult to quantify the effect of clouds in a changing climate.”

Although the “gaps in our understanding of the process” are shrinking, and increasingly efficient, higher resolution models are available, Possner wants to understand the processes in the clouds and their interaction with the climate system even better and map them in climate models with even greater precision. “Only then will it be possible to pinpoint climate sensitivity more accurately.” Climate sensitivity reveals how much warmer it will become if the concentration of greenhouse gases in the atmosphere doubles from the pre-industrial level of 280 ppm to 560 ppm. The Intergovernmental Panel on Climate Change (IPCC) recently predicted global warming of between 2.5 and 4 °C in such a case.

Ship tracks over the North Atlantic off Portugal and Morocco: ships emit aerosols that produce characteristic contrails.

As far as future living conditions are concerned, there are worlds between. To calculate this down to the last degree, we need to know more about clouds.

Low clouds as sunshade

To achieve this, Possner is looking at very specific types: flat, low stratus and stratocumulus clouds over the oceans. Stratus clouds, similar to a thick layer of fog, have no structure whatsoever, their water content is homogenous. In stratocumuli, by contrast, water content varies. Together, both types of cloud form a semipermeable “sunshade” that has a cooling effect. This is because with these low clouds the short-wave effect predominates wherever the sun shines, in the tropics just as in the Arctic during summer, meaning that more short-wave solar radiation is reflected than long-wave thermal radiation absorbed. The cooling sunshade over the oceans is huge: it spans more than a fifth of all ocean surface. If its properties change in any way, the consequences for Earth’s climate are particularly dramatic, as Possner explains: “Oceans cover 71 percent of Earth’s surface. They are extremely dark and on average absorb 99.3 percent of incoming solar radiation. This is considerably higher onshore, where different land surfaces reflect between 10 to 40 percent. In terms of global warming, the sunshade’s effectiveness over the oceans is therefore much more important than over land. It makes a tremendous difference whether or not there is a layer of cloud over the dark ocean surface that reflects between 20 and 40 percent of irradiation.”

Ship emissions make clouds brighter

And now for the bad news: because of global warming, the sunshade over the oceans is shrinking, its material thinning. “The low clouds are literally burning off and reflecting less solar

radiation as a result.” But there is a counterforce with a cooling effect: anthropogenic aerosols. The same applies for these too: the effects are much more dramatic at sea than on land. Possner is looking closely at the impact of exhaust plumes from merchant ships that journey back and forth across the oceans, blowing vast quantities of minute particles into the atmosphere as they go. Under certain conditions, “ship tracks” form, which can be spotted clearly on satellite pictures. “They look like contrails behind a passing aircraft. Only they form far lower down, within the lowest kilometre of the atmosphere.” How much brighter clouds become due to these particles can be measured with great accuracy within these tracks.

This brightening causes the clouds to reflect more sunlight because the more aerosols there are, the greater the number of condensation nuclei for cloud droplets. This means that the same amount of cloud water is now dispersed among several smaller droplets. These, in turn, occupy a larger total surface area for the same water content, which increases cloud albedo. “The disturbed cloud therefore provides more shade than the undisturbed cloud,” says Possner.

Major global impact

She discovered the extent of this effect in a study with American colleagues. “We succeeded for the first time in corroborating and quantifying, by means of satellite observations, a brightening effect caused by ship emissions. We looked at a shipping corridor on the west coast of Africa. In this corridor, the wind blows for parts of the year in such a way that individual exhaust plumes overlap. As a result, the signal was stronger compared to the overall variability, and we were thus able to isolate it.”

This robust and unambiguous finding was described in the scientific article “Substantial Cloud Brightening from Shipping in Subtropical Low Clouds”, published in 2020 and extrapolated on a global scale. According to this, particles from ship emissions worldwide reflect around 1 watt of incident sunlight per m^2 by brightening marine stratus clouds. “Compared to current global warming through anthropogenic greenhouse gases, which is 4 watts per m^2 , this is sizeable. It means that about a quarter of human-induced global warming is offset by the cooling cloud effect of anthropogenic aerosols over the oceans.”

Ice crystals reduce cooling effect

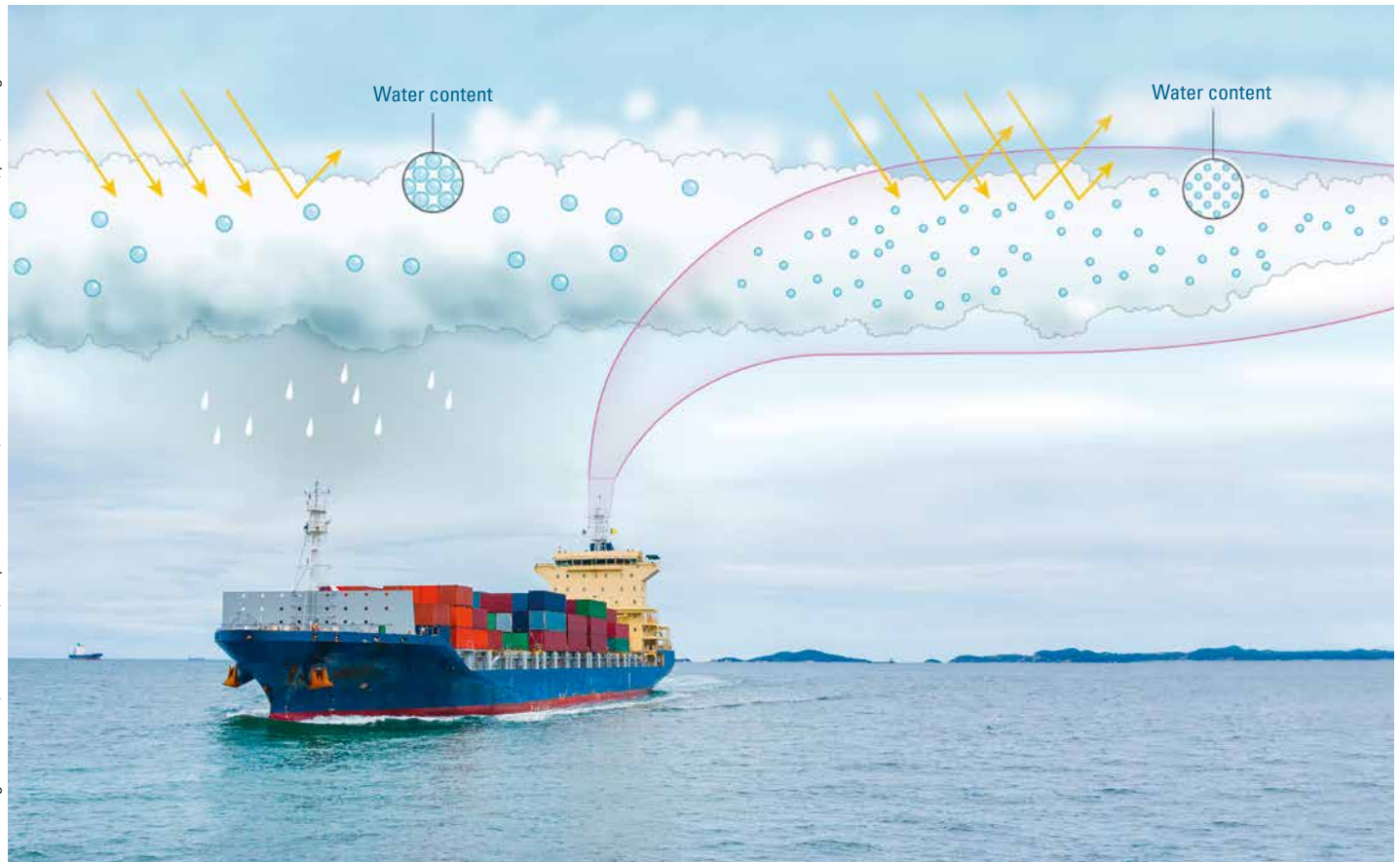
Possner is currently looking at low clouds in the Southern Ocean beyond the 40th parallel south, where anthropogenic aerosols are insignificant because there is little shipping traffic in that area. There, too, stratocumulus decks stretch

ABOUT ANNA POSSNER



Anna Possner, 34, came from prestigious Stanford University in the USA to Frankfurt in 2018 to set up the “Atmospheric Physics and Climate” research group, which is looking at the role of clouds in climate change. Financial support comes from the German-French research initiative “Make our planet great again”. It was through programming work in the course of her mathematical physics studies in Edinburgh, Scotland, that she turned her attention to clouds. Possner enjoys solving problems by building and running models. After an internship at the Max Planck Institute for Meteorology in Hamburg, Possner worked for several years at ETH Zurich in Switzerland before moving to the USA.

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Aerosols from ship emissions lead to the formation of smaller and more numerous water droplets (small circles) than usual in the low clouds over the ocean. Such clouds are brighter and therefore reflect more sunlight (yellow). At the same time, they shed less rain because of their lower water content.

over hundreds of kilometres, cooling the almost undisturbed ocean surface beneath. In contrast to the subtropics, it is so cold in the Southern Ocean that 40 to 70 percent of the low clouds are composed of a mixture of water droplets and ice crystals. A fraction of all cloud droplets freeze – and this reduces cloud albedo. This is because cloud droplets are smaller than ice crystals and occupy more surface area with the same water content, meaning that cloud droplets are far more efficient at reflecting sunlight than ice crystals. Or conversely: the more condensate that enters the ice phase, the lower cloud albedo is.

But as far as clouds are concerned, things can quickly become rather complicated, and there is therefore something else that also determines radiative properties: the cloud's internal organisational structure. The stratocumuli in the Southern Ocean display regular patterns that resemble honeycombs. There are “full” and

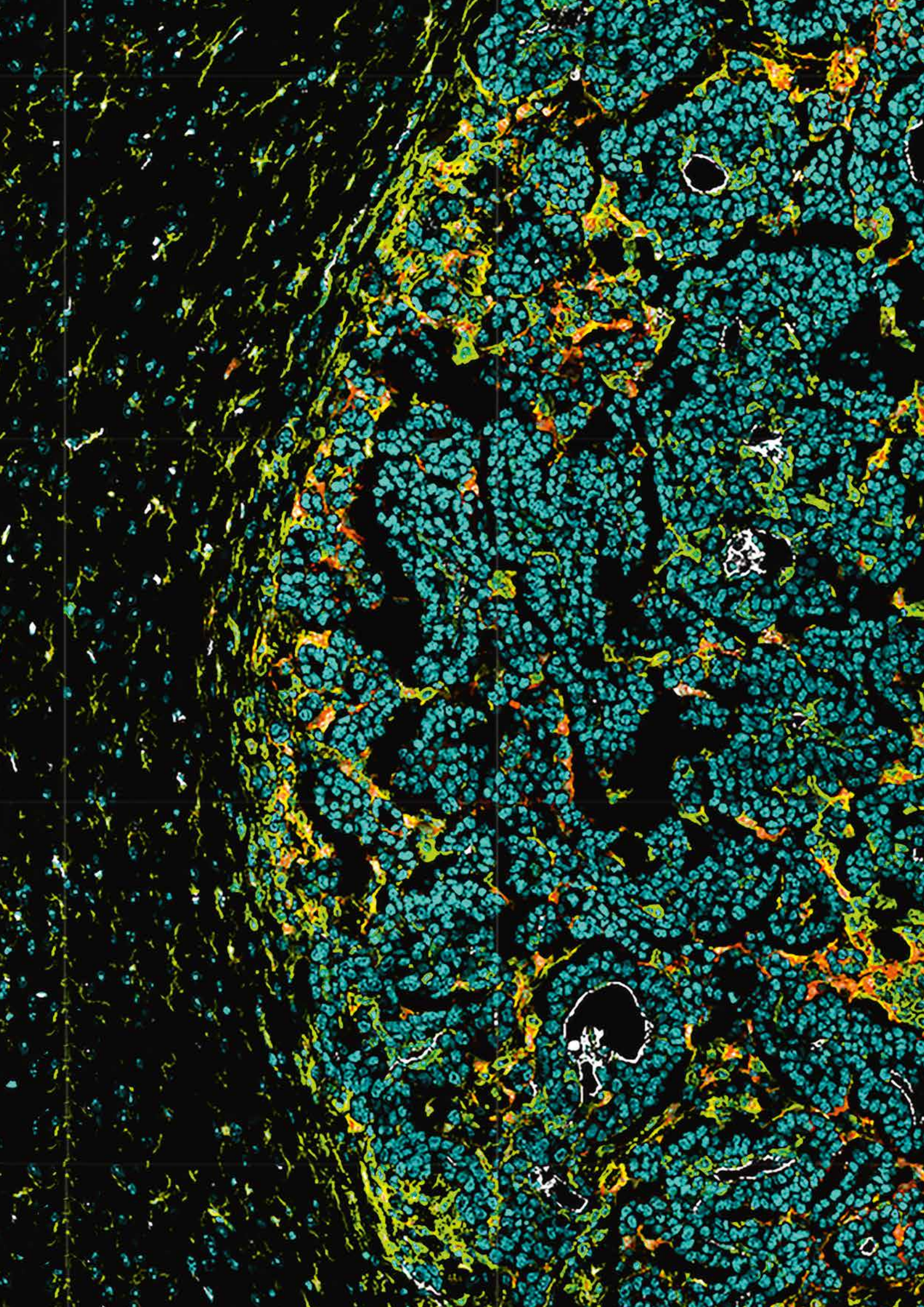
“empty” ones. “Full” means cloud formation starts at the centre of the honeycomb while “empty” means it begins at the edges. “Two dynamically different systems with different radiative properties. Closed, or “full”, cell structures have higher cloud albedo than open, or “empty”, ones at the edge of the cloud, so they have a greater cooling effect.” At the present time, Possner is looking closely at a specific detail: Does ice crystal formation change this internal organisation? Does a “full” honeycomb with a greater radiative effect then become an “empty”, less radiative one? That would mean an additional warming effect. According to a first statistical analysis, however, that does not seem to be the case: “So far, we’ve no evidence that ice crystal formation propels stratocumuli into a less radiative organisational regime.” Meaning that “full” combs stay that way. Should further studies confirm this preliminary result, that would be a little bit of good news as far as global warming is concerned. ●



The author

Andreas Lorenz-Meyer, born in 1974, lives in the Palatinate and has been working as a freelance journalist for 13 years. His areas of specialisation are sustainability, the climate crisis, renewable energies and digitalisation. He publishes in daily newspapers, specialist journals, university and youth magazines.

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When cancer cells migrate

How metastases develop in the brain

By Anja Störiko

Although many types of cancer can be treated very successfully nowadays, fatal metastases often develop in the brain. How cancer cells manage to overcome the blood-brain barrier, survive in such a well-protected organ as the brain and continue to divide is something that Lisa Sevenich's research group at the Institute for Tumour Biology and Experimental Therapy, Georg-Speyer-Haus, is investigating.

Using tissue cultures from the brains of mice, the cancer research team in Frankfurt monitors via video how cancer cells migrate into the brain: a cell from the brain tissue stretches further and further towards the blood vessel, literally snuggles up to the cancer cell washed up in the bloodstream and ultimately allows it to enter the brain tissue – through the normally more or less insurmountable blood-brain barrier. Cancer cells, as the video shows, evidently manipulate brain cells across the blood-brain barrier for their own benefit.

Observations such as these allow far-reaching insights into how cancer spreads. "We're interested in this fascinating interaction between cancer cells and brain cells," explains Lisa Sevenich. Her research group has taken on a difficult topic: metastases.

Although it is often possible nowadays to combat tumours at the initial site through surgery, radiation or chemotherapy, in many cases cells have already broken away from the original (primary) tumour beforehand and travelled to other organs. This is why metastases, that is, secondary tumours in organs other than the primary site of the tumour, are meanwhile the most common cause of death among cancer patients. "In the past, patients died from the primary tumour or undetected metastases. Today, thanks to earlier diagnosis and better treatment, they survive – but all too many die from secondary brain tumours," says Sevenich. Until now, it has been difficult to treat brain tumours because surgery is risky, but also because insufficient research has been conducted on the cellular and molecular principles of how brain metastases develop.

Brain metastases are frequent, but research is scarce

Metastases often develop in the brain above all in breast, skin and lung cancer – according to the German Cancer Society in 20 to 45 percent of patients. "When and why single cancer cells dislodge from the primary tumour is still not entirely clear," says Sevenich. As they spread through the body, the cancer cells are at the mercy of the immune system, which identifies and destroys most of them. Less than one percent of the cells that spread through the body via the bloodstream survive the immune system's attacks and manage to colonise elsewhere. However, scientific knowledge about this journey and the colonisation of metastatic cells is still in its infancy. There are cells that break away very early in the cancer process and colonise other organs, but often "hibernate" there – until one day they "wake up" and start reproducing: a dangerous development.

Cancer cells penetrate the protected brain

Lisa Sevenich and her team are exploring questions related to metastasis: "How does an organ, in our case the brain, react to the incoming cancer cells? And how must the cancer cells adapt in order to survive there?" After all, the brain is a very special and well-protected organ. Its blood vessels are more or less impermeable, and this is what shields it from the rest of the body. This blood-brain barrier restricts and regulates both the exchange of soluble factors as well as cell penetration, meaning that the brain is also shielded from the body's immune system. It has its own immune cells that protect it from life-threatening inflammation with great effect.

Beautiful but dangerous: in a metastatic brain tumour, the cancer cells are densely packed together (cell nuclei: turquoise). The microglia (green and red), the brain's defence cells, cannot fight the tumour effectively.

Immune system vs. cancer cells Disguise, hide-and-seek and misunderstandings



Illustration: Lisa Sevenich

To protect sensitive neurons (N) from inflammation, the brain normally suppresses immune reactions. Cancer cells that colonise the brain (BM) exploit this. Although the microglia (MG), the brain's immune cells, recognise these invaders, they are not particularly specialised and therefore unable to efficiently fight off the very versatile cancer cells. They require the help of T cells, which have learned to attack cancer cells systematically. Cancer cells, however, use camouflage to resemble neurons. In this way, they can hide from the immune system and feed on the nutrients actually intended for the neurons. In addition, the cancer cells make it possible for other immune cells to enter the tumour and prevent the T-cells there from attacking it. Through the cancer cells' deception, misunderstandings between the T cells and the microglia arise – they launch processes designed to repair tissue, but the cancer cells disguised as neurons take advantage of this: they multiply.

Yet cancer cells manage to break through the blood-brain barrier – and even to manipulate the brain cells across this barrier, as described in the scenario above. This is because the cancer cells bring along certain protein-degrading enzymes and have specific tumour factors that make the brain, actually a closed system, mechanically permeable and reprogramme it with the help of soluble factors. Although immune cells from the blood can pursue the invading cancer cells, the cancer cells make sure that these immune cells remain inactive in the brain. "We've discovered that cancer cells literally block the body's defences and even use them for their own benefit," says Sevenich. The cancer cells switch off the brain's defence mechanisms and actively reprogramme the immune cells for their own reproduction.

Like a gripping film

First, Sevenich's team attempted to block the immune cells exploited by the tumour. But it proved very difficult to interrupt the interaction between cancer cells and normal cells. "In the process, we found everything you need for an exciting film script: disguise, hide-and-seek, misunderstandings!" she says. For example, tumours can disguise themselves as neurons and in this way confuse the brain's defence cells (see box). Recently, Sevenich's research team succeeded in luring more anti-tumour immune cells (T cells) into the tumour with the help of radiation therapy. At the same time, they inhibited a signal that usually blocks T cells, thus making them attack the tumour. Unfortunately, however, this only works for a limited period, meaning that the tumour still wins in the end. "It was frustrating to see that certain blockades work for a short time, but after a few days or weeks, the cancer cells are back in the director's chair – if anything more potently than before." The goal must therefore be to understand the entire chain of effects and only then intervene in a targeted way.

This is, however, not quite so easy: the group conducts most of its research on mouse models, combined with cell cultures (which, however, only ever allow the study of a single aspect). In both experiments, the cancer cells enter the mouse's bloodstream; a few colonise the brain. From there, the cancer cells can be isolated, grown in cell cultures and analysed. To obtain sufficient cancer cells that manage to enter the brain, this cycle is repeated so that the cancer cells accumulate there. In this way, the researchers can detect changes in cell, protein and effect patterns.

"We want to understand how the cancer cells 'train' their environment to serve their purpose – and sooner or later we want to succeed in blocking this process," Sevenich hopes.

ABOUT LISA SEVENICH

Lisa Sevenich, 41, studied biology with a focus on immunology. After her doctoral degree in Freiburg, she discovered her fascination for brain metastases during her postdoctoral work in New York. Particularly important for her is the relevance of her research to the disease itself, with the goal of one day being able to contribute to a cure. In 2019, she was awarded the Beug Foundation's Prize for Metastasis Research for her work, which is funded by the Max Eder Junior Research Group Programme of German Cancer Aid.

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Dr Lisa Sevenich and doctoral candidate Dominic Menger with a Petri dish containing a thin section of a mouse brain. The tissue is first made transparent before the cells are stained and analysed under the microscope.

Photo: Uwe Dettmar

“Expressed in human terms: the immune cells are trying very hard, but misunderstandings between the different types of immune cell arise again and again. Although they want to protect the brain cells and destroy the cancer cells, tricks performed by the latter make them confuse these tasks. We want to help them do their job.” To this end, the researchers will continue to search for strategies to keep immune cells in brain metastases awake until they know how to attack and ultimately conquer just the tumour and not the brain cells.

Useful findings for many pathologies

The route to healing patients is still a long way off. But Sevenich, a keen athlete, likes such difficult challenges. Only a few research groups are working in the field of brain metastases because, firstly, brain surgery is risky, and, secondly, patients usually survive only a few months once brain metastases have been detected, so the time available for treatment is extremely limited.

“In my opinion, the body’s reaction to the tumour is not particularly specific, but instead resembles more a stress response,” explains Sevenich. “If we understand the process of who is manipulating whom here, then we can presumably transfer this to other diseases too – because neurological diseases such as Alzheimer’s trigger similar responses in immune cells.”

The worrying thing is that cancer cells often set off on their journey to new tissue early on – sometimes even before the original tumour has been detected. They often “hibernate” there and then begin one day, often decades later, to divide. The reasons for this are unknown. One of the goals of Sevenich’s research group is to understand these mechanisms and possibly find ways to sustain the harmless dormancy stage of cancer cells.

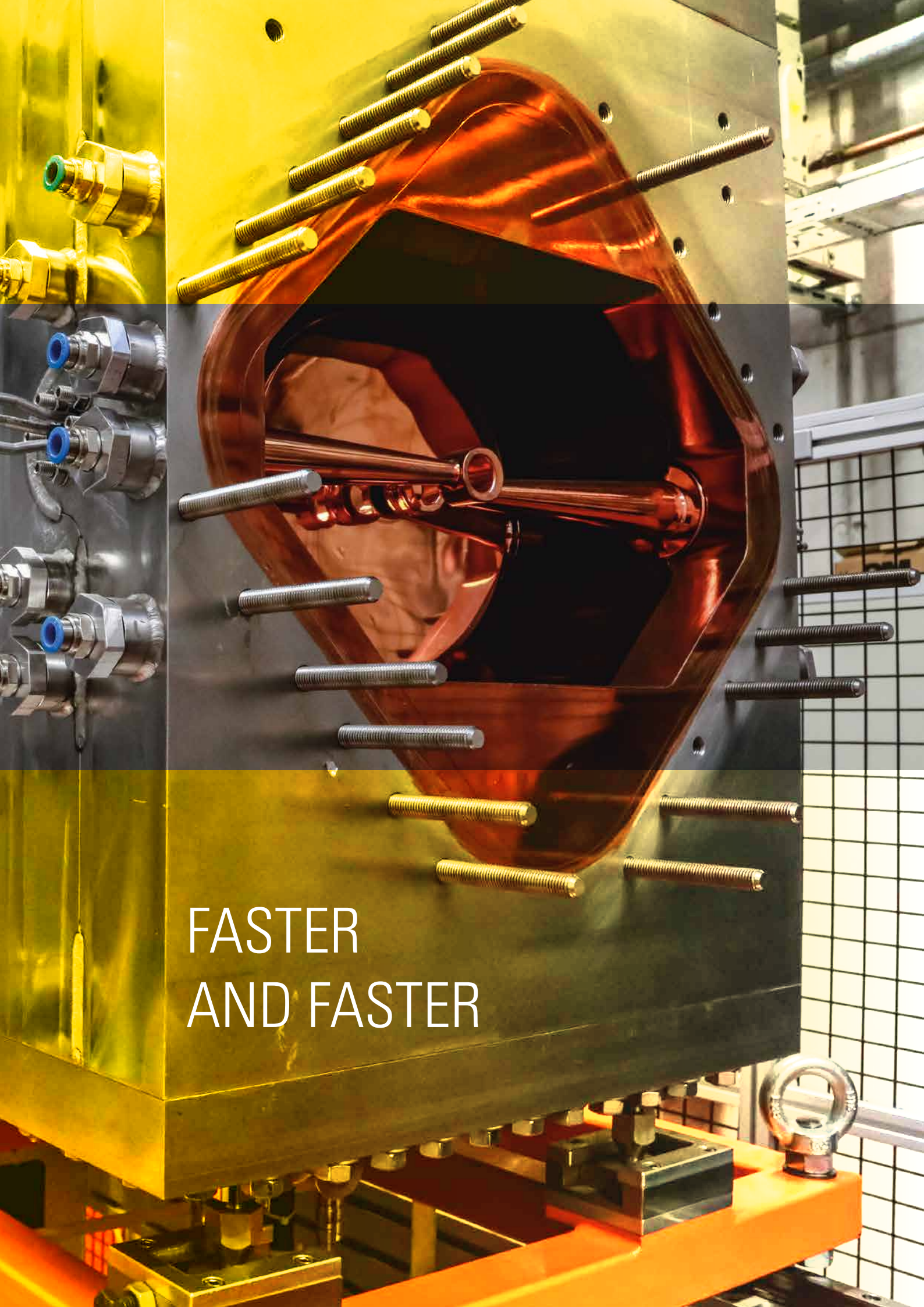
Sevenich herself finds many of her research findings exciting but also frightening: “Unfortunately, the path from our still very fundamental knowledge of brain tumours to therapeutic approaches is still very long,” she says. “But the worry that it could happen to us or someone close to us is naturally also our motivation for understanding the ecosystem of tumours.” ●



The author

Dr Anja Störiko, 56, holds a doctoral degree in microbiology. She works as a freelance journalist for general interest magazines, is editor of “BIOspektrum”, a biosciences journal, and has written books on health topics. Sevenich’s findings on metastases aroused mixed feelings in her: she found them alarming, but also admired the researchers’ courage in taking on the challenge of brain metastases.

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FASTER
AND FASTER

The unmoved mover

How the tiniest particles approach the speed of light

By Dirk Eidemüller

Particle accelerators are an indispensable part of the modern research landscape. Some of their main components come from Frankfurt.

They are the unmoved movers of modern science, transfixed atop massive foundations: particle accelerators. After all, they are precision instruments whose components are aligned with each other to within a fraction of a millimetre. All the gigantic magnetic coils and accelerator structures that make up the centrepiece of particle colliders must stay firmly in place during operation. Inside, however, extreme conditions prevail.

An almost perfect vacuum ensures that tiny particles can whizz through the tubes without colliding. Thanks to ingenious electronics, huge electromagnetic forces tug at the particles and accelerate them to the verge of what natural laws allow – namely, almost to the speed of light.

“No particle made of matter can move at the exact speed of light or faster,” says Ulrich Ratzinger, professor for accelerator physics at Goethe University. “That’s what Albert Ein-

stein’s theory of relativity tells us.” But you can get closer and closer to this threshold, and then an interesting effect occurs: if you are already close to the speed of light and continue to pump energy into the accelerated particles with the help of electromagnetic fields, their speed hardly increases any further. But their mass increases more and more. In line with Einstein’s famous formula that energy is equal to mass times the speed of light squared, particle accelerators can thus convert acceleration energy into particle mass.

Giant stars and Big Bang research

“This allows us to enlarge lightweight particles, such as electrons or protons, to many times the original mass they have in their resting state,” explains Ratzinger. This additional mass gives them correspondingly greater momentum when they collide with other particles or hit a target. Researchers then search for new types

Copper and steel colossus: inside the accelerators, electromagnetic fields accelerate the particles between the drift tubes. They are shielded as they fly through these tubes. The field can now change direction and give the particles further thrust as they exit the ring. All inner surfaces are plated with copper to damp the radio-frequency wave as far as possible.

of particle or physical effects in the debris of such collisions. But the radiation produced in a particle accelerator can also be used to x-ray materials.

At any rate, modern science is inconceivable without these unmoved movers. Scientists use them not only in their search for elusive dark matter and to measure the properties of elementary particles. With the help of fast particles, it is also possible to reconstruct the processes inside giant stars or produce the ultra-hot plasma from atomic nuclear matter that prevailed in the Universe shortly after the Big Bang. Extremely brilliant x-rays with laser characteristics can be decoupled from particle accelerators like at the European XFEL in Hamburg, which produces the sharpest x-ray pulses in the world and has made Germany a global leader in this field of research. The apparatus there can be used to

x-ray new materials, biological samples and chemical processes on the shortest spatial and temporal scales.

“Neutrons don’t come off the shelf”

But particle accelerators are also currently being built in two other parts of the country that will facilitate work at the cutting edge of science. Close to Darmstadt, the FAIR accelerator centre (Facility for Antiproton and Ion Research) is near completion. Building on decades of expertise in heavy ion research at GSI in southern Hessen, an international consortium is building a particle accelerator complex capable of answering hundreds of questions from basic and applied research. And in Frankfurt, FRANZ, the “Frankfurt Neutron Source at the Stern-Gerlach-Zentrum”, is currently under construction. Although small in comparison to FAIR, thanks to technological innovations it should also allow measurements to be conducted that have so far not been possible in this form.

“With FRANZ, we want to produce high-definition neutron beams with unique beam quality,” says Ratzinger. Neutrons are perfect for radiographing materials and complement x-rays very well, but while it is easy to decouple x-rays as electromagnetic radiation from x-ray tubes or from the European XFEL, generating neutron radiation is far more difficult. Neutrons don’t come off the shelf: they are found together with protons in atomic nuclei and must first be released from this “cage”. Until now, this has mainly been done in research reactors. “But in future, these reactors will be replaced by special particle accelerators like FRANZ, since these can produce high-definition neutron beams that can be controlled with great precision,” explains Ratzinger.

FAIR is a new accelerator facility currently under construction at the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt. The technology for one of the first two acceleration stages, a linear accelerator for protons, comes from Frankfurt.



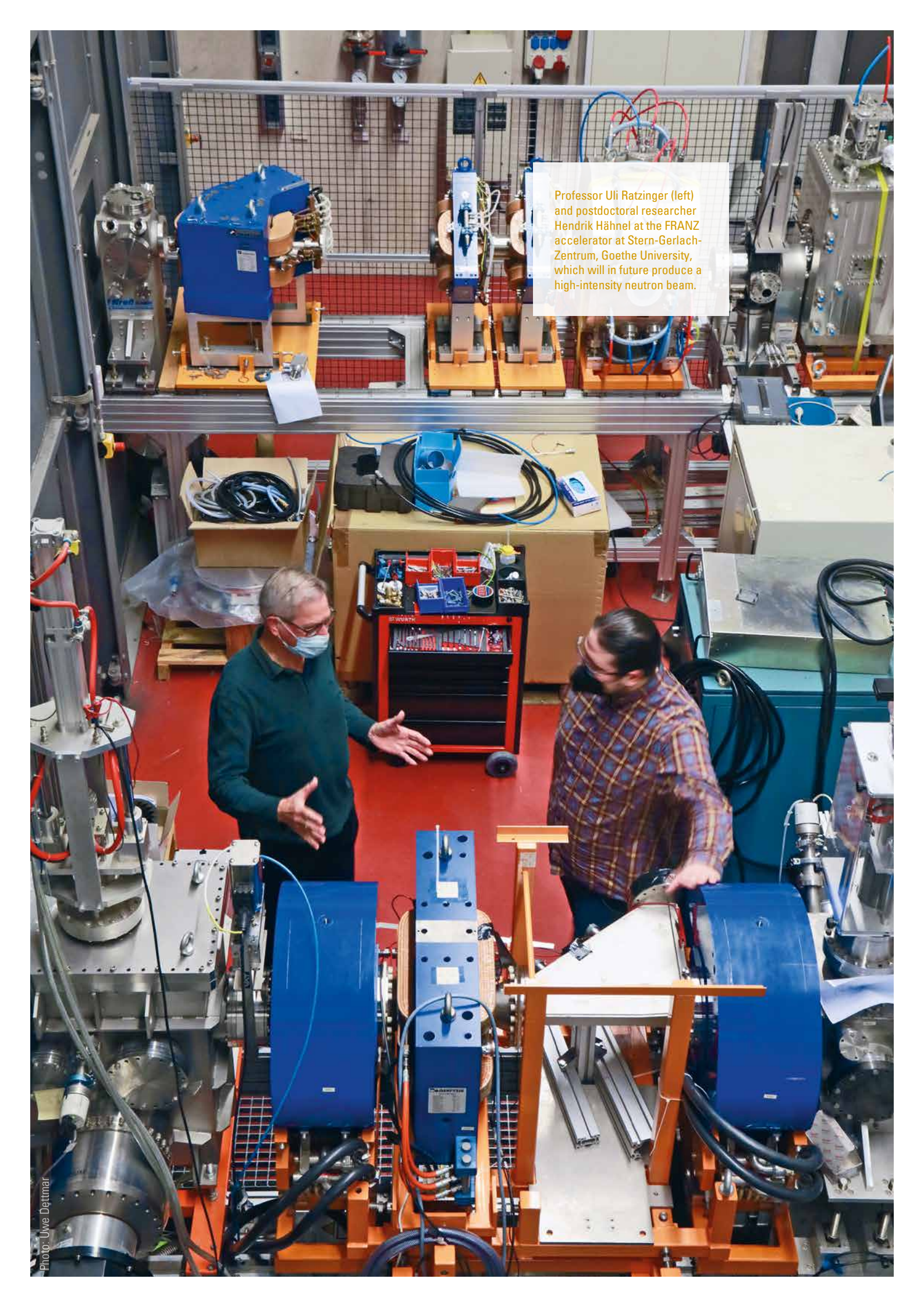
Photo: Dieter Fehrenz/GSI/FAIR

ABOUT ULRICH RATZINGER



Uli Ratzinger, born in 1956, studied physics at the Technical University of Munich. He wrote his doctoral thesis on the development of particle accelerator cavities. He joined GSI Darmstadt in 1987, where he is responsible for the design and development of new linear accelerator technology for GSI and CERN. He also contributed to the development of a special type of accelerator for tumour therapy, which was used at Heidelberg Ion Beam Therapy Centre (HIT) and later at other therapy centres. Since 1999, he has concentrated on superconducting accelerator components and especially the new high-current proton linear accelerator at GSI/FAIR. Uli Ratzinger was appointed as professor at Goethe University in 2000 and as Gerald Kucera Laureate Professor for his excellent contribution to accelerator physics in 2009. In 2003, he co-founded Bevattech, a consulting company in the field of linear accelerators.

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Professor Uli Ratzinger (left) and postdoctoral researcher Hendrik Hähnel at the FRANZ accelerator at Stern-Gerlach-Zentrum, Goethe University, which will in future produce a high-intensity neutron beam.

IN A NUTSHELL

- With the help of electromagnetic fields, particle accelerators propel tiny particles almost to the speed of light.
- Scientists at Goethe University are developing concepts for linear accelerators, for example for FRANZ, the university's own neutron accelerator, and for the FAIR ion accelerator in Darmstadt.
- Accelerators are mainly used in basic research. However, at GSI in Darmstadt, for example, a method for cancer treatment based on carbon ion beams was also developed.

Exotic requests

At FRANZ, a linear accelerator will generate 250,000 proton pulses per second, which are then fired at a target. In the process, neutrons are released with each pulse that can be separated according to speed. In this way, neutrons with clearly defined properties are obtained, which on the one hand can help to solve astrophysical questions – such as the fusion of elements in giant stars. On the other hand, the researchers also hope to find new approaches for cancer treatment by allowing the neutrons to react with a boronic substance that docks onto tumours.

“Initially, the specifications expected of FRANZ had us racking our brains quite a bit. The research community expressed rather exotic requests, well beyond conventional accelerator technology,” says Ratzinger. This meant that the specialists in Frankfurt not only had to design an extremely fast pulse sequence of 250,000 pulses per second – far greater than any other particle accelerator. FRANZ was also expected to generate a very powerful beam at the same time so that as many neutrons as possible are produced. “To do this, we had to develop new components, such as a compact, high-frequency accelerator for high-current proton beams and fast-switching transverse electric fields that shape the protons flying out of the source into pulses in the course of microseconds.”

Space-saving design for FAIR accelerators

While FRANZ is a regional project, FAIR will in future be the most important international facility for heavy ion research. Its main components are the accelerator technology and the particle detectors. In large particle accelerators, coupling

two types of accelerators has proved effective: first, a linear accelerator propels the particles up to speed, then ring accelerators – known as synchrotrons – pick up the already fast particle bunches and accelerate them to the highest energy level. FAIR has two ring accelerators: the two heavy ion synchrotrons “SIS18” and “SIS100”. The technology for the pre-accelerators comes primarily from Frankfurt.

“We’re basing the new FAIR proton linear accelerator on an innovative, compact design that has enabled us to reduce its size by around half in comparison to earlier models,” says Ratzinger. This is possible thanks to the clever geometry of the cavities and the electromagnetic fields that oscillate in them, accelerating the particle bunches in the process. This space-saving and energy-efficient design saves not only electricity during operation but also vast quantities of concrete: such a powerful particle accelerator has to be shielded with thick concrete walls so that no dangerous particle radiation leaks out.

Cancer treatment and neutron star research

When FAIR goes into operation in a few years’ time, it will be possible to accelerate particles of all sizes, from lightweight protons to heavy elements – and even to produce antiprotons, that is, antimatter particles. “In addition, the experimenters will be able to separate rare, short-lived and exotic atomic nuclei, which are the result of collision experiments, from the particle beam and conduct precision experiments with them,” says Ratzinger.

Testing innovative cancer therapies, getting close to the Big Bang, studying matter under extreme astrophysical conditions, exploring the origin of the elements: none of this would be possible without particle accelerators. The unmoved movers unveil to us what’s going on in the world’s innermost core. ●



THE AUTHOR

Dirk Eidemüller, born in 1975, studied physics (major) and philosophy (minor) in Darmstadt, Heidelberg, Rome and Berlin. He graduated in astroparticle physics and holds a doctoral degree in philosophy of science. He lives in Berlin and works as a freelance author and science journalist.

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Video recognition: Spot the difference?

By Markus Bernards

Computers can already recognise objects and faces quite well, and also that something is moving and in which direction. However, artificial intelligence still has difficulties in spotting the type of movement involved. This is what computers are now learning in Professor Hilde Kühne's laboratory at Goethe University.

Following her 80th birthday, Lydia S., a lady living on her own, registered with a home emergency call service run by Caritas. They gave her a button on a lanyard. Pressing it would set off an alarm at the service's call centre, and a member of staff would call to ask if everything was all right. When she was at home, she hung the button round her neck and found it reassuring to be able to summon help, for example if

she were to fall. When Lydia S. then suffered a mild stroke, fell and urgently needed the emergency service, the button was lying on the armchair where she had put it when watching television. She was lying on the floor, and it was out of her reach. It was a while before she managed to get up and drag herself to the telephone to call for help.

The disadvantage of emergency call systems for elderly people worn around the neck or on a wristband is that people can put them down and they are then out of reach at the crucial moment. However, video cameras in the home, for example, are hardly an acceptable alternative. "Nobody wants an emergency service monitoring their home via video," says Hilde Kühne, assistant professor for image recognition systems and machine learning at Goethe University. "And certainly not in the bedroom or the

The computer learns from thousands of cooking videos which movement is "cutting".

bathroom, although it's usually here that people quickly find themselves in a critical situation."

Protection of personal privacy

Perhaps it would be a different matter if video cameras were indeed mounted in the home, but only a computer could see the pictures and not a human? If the computer were to alert the emergency service in the event of a fall, but without transmitting the actual video data? This would guarantee privacy because "the computer isn't interested in the person moving around in the apartment," says Kühne, whose current research topic is automatic motion recognition. "For the computer, videos are simply columns of figures."

To report a fall, the computer would, however, first have to be capable of distinguishing it from other types of movement. However, this is more difficult than identifying faces and objects in photos since computer training with videos is more complex – simply because of the vast amounts of data to be processed. For a movement to become visible, 50 to 100 frames are needed – so 50 to 100 times the data volume of a photograph.

material in the process is much more time-consuming by virtue of the large amounts of data and the greater length of time that needs to be calculated for videos.

There are two further problems on top: firstly, there are often different words for the same movement, which also depend on how long a movement is observed. Kühne: "If I watch someone for just three seconds, I can say, for example, 'he's running' or 'he's walking'. If I watch him for 20 seconds, I know 'he's sprinting' or 'he's jogging'. If I watch even more of the video and a dog appears, or I see a bus stop, I recognise that 'he's running away from the dog' or 'he's rushing to the bus stop'. That makes the task of recognising movement difficult to define, for humans as well as computers."

Solution: autonomous learning

The second problem lies in how humans process the flow of data received via their eyes and ears. We do not perceive movements as something continuous, but instead divide them into smaller segments in order to remember them. These segments are then pieced together again in the brain to form a continuous motion sequence. How many separate segments are perceived depends on the individual experiences and abilities of each observer. Hilde Kühne gives figure skating at the Olympic Games as an example: "The judges are trained and able to analyse the motion sequence in figure skating very precisely. A layperson sees the same sequence but can hardly distinguish between the individual elements."

So how is the computer supposed to learn? In Hilde Kühne's opinion: autonomously, by itself and no longer on the basis of annotations. Here, Kühne's team draws on a pool of 100 million YouTube videos. To learn, the computer is equipped with an artificial neural network. These are algorithms which in principle function like nerve cells in a brain. "But they are actually mathematical functions that convert columns of figures into other columns of figures," says Kühne.

Computer training

The computer is fed three pieces of information from each video clip: the actual video sequence showing a movement, the soundtrack and any subtitles that are perhaps superimposed on the video. An example would be a sequence from a cooking video in which the YouTube chef dices a pepper and says: "Now we're going to dice the pepper." "Dice the pepper" appears in the subtitles at the same time.

For the computer, the information – video, sound and subtitles – is three columns of figures, from which it calculates, with the help of a

ABOUT HILDE KÜHNE



Professor Hilde Kühne, born in 1979, studied computer science (computational visualistics) at the University of Koblenz-Landau and earned her doctoral degree at Karlsruhe Institute of Technology. In the course of her academic career, she worked at the Fraunhofer Institute for Communication, Information Processing and Ergonomics (FKIE) and the University of Bonn before moving to the MIT-IBM Watson AI Lab of the Massachusetts Institute of Technology in the USA as a researcher. Since 2021, she has also been assistant professor for image recognition systems and machine learning at Goethe University. She is co-founder of ks-research and was recently awarded the ICCV Helmholtz Prize in acknowledgement of a paper which, ten years after its publication, has proven significant for research.

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Many different words for the same movement

Moreover, computers are usually trained with texts that describe what can be seen in photos or video sequences. Such keywords, known as annotations, are formulated by humans who look at the pictures and describe them. In this way, the computer learns, for example, what a cup is when it sees lots of pictures with the annotation "cup". In the case of videos, compiling annotations and obtaining sufficient training

IN A NUTSHELL

- Computers in the lab learn from 100 million YouTube videos how to recognise movements.
- As text descriptions for motion videos are relatively complex, the computers train by themselves. The goal: to use algorithms to link together the video images, sound and subtitles of a movement.
- Potential applications are found in assisted living or the recognition of dangerous situations in video surveillance.

mathematical function, three points in an “embedding space”. This can be envisaged as a large, transparent cube. Kühne explains: “We want to find a mathematical function which translates the three columns of figures for the ‘cutting’ movement in such a way that they form three points close to each other in the embedding space. Video, sound and subtitle data of another movement, such as ‘waving’, should in turn generate three points at a different spot in the embedding space.”

Training the computer consists now of analysing lots of videos and generating respective groups of points in the embedding space for different movements. In the next step, the computer scientists show the computer annotated videos so that it can link the groups of points to the corresponding words, such as “cutting” or “waving”, and now “knows” what the respective movements are called.

Many applications

At some point in time, the computer should then be able to recognise a wide variety of movements, even if they are part of a longer video with lots of scenes, and assign the same movements to “cut”, even if the person in the video says “chop”, “slice”, “debone”, “dice” or “trim” instead of “cut”. And it will also be able to distinguish *what* is being cut: vegetables, the garden hedge or a video.

And if it can differentiate between “fall” and “kneel”, “bend down” or “sit down”, it is perhaps ready to be a discreet helper in emergency care. Other applications could be autonomous driving, where it can contribute to preventing accidents, or science, where it can assist in the evaluation of behavioural studies.

So far, so good: a positive outlook for the future. But won’t this technology also lead to us

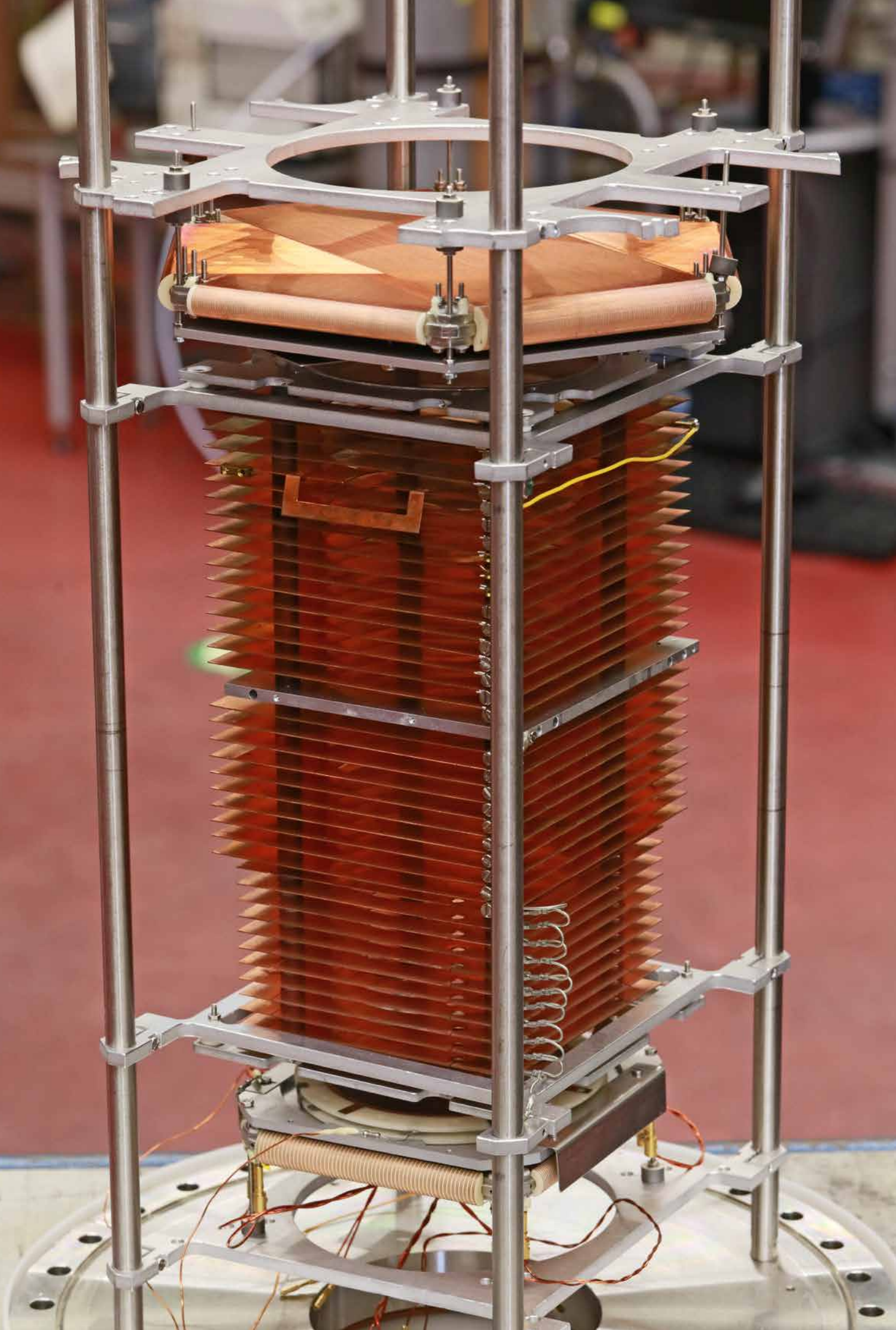
being kept under surveillance even more than we already are? “Surveillance in itself is not a bad thing,” says Hilde Kühne. “In my opinion, surveillance is first of all neutral. Of course, it can be misused, like almost any technology, and we ought to keep a close eye on that. But motion recognition is precisely what could help protect personal privacy, for example in assisted living. If you want to spot a dangerous situation in an underground station, such as a fight, the computer can help prioritise certain activities over, for example, the picture of a platform with children playing catch. After all, nobody can watch all the surveillance videos the whole time. The idea is therefore not that the computer will become master of the Universe, but that by being able to process and filter vast amounts of data automatically, we will make decisions *easier* for people and in this way also enable them to make *better* decisions.” ●



The author

Markus Bernards, born in 1968, holds a doctoral degree in molecular biology. He is a science journalist and editor of Forschung Frankfurt.

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Tickling Schrödinger's cat

When a molecule flies apart and stays bound at the same time

By Dirk Eidemüller

In Erwin Schrödinger's thought experiment, a cat in a box is both dead and alive at the same time. What cannot exist in our world is by all means possible in the microcosm of quantum physics: things that are in fact mutually exclusive occur simultaneously. A reaction microscope such as COLTRIMS – a Frankfurt development – presents the enigma of quantum dynamics on a silver platter.

No other scientific theory is as triumphant in its predictions, yet at the same time as controversial in its interpretation, as quantum physics. Since its origins around 100 years ago following works by Niels Bohr, Werner Heisenberg, Erwin Schrödinger and a few other colleagues, the strange implications of quantum theory have confused generations of physicists and philosophers.

Can nature really be as bizarre as quantum physics claims? Are particles at the same time waves? Do things happen by sheer chance, without causal root? Can it be that particles far apart from each other nevertheless form a closely connected system, even if they are not connected by physical forces?

According to the current state of science, all these counterintuitive claims must be answered with a resounding 'Yes'! Yet even to Albert Einstein, who himself laid important foundations for later quantum theory through his work, they seemed so absurd that he opposed them throughout his entire life. Indeed, he even argued against them and for many years searched in vain for an alternative theory. Today, we know that Einstein was barking up the wrong tree. Quantum physics – strange as it might be – works, even if it severely overtaxes our everyday understanding of reality. However, impressive new instruments are mean-

while available that allow us to observe the mysterious happenings in the microcosm on a magnified scale. One such device is COLTRIMS (Cold Target Recoil Ion Momentum Spectroscopy).

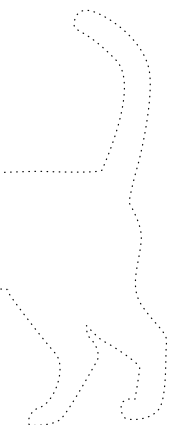
"We also call this apparatus a 'reaction microscope' because it allows us to observe ultrafast chemical reactions and investigate the changes in atoms and molecules at the fundamental level of quantum physics in the process," explains Reinhard Dörner, head of an atomic physics research group at Goethe University.

Microscope for atomic dynamics

Generally speaking, the operating principle of a reaction microscope is not that complicated: in a vacuum chamber, a very powerful laser beam or x-ray is fired at the molecule under study, which then bursts apart. As the fragments fly apart, they are guided by electromagnetic fields to sensitive detectors where they are registered. "In a nutshell, we shatter atoms and molecules to find out more about their structure," says Dörner. Since all parameters are known, conclusions can be drawn from the image on the detector about the original molecule, that is, the position of the individual atoms in the molecule and the orientation of the molecule in space.

In this way, it is possible to determine not only the general structure of molecules but also

The heart of the COLTRIMS reaction microscope: the many copper plates cut out in a circle at the centre produce electric fields. When a laser beam shatters a gas molecule in the centre of the device, these fields direct the electrons upwards and the positively charged ions downwards.



$$i\hbar \frac{\partial}{\partial t} |\psi_n(t)\rangle = \hat{H} |\psi_n(t)\rangle$$



In our world, a cat cannot be dead and alive at the same time. However, Erwin Schrödinger calculated that in the quantum world this would be possible. Quantum particles can adopt multiple eigenstates at the same time.

their handedness, that is, whether the molecule is a levorotatory or dextrorotatory variant. This is important above all for drugs because biomolecules with the wrong chirality can be highly toxic in extreme cases. This analysis already works for simple molecules with up to 20 atoms.

Yet the technology is still relatively young and has only been established for about 20 years. “COLTRIMS was developed in Frankfurt, and the driving force behind it was Professor Horst Schmidt-Böcking,” says Dörner. “Ten years ago, there were still only about two dozen of these reaction microscopes worldwide. Today, there are already well over 100, and the number continues to rise.” What makes these devices attractive is their ability to visualise quantum processes on tiny spatial and temporal scales.

Because quantum particles behave not only like waves. They can also – when not under observation – exist in peculiar superposition



states in which they adopt two or more eigenstates at the same time. Erwin Schrödinger found this consequence of his own theory so incongruous that he later turned his back on quantum theory and devoted himself to entirely new activities. He illustrated these superposition states with his famous paradox of “Schrödinger’s Cat”. In this thought experiment, a cat is confined in a box with a mechanism based on quantum physics that kills it with 50 percent probability. According to Schrödinger, the poor cat is in a half-dead and half-alive state as long as the box remains closed. The state of the dead-and-alive cat is “smeared” across the box, as it were.

Cat-like helium molecule

“However, what’s impossible with cats and other large objects can by all means be achieved with molecules,” explains Dörner. The working group in Frankfurt has devised a sophisticated experiment that visualises precisely this effect. To do this, the researchers cooled helium atoms down to an extremely low temperature. This noble gas does not, in fact, form any bonds. Nevertheless, at very low temperatures, two helium atoms can join together to form a very loosely bound molecule.

“We then fire two laser pulses one after the other at this helium molecule, one weak and one strong,” says Dörner. The first pulse transposes the molecule into one of the peculiar superposition eigenstates typical in quantum physics. Just as Schrödinger’s cat is both dead and alive, the helium molecule is now half-intact and half-broken. However, this superposition, which cannot occur in the macroscopic world and therefore contradicts how we see things, has very real effects when magnified with the help of the reaction microscope.

This is achieved with the second laser pulse, the strong one. It knocks the electrons out of the system, so that the “naked”, positively charged helium ions now repel each other. Due to the previously induced superposition eigenstate, this leads to interesting interference effects that can be measured at the detector.

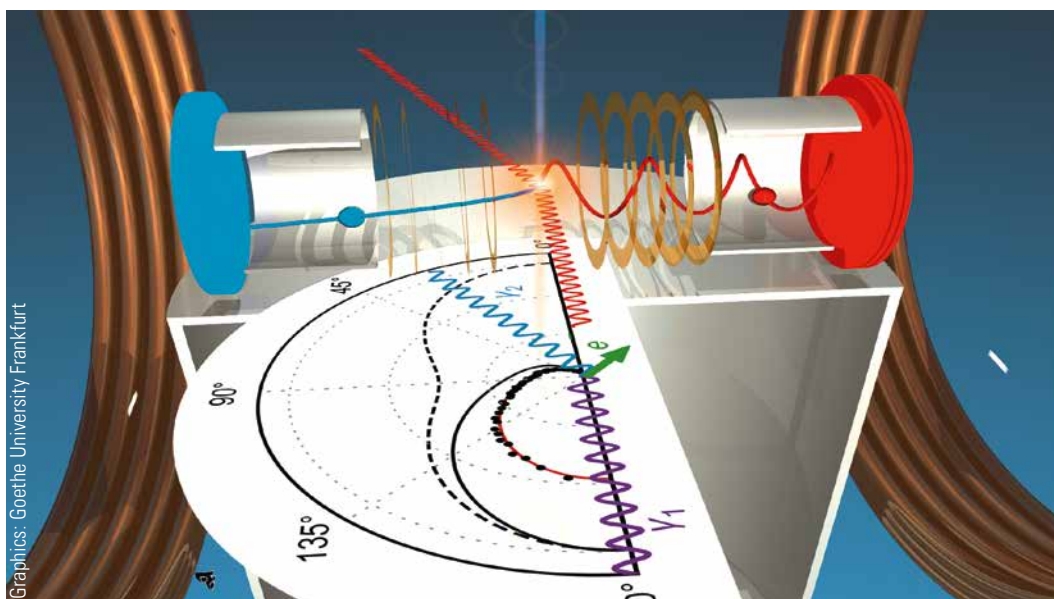
ABOUT REINHARD DÖRNER



Reinhard Dörner, born in 1961, studied physics and philosophy in Frankfurt and Aachen and earned his doctoral degree in physics at Goethe University. A stay at Lawrence Berkeley National Laboratory in the USA followed, after which he returned to Frankfurt. He was appointed as professor at the university’s Institute of Nuclear Physics in 2002 and since then has also been dean of studies for physics several times. From 2010 to 2017, he was managing director of the Institute of Nuclear Physics. In 2016, he won the Helmholtz Prize, the highest award for metrology in Germany, which is conferred for special achievements in the development of precision measurements. Since 2016, he has also been a member of the editorial board of Physics Review Letters, the most important physics journal.

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Cat: local doctor/shutterstock, Photo: IMAGNO/Votava/Süddeutsche Zeitung



Graphics: Goethe University Frankfurt

This is how the COLTRIMS reaction microscope works: if a laser beam or an x-ray (photon, wavy red line) knocks an electron out of a molecule, the electron is deflected to the right along a helical path by electric fields. The positively charged ion, on the other hand, is directed in a straight line to the left. Detectors on both sides measure how long the particles need until impact once the molecule has been shattered.

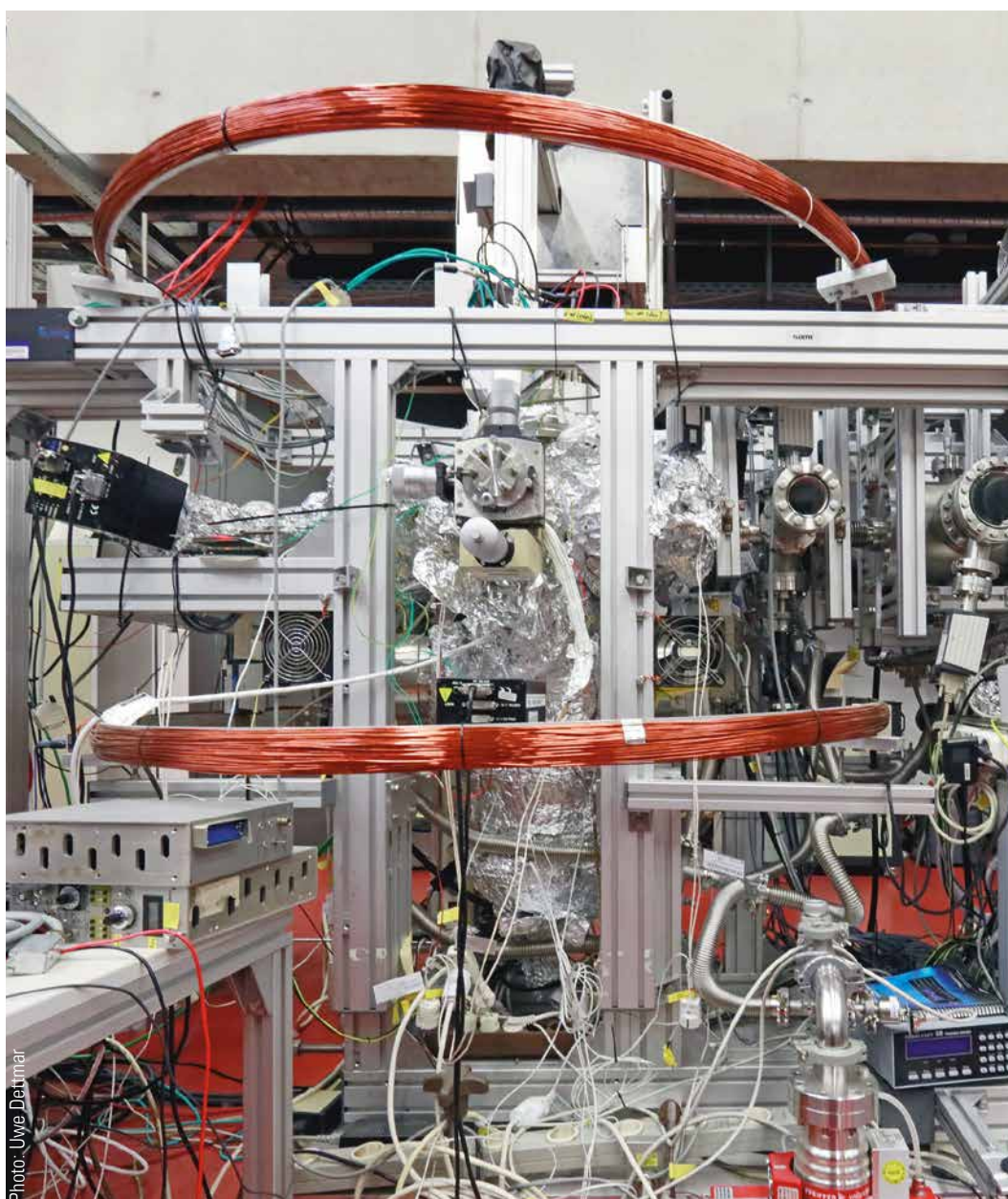


Photo: Uwe Deitmar

High-tech: the COLTRIMS reaction microscope in Frankfurt.

A close-up photograph of a copper mesh screen, likely a component of a reaction microscope. The mesh is composed of fine, parallel copper wires forming a grid pattern. The screen is circular and occupies most of the frame. A yellow rectangular text box is overlaid on the left side of the screen. The background is a light-colored, possibly white, surface.

IN A NUTSHELL

- With the COLTRIMS reaction microscope, it is possible to observe extremely fast chemical reactions. For example, the current world record in short-time measurement (247 zeptoseconds) was established with such a reaction microscope.
- The instrument can, for example, visualise the superposition of two electron waves, each of which only occurs with a certain probability – an effect from the quantum world.



The PETRA III x-ray radiation source at the DESY accelerator centre in Hamburg produces high-energy x-rays. A COLTRIMS reaction microscope, nowadays one of many such instruments around the world, is mounted at beam pipe P04 in the "Max von Laue" experimental hall (long, curved building on the aerial photograph). Physicists from Frankfurt are also conducting experiments in Hamburg.

"We tickle Schrödinger's cat, as it were, and make it move," explains Dörner. "What we can then observe at the detector is how both the motionless, dead cat and the live, goaded cat influence the measurement result." Being able to visualise such phenomena, which drove eminent authorities such as Einstein and Schrödinger to despair, is, however, only one of the fascinating possibilities that reaction microscope open up.

Fastest time measurement

Because they magnify things on tiny scales, they have recently even enabled the fastest time measurement of a natural process. "We were able to determine how long a light pulse needs to fly through a hydrogen molecule," says Dörner. It takes 247 zeptoseconds – orders of magnitude shorter than light needs for a single oscillation. A zeptosecond is a trillionth of a billionth of a second. But no measuring device exists that could measure such an incredibly short interval directly. Instead, the scientists used the high-energy x-rays at the DESY accelerator centre in Hamburg, which they directed at hydrogen molecules in a reaction microscope housed there. The x-ray beam ejected an electron out of the molecule (consisting of two protons and two electrons) at one end or the other, something that only occurs with small probability.

Since quantum particles are at the same time waves, this reaction produced two superimposed electron waves (like in the case of Schrödinger's cat), but these were slightly stag-

gered – like the ripples of water produced when you skim a flat pebble across a pond. In contrast to a direct time measurement, however, it is easy to determine the interference between these waves in the reaction microscope – and from this it is possible to calculate the length of time needed by the x-ray pulse to reach the electron on the one side or the other.

This record-breaking measurement demonstrates very impressively how reaction microscopes can be used to make extremely short time scales accessible. "Conversely, we also want to investigate with larger molecules how the dissemination of information decelerates when a large number of electrons are involved," says Dörner. What Einstein and Schrödinger would have said about these quantum tricks with time measurements based on particle waves and semi-stationary, semi-expanding cat molecules is, however, written in the stars. ●

Close-up of the main component of the COLTRIMS microscope: the electron detector consists of fine copper threads. When an electron hits these threads, a signal is triggered.

The author

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(see page 24)

A high-angle, blurred photograph of a busy public space, likely a transit station or a large indoor arena. The floor is composed of light-colored, rectangular tiles. Several people are captured in motion, their figures blurred to convey a sense of activity. A large, semi-transparent red circle is overlaid on the left side of the image, containing the text "HUMANS IN MOTION" in a bold, red, sans-serif font. In the foreground, a woman with dark hair, wearing a black tank top, is seen from behind, looking towards the right. She is holding a blue water bottle and a black bag. The overall atmosphere is one of constant movement and human presence.

HUMANS
IN
MOTION

Kids' stuff?

ADHD can affect adults too

By Jan Schwenkenbecher

ADHD is a childhood disorder? That's not quite true. It persists into adulthood in about half of all those affected. The right dose of the right medication helps, but this is not always easy to gauge. Psychiatrist Oliver Grimm wants to help in the search.

The cocaine helped. It didn't make him fidgety or hyper like it did so many other people. The right amount calmed him down, he could concentrate better, and didn't constantly forget to send the invoice each time he'd finished a paint job on a building site. It was self-medication – no doctor prescribes cocaine – but it helped. At least for a while. “But in the long run things went awry,” says Oliver Grimm, who met the man, a professional painter, in the outpatient department at the Department of Psychiatry, Psychosomatics and Psychotherapy of University Hospital Frankfurt. “At some point, he lost his driving licence.”

Grimm is a consultant psychiatrist and head of the outpatient department. Alongside his everyday work with the patients who present there, he also conducts research. One of his main interests is attention deficit hyperactivity disorder, in short: ADHD. And it was from ADHD that the painter Grimm met at the outpatient department was suffering.

Cause of ADHD still unknown

Hold on a moment. Isn't ADHD a childhood disorder? After all, the first reported “case” is a fictional little boy called Fidgety Philip in “Struwwelpeter”, the colourfully illustrated book written by Frankfurt physician and psychiatrist Heinrich Hoffmann in 1844. Isn't ADHD

that disorder where children are given Ritalin so they can concentrate in school and take part in lessons, but which they then grow out of in their teens?

Yes and no. It's correct that the disorder frequently occurs in childhood and adolescence, affecting about five percent of all youngsters in this age group. The symptoms are inattentiveness, impulsivity and extreme restlessness. Current research suggests that ADHD is caused by a delay in the brain's maturation process due to premature birth or birth complications – the outcome of this debate is, however, still open. Nevertheless, saying that ADHD is solely a children's disorder is wrong because adults are also affected. Although the disorder always starts in childhood, symptoms persist into adulthood to a greater or lesser degree in about half of those affected.

Adult ADHD in stress situations

“Many psychiatrists and psychotherapists are also unaware of this,” says Oliver Grimm. That's why the outpatient department headed by Grimm offers a special clinic for ADHD in adulthood. “The focus is on diagnosis and not so much on treatment,” he says. Visitors to the outpatient department are examined, and then the doctors discuss with them whether they might have ADHD. If that is the case, they

Inner restlessness: even when they seem to have overcome the ADHD of their childhood, many adults still suffer from it. When things become particularly challenging – career, family, mortgage – those affected soon start to flounder.



Various symptoms: in addition to inattentiveness, hyperactivity and impulsivity, adult ADHD sufferers often experience several secondary symptoms, including depressive moods with feelings of inferiority and hopelessness.

recommend doctors who can treat them.

“People of all ages come to us. Some have just turned 18, others are already 60 or older,” Grimm says. “But most are between their late 20s and late 30s.” ADHD surfaces above all when there is particular pressure from outside. And it’s precisely at this age that lots of things come together: starting a career, buying a house, getting married, perhaps children come along. “People often come to us who were once diagnosed with ADHD as a child, but then didn’t have any problems with it for a long time. They got through it on their own, and then, in their mid-30s, they come to our outpatient department because they’re floundering,” says Grimm.

No magic pill

However, according to Grimm, the idea behind the special clinic is to look again for ADHD specifically in young adulthood. “Even at the age of 60, ADHD can still compromise a person’s life and cause problems. But by then, lots of things have already been decided. At 18, 19, 20, the

right diagnosis can still make a real difference for the rest of a person’s life.”

For many visitors to the clinic, that’s the most important thing: the right diagnosis. Some want a magic pill that will make life easier again. Others simply want an explanation as to why they find some things so difficult. Others, in turn, would even rather hear that they don’t have ADHD – for example because they were once diagnosed as a child, but no longer have any trouble with it and want to join the police. “Clarifying that – whether it’s a case of immense psychological stress or whether they just want an ‘explanation’ – is a very important task for us when we talk to them for the first time,” says Grimm.

And those looking for a magic pill? In general, Grimm has to disappoint them. Medication can indeed have a tremendous effect in some cases. It is, however, mostly rather the case that, although it indeed helps, it does not solve all the patient’s problems. And sometimes doctors have to try different drugs in different strengths until they find a remedy. The research that Oliver Grimm and his team are conducting targets pre-

Photos: Aninka Bongers/Sutherland/Shutterstock (blister), Alex Green/Pexels (person)

ABOUT OLIVER GRIMM



Oliver Grimm, born in 1975, is a consultant psychiatrist and psychotherapist. In the course of his academic career, he worked in Mannheim, Berlin and Zurich before joining the Department of Psychiatry, Psychosomatics and Psychotherapy at University Hospital Frankfurt as senior physician in 2016. He has been responsible for the hospital’s outpatient department since 2019. Alongside his work there, Grimm also conducts research into ADHD and heads the research group “Adult ADHD and Reward System Pathologies.” His research results have been published in numerous scientific journals. Alongside his work on ADHD, schizophrenia is another of his research interests.

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cisely these cases: Which treatment helps which patient best?

Genetic risk profile

One of his main research topics is genetics. ADHD tends to run in families, and experts estimate that around 70 percent of the reasons why it develops are down to genes. This has been known for some while: “Studies with twins showed a long time ago that ADHD is distinctly overrepresented in identical twins compared to non-identical twins, meaning that genetics had to play a significant role,” says Grimm. “But through genome-wide association studies we can meanwhile say which areas in the genome are involved.”

In this type of study, researchers look at different gene variants and examine what influence they have. For example, at one location in the gene, one of the base pairs might be structured differently in one third of people than in the other two thirds – referred to by scientists as different alleles. This does not necessarily matter, but it can have an influence. If available, huge databases with the genetic information of tens of thousands of people could be used to calculate whether a particular gene variant increases the probability of developing ADHD.

“But we don’t look for individual genes,” explains Oliver Grimm. “Many of these small differences can increase the likelihood of developing ADHD by a small fraction, their influence is minimal.” That’s why one idea for future ADHD research worldwide, he says, is for doctors to draw up a genetic risk profile, something that Grimm is also working on. “With that, we could possibly forecast whether this or that type of treatment is more suitable for this or that risk profile.” The score is then calculated – explained in somewhat simple terms – by adding up all the miniscule gene variants and their respective influence on the risk of developing ADHD. “Such risk profiles are already drawn up in clinical diagnostics in other fields, such as oncology,” says Grimm.

Research with artificial intelligence

At some point in time, other results could then be included in the calculation, such as fMRI brain scans. “Perhaps we’ll soon be cramming all the data into an AI model, and an algorithm will tell us in advance which treatment will benefit the patient,” says Grimm. “Or whether a patient has a high risk of ADHD – that would already be very helpful.” However, this would mean foregoing information on how and why ADHD develops and how and why which therapy helps. Although these insights are interesting for research, he says, for the therapist, and especially for the patient, it is much more important

that the treatment helps – irrespective of how and why it works. Grimm explains that it’s always important not to introduce bias into data when algorithms are involved. Otherwise, this could lead to a model which perhaps discriminates against minorities. It is conceivable, for example, that AI might be better at calculating the risk of ADHD for boys than for girls because ADHD symptoms are less visible in girls, meaning that the condition is not as noticeable and diagnosed less often, and consequently the dataset delivers more detailed information about the correlation between ADHD and the male gender. “But these are known problems in AI research that can be controlled.”

It is equally important, however, to educate people about the clinical picture. About the symptoms, about the treatment methods with which doctors can usually achieve good results and that can help with the problems of those affected. And, above all, that ADHD can affect adults too. ●



The author

Jan Schwenkenbecher, born in 1998, is a freelance science journalist and lives in the Rhine-Main region. He studied psychology in Giessen and Marburg and then learnt the art of journalism in the framework of practical training at the Süddeutsche Zeitung newspaper.

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WHAT CAN SPORT ACHIEVE?

Final score from a research project on immigrant integration

By Jan Schwenkenbecher

Sport, it's always said, is one of the greatest drivers of integration. That can indeed be true if the baseline is right. In the "InBewegung" ("Keep Moving") project, researchers from Goethe University studied what this baseline looks like and what sports clubs require for setting up integration programmes.

In 2020, 1,186,702 people moved to Germany from abroad. Immigration peaked in 2015, with 2,136,954 people. In the past 30 years, the annual figure has always exceeded 660,000. Only in two of those 30 years did more people leave Germany than arrived. Germany, an immigration country.

Frankfurt. They conducted surveys, used participant observation and held interviews with hundreds of club managers and members as well as non-members and refugees.

And what's the conclusion now that the project has just ended? Is Sportkreis Frankfurt good at integration? Michael Fingerle, professor of educational sciences, head of the Diagnostics and Evaluation Department at the Institute of Special Education at Goethe University and one of the "InBewegung" project leaders, responds with a loud laugh. A big question, too big a question. "It's a question that you can't answer with 'Yes' or 'No'," says Fingerle. But he also says: "Sport can

gration," he says, "so she launched a sports programme for refugee minors." Soon, however, it didn't stop at the one training session per week. She built up contacts and relationships with the children and gradually became their go-between with German society. The children turned to her with questions about residence permits or accommodation, and they phoned her at night when they weren't feeling good. "You can't demand something like that of people," Fingerle says, "you can just be jolly glad if you find someone now and again who'll oblige."

To offer more, the clubs would need many more such individuals, that is, more volunteers. From their findings, Fingerle and his colleagues have derived three recommendations as to how Sportkreis Frankfurt as an umbrella organisation could help:

- It could assist club managers with their work.
- Together with the relevant institutions in the City of Frankfurt, it could commit to developing municipal integration management and a strategy to encourage voluntary work.
- It could implement activities aimed at securing resources, which it could then use to support individual clubs in their integration efforts.



ABOUT MICHAEL FINGERLE

Professor Michael Fingerle, born in 1962, studied psychology and graduated in 1991. He worked as a research associate at the universities of Mannheim, Leipzig and Halle and earned his PhD at the University of Jena. He was appointed as professor at the Institute of Special Education (Faculty 04, Educational Sciences) at Goethe University in 2004.

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In light of this, giving newcomers sufficient opportunities to come into contact with the local population and make new friends would seem all the more important. And scarcely anything is considered a more suitable springboard for integration than sport. When it comes to football, boxing, swimming, running, cycling or bowling, everyone is on a level playing field, and you can get along just fine without mastering the lingo. But is it really that simple? Come to Germany and join a sports club – no sweat?

Sport can help

Over the past two years, researchers from Goethe University and the University of Hildesheim have been looking for answers to this question in the "InBewegung" project funded by Germany's Federal Ministry of Education and Research. The researchers approached Sportkreis Frankfurt, the umbrella organisation for over 400 sports clubs in

by all means help to foster integration. But whether it actually does so will always depend on the conditions on the ground, and by 'conditions' I mean above all resources." Resources, in this instance, are two things: money and people.

Personal commitment

"As far as integration is concerned, Sportkreis Frankfurt already took up the gauntlet many, many years ago," says Fingerle. Nevertheless, it's not always easy, he says, because – for starters – clubs are independent, and you have no top-down access to them. "What's more, everything is down to volunteers," Fingerle says. "Often, just a handful of people do an awful lot. And you can't really go and say: 'Please can you do this or that as well'."

One particular case has stuck in Fingerle's mind. "We had a club with a very dedicated trainer who also wanted to do her bit for inte-

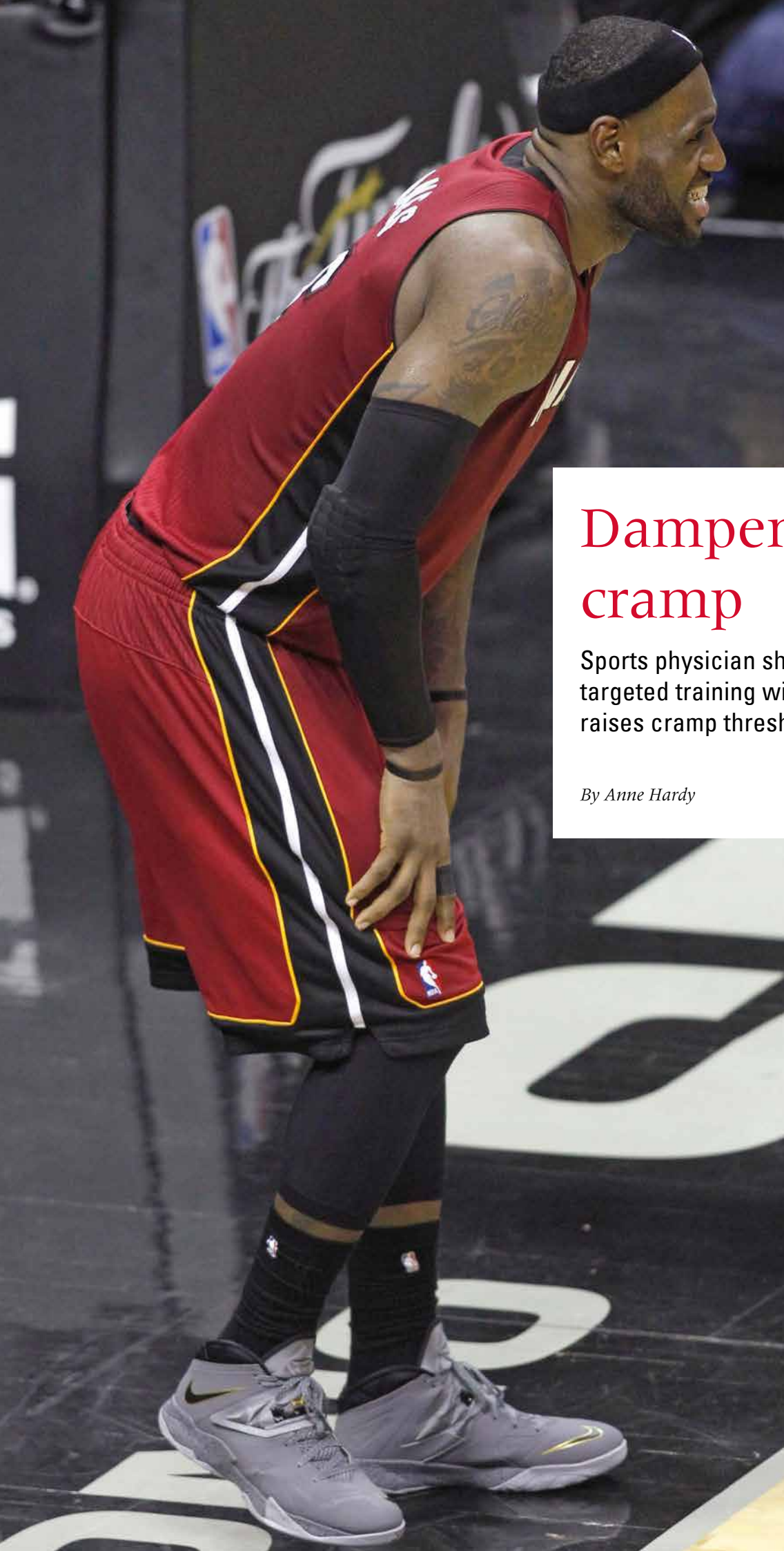
The author

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Photo: Sportkreis Frankfurt/Mohamed El Hamdaoui

The photograph of the two young footballers was taken during "Frankfurter B6lzplatzliga F 43+", a project centring on Frankfurt's amateur football league. Through this project, Sportkreis Frankfurt encourages sport, physical exercise and social learning among adolescents and works together with child and youth welfare organisations as well as refugee housing associations, which all take part with their own teams.



Dampening cramp

Sports physician shows that targeted training with electrical impulses raises cramp threshold frequency

By Anne Hardy

Most people take magnesium against skeletal muscle cramps. However, scientific evidence is thin – and that cramps are caused by an electrolyte deficiency is a theory dating back over 100 years. In his search for what causes cramps, sports physician Michael Behringer has made an interesting discovery: cramps triggered artificially can significantly reduce the tendency to cramp.

It was an abrupt end for top basketball player LeBron James when he had to be carried off the court during the 2014 NBA Finals due to sudden cramp in his calf. Leg cramps are common among professional athletes, especially triathletes and marathon runners. It's hamstrung many a victory. Especially at the Olympic Games, this is a bitter disappointment for athletes after four years of hard training.

But athletes are not the only ones plagued by muscle cramps. Some people have frequent and extremely painful cramps in their calves at night, which forces them to get up and stretch or massage their legs. "In severe cases, the combination of pain and lack of sleep sometimes even leads to suicidal thoughts," says Professor Michael Behringer, sports physician at Goethe University.

Biarticular muscles, such as those forming part of the calf muscles, are particularly prone to cramps. They run across the knee and ankle joints and can therefore shorten more drastically when the joints are in certain positions. At night, for example, when the leg is bent, and the bedding presses down on the toes. Behringer tells the story of a truck driver who has suffered from cramps in his thighs since the age of ten. The frequency and intensity have meanwhile increased to such an extent that he is unable to work. Even the quinine-based medication usually prescribed in these cases has not helped.

Magnesium: effect in athletes not yet studied

In grassroots sports, magnesium is the most popular remedy for cramp. Prior to or after a run, the amateur athlete dissolves a tablet in water to compensate for the electrolyte deficiency caused through perspiration. In doing so, the athlete is following a theory established over 100 years ago. Miners in the USA often suffered from cramps during their hard and sweaty work underground. Blood tests showed that they lacked electrolytes, which is how the theory originated.

"Regretfully, however, little has happened in research since then because it hasn't been possible to trigger and study cramps in the laboratory," says Behringer. According to a meta-analysis published in the Cochrane Database in 2020, there is very little evidence that magnesium prevents or relieves cramps. Most of the studies, however, referenced spontaneous cramps in people between 60 and 70 years of age. Studies were inconclusive on leg cramps at night during pregnancy. And randomised controlled trials (RCTs) on the effects of magnesium in athletes are lacking altogether.

Cramps from fatigue?

In 1997, Martin Schwellnus and colleagues from the University of Cape Town Medical

School in South Africa published a new hypothesis that explained muscle fatigue as the cause of exercise-related cramps. Fatigue, they said, throws the regulatory circuits off balance that the nervous system uses to regulate muscle tension and length. If the muscles are overtired, the activating signals from the spinal cord dominate over the inhibitory ones.

At the present time, cramp researchers are divided into two camps: fans of the electrolyte theory and fans of the Schwellnus deregulation theory. Behringer attempts to link the two by assuming that fluid loss is a common element in both theories, which is supported by the fact that people are more prone to cramps in the summer. For example, an analysis revealed far more Google searches for "leg cramps" during the hot months. Perspiring as a result of physical activity in hot, humid weather thus appears to increase muscles' tendency to cramp. "This could also be observed during a particularly hot summer at Wimbledon," says Behringer. "An unusually large number of matches had to be interrupted because of cramps."

On the other hand, the fact that cramps in the calf are quickly relieved by stretching, that is, by flexing the foot upwards (dorsal extension) supports Martin Schwellnus' theory that the regulatory circuit between muscle fibres and the spinal cord is dysfunctional. In addition, muscle cramps are difficult to trigger if impulse conduction between muscle and spinal cord is temporarily switched off by a local anaesthetic.

Dehydration and lower susceptibility threshold

According to Behringer, fluid loss intensifies this effect known as deregulation. The interaction of nerve impulses that control muscle tension and relaxation is dysfunctional because the muscle loses some of its volume when the body is dehydrated. According to current theory, this in turn increases the probability of spontaneous peripheral activation, that is, activation originating close to the nerve. The muscle contracts even more. If it now tenses and thus shortens even further, it is dangerously close to contracting and shortening as far as it can, which triggers cramps. According to current understanding, this is caused by an imbalance between activating and inhibitory nerve impulses from the muscles to the spinal cord. Cramps can occur in mild temperatures too if the muscle is tired and thus more "susceptible" because the inhibitory

IN A NUTSHELL

- There are surprisingly few hard scientific facts on the cause and treatment of muscle cramps.
- At present, there are two opposing theories: the electrolyte theory and the nervous system deregulation theory.
- The cramp training developed by Professor Michael Behringer raises the cramp threshold frequency but is unsuitable for milder cases because it is accompanied by severe pain.

Even superstars like American basketball player LeBron James are not immune to cramps. Again and again, he has led his team to victory in pain – but was also sometimes obliged to abandon the game.

feedback from the muscles is weak, thus oiling the works for cramps.

It was these considerations that led Behringer to examine muscle tension in people more prone to cramps. The experimental setup is extremely simple: the test candidate is asked to sit on a bench with their legs dangling down and two electrodes are stuck to one of their legs. An alternating current is applied to the electrodes, which stimulates the muscle in a similar way to physical exercise or work – but shortens it to a



Photo: Christoph Skuttschik

Muscle cramps are triggered in the laboratory by raising the frequency of electrical impulses. The purpose of this “training” is to gradually increase the susceptibility threshold for cramps – a source of relief for athletes.

maximum. The frequency is now gradually increased with the same current until the muscle begins to cramp. Sports scientists define the cramp threshold as the frequency that is just enough to trigger cramps.

Cramp training only for severe cases

The measurements showed that people more prone to cramps also have a lower susceptibility threshold. Their muscles evidently have a higher resting tone, and it is therefore easier to induce the cramp threshold. In the process, Behringer made a surprising discovery: in the course of successive measurements, his test candidates’ threshold rose from week to week until no artificial cramps could be triggered at all. “We were able to show that the muscles grow as a result of such cramp training,” Behringer explains. “But far more exciting was our observation of the ris-

ing cramp threshold frequency, which so far no other method has been able to achieve.”

Behringer stresses that his “cramp training” is currently only being investigated in the framework of studies. And even if it should enter clinical practice, it will be reserved for people with severe cramps. “How painful artificially induced cramps are should not be underestimated,” he says. When it comes to application in practice, he is thinking about cases such as that of a former pole vaulter, whose tendency to cramp stopped him from competing altogether, or of people who suffer frequently from cramps due to a narrowing of the spinal canal or a slipped disc. He was able to show in a study that the treatment reduced their cramps significantly.

Nobel Prize laureate’s spicy cocktail

Recently, Behringer has taken a closer look at HOTSHOT, which was developed in 2016 by Nobel Prize winner Rod MacKinnon to prevent cramps or muscle strain and is widely used by professional athletes in the USA. According to the story on the website as to how the company was founded (<https://teamhotshot.com/founders>), MacKinnon, neuroscientist and endurance athlete, was overcome by severe cramps while kayaking at sea with his friend Dr Bruce Bean. Both could barely steady their kayaks. It seems that MacKinnon saved himself from this dangerous situation by drinking the vinegar of pickled gherkins – presumably with the idea of replenishing his electrolyte balance. But the cramps subsided much faster than expected.

Back at their institute, the two neuroscientists searched for an explanation. They discovered that the acidic concoction, with spices such as peppercorns and mustard seeds, stimulates sensory nerve tracts from the mouth to the stomach. These send signals to the spinal cord, which in turn dampens excitation signals to skeletal muscles. “The truth is that cramps are caused by misfiring nerves,” it says on the website. Or put even more simply: “It’s the nerve, not the muscle.”

“HOTSHOT” put to the test

To stimulate the receptors in the mouth and stomach even more effectively, MacKinnon and Bean chose ginger, cinnamon and very hot chili peppers (jalapeño) as even hotter ingredients for their “HOTSHOT”. Capsaicin, the active ingredient in these spices, is also found in pepper spray. “I doubt that a marathon runner’s gastrointestinal tract can easily digest such a cocktail at the starting line,” comments Behringer.

But can HOTSHOT at least prevent muscle cramps? Behringer and his colleagues studied this with the help of their experimental setup. They were able to detect only a minor effect,

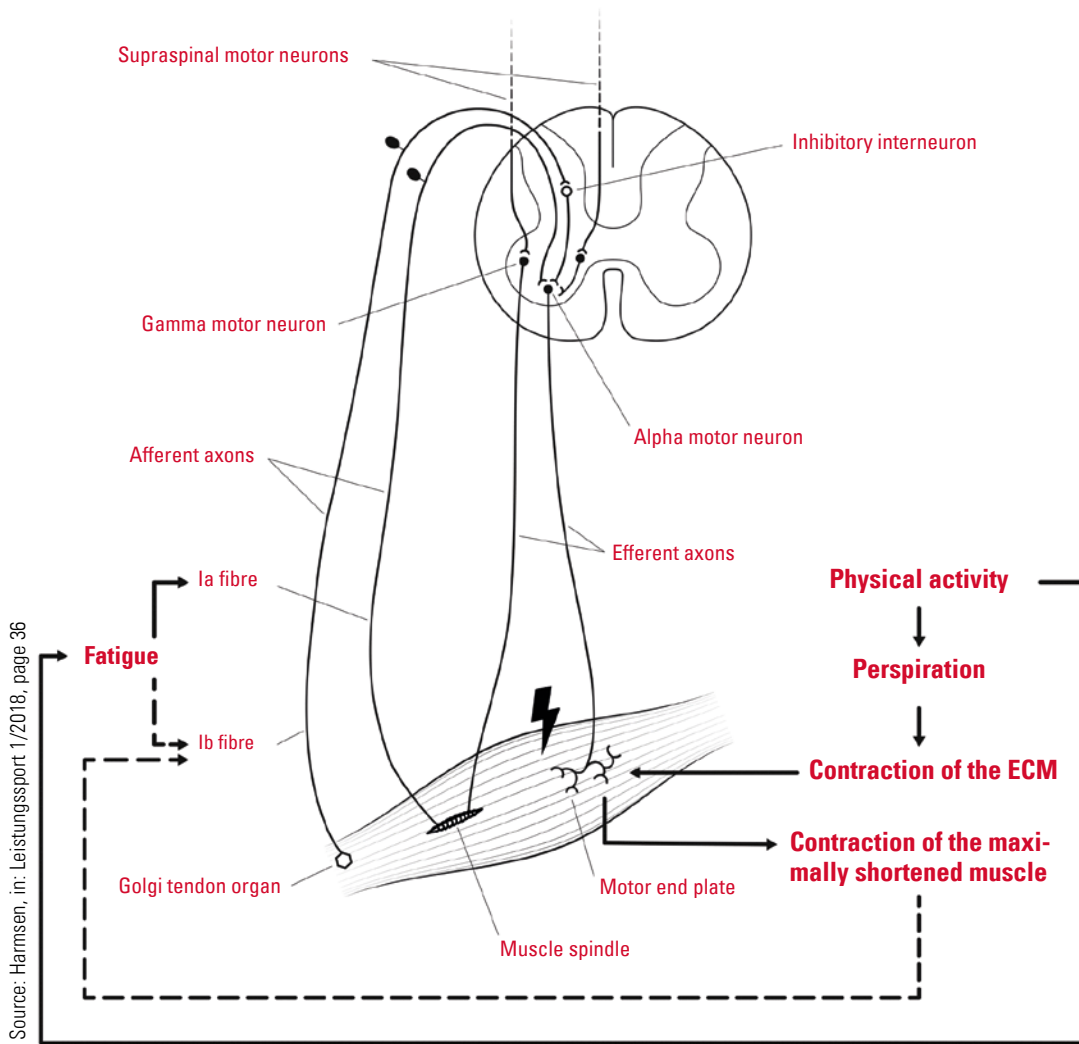
ABOUT MICHAEL BEHRINGER



Professor Michael Behringer, born in 1978, studied medicine at Heinrich Heine University Düsseldorf. He has headed the Department of Sports Medicine and Exercise Physiology at Goethe University since 2017, before which he led the Muscle Research Group at the Institute of Exercise Training and Sport Informatics at the German Sport University Cologne for ten years. In parallel, he worked at the German Research Centre of Elite Sport (momentum) in Cologne.

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CRAMPS CAUSED BY FATIGUE AND HEAT



When the body is under extreme physical stress, muscle fatigue and dehydration often occur at the same time and, according to current theories, lead to cramps via various mechanisms. In the case of fatigue, an imbalance of inhibitory and activating signals occurs in favour of the latter. A severe loss of volume due to excessive perspiration can cause muscle contraction through mechanical deformation of the nerve endings, causing maximum shortening of the muscle. In this position, the imbalance between inhibition and activation induced by fatigue increases even further.

Source: Harmsen, in: Leistungssport 1/2018, page 36

which subsided after a few hours. In comparison, the effect of cramp training lasts for weeks and months.

For Behringer, many questions remain unanswered. For example, he does not rule out the possibility that electrolyte deficiency influences the tendency to cramp. Christoph Skutschik, his doctoral student, is currently examining the significance of magnesium in treating cramps. Magnesium plays a role in over 300 enzymatic reactions in the body. Its inhibitory effect on the nervous system is known, and in cases of an extreme deficiency, cramps that disappeared after magnesium was administered intravenously has been observed in studies. "This shows that the correlation between magnesium deficiency and cramps is not plucked out of thin air," says Skutschik, "the question is rather whether magnesium supplements have an additional protective effect for athletes." Until the data are clearer, he believes that taking a low dose of magnesium can at any rate not

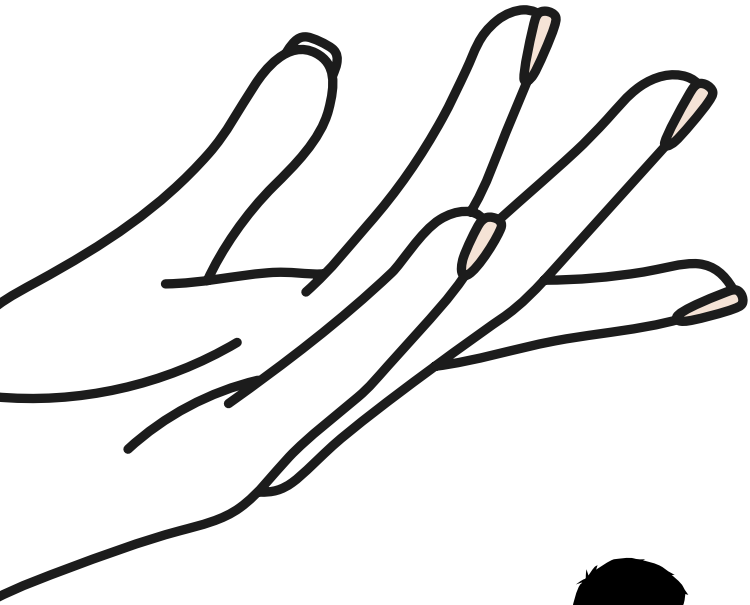
harm. However, it would be better to meet the body's daily magnesium requirement through a balanced diet rich in magnesium, with whole grains, leafy vegetables, nuts, seeds and pulses. According to Behringer's experience, stretching remains the most effective strategy for people with "normal" cramps that occur now and then during physical exercise or hot weather. ●



The author

Dr Anne Hardy, born in 1965, graduated in physics and holds a doctoral degree in the history of medicine and technology. She works as a freelance science journalist in Frankfurt.

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Motion
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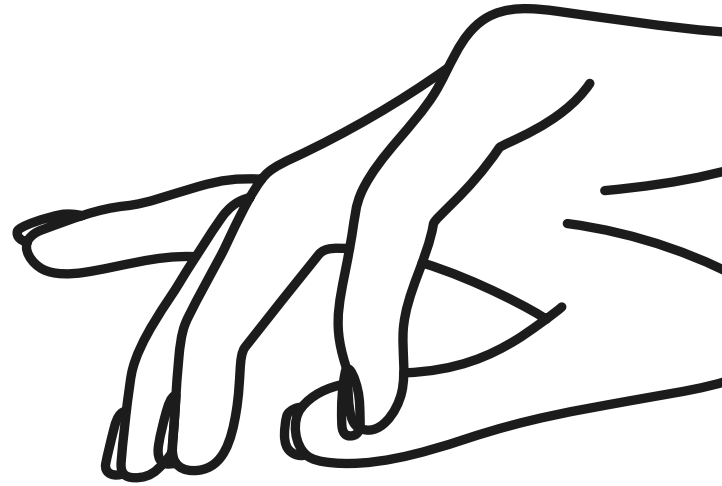
MEANING



Speaking with our hands

How gestures and facial expressions can underline, supplement and modify the meaning of words

By Anke Sauter



To communicate, we need not only our mouth, vocal cords and breath. Our hands and our face muscles also make a major contribution to making ourselves understood or giving what we say a certain focus. But how does the interaction between spoken language and hand motions actually work? A new Priority Programme aims to investigate the semantics of facial and manual gestures in spoken and sign languages. The individual projects will start in the course of 2022.

Turn right at the next crossroads (points to the right), then take the third left (points to the left) until you come to a roundabout (draws a circle in the air). On the right-hand side you'll see an entrance (draws an archway in the air) that leads to the museum." Imagine these directions with and without the gestures. It soon becomes apparent that gestures are part of everyday communication, they make it easier to transmit information by adding a visual channel to the acoustic element. The person getting the directions can visualise more in their mind's eye and will probably reach their destination more easily.

Toolkit for theoretical linguistics

Yet how does the communication level of gestures work? Where and when did we learn this "language"? How do we decide whether, when and how to gesticulate? And how can the semantics of gestures be arranged in a general system? Until recently, visual contributions to meaning were mainly treated in communication studies rather than in formal branches of linguistics. Gestures have also long been a part of rhetoric, semiotics and psychology. Not to

mention the many years of research on sign language.

Theoretical linguistics, however, has so far scarcely explored the form and function of gestures. All that is about to change: a Priority Programme of the German Research Foundation, headed by Goethe University, wants to bring together existing findings from various disciplines and link them with linguistics – although it is concerned not only with gestures but also other visual forms of conveying meaning. "I'm pleased to say that the topic is now gathering pace in my subject area too," says Cornelia Ebert, semantics professor at Goethe University, who applied for the Priority Programme together with Professor Markus Steinbach, sign language researcher from the University of Göttingen, and is responsible for its coordination.

Gestures deliver hard facts

Apart from gestures, the visual forms of communication on which the Priority Programme will focus are sign languages, animal communication, educational and clinical aspects, human-machine interaction and visual studies, that is, communication via pictures and films. Applica-



tions for exciting projects on each subtopic were submitted, including three from Goethe University. A committee of the German Research Foundation will decide in March 2022 which of the 46 applications will be funded. The overall funding period will last six years, and €12 million are available.

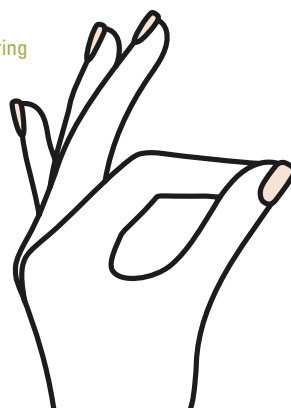
As a semanticist coming from computer linguistics, Cornelia Ebert is above all interested in how the meaning of gesture and of speech combine and work together and how this interplay can be formally modelled. With the help of already existing expertise, which the Priority Programme brings together, theoretical linguistics is to “take a big step forwards”. The goal is a toolkit for theoretical linguistics that helps to better capture the gesture phenomenon and to derive a theory from it. To date, there simply hasn’t been any “formal instrument”.

At the Institute of Cognitive Science in Osnabrück, Ebert studied how the temporal sequence of gestures and speech – Ebert calls it alignment – affects meaning. “We’ve known since the 1960s that gestures and speech are temporally aligned,” says Ebert. She by no means sees gestures in the first instance as an expression of emotions, as they often transport “hard facts” – like in the above-mentioned example of giving directions.

Gestures structure and accentuate

Giving directions is also a good example of how gestures can be of very different types: some are deictic, that is, pointing; this category evolves very early in children’s language learning. “As soon as a child points to something and says ‘There!’, things really take off,” says Ebert. Adults also use this type of gesture in an abstract sense and point to an object or in a direction that is still unspecific at that particular moment. Gestures, by contrast, that are firmly anchored in their meaning like a lexeme are known as conventionalised gestures. This category includes insulting gestures such as the “middle finger” or the rubbing together of index and middle fingers and thumb to mean “money”. When we speak of “iconic gestures”, on the other hand, these are ones that mimic an action or an object – in the above-mentioned example of giving directions, these are the roundabout and the archway. And finally, there are gestures

What difference does it make whether the gesturing narrator assumes the role of spectator or actor? With the help of actress Magdalena Schmitz, students are asked to gauge the effect of visual communication.



with metaphorical meaning and ones intended to rhythmise spoken language or highlight certain elements. All types of gesture have in common that they can accentuate, modify and structure spoken utterances; some also add new information. They direct our attention to certain parts of the utterance and can sometimes make it more precise – as in the example of giving directions, where we learn that the entrance is evidently an archway. It is, however, impossible to negate an utterance purely by means of a gesture. The structuring function of gestures can probably best be compared to the prosodic possibilities of spoken language, such as speed, duration or voice pitch.

IN A NUTSHELL

- Communication is composed not only of spoken or written language. Facial and manual gestures also play an important role in transmitting information.
- Gestures that accompany speech accentuate, modify or structure the meaning of the spoken word and thus make an important contribution to understanding.
- Theoretical linguistics has so far scarcely explored the form and function of gestures. A Priority Programme of the German Research Foundation, led by Goethe University, will help close this research gap.

When gestures and words send different messages

Cornelia Ebert’s own Priority Programme project, which she applied for together with Dr Stefan Hinterwimmer from the University of Wuppertal, is concerned with the narrative perspective that introduces gestures into communication: How do gestures make it clear whether the person speaking occupies the observer viewpoint or the character viewpoint? If a person tells of an event without their own participation, the space in front of their body becomes the stage, their hands are the actors.

If the narrator themselves is the actor, their hands play their hands, and the narrator slips pantomimically into the role of the actor. “The gestural perspective does not always coincide with that of the linguistic narrative. We want to find out how this affects the listener and why it doesn’t necessarily have to be congruent,” says Ebert, describing her project. In one experiment, an actress performed various alternatives.

GESTURE RESEARCH AT GOETHE UNIVERSITY

How do we communicate with our eyebrows? What role do gestures play in lies and deception? And how do children use gestures to help them convince their peers? Almost 50 project proposals were submitted for the “Visual Communication” Priority Programme. A wide variety of disciplines at Goethe University are also conducting research into visual communication.

Together with a colleague from Barcelona, linguist Professor Frank Kügler is looking at the interaction of intonation and gestures: in spoken language, the transmission of information is accompanied by melodic (prosodic) elements, closely interlinked with gestures that accompany speech. But how are such melodic and gestural elements coordinated in the transmission of information? And how does this contribute to (successful) communication?

Dr Andy Lücking and Professor Alexander Mehler from the Institute of Computer Science, on the other hand, want to capture the meaning of gestures with the help of artificial intelligence. They are using virtual reality tools to create a corpus of multimodal dialogues. By means of computational linguistic methods taken from distributional semantics and deep learning,

associations and semantisations of visual means of communication, both between them as well as in relation to their linguistic context, will be obtained on this empirical basis. This would make it possible to analyse dialogues more holistically in future and to translate them, for example in a multimodal way.

The role of multimodal utterances in mathematics teaching at primary school level is at the focus of research conducted by Rose Vogel, professor for mathematics education and computer science, and her colleagues Melanie Huth and Lara Billion. Gestures as well as handling of the material make mathematics learning a visible activity. The researchers are especially interested in the interfaces and interaction of different modes – also with regard to digital media.

Can children remember words better if they carry out iconic gestures when learning them, that is, gestures that depict the corresponding word? This is what developmental psychologist and neuroscientist Dr Elena Galeano-Keiner is investigating at the Leibniz Institute for Research and Information in Education (DIPF). The project follows on from previous work by Professor Cornelia Ebert and Professor Garvin Brod.

“What was surprising was the fact that the test subjects were not bothered when linguistic and gestural perspectives deviated from each other,” reports Ebert. The project aims to answer why this is.

The Priority Programmes of the German Research Foundation are designed to explore the scientific foundations of particularly topical or emerging fields of research, whereby interdisciplinarity plays an important role. In the “Visual Communication” Priority Programme, disciplines as wide and varied as neurology, education, computer science and, of course, linguistics have joined forces. This facilitates the exchange and use of existing findings – such as knowledge about how speech and gestures change after brain damage: some people whose speech is impaired can nonetheless master iconic gestures like they did before – and vice versa. As a rule, however, our perception of speech and gestures occurs via similar mechanisms, which means that people often cannot remember whether they received the information via gestures or via the spoken word. Interestingly, blind children also communicate via

certain gestures, regardless of whether their counterpart can see or not.

It is often said that above all southerners speak “with their hands and feet”, but this is in any case quite clearly a stereotype. Although there are indeed differences between language communities as to what certain gestures mean, and sometimes even families have an intra-family repertoire. A dissertation evidenced this scientifically as long ago as 1998: southerners do not communicate *more* with their hands than people from the North. Their gestures are, however, *more flamboyant*. ●

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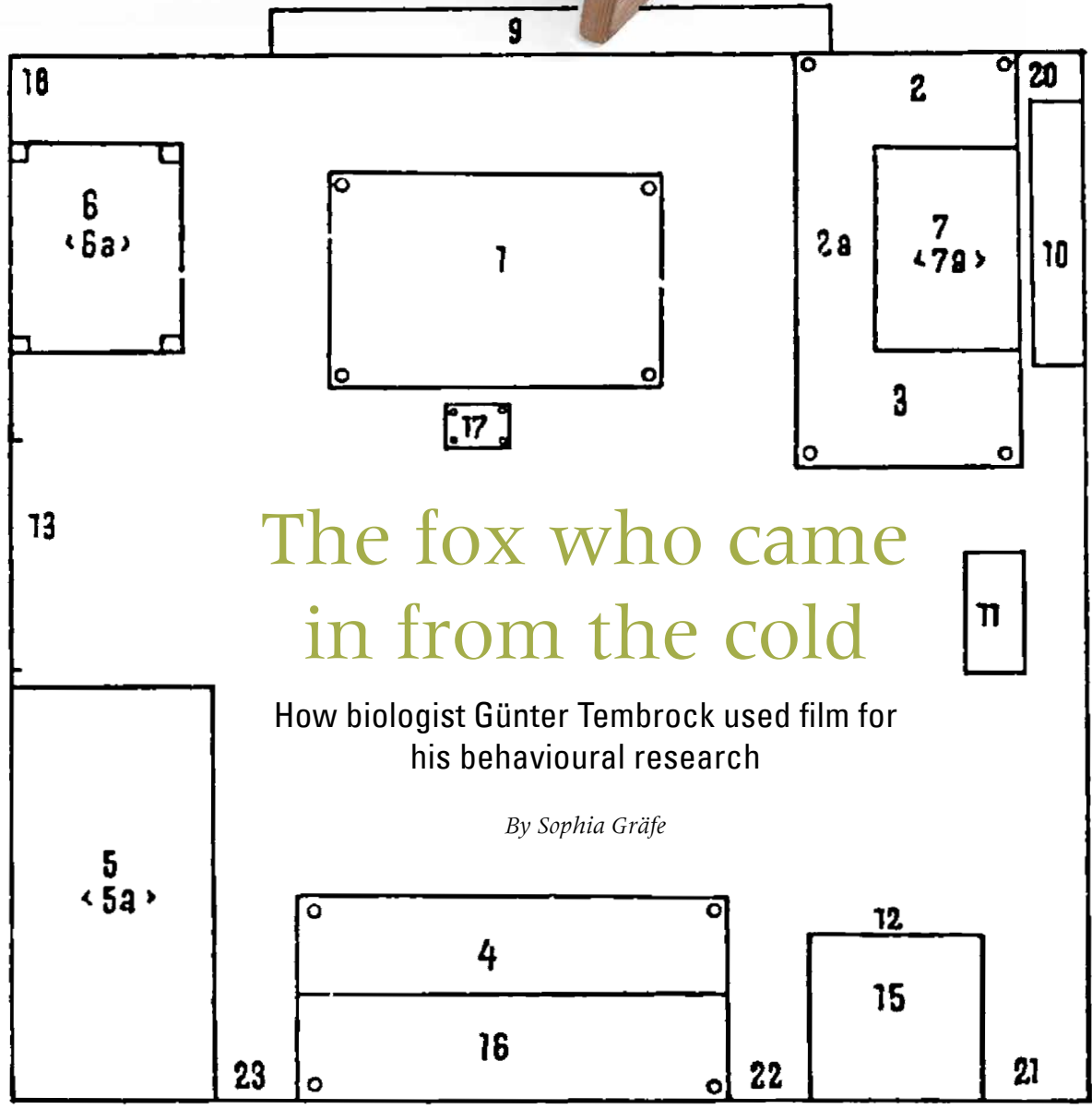
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The fox who came in from the cold

How biologist Günter Tembrock used film for his behavioural research

By Sophia Gräfe

Abb. 1. Das Fuchszimmer

Is the behaviour of wild animals best observed in their natural habitat? Günter Tembrock (1918–2011), ethologist from East Berlin, showed how valid results can also be obtained in an artificial environment – with the help of film.

We are still living among our foxes here (...),” wrote biologist Günter Tembrock in a letter he sent from Invalidenstrasse, Berlin, to Basel in the summer of 1951. The addressee was Heini Hediger, a Swiss zoo director, who had made a name for himself as an author and animal connoisseur. His book “Wild Animals in Captivity” (“Wildtiere in Gefangenschaft”, 1942) is regarded as the seminal work of modern zoo biology. In it, he expounds the territorial features that must be taken into account if individual species are to be kept successfully in artificial habitats. But what led Günter Tembrock to write to a zoo?

Ethology in the metropolis

In 1948, Tembrock started building a kind of scientific “mini zoo” for himself (see photo right and p. 50). Primarily entrusted after the Second World War with restoring the Zoological Institute and reorganising teaching at Humboldt-Universität, Tembrock had envisioned his own research institute from early on, the Forschungsstätte für Tierpsychologie (Research Centre for Animal Psychology), where he wanted to study not only anatomy or physiology but also animal behaviour. How does an animal behave in relation to others? For what reasons in evolutionary biology do animals move in a way typical for certain species? Is this firmly anchored in the behavioural repertoire of each animal, or does it even disappear if inactivated or in an unnatural environment? Here, Tembrock followed a branch of research that had been gaining strength since the 1930s, which assumed that it must be possible to distinguish congenital forms of behaviour from acquired ones by closely observing living animals under conditions that were as natural as possible. Modern, comparative behavioural research (ethology) thus bode farewell, at least

ostensibly, to the practice of earlier animal psychology, which was based on experiments and animal training.

Konrad Lorenz (1903–1989), Austrian zoologist and later Nobel Prize laureate, was to produce the most popular images for this line of research. How, then, could Tembrock’s research on wild animals in the middle of the big city, taking place at the same time, succeed? Archives help to solve this anachronistic riddle.

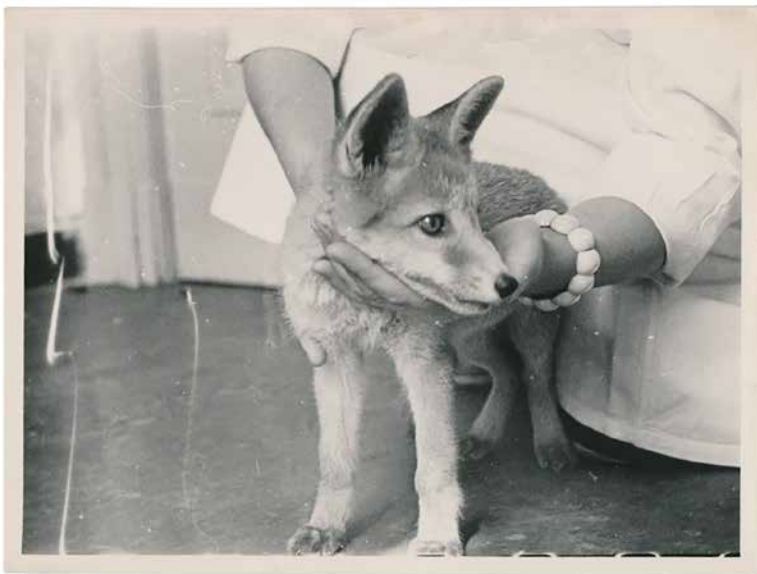
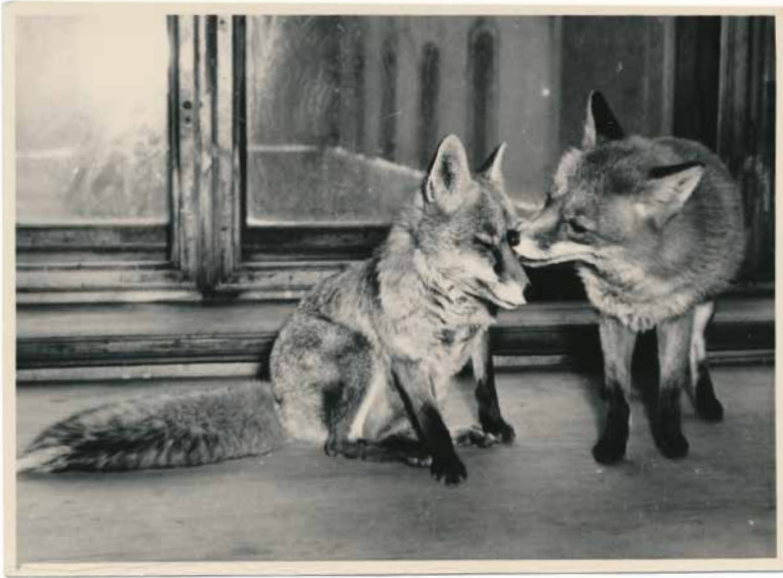
Behavioural biologist Günter Tembrock with “Fiffi”, a red vixen (below). In his “fox room” (floor plan on the left) at the Forschungsstätte für Tierpsychologie (Research Centre for Animal Psychology), he meticulously recorded his foxes’ movements. Index card boxes in which he collected photographs of his lab animals’ behaviour were an important tool in his research work (top left).



Researchers’ estates as important sources for history of science

Günter Tembrock’s estate clearly shows that he used para-academic sources for his studies of red foxes in addition to specialist literature: he corresponded with numerous directors of zoological gardens to gather suggestions on the care and taming of wild animals on the basis of their knowledge and experience. Tembrock and his

two assistants kept domesticated red foxes in rooms in the west wing of what is today the “Museum für Naturkunde” (Berlin’s Museum of Natural History). There are said to have been about 60 foxes in total over the course of 20 years. From 1955 onwards, Tembrock was able to keep his animals in an outdoor enclosure in the institute’s garden. His estate thus not only sheds light on the theories concerning the study



The red foxes “Fiffi” and “Jupp” on a windowsill in the west wing of what is today the Museum für Naturkunde (Berlin’s Museum of Natural History) (top). A keeper takes care of “Nedda”, a young fox from a “Kaspar Hauser” experiment (bottom).

IN A NUTSHELL

- In the middle of the 20th century, comparative behavioural research was a flourishing field of biology.
- Especially German-speaking ethology set itself the task of distinguishing congenital from acquired forms of behaviour by observing animal movements as accurately as possible.
- While many colleagues elsewhere pursued the new ideal of field research, Günter Tembrock, an East German biologist, set up a research centre right in the middle of Berlin in 1948.
- The success of Tembrock’s behavioural studies in such a confined space can be explained above all by his extensive use of research media, such as logbooks, photographs, drawings and films.
- The archive reveals, however, that the films produced in large numbers in the laboratory were only a temporary phenomenon.
- At the latest in the 1960s, charts and statistics substituted films. Observing actual movement was replaced by what was, from then on, data-based behavioural research, which we now encounter every day.

of animal behaviour that were debated in behavioural biology in the post-war period, it also delivers insights into the history of science, which is currently interested in the scattered arenas and personal networks of earlier biological knowledge. In Tembrock’s archive, academic and para-academic voices combine.

Tembrock also incorporated hunters’ knowledge into the behavioural research he conducted in his study. Through the library of the Zoological Institute, he obtained literature on hunting, such as the journal “Wild und Hund”, which is still published today, and drew on its reports on the behaviour of red foxes to compare his laboratory studies. He distilled information about behaviour observable in natural contexts from wildlife experts’ accounts of adventures and their hunting trophies. His approach to behavioural biology was thus comparative in several ways: first, Tembrock included colleagues’ findings on other species, such as wolves, jackals and dingoes. Second, he aligned his laboratory observations with written evidence from practitioners. One such practitioner, hunter and hunt-

ing expert Detlev Müller-Using, would later applaud, in 1957, Tembrock's doctoral thesis on the behavioural repertoire of red foxes, published in the journal "Der Zoologische Garten". In his tiny "fox room" measuring just 5 x 5 metres (see floor plan, bottom of p. 48), Tembrock had succeeded in making valid statements about the behaviour of wild animals. How did he achieve this?

Observation through extensive use of media

The answer lies in the records and objects of Tembrock's research practice, which suggest an extensive use of media. This practice is symptomatic of the growing mechanisation and media-isation of behavioural research in the mid-20th century, which can be studied in an interdisciplinary way using tools from the history of science and media studies. The ethologists set themselves the task of observing their research animals as comprehensively as possible in order to ultimately be able to reveal patterns and causalities in their behaviour. Contemporaries tell of their patience, perseverance and powers of observation – qualities with which they sought to distance themselves, so to speak, from the partly anecdotal research reports of old-school animal psychology by now frowned upon.

Günter Tembrock entered his detailed observations in a logbook just as tirelessly. In daily records, he put down on paper all elements of the animals' behaviour however inconspicuous they were (see photo, top of p. 52). And other media were also at the service of his extensive logging activities. A special feature is the ethological collection of the Forschungsstätte für Tierpsychologie (Research Centre for Animal Psychology), which comprises four wooden index card boxes (see photo, p. 48), crampacked with photographs of the lab foxes' behaviour. Thanks to written notes and numbering on the back of each small black-and-white photograph, they can be assigned to individual lab animals and observation dates as well as to specific forms of behaviour. This logging system constitutes a kind of register of animal behaviour, which served in practice as a reference work and picture repository.

Behaviour from an ecological perspective

From the perspective of visual culture studies, it is interesting that the photographic documents mentioned here are always annotated with many different cross-references; they were not intended as individual pictures, but as movable points in a grid. A picture always refers to other pictures, whereby its significance turns out to be relational. Looking at what the photographs show – fox behaviour as studied by Tembrock and his colleagues – produces a similar result: as

the ecological perspective on the biological principles of behaviour gained strength in the 1950s, it was no longer only the physical attributes of an individual animal that were considered insightful. The focus now was on the dynamic relationship between the animal and its physical and social environment. That is, the facial expression of a fox, its posture, sounds, etc. only assume meaning in terms of its relationship to its surroundings. The individual animal, to whose behaviour an invariable meaning was previously attributed, was now replaced by animal communities and frames of reference that were no longer considered static.

The numerous ethological collection projects can be regarded as evidence of this approach. Among the best known is the "Encyclopaedia Cinematographica", a film encyclopaedia published between 1952 and 1993 by the Institute for Scientific Film in Göttingen. The aim of this scientific collection of moving images was to make short reels of 16mm film available as raw data for comparative research questions, much like biological specimens. The first entry in the encyclopaedia shows the locomotor "step" of an Indian elephant in Munich's Hellabrunn Zoo. Other forms of animal locomotion and species followed.

Film as source material for data acquisition

Günter Tembrock too was to expand his repertoire by using film as an analytical medium. From 1951 onwards, his logbooks contained

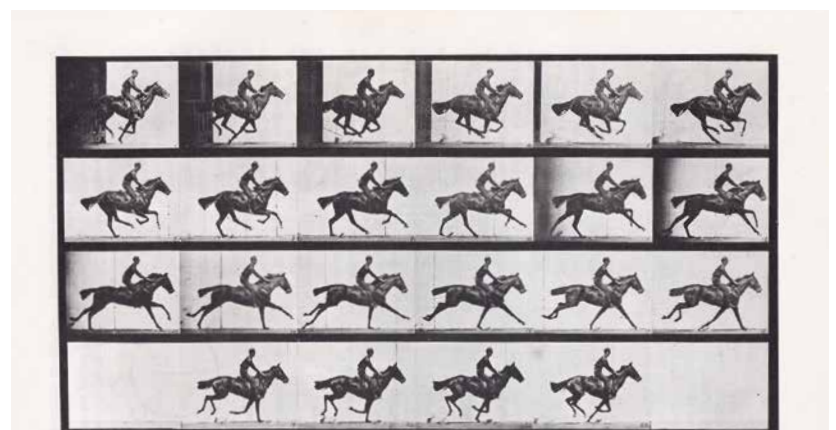
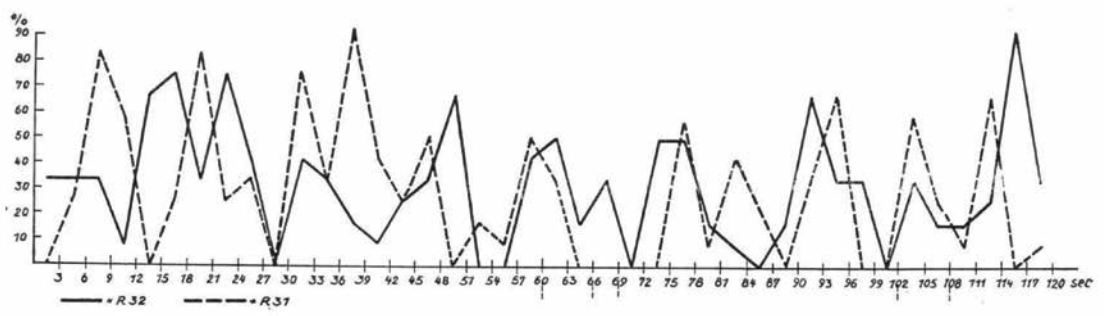
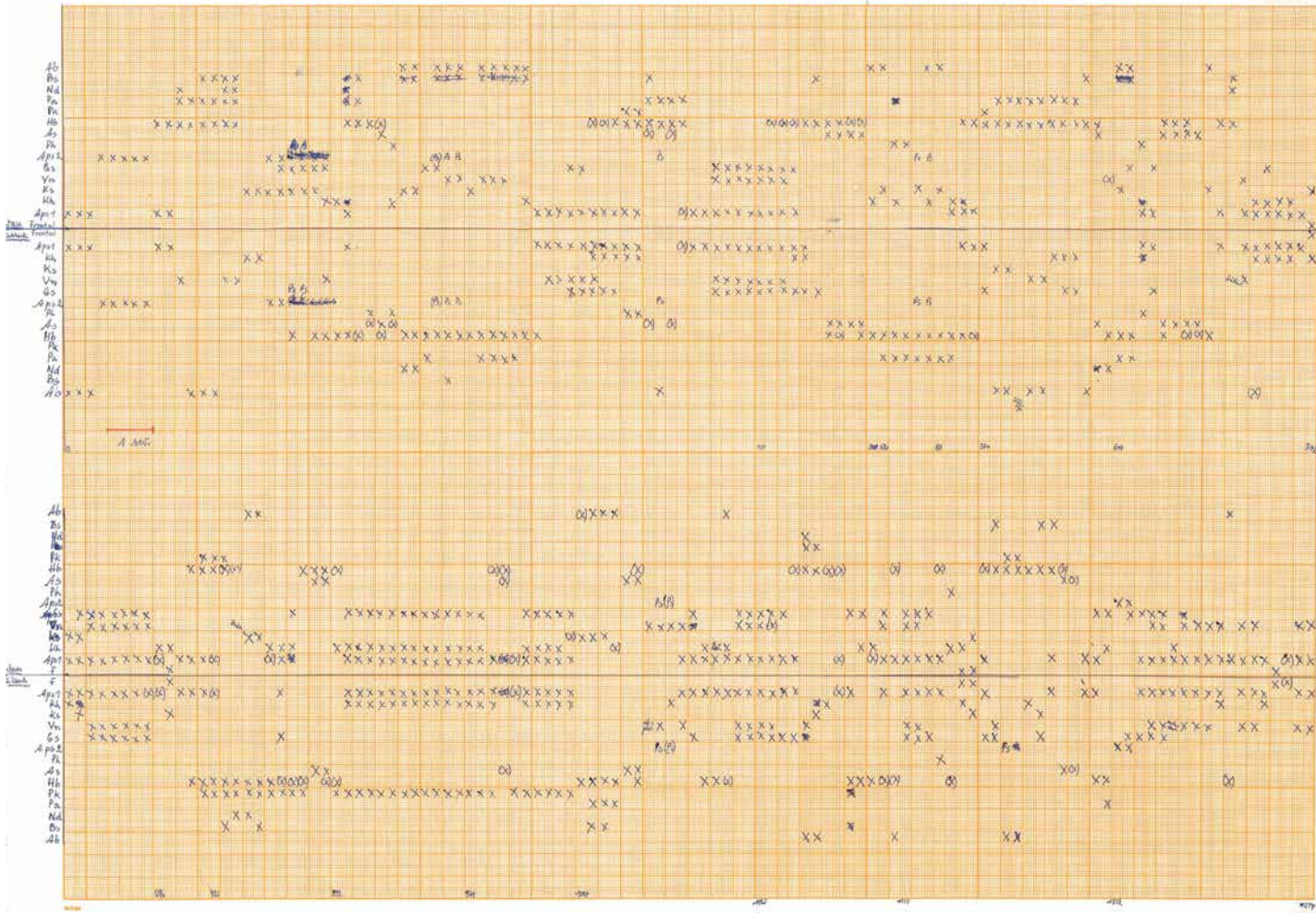
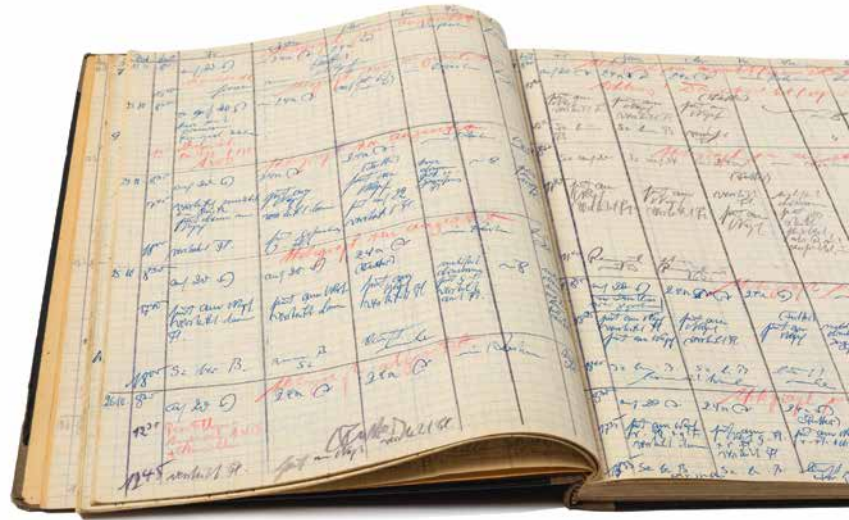


Illustration 14. The Gallop

The history of modern behavioural research is closely linked with the development of modern visual media. Since the end of the 19th century, especially film has crystallised as an important research tool alongside drawing and photography. With the help of film, human and animal behaviour should play out and be compared in an almost natural way before the researcher's very eyes. Not only today's film scholars are familiar with the work of Eadweard Muybridge, whose series of photographs, which once laid the groundwork for cinematographic techniques, show the movements of a galloping horse.

Motion with meaning

Günter Tembrock's open logbook showing his observations of red fox behaviour (top). Tembrock analysed fox behaviour down to the smallest detail by capturing the foxes' fighting movements on film, plotting them on graph paper (centre) and then statistically evaluating a specific detail, the neck bite, and visualising it with the aid of a chart.



countless references to footage he had produced. However, the archive is unusually silent at this point. Many of his films no longer exist – a fate shared by many scientific films. Unlike feature films, they rarely end up in archives. Only one of Tembrock's scientific films, documenting the fighting behaviour of two red foxes, is extant. Two educational films made by Tembrock in cooperation with the DEFA Studio for Popular Science Films have also survived. What remains are the paper witnesses of Tembrock's films: large sheets of graph paper proving that he definitely used film. In the early 1960s, Günter Tembrock plotted the movements of the animals under observation one by one on these sheets with a ballpoint pen (see photo, centre of p. 52). By charting the film material in this way, he was able to make statistical statements about role allocation between the two laboratory foxes during a fight (see graph, bottom of p. 52). What we see here is a turning point in the history of both behavioural research and scientific films: a practice where film is converted into data. Both – the study of animal behaviour and the study of moving images – were abstracted into calculable

units in the course of the cybernetic turnaround of the 1960s. In this context, Günter Tembrock's estate shows that the increasing calculability of behaviour, which is achieved today with the help of digital technology, had its precursors in analogue logging practices – abstraction by means of a ballpoint pen and paper.

Red fox as object of modern ethology

The behaviour of Berlin's red foxes continues to fascinate researchers today. Wildlife biologist Dr Sophia Kimmig is dealing with red foxes' adaptability to the urban biotope. To do this, however, a fox no longer needs to come in from the cold. Kimmig uses GPS transmitters to record data on the movements of free-living foxes. These transmitters, as well as wildlife cameras, are able to capture specific forms of behaviour. In contrast to Tembrock, and in line with current scientific standards, Kimmig backs up her research with statistical tools. Using tens of thousands of GPS coordinates from the foxes, she creates models of urban wildlife activity and compares the areas they frequent with what the animals have at their disposal in the city. In this way, she identifies the foxes' preferences and detects avoidance behaviour. Genetic studies also deliver insights into fox behaviour. Here, a series of models of wildlife activity in the city simulate dispersal scenarios. These are then compared with kinship data from the wild. The model variant with the greatest similarity to the field data at the end of the experiment represents fox behaviour. For example, it was possible to establish that foxes from Berlin and Brandenburg do not like to mix and that there are big genetic gaps between foxes from East and West Berlin. ●



The author

Sophia Gräfe, born in 1988, is a media and cultural studies scholar. She has been researching the history of media and knowledge in the field of behaviour at Philipps-Universität Marburg since 2018. In 2021, as a guest of the History of Science Department at Princeton University, she debated the role of media in the historical reconstruction of past knowledge in the field of biology with historians. Her search for films, photographs, drawings and other media in the context of modern behavioural research has also taken her to the archives of renowned biologists, including Konrad Lorenz, Nikolaas Tinbergen – and East Berlin biologist Günter Tembrock. In December 2021, she presented her latest discoveries from Tembrock's Berlin archive at the international conference "Visible Evidence" at Goethe University.

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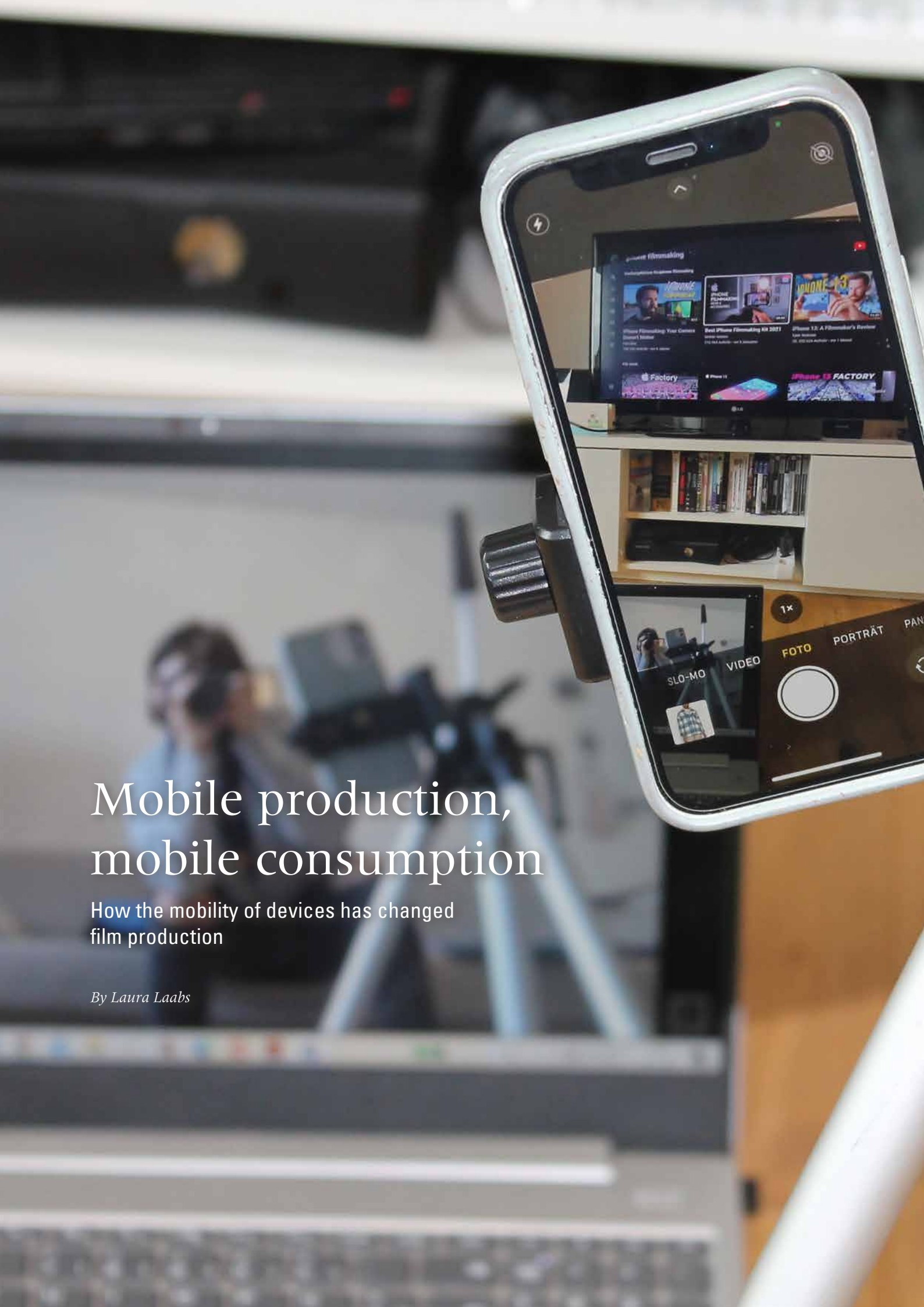
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Picture credits

p. 48 top: Photo: Carola Radke MfN 2021; bottom: Picture from: Tembrock, Günter: Zur Ethologie des Rotfuchses, p. 294.
p. 49: Tembrock Forschungssammlung Berlin (TFSB), undated.
p. 50: Tembrock Forschungssammlung Berlin (TFSB), 1953 and 1957.
p. 51 box: Illustration 14: "The Gallop", from Muybridge, Eadweard: Animals in motion, p. 50.
p. 52 top: Photo: Hwa Ja Götz MfN 2020; centre: Tembrock Forschungssammlung Berlin (TFSB), undated; bottom: Tembrock, Günter: Zur Strukturanalyse des Kampfverhaltens bei *Vulpes*, p. 274.



Mobile production, mobile consumption

How the mobility of devices has changed
film production

By Laura Laabs

While our parents were still labouring away at editing strips of Super 8 film, smartphones today place the most sophisticated pocket-sized technology at our disposal. But what is the impact on film when anyone can produce a video and upload it? And to what extent are mobile devices already being used in film production?

On 17 October 2021, TikTok user Becca Murray (@thebeccamurray) uploaded a video of herself. It shows her in the kitchen, laughing and eating a carrot. Murray's caption puts the video into its jokey context: "filming myself so this can be played at my funeral because my partner doesn't film me." My wording, that she'd "uploaded a video of herself", is, in principle, superfluous. What's funny about Murray's clip is the fact that she, and countless other users of TikTok, YouTube and many other platforms and programmes, almost constantly produce and share films of themselves. Why, then, should there be any reason for another person to film you as well? How does this video on Becca Murray's account differ from her other videos?

To pose or not to pose

The clip has been edited with TikTok's retro camera filter. When used on videos recorded with modern smartphones, the filter simulates certain visual features that film formats now virtually obsolete used to have. These include film grain and signs of wear as well as an interface – in the sense of a user interface – comprising symbols that show details of exposure time or frame rate, for example. Murray's video is also interesting because it aims for an affective and nostalgic use of the "vintage look" that we encounter again and again, for example in Hollywood films or the true crime genre: the embedding of (apparently) amateur footage, which often shows happy and smiling housewives in trivial everyday situations or on holiday with the family, as a memento in funeral or deathbed scenarios.

Murray's video parodies this use. Or more precisely: she uses the filter to parody a certain authentication strategy. As part of such a strat-

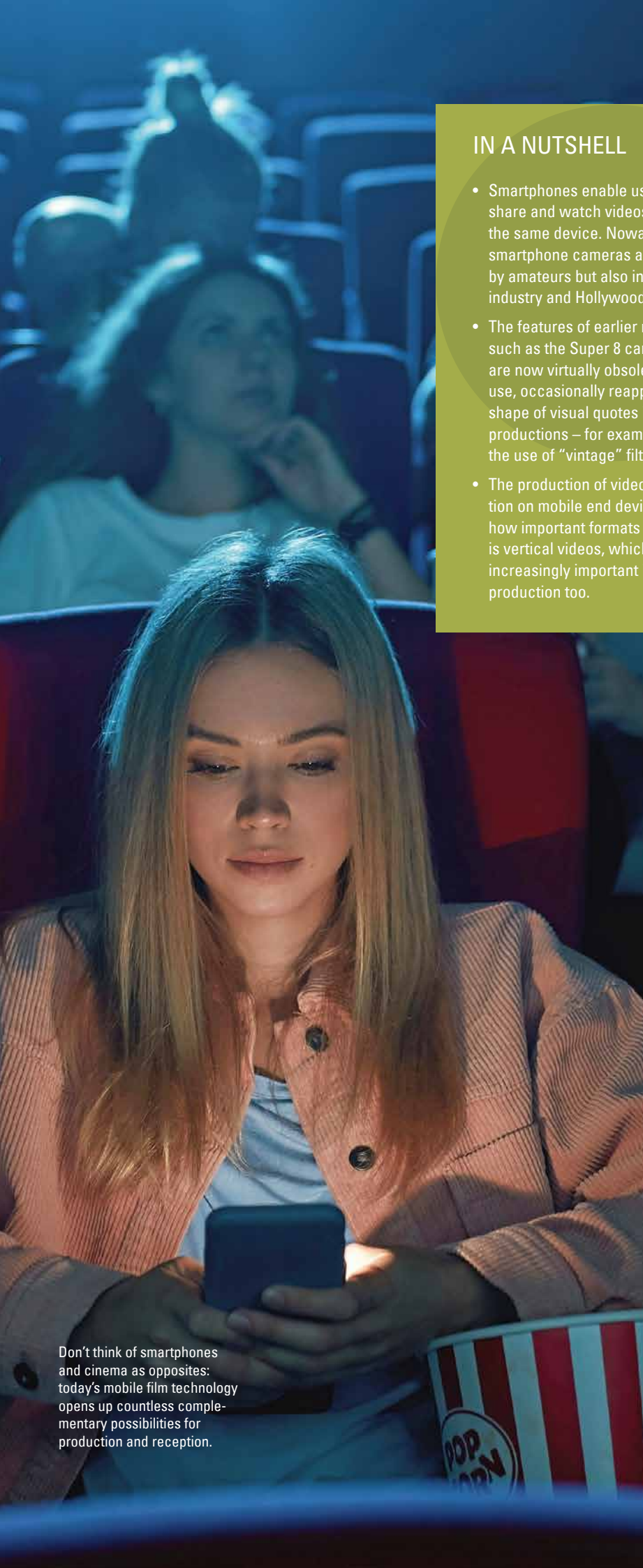
egy, seemingly uncontrived and accidental – "natural" – pictures create an effect of closeness to the person shown, or of their "authenticity". At a funeral, it would be nice to be able to say: "Just like her." It is a truism that content shared on social media is situated in precisely this field of tension between the orchestrated and the uncontrived. On closer inspection, then, Becca Murray's parody reveals to us a particular aesthetic value of footage recorded on mobile devices.

Off to Hollywood

However, video production for social media channels also gives rise to questions about the relationship between the private and the public domain, between amateur productions and professionalisation. In social media, it is often difficult to differentiate between advertising and entertainment. For example, make-up influencers, who have become successful above all thanks to YouTube, often collaborate with famous cosmetic brands or set up their own. TikTok user Julian Bass (@thejulianbass) made it to Hollywood thanks to a video that quickly went viral (Rahman, 2020). The video shows not only Bass himself but also above all his ability to produce special visual effects, or VFX in short. In the video, he personifies fictional heroes such as Spider-Man or a Jedi, making a conscious connection with already established brands. According to recent figures, the video has been viewed 17.2 million times on TikTok and another 27.1 million times on Twitter. Among others, Bass caught the eye

Non-stop film production: Becca Murray playing tongue-in-cheek games with her phone.





IN A NUTSHELL

- Smartphones enable us to produce, share and watch videos on one and the same device. Nowadays, modern smartphone cameras are used not only by amateurs but also in the advertising industry and Hollywood.
- The features of earlier mobile devices, such as the Super 8 camera, which are now virtually obsolete in private use, occasionally reappear in the shape of visual quotes in contemporary productions – for example through the use of “vintage” filters.
- The production of videos for consumption on mobile end devices makes clear how important formats are. An example is vertical videos, which are becoming increasingly important in professional production too.

Don't think of smartphones and cinema as opposites: today's mobile film technology opens up countless complementary possibilities for production and reception.

of Bob Iger, former CEO and still a member of Disney's executive board (Rahman, 2020). Bass is currently working, as he himself announced, on a larger project of which no details have been provided.

Semi-professionalisation typical for social media

In many areas, video production for social media is characterised not only by amateurs still wet behind the ears, on the one hand, and full-time professionals on the other, but especially by semi-professionalisation. For many users, this is the transition from private production to their main source of income – following in the footsteps of Julian Bass.

Meanwhile, smartphones are used in production in the professional film business too. Examples are Steven Soderbergh's *Unsane* (2018) and *High Flying Bird* (2019), but also the Netflix series *Homemade* (2020), which was made during the COVID-19 pandemic and deals with it in short films.

Whether smartphone or camcorder, Super 8 or Polaroid: their aesthetic and discursive charge as the simultaneous producers and mediators of spontaneity, closeness and authenticity has a lot to do with format. Formats are means of giving structure that organise and present the information conveyed – the video, for example – in a specific way (Volmar/Jankovic/Schneider, 2020). The word “format” can mean material properties (for example, the 35mm of the respective film material) just as much as structural or organisational features (such as file formats). Thus, the granularity of film images in Super 8 format is reappearing as a filter on Instagram and TikTok. Conversely, it can be seen that mobile end devices and their formats are not only leaving aesthetic traces in film productions. They also have a direct influence on the production of the images. Without going so far as to speak of technological determinism, production for and with certain formats often also includes production for certain end devices or purposes. One example is the production of advertising content for social media, which is primarily consumed on mobile phones.

Different end devices require different formats

Peter Merziger, managing director of M7, a marketing agency in Saarlouis, explains this in the

context of video advertising for clients' social media channels. Talking to him makes it clear that film industries must always be referred to in the plural – looking solely at the entertainment segment is not enough. M7 produces films both for internal and external corporate purposes; for classic projection as well as optimised for smartphones. In the area of social media, the vertical 9:16 format is becoming increasingly important, alongside the already familiar square format, because vertical formats correspond to the conventional way of using and holding a smartphone and can fill the display better. Some platforms, such as Instagram, enforce this vertical use by not scaling the image when the device is rotated, even if they theoretically could. 9:16 is the vertical reverse of the 16:9 aspect ratio that we know from television. As a vertical format, it demands specific approaches and editing techniques from filmmakers. Merziger recounts the specific case of an advertising film containing a dialogue between two people. It was not possible to show them both at the same time in the long or medium long shot, as would be the case in a horizontal format, meaning that alternatives had to be found during recording and post-production, for example a camera perspective that “looked over the shoulders” of the two interlocutors.

However, M7 does not only produce videos intended for consumption on mobile devices. They also use smartphones for filming, and Peter Merziger draws attention in this context to their high-performance cameras and recording technology. He says that modern iPhones, for example, are capable of producing not only photos but also videos with bokeh effect, that is, where the main motif is sharp, but the background is out of focus. M7 tends to use the devices' own software to produce films (for instance Apple's camera app) rather than programmes offered by third-party suppliers. In addition, optical image stabilisation makes production easier, he says. Gimbals – put simply, brackets or mounts that serve as external stabilising systems for cameras – are nowadays superfluous in some situations.

Ready to roll

The logical price for the greater mobility of cameras was and continues to be the reduction of their technical capacity and, depending on the situation in which they are used, thus also limited functions. Production with or for mobile devices does not automatically involve less effort – something that Merziger also stresses. For him, however, one thing is clear, especially as far as private use is concerned: “The best camera is the one I've got with me when I need it.” Smartphones can, for instance, eliminate

the need to take other cameras on holiday with you. Lots of people carry their mobile cameras on them, in their trouser pocket or shoulder bag. The “closeness” described above then also means, in a pragmatic sense, ready to hand, which in turn allows for flexibility.

Smartphones allow us to produce, share and consume videos on the same device. Becca Murray's short video, however, obliges us to ask who produces footage for which audience and with which means and which technical effects are used specifically in the process. Conversely, it illustrates that the devices and apps we use are not neutral at all, as ubiquitous and seemingly self-evident as they may be. When we think about videos, we should not only consider their aesthetics but also keep in mind the respective devices and formats as well as the production and consumption circumstances alike. ●



The author

Laura Laabs, 29, is a research associate and doctoral candidate in the German Research Foundation's Research Training Group “Configurations of Film” at Goethe University. She studied theatre, film and media studies, English, and film and media culture research in Frankfurt and Munich. Currently, her main research interests are paratexts of computer and video games, and she is dealing in general with digital games from the perspective of media and culture studies. She has been editor of PAIDIA, a journal for computer games research, since 2020.

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Biodiversity of Earth's islands in peril

Life on Earth's islands can be described as vast biodiversity concentrated in a small area. Islands only comprise seven percent of Earth's land surface, but they are home to 20 percent of all plant and animal species. In the journal "Global Ecology and Conservation," biogeographer Professor Severin Irl from Goethe University and colleagues describe the current state of biodiversity. It makes for alarming reading.

less able to adjust to changes than species on a continent. More than 800 species have become extinct in the past 400 years. "If this trend continues, islands will carry the bulk of extinct species in the future," says Severin Irl.

The authors of the article, who see themselves as the international mouthpiece for endemic species, suggest concrete measures for avoiding further extinction.

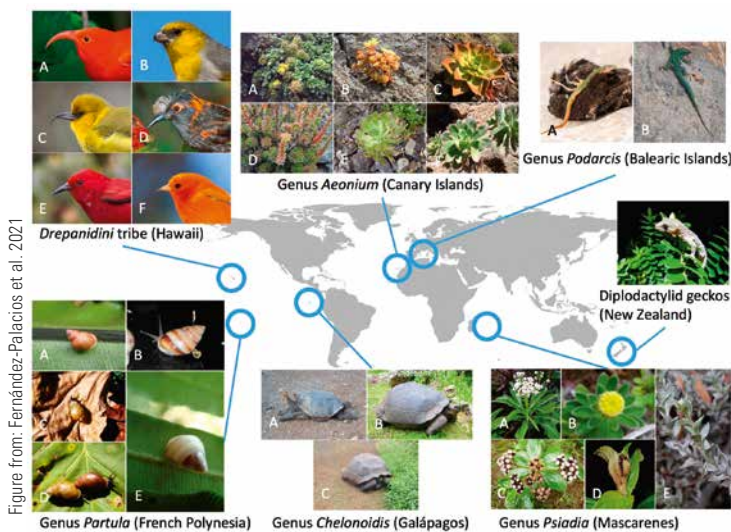


Figure from: Fernández-Palacios et al. 2021

Island biodiversity is in great peril.

The authors, all board members of the Society of Island Biology (SIB) founded in 2020, describe how island ecosystems are under great pressure due to human actions. Isolation from a continent has led to the development of unique plant and animal species, known as endemic species, that exist only on a particular island or archipelago. The pressure they are experiencing results from the overexploitation of ecosystems, the destruction of habitats through, for example, agriculture, as well as from the introduction of alien species and climate change. Island species, however, are often

They say that a complete inventory of the species on islands is required as a starting point. The fact that such data often simply do not exist makes it difficult to develop appropriate nature conservation concepts. Any such measures, the article states, ought to take the needs of the local people into consideration, who should act as the custodians of biodiversity and work with scientists to develop the necessary capacities.

Alliance for the future: Helmholtz Centre and Goethe University

Goethe University and the Helmholtz Centre for Environmental Research in Leipzig have set themselves the goal of advancing water research and concluded a corresponding cooperation agreement. Joint research projects are planned, and both institutions will train early career scientists in interdisciplinary environmental research. "In particular, our Faculty of Biological Sciences and the Helmholtz Centre research unit 'Chemicals in the Environment' both have expertise that complements each other perfectly. In terms of research strategy, we are united, on the one hand, by the goal of bringing environmental research and health research closer together in the 'One Health' approach and of further linking it with biodiversity research on the other," says Professor Enrico Schleiff, president of Goethe University. Climate change will pose even greater challenges for the sustainable management of water, a resource already scarce and at risk. These are the challenges that the two research institutions want to address within their strategic partnership. The Helmholtz Centre for Environmental Research in Leipzig looks at the complex interactions between humans and environment in exploited and disturbed landscapes, in particular densely populated urban and industrial metropolitan areas as well as near-natural landscapes. Research on the conservation of the natural foundations of human life and biodiversity is one of Goethe University's key research areas.

Reading and speaking follow a similar rhythm

When we read, our gaze moves over the text in a certain pattern. This pattern resembles – to a surprisingly high degree – the rhythm of spoken language, as a team of researchers, with the significant involvement of Goethe University, has discovered. Their research results were published on 6 December 2021 in the journal “Nature Human Behaviour”.

An international team of researchers, in which Goethe University was significantly involved, discovered in the course of a meta-study with 14 different languages that the temporal structure of reading is almost identical to the dominant rhythm of spoken language. It can be concluded from this that the processing of written and spoken language are far more similar than previously assumed. Other research institutions involved were the University of Vienna, the Ernst Strüngmann Institute in Frankfurt, New York University, the Max Planck Institute for Empirical Aesthetics, also in Frankfurt, and the University of Salzburg.

Languages and writing systems are central elements of human communication. For thousands of years, writing systems have enabled us not only to share information face

Recent research shows that the rhythm of reading resembles that of speaking.



Photo: Shutterstock/Wavebreakmedia

to face but also to store it in a tangible form and make it permanently available. “Reading is one of humanity’s most fascinating cultural achievements,” says lead author Dr Benjamin Gagl, who until recently was a research associate at the Institute of Psychology at Goethe University. “Spoken language also influences reading. Until now, however, little has been known about the common underlying mechanisms of reading and spoken language,” explains Gagl, himself a psychologist.

Together with an international team led by Professor Christian Fiebach, Gagl explored

these mechanisms by comparing the temporal structures of reading with those of spoken language. This revealed that the rhythmic sequences of eye movements when reading and the dominant rhythm in speech signals are almost identical. These findings shed new light on the interface between written and spoken language.

<https://tinygu.de/language-rhythm>

Six of the most-cited researchers work at Goethe University

Of the 6,600 researchers in the world most cited in scientific publications, six work at Goethe University. This was determined by the 2021 “Web of Science” citation ranking. Those whose publications are often cited have also made ground-breaking discoveries. That is why the frequency of citations – especially in the natural sciences and medicine – is an indication of the scientific significance of a publication as well as of the author’s standing in the scientific community. The most frequently cited professors at Goethe University are Ivan Đikić (Biochemistry II), Stefanie Dimmeler (Medicine), Petra Döll (Physical Geography), Stefan Knapp (Pharmacy), Sibylle Loibl (Medicine) and Stefan Zeuzem (Medicine).

Excellent research on the environment and sustainability

Cultural anthropologist Kathrin Eitel and biologist Christian Schwerer were awarded the Frankfurt Prize for Environment and Sustainability 2021 for their theses. In her dissertation “Recycling Infrastructure, Practices of Waste Handling in Phnom Penh,” Kathrin Eitel portrays vividly, the committee said, how waste enters nature in a city landscape. Eitel argues for a recycling economy that would enable the metropolises of the Global South to develop sustainably. In his doctoral thesis, Christian Scherer examined the origin, fate and impact of microplastics in inland waterways (“Mikroplastik in Binnengewässern – Herkunft, Verbleib und Wirkung”). The award committee commended his comprehensive account of this phenomenon from its source to its effects. Advancement awards went to sociologist Anita Kalustian, bioscientist Jasmin Thal and environmental scientist Jonas Wallraff.

Research Training Group on “Resolution of Inflammation” continues

Funding of the German Research Foundation’s Research Training Group “Resolution of Inflammation” at Goethe University will continue for another four and a half years. The group, which was set up in 2017, focuses on the relatively recent discovery that the resolution of inflammation is also actively controlled by the body. Research will be conducted into how this happens at cellular and molecular level – and why it sometimes fails. For a long time, it had been assumed that although an inflammation process was actively initiated by the body following injury or chemical stimuli, its resolution occurred as a result of the gradual death of the immune cells and the dilution of inflammatory signal substances. Research Training Groups work on interdisciplinary research projects and provide a training framework for early career researchers.

The Celts and Romans operated mines in the Montafon

Could “Montafon” actually be derived from the word for “mining mountain” in Montafun dialect? Archaeologists at Goethe University have discovered that mining already took place in the 39-kilometre-long valley in Vorarlberg, Austria, in late Celtic and Roman periods.

The history of mining in the Montafon is evidently long and continuous. As research has shown, ore deposits were exploited for centuries, beginning as early as the late-Celtic period. But it was previously unknown that there were activities inside the mountain as early as Celtic and Roman periods. This new discovery makes the mining district one of the most remarkable in the Alps. “We did not expect this,” says Rüdiger Krause, professor of prehistory and early history at the Institute for Archaeological Sciences at Goethe University. Archaeological research in the past years had already shown that the small mining area of Bartholomäberg is a very exciting and special research region, which has yielded many finds and features from mine dumps, old surfaces and bogs, and from which samples have been recovered



During excavation work at Bartholomäberg, Frankfurt archaeologists uncovered something surprising.

and numerous data obtained. However, archaeological sources on Roman mining in the Eastern Alps were previously unknown. The new excavations in the Knappagruaba in September, in which students were involved,

revealed a small sensation: traces of early mining were clearly visible on surface areas, consisting of heaps of waste rock, round shafts hewn into the rock, and indications of deeper lying iron ore veins. For the first time, it was possible to uncover archaeological features from mining in the Roman period, which are unique not only for this small mining area but for all the Eastern Alps. Two backfilled mining shafts that had been dug near an area of mineralisation were excavated to three metres below the surface. These are evidenced on the rock surface by fissures containing iron oxides and quartz veins, forming what is referred to as the “iron cap” – the oxidation zone of an ore vein. Ram core drilling will be used to determine how deep the shafts extend underground.

From machine learning to machine teaching: Volkswagen Foundation funds interdisciplinary AI research

The Volkswagen Foundation is donating approximately €10 million to research into how artificial intelligence will affect society. Goethe University was successful with an application that focuses on developments within education.

“From Machine Learning to Machine Teaching (ML2MT) – Making Machines AND Humans Smarter” is the title of the project submitted by economist Professor Oliver Hinz together with colleagues from various other disciplines. The scientists were inspired by the success of learning machines, a prime example being the board game “Go” in its computer version “AlphaGo Zero”. Their project aims to achieve a better understanding of how humans and machines can gain new knowledge through symbiotic interaction in collaborative human-AI systems. The following researchers are involved in the project: Professor Oliver Hinz (Economics, GU (project leader)), Professor Yee Lee Shing (Developmental Psychology, GU), Professor Lorian Pelizzon (Economics, GU)



What effect does the use of AI have on society? An interdisciplinary project looks at developments in education.

and Professor Tobias Tröger (Law, GU; both also at the Leibniz Institute for Financial Research SAFE, Frankfurt/Main), Professor Gernot Rohde (University Hospital Frankfurt and GU), Professor Kristian Kersting (Computer Science, TU Darmstadt), Professor Hendrik Drachsler (Computer Science, GU, and Leibniz Institute for Research and Information in Education, Frankfurt/Main).

New discovery in the treatment of COVID-19

The Institute of Medical Virology at Goethe University and the School of Biosciences at the University of Kent have succeeded in identifying new points of attack for the treatment of COVID-19. During an infection, the coronavirus reprogrammes host cells so that they produce new viruses. In the process, the metabolism of the infected cell is also altered. Professor Jindrich Cinatl and his team had already shown in earlier projects that the affected cells process glucose differently from non-affected cells. It has now been revealed that an infection also causes changes in the pentose phosphate pathway. Active substances that interfere with virus-induced metabolism changes could be a starting point for new treatment options. “Targeting virus-induced changes in the host cell metabolism is an attractive way to interfere specifically with the virus replication process,” says Professor Cinatl.

<https://tinygu.de/COVID-treatment>

€2.7 million for inclusive education research

Germany's education system is to become more inclusive. This requires qualified specialists and good diagnostics. Since 2017, the Federal Ministry of Education and Research has funded scientific projects in the field of inclusive education as a separate priority in its Framework Programme for Empirical Educational Research. The first funding phase was about training educational professionals, and the second will be concerned with diagnostics. Goethe University has again been successful – with four collaborative projects and a meta project.

The development of new concepts and material for the training and (continuing) education of staff in the education system was at the forefront of the Ministry of Education and Research's funding guidelines "Qualification of Educational Professionals for Inclusive Education" ("Qualifizierung der pädagogischen Fachkräfte für Inklusion"). This development work was to be based on scientific principles and conducted at different locations. The first phase comprised 20 individual and 18 collaborative projects, five of which involved Goethe University. In addition, Professor Dieter Katzenbach and Professor Michael Urban, Frankfurt educa-



For inclusion in the education system to be successful, staff must be well-trained.

tional scientists, secured a meta project, which was responsible for networking, transfer and research at meta level – for example on the state of research worldwide. A central website was set up that can be found at www.qualifizierungs-inklusion.de, and a peer-reviewed online journal entitled "Qfi" – Qualification for Inclusion – was also

established (www.qfi-oz.de). Special events brought together not only those involved in the project but also other stakeholders from practice, administration and politics.

This diverse and successful work can now be continued for another five years: the Federal Ministry of Education and Research has pledged a further €1.7 million for the meta project alone, with an overall sum of €2.7 million allocated to Goethe University. This second funding phase is entitled "Support-related Diagnostics in Inclusive Education" and thus focuses on diagnostics. The meta project team working with Professor Katzenbach and Professor Urban will above all devote itself to establishing and maintaining a contact point for all those involved in education. In addition, research findings, along with the products and material developed by the projects, are to be made accessible to people outside the scientific community too. The four collaborative projects under the leadership of Goethe University are headed by Dr Julia Gasterstädt and Professor Vera Moser (who leads two projects), both from the Institute of Special Education, and by Professor Ilonca Hardy from the Institute of Elementary and Primary Level Education.

Cooperation with FIAS

Starting in 2022, Goethe University and the Frankfurt Institute for Advanced Studies (FIAS) will intensify and expand joint research projects and the exchange of scientific knowledge. A new cooperation agreement was signed in November 2021. Since FIAS was founded in 2003, the university and the institute have been collaborating in interdisciplinary basic research in the natural sciences, life sciences, neurosciences and computer sciences. "The contract gives us the freedom to conduct even more interdisciplinary research and to design our projects to answer questions relevant to both partners," said Professor Enrico Schleiff, president of Goethe University, about the alliance. For example, there are plans to explore technical and content-related topics concerning high-performance computing in the natural and life sciences within the Goethe Center for Scientific Computing.

<https://tinygu.de/FIAS-collaboration>

Sandra Ciesek receives additional funding for her research – and the Hessian Culture Prize

Virologist Professor Sandra Ciesek has been awarded €1.4 million by the Federal State of Hessen as part of a LOEWE top professorship. These funds and the generous support of the Willy Robert Pitzer Foundation have made it possible to retain Ciesek, a leading physician, at Goethe University. The funds will support an additional professorship at the Institute of Medical Virology, and after five years the foundation will finance another five years with €1.75 million. In addition, Sandra Ciesek was awarded the Hessian Culture Prize by Volker Bouffier, Prime Minister of the Federal State of Hessen, for her contribution to science communication. The laudatory speech was given by her colleague, virologist Professor Christian Drosten from Charité. They were both acknowledged as "University Teacher of the Year" in the spring. Ciesek and Drosten feature regularly in the award-winning NDR podcast "The Coronavirus Update." In his speech, Drosten said that it was "a great stroke of luck" that Ciesek had agreed to



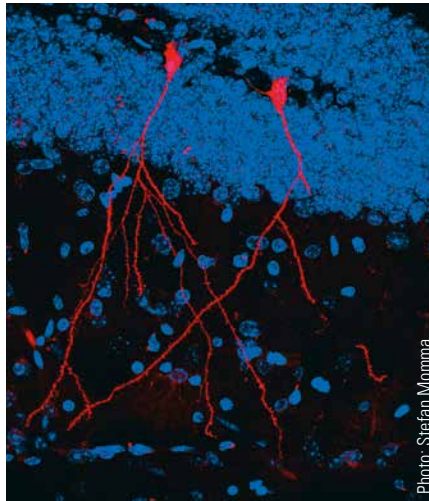
Virologist Sandra Ciesek was awarded the Hessian Culture Prize.

step into the public eye despite her extensive workload. "With her keen and discerning approach, she always gets to the heart of the matter – with the same care and empathy that distinguish her as an experienced physician who has worked with patients for many years."

By capsule through the bloodstream

Bacteria in the intestine pack biomolecules into capsules and transport them via the bloodstream to various organs in the body, where they are absorbed and processed. This has now been shown for the first time by a team of researchers from Goethe University, FAU (University of Erlangen-Nuremberg) and the University of California in San Francisco.

It is estimated that there are 1.3 bacterial cells for each human cell. Their genetic diversity is correspondingly large. All intestinal bacteria together have 150 times as many genes as humans. The intestinal bacteria's metabolic products have a variety of effects on our body. For example, they train our immune cells, control metabolic processes in the body and regulate how often intestinal mucosa cells renew themselves. The bacterial metabolites act on the cells of the intestinal mucosa via direct contact. But how do such bacterial substances travel to peripheral organs, such as the liver, kidney or brain? It was assumed that small capsules (membrane vesicles), released by bacteria into their environment, were the means of transport. An international research team led by Dr Stefan Momma from the Neuroscience



Looking into the brain of the transgenic mouse: nerve cells that have absorbed protein from intestinal bacteria glow red.

Centre of Goethe University, Professor Claudia Günther from FAU (University of Erlangen-Nuremberg) and Professor Robert Raffai from the University of California has now investigated in mice how bacteria distribute their metabolic products in such vesicles. For this purpose, the researchers colonised the intestines of mice with *E. coli* bacteria, which

produced a specific type of gene scissors (Cre) and released these into their environment via vesicles. The mice cells contained a gene for a red fluorescent protein, which could be activated by the Cre gene scissors (Cre/LoxP system). The result: in the subsequent examination of the mouse tissue, the bacterial vesicles had been absorbed by individual cells in the intestine, liver, spleen, heart and kidneys as well as by immune cells. Even individual nerve cells in the brain glowed red. Stefan Momma: "Particularly impressive is the fact that the bacteria's vesicles can also overcome the blood-brain barrier and in this way enter the brain – which is otherwise more or less hermetically sealed. And that the bioactive bacterial substances were absorbed by stem cells in the intestinal mucosa shows us that intestinal bacteria can possibly even permanently change its properties." The newly established research method will help to better understand the influence of intestinal bacteria on diseases and could support the development of innovative forms of drug or vaccine delivery.

<https://tinygu.de/intestinalbacteria>

CERN: Goethe University participates in first particle collisions after reconstruction

After ten years of preparation and three years of reconstruction, the new ALICE detector at the CERN particle accelerator in Geneva has delivered first data. This demonstrated that the reconstruction – led, among others, by Professor Harald Appelshäuser from Goethe University – was successful.

Scientists from 30 countries participated in the reconstruction. Its purpose is to investigate an extremely hot and dense state of matter called quark-gluon plasma that prevailed in the Universe microseconds after the Big Bang. It is created when the atomic nuclei of lead from the large LHC accelerator at CERN collide with great energy and break down into their elementary components for a brief moment. With ALICE, insights can be gained into how the Universe as we know it today once evolved. The accuracy of its results had previously been limited by the number of collisions that took place at the LHC and that ALICE was able to record. The reconstruction, which took ten years of preparation and also involved



Goethe University helped develop ALICE detector.

Goethe University, has significantly expanded these capabilities. After the successful trial run at the end of November 2021, the measuring campaign, which will last until 2030, can soon begin. "This is an important milestone for the entire ALICE collaboration," said a delighted Harald Appelshäuser, professor at the Institute of Nuclear Physics at Goethe University.

Goethe University is new partner in National High-Performance Computing Alliance

Goethe University became part of the National High-Performance Computing Alliance at the end of October 2021. The Joint Science Conference (GWK) approved the "NHC South-West Alliance" for ten years. The project will receive funds of €124 million. The alliance covers three federal states, Hessen, Rhineland-Palatinate and Saarland, with facilities at Goethe University, Johannes Gutenberg University Mainz, Technical University of Kaiserslautern and Saarland University. €45 million are earmarked for the future development of high-performance computing at Goethe University, whose own contribution is €30 million. With this decision, the Joint Science Conference is also underlining Goethe University's excellent performance in the area of green IT, for which the Frankfurt team led by Professor Volker Lindenstruth is responsible. <https://tinygu.de/high-performance-computing>

New insights into black hole

Using complex supercomputer calculations, Dr Alejandro Cruz Osorio and Professor Luciano Rezzolla from Goethe University, together with an international team of scientists, have succeeded in developing a theoretical model of the morphology of the jet of the giant galaxy M87. The jet consists of a gigantic beam of particles ejected from the galaxy. The images from these calculations are an unprecedented match with astronomical observations and confirm Einstein's theory of general relativity.

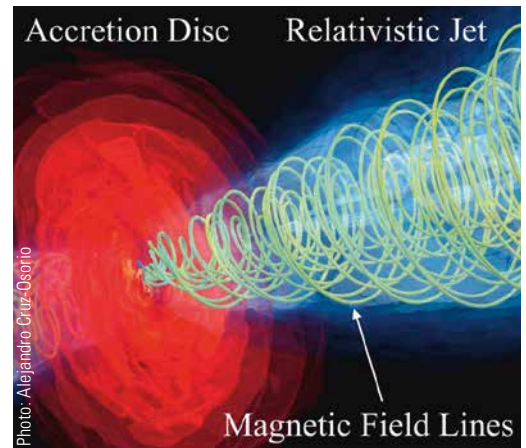
The galaxy Messier 87 (M87) is located 55 million light years away from Earth in the Virgo constellation. It is a giant galaxy with 12,000 globular clusters, making the Milky Way's 200 globular clusters appear modest in comparison. A black hole of six and a half billion sun masses is harboured at its centre. It is the first black hole for which an image exists, created in 2019 by the international research collaboration Event Horizon Telescope.

This black hole shoots a jet of plasma at near the speed of light, known as a relativistic jet, on a scale of 6,000 light years. The tremendous energy needed to power this jet probably originates from the gravitational

pull of the black hole, but how a jet like this comes about and what keeps it stable across the enormous distance is not yet fully understood.

Theoretical physicists at Goethe University, together with scientists from Europe, the USA and China, have now modelled the region from which the jet is ejected, the accretion disc, in great detail. For this they used highly sophisticated three-dimensional supercomputer simulations. The result was a model in which the values calculated for the temperatures, the matter densities and the magnetic fields correspond remarkably well with what was deduced from the astronomical observations. This represents "further important confirmation that Einstein's theory of general relativity is the most precise and natural explanation for the existence of supermassive black holes in the centre of galaxies," says Professor Rezzolla.

On this basis, scientists were able to track the complex motion of photons in the curved spacetime of the innermost region of the jet and translate this into radio images.



Along the magnetic field lines, the particles are accelerated so powerfully that they form a jet out of M87 which is 6,000 light years in length.

They were then able to compare these computer-modelled images with the observations made using numerous radio telescopes and satellites over the past three decades.

<https://tinygu.de/giantgalaxyM87>

Supporting top athletes even more individually



How can top athletes get more individual support? That is what a new project by Giessen University, German Sport University Cologne and Goethe University is investigating.

Being successful in professional sport requires consistent and hard training, carefully preparing yourself mentally for competitions, mastering techniques, taking care of your own health and knowing yourself well. Scientists at Giessen University, Goethe University and the German Sport University Cologne have joined forces in the research project "Individualised Performance Development in Sports" to provide scientific support for professional athletes in Germany in the coming years. The consortium will look at the topic from the perspective of different

disciplines to better understand and explain how individual performance develops. Here, scientists will work closely with both coaches and athletes. The Federal Institute of Sport Science is funding the project for an initial four years with a total of €2 million.

Goethe University is involved in two subprojects. The Movement and Exercise Science working group led by Professor Karen Zentgraf focuses primarily on individual diagnostics in training and movement science. Computer scientist Professor Lena Wiese is working on a data management system. To bring together and evaluate complex, discipline-specific diagnostics as well as training and competition data from professional associations, the development of an integrated database system is planned.

Princeton University and HEC Paris now also rely on LiveX

Numerous top European universities have already made their decision and are using the LiveX stock market simulation software for digital and interactive knowledge transfer in the area of financial markets and securities trading. As of late, the world's leading business school, HEC Paris, has also been using LiveX to train its students in stock market scenarios. With elite Princeton University as the second new user, Goethe University's simulation programme has now established itself for the first time on the US market too.

In contrast to simple stock market simulation programmes, LiveX simulates real stock market events in all their complexity and provides all important market models. LiveX thus enables universities and institutions in the financial sector to realistically reproduce the world of securities trading when training traders, staff and students.

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THE NEXT ISSUE



TAKING A NEW LOOK AT AFRICA

Rich fauna and fascinating traditions on the one hand – violence, hunger, corruption on the other: scarcely any other region in the world prompts as many clichés as the continent on the southern half of the globe. But neither the romanticised view of Africa nor the one that focuses on its downsides really does the continent justice. In the next issue of *Forschung Frankfurt*, we want to take a closer look. Goethe University has vast and impressive expertise in this field. We will present innovative and pioneering research projects and researchers from linguistics, cultural studies and social sciences, but also geography, biology and medicine. The focus is above all on the opportunities and potential offered by this demographically young continent.

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Street art in Soweto near
Johannesburg, South Africa.

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