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Stuttering: Poorly Wired | **Research Policy:** Shaping the Sciences and Humanities in the Digital Age | **Changing Social Movements:** Many Roads to Another World | **Innovative Detection:** The War on Landmines | **Series on Migration and Refugees:** The Litmus Test of Integration | **New Material Synthesis:** Reaching for the Light

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At a loss for words: New imaging and neurophysiological techniques continue to contribute to a better understanding of the possible causes and treatability of stuttering.

Peter Strohschneider

Shaping the Sciences and Humanities in the Digital Age

Digitalisation and digitality are changing the world – and the sciences and humanities with it. This transformation gives rise to unpredictable opportunities for knowledge yet at the same time poses enormous challenges that must be addressed in science-driven research funding.

We live in an ever-changing world. Science is characterised, among other things, not only by its capacity to effect change but also to experience change. It is subject to a constant process of transformation. And the process that we are currently witnessing is what I refer to as *Weltenwandel*, or fundamental and ongoing change brought about by technological advancements but affecting all areas of society.

This *Weltenwandel* encompasses much more than the digitality addressed in academic research and politics; where it is often reduced for convenience's sake to technical catchphrases or policy questions in the areas of innovation, education, law or democracy – such as Industry 4.0, broadband roll-out, tablets for primary schools, artificial intelligence, the Network Enforcement Act, or e-democracy. The opportunities and responsibilities associated with computerisation, with the digitalisation of texts, images, sounds and things, and with the ubiquitous networking of all the foregoing on the internet are a great deal more complex and have a far deeper and broader impact than this. They concern questions about individuality and collectivity, about economy and society, about the state and law, about knowledge and power. And, of course, questions about the sciences and humanities too.

This *Weltenwandel*, as dynamic as it is all-encompassing, confronts us with the same experience that Søren Kirkegaard encapsulated at the start of the modern age when he said that although life can only be understood backwards, it must be lived forwards. We live in this era of transformation and, knowingly and unknowingly, help shape it, and yet it remains opaque and in many ways incomprehensible to us. At the same time we act – amid an excess of information – under the conditions of a serious lack of information and dramatic uncertainty. The only thing it seems we can depend on is the prospect that linear extrapolation of what we already know will not succeed in predicting the future. It will certainly be different from what is promised by the utopias or threatened by the dystopias. This is already the case, because *Weltenwandel* through digitality will neither come to an end in the foreseeable future nor allow itself to be objectively limited. It does not have the profile of a "problem" for which definitive "solutions" or even the one and only solution might be found.

This article is a revised version of an address given by the DFG President at the DFG's New Year Reception on 15 January 2018 in Berlin.

These constellations of digitality and sociality, of open future, uncertainty and the necessity to act, also define the sciences and humanities – and research administration, research funding and research policy are no less concerned with them.

Research is playing a crucial role in driving this *Weltenwandel* – for example, in mathematics, computer science, materials sciences and new fields for which we presently use the imprecise term "data sciences". At the same time, the sciences and humanities, just like all other parts of society, are also subject to this *Weltenwandel* – with all the unpredictable opportunities for knowledge and challenges that follow from this.

"Research" is a concept with historical origins and is thus susceptible to change. And through digitality, research is being transformed in that previously analogue data is now available in digital form, allowing it to be analysed with new methods and research questions. In the life sciences and physics, for example, data-intensive technologies are now making completely new forms of research even possible. Meanwhile, established forms

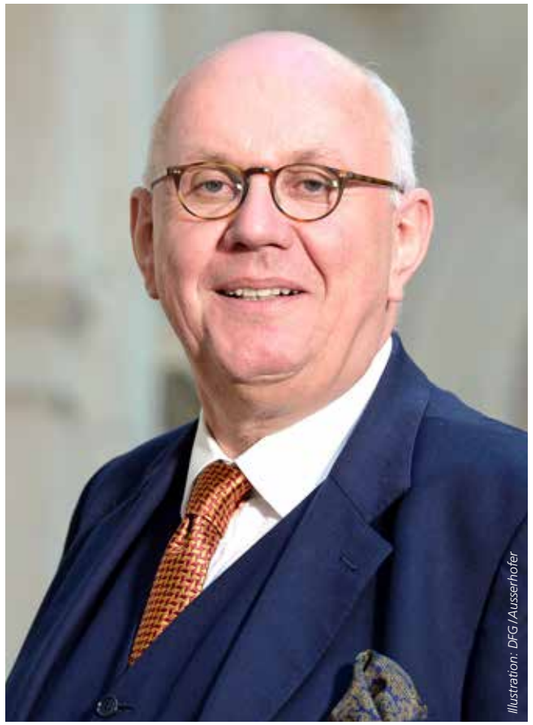

Illustration: DFG/Ausserhofer

of research are being superseded, and we can observe across whole scientific disciplines that new mathematical methods are gaining in importance.

From these questions, methods and research practices, we quickly move on to the transformation of that which can be understood as research and science from an epistemological perspective, and that which constitutes the preconditions and circumstances of its practice from a sociological point of view. What is "research", "knowledge", a scientific "argument", "proof" or "evidence", if the line between correlation and causality becomes blurred or "algorithms" take the place of "theories"? When, for example, an experiment is replaced by a digital simulation; when research is dominated by a neo-positivist faith in numbers that can no longer discriminate between the possible unambiguous nature of data, the controversial nature of its interpretations and the ambivalence of its social consequences of action; when the research result is owed to an algorithm which is, in turn, the result of processes of machine learning?

And such epistemological shifts are followed by questions from the sociology of science. Because what remains of a research "achievement" if thinking begins to be automated? How is it attributed to an individual? What will scientific reputation be based on in the future? Not to mention the legal and financial questions that arise: Who is responsible for the research? Who is liable for its consequences? How will this be regulated legally? And financially and economically?

These and other questions – including those relating to good scientific practice, the publication system and research ethics – are linked to new challenges for research policy and research administration, and of course for academically driven research funding.

To give an indication of just how radical the implications of the digital transformation are, consider that the entire funding system – not only that of the DFG – relies on the participation of academic peers. But are their powers of judgement irreplaceable? Could funding decisions not also be automated, that is, be taken on the basis of algorithms that rank the project proposals? In that case we could get by with just a few administrators and an IT support group. However, the incentives to optimise project proposals through algorithmic streamlining would be unpredictable, just as the consequences for the quality and originality of research would be. But above all, would not such automation come at the price of weakened justifiability and transparency of funding decisions – and hence a loss of legitimacy?

This is another area in which the *Weltenwandel* brought about by digitality presents an enormous need for careful planning and management. The knowledge regimes and social orders of science and scholarship, the epistemic, economic, financial, legal and policy aspects of this transformation, influence each other in many different ways and must be considered within the framework of these complex and contingent relationships.

This latter requirement is one in which a particularly prominent attempt to shape the *Weltenwandel* in terms of research policy appears to fail. The so-called 3O strategy (Open Science, Open Innovation, Open to the World), as developed by EU Research Commissioner Carlos Moedas, is turning the technical level of digitalisation currently achieved into a benchmark of research policy programme-making. Yet the ideological catchphrase "open" is more likely to obscure the openness and unpredictability of the *Weltenwandel* than to address its conceptualisation seriously and get it moving in the right direction.

(continued on page 4)

Graphic: Shutterstock

Digital Transformation: Time to Take Stock

Internal DFG project collects information on subject-area cultures and funding activity

A longer-term project is underway at the DFG Head Office in Bonn with the aim of preparing an official position on the digital transformation in research. The project follows a resolution by the DFG Senate.

The goal is to attempt a discipline-based appraisal, analyse funding activities and identify relevant areas for policy advice. The concept phase, initially lasting six months, focussed on gathering wide-ranging expert knowledge from within the DFG and analysing past experience in funding practice with a view to preparing future activities.

Evaluations so far have identified nine relevant dimensions of the digital transformation in research, ranging from practical, institutional and ethical to commercial and policy dimensions.

A distinction is also made between at least three forms of digital transformation: a "transformative" one, referred to here as digitisation, an "enabling" one brought about by instrumentation and new technologies, and a "substitutional" one. The project will be continued in 2018 on this basis.

As a funding body and as the self-governing organisation of science and research in Germany, the DFG has a responsibility in this area. We are resolved to fulfil this responsibility in three ways. Firstly, by initiating forums and supporting subject-specific reflection on digital transformation in all areas of science and the humanities (and what subject-specific means here will itself change under the conditions of digitality). Secondly, our funding activities and the associated instruments and procedures will need to be further refined. And, thirdly, the DFG will face new responsibilities in advising government and society with respect to the development of the sciences and humanities in the digital age.

In order to do justice to this threefold responsibility, we are carrying out a comprehensive project at the DFG Head Office. The DFG Executive Committee will also appoint a high-level expert commission to address science and academia in the digital era and, through this and other organisational forms, seek to support the advancement of the digital transformation of the sciences and humanities.

We are guided in this process by the view that what will still matter in the future is research in the sense defined in constitutional law as a specifically professionalised form of the free, methodical search for truth. Research continues to require public sponsorship and funding – in the data sciences as well. And these must be implemented legitimately in the form of funding decisions that are based – and will continue to be based – on the (non-automatable) human capacity for judgement.

Such capacity for judgement is not simply a given; it remains a quest. This capacity must be nurtured, and it requires the necessary scope for institutional freedom in order to develop. Without it, there would be no ability to attribute research achievements and no justifiability of funding decisions, which are central to the DFG. The complex interwovenness of the technological, epistemic and social aspects of all things digital cannot simply be bypassed by digital means. Productive and fascinating research that justifies the trust placed in it by society requires far more than such an approach could provide.

The research community and we at the DFG should therefore address the task of shaping the sciences and humanities in the digital era with this firmly in mind. These tasks involve action and insight alike.

Prof. Dr. Peter Strohschneider
is the President of the DFG.

Information Infrastructures of Tomorrow

New strategy paper on the orientation of funding for Scientific Library Services and Information Systems

The DFG has adopted a new strategy paper on the future development of scientific information infrastructures in the context of digitisation, open access transformation and research data management. At its meeting in March, the Senate approved the strategy paper prepared by the Committee on Scientific Library Services and Information Systems (AWBI), "Funding of Information Infrastructures for Research". In light of the comprehensive digital transformation currently underway in the sciences and humanities and the continued rapid pace of change, this paper analyses the current situation, identifies challenges and priority action areas, and provides a set of guidelines for funding activities in the area of Scientific Library Services and Information Systems (LIS).

"As a self-governing organisation of the German research community and a national research funding organisation, the DFG is playing an active role in shaping the digital transformation in the sciences and humanities," says President Prof. Dr. Peter Strohschneider. The strategy paper outlines current challenges relating to networked, data-intensive research and the growing requirements in terms of coordination and cooperation at multiple levels: within scientific communities, between infrastructure facilities, and between infrastructure and researchers. The paper is primarily concerned with three areas of funding: the indexing and digitisation of information resources, open access transformation, and research data.

"The position paper is an important element in the DFG's strategy of systematically participating in the ubiquitous impacts of the digital transformation of research, evaluating the opportunities and risks and aligning its activities to respond to the needs of researchers and universities," Strohschneider said.

www.dfg.de/en/research_funding/programmes/infrastructure/lis/publications

Alliance Sets Out Its Position

Priority initiative – Digital sequence information – European Open Science Cloud

Digitisation and digitality in research have also been a matter of interest to the Alliance of Science Organisations in Germany, which recently addressed three separate aspects of the topic. The Alliance Digital Information Priority Initiative established in 2008 was recently reoriented and extended to 2022. It now takes greater account of the fact that today's research is heavily dependent on digital data and communication. The Alliance is concerned about efforts to make the use of digital sequence information on genetic resources subject to the provisions of the Nagoya Protocol and the Convention on Biological Diversity, which could have far-reaching consequences for the international environmental and life sciences. However, the organisations fundamentally welcome the European Commission's European Open Science Cloud Initiative. At the same time, they are calling for an appropriate balance of scientific and political interests.

The Alliance's priority initiative and statements can also be found at www.dfg.de

Nicole Deitelhoff, Priska Daphi and Felix Anderl

Many Roads to Another World

"Another World is Possible": under this motto, a transnational movement is opposing neoliberal globalisation. While activists share an image of neoliberal globalisation as being unfair and destructive, the forms their protest takes are as varied as their short-term and long-term goals. A comparative perspective reveals how the repertoire of social movements forms and reforms.

Global Justice activist art to coincide with the G8 summit in 2007: during filming of the "dropping knowledge supercamp" commercial, a five-metre-long painted baby doll named Madele floats in the River Spree. She is intended to represent the fate of Africa.

Illustration: dpa / Arno Burgi

Edo Supismo (not his real name) welcomes his guest on his scooter in front of the fish stall at a small market in central Java. He wears a Muslim prayer cap, has flip-flops on his feet and a cigarette in the corner of his mouth. With friendly gestures he invites his visitor to hop on. After a ten-minute journey through the rice fields we reach his small house, where his family, fellow activists and two reporters from the local daily newspaper are waiting.

Edo is a minor celebrity in the area. He spearheads a protest campaign against transnational companies and especially the practice of "land grabbing" – the illegitimate or illegal acquisition of land. Increasingly, this practice is costing farmers the ability to cultivate their fields as many governments are selling agricultural land to transnational companies at low prices. In addition, farmers with a debt burden are often forced to sell their own land.

"What are you doing about it?" asks one of the journalists – and Edo launches into a speech that ranges from global capitalism and the resource-intensive development model to the international "multitude" of movements and counterpublics. By way of conclusion, he returns to the local level: "We need to act locally, but we know we have brothers and sisters all over the world on our side."

At first glance there is little to distinguish the men sitting here, drinking the coffee they themselves have grown, from other Javanese farmers. It's hard to imagine that they blockaded the factory belonging to Holcim, a building materials company. But when there is no other help available, says Edo, you have to try other forms of protest.

In September 2012, Edo led a march involving thousands of peasant farmers under the banner of *Serikat Petani Indonesia (SPI)*, the biggest peasants' union in Indonesia. The march led activists through various villages to the regional government in Semarang, and later even to the presidential building in Jakarta, the capital city. Jakarta is also home to the headquarters of SPI, which coordinates member groups in ten provinces – representing an estimated 2 million peasants.

Illustration: dpa | David Parry

Sarcastic, creative scene by the IF campaign on the "Isle of Shady" against the backdrop of the City of London: two businesspeople have lined their pockets with "Africa's billions".

Illustration: dpa | Warren Toda

Brought down by globalisation: street protest in Toronto in connection with the G20 summit in Canada in 2010.

Between 2005 and 2013, the association *La Via Campesina*, the world's largest movement of peasant farmers, was also coordinated from Jakarta. With 164 member groups and encompassing – by its own account – about 200 million agricultural activists, the network won significant influence on world politics. For example, the United Nations formulated much of the "declaration on the rights of peasants" in line with the movement's proposals. The network's chairperson, Henry Saragih, earned such a high profile that the British newspaper *The Guardian* named him one of the "50 people who could save the planet".

A personal interview with Saragih reveals how his ideological viewpoint on and knowledge about the global situation is shaped by *La Via Campesina*. The network offers training for members and organises various public events, whether in the form of professional lobbying at the United Nations, mass protests as in Seattle in 1999, or demonstrations at the UN Climate Change Conferences. Particularly around the turn of the millennium, resistance against global economic institutions and their neoliberal policies intensified and became more disruptive. At a WTO Ministerial Conference in 2003, a Korean farmer publicly stabbed himself in front of a sign declaring "WTO kills farmers". How was it possible for such drastic protest actions to emerge? And how did different groups within the movement become radicalised? In more general terms, under what conditions do protest repertoires change?

Common assumptions in social movement studies suggest that the repertoires within movements undergo little change. Changes in repertoires like the one mentioned above thus offer helpful insights into how and under what circumstances repertoires do change. Our knowledge about processes of radicalisation and deradicalisation is still limited – partly because research is too often focussed on violent repertoires and thus loses sight of the processes of other repertoire changes. If we understand radicalisation and deradicalisation as developments on a continuum of possible protest practices and objectives, then the use of violence may form part of this process but does not necessarily need to do so. Instead, the key factor is the shift away from or towards the common rules of political participation (practices) and ideas of political order (objectives).

In retrospect, the diversity of the Global Justice movement is what makes it stand out, both geographically and argumentatively. The research team is therefore examining four transnational networks with the aim of cover-

Illustration: Wiki Commons / Jonathan McIntosh

Left: "Another World is Possible" – anti-G8 protests in Le Havre in 2011. The Global Justice movement has developed many forms of expression and protest. Below: Irresponsibly, even fatally, looking away? Activists accuse heads of government ahead of the G8 summit in France in 2011. Right: Against the power and logic of monetary flows – anti-World Bank protests in the Indonesian capital Jakarta in 2004.

ing the breadth of the "movement of movements". In each of these networks, we compare protest forms (repertoires) in two countries between the mid-1990s and the mid-2000s. More specifically, we analyse local chapters of *La Via Campesina* and the feminist *World March of Women* in Indonesia and the Philippines, as well as local chapters of the international debt cancellation campaign and the autonomous network *Peoples' Global Action* in the UK and Italy. All groups consider themselves part of the Global Justice movement. Drawing on over 60 interviews with activists as well as activist documents, we aim to answer the question: how do the repertoires of the groups change over time and why?

Within the Global Justice Movement, protest forms are subject to dynamic change. There are different paths of change: while some groups choose increasingly disruptive and sometimes aggressive forms of protest, others opt for more moderate methods. Such changes also significantly differ in terms of whether and how new forms of action are linked to new objectives. The varying relationship between tactics and goals can for example be observed in the contrary developments of the Indonesian farmers described above and of the UK movement *Reclaim the Streets* (as part of the transnational network *Peoples' Global Action*).

Illustration: dpa / Abir Abdullah

A preliminary finding here is that in Indonesia SPI changed at the level of both aims and means. In the mid-2000s, sustainable agriculture was more strongly linked with anti-capitalist aims than was the case in the mid-1990s. At the same time, the protest repertoire shifted: the group diversified its activities and addressees, while actions themselves became increasingly disruptive. The group's new protest repertoire included demonstrations, occupations, civil disobedience and other disruptive forms.

With *Reclaim the Streets* in the UK, the situation is different: the protest repertoire remained relatively stable during this period although the objectives shifted. To begin with, actions primarily opposed the destruction of public spaces and of the local environment in the context of road construction. Later, the focus shifted to the capitalist economic system as a whole. Regardless of this change at the level of ends, the protest repertoire remained similar. While numbers of participants grew, the strategy of combining road blocks with street parties was maintained.

This reveals how multiple factors interact at the local, national and international levels, including opportunity structures (e.g. how easy is it to exert influence on institutional politics?), protest cycles (e.g. is mobilisation growing or declining?), relations with opponents and allies, and learning processes within the movement. From an analytical perspective, it is evident that – contrary to assumptions – the international level of the movement plays only a secondary role in local repertoire changes. Transnational networks appear to constitute a resource for Global Justice activists in order to obtain theoretical and practical know-how, but the choice of protest forms seems to depend first and foremost on local opportunity structures and learning processes.

However, both the Indonesian farmers and the British activists of *Reclaim the Streets* considerably drew on input from the transnational network in revising their analysis of the problem and aims. In dialogue with activists from other countries, for example, it became clear that the exploitation of farmers, environmental destruction and the restriction of public spaces form part of an overarching phenomenon: neoliberal globalisation and the associated processes of privatisation and commercialisation.

The choice of specific forms of protest was made in the light of – and shadow of – the local and national situation and on the basis of tried-and-tested protest traditions. "What protest actions attract the broadest public attention?" was a central question driving the activists in this context.

Illustration: Wiki Commons / Guillaume Paumier

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www.goethe-university-frankfurt.de/44187983/forschung

Christoph Baer, Ilona Rolfes, Thomas Musch and Jürgen Sachs

The War on Landmines

Decades of guerilla warfare in Colombia have left behind a deadly legacy of thousands of landmines. Now a German-Colombian partnership is developing new ways of detecting these often improvised devices. Innovative technologies such as these can help further the incipient peace process.

In what could be a new start for Colombia, last year the bloody civil war which raged intermittently for five decades was finally brought to an end. A long hoped-for peace agreement was signed between the government in Bogotá and guerilla group FARC. Prior to this, over 220,000 people were killed in conflicts between state security forces, left-wing rebels and right-wing paramilitaries. Millions of people were also driven from their homes. President Juan Manuel Santos, who has led the country since 2010, was a standard-bearer of the peace process. For this, he was awarded the Nobel Peace Prize in December 2016.

Colombia now has the chance to improve its economy, political culture and human rights and perhaps also rehabilitate its murky image abroad. But for the people of Colombia, everyday life is still marred by danger. The country is still peppered with landmines from the armed conflict with the guerilleros. The statistics are horrifying: over 10,000 people have been injured or killed by landmines in the last 15 years. According to the international Landmine Monitor 2016, this puts Colombia in sixth place in the casualty statistics, and with up to 99 square kilometres of the country being mined, it is still classified as "heavily mine-contaminated". The forecast in the ten-year plan drawn up in 2011, that the country would be completely cleared of mines by 2021, is considered "not on track". The reason for this sober prognosis has to do with both the type of mines used and the relatively inefficient detection technology employed so far.

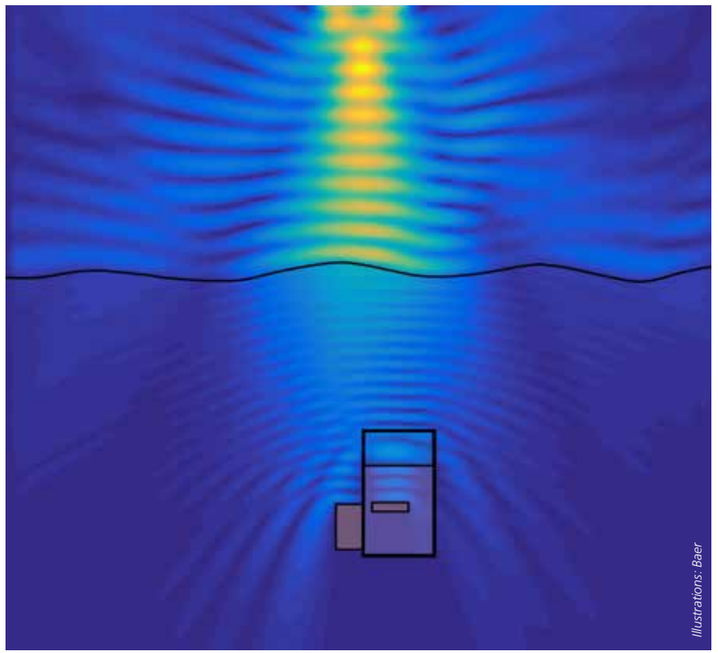
Unlike purely military conflicts, in which industrially manufactured mines are used, Colombia's landmines are improvised from everyday objects. These Improvised Explosive Devices or IEDs vary so much in their construction and ignition mechanisms that established detection methods work very poorly or are not effective at all. In addition, the terrain in Colombia's interior is sometimes extremely difficult to traverse, preventing the use of conventional, large-scale clearing technologies. Mine clearance remains a time-consuming manual job.

To help find a solution to this enormous challenge, in 2012 researchers from Ruhr-Universität Bochum and Technische Universität Ilmenau in Germany, Universidad Nacional de Colombia, and Universidad de los Andes in Bogotá joined forces in the German-Colombian Collaborative Research Initiative in Electrical Engineering (GeCoCo) set up by the DFG. The resulting joint research project, "Humanitarian Microwave Detection of Improvised Explosive Devices in Colombia – MEDICI", is designed to provide new technological approaches to improve the search for IEDs and accelerate mine clearance. The focus of the research project, which got underway in 2015, is to develop new hardware concepts and implement software algorithms. The chosen approach is to link broad-

Left: Display case showing the different ways of planting a mine, installed at Tolemaida Air Base in Colombia. Below: Danger! Landmines! After decades of guerilla warfare, the country is alarmingly mine-contaminated.

Illustrations: Baer

During a scanning campaign in Colombia, German researchers test the equipment currently in use by the Colombian military. Below: Simulation of the electromagnetic response of an explosive buried in the ground. The wave fronts emitted by the radar system are visible.



Illustrations: Baer

band and rapid-scanning multi-channel radar technology with high-resolution radar imaging algorithms which create an image of concealed objects just below the ground.

First the researchers developed basic hardware components to allow test scans to be carried out at the universities in Colombia. The M-sequence wideband radar device developed in Ilmenau achieves a scan repetition rate of over 1000 measurements per second. Any of the eight available transmit and receive channels can be selected, allowing a wide range of test scenarios and antenna arrangements to be used. Combined with a special wideband antenna developed in Bochum, with a low self-reflection which makes it ideal for ground radar applications, additional parameters can be added.

The test equipment was handed over to the Colombian team in October 2015, when it was put to joint use as part of an initial measuring campaign. During this campaign the German researchers were also able to form an accurate picture of the current research and teaching at the partner universities. During a visit to Tolemaida Air Base, the team were also given a demonstration of the standard mine detectors currently in use and the training of mine clearance personnel. To gain an impression of the difficult and hazardous work of the demining teams, the researchers visited a test minefield. These images will stay in their minds for a long time.

The team is currently working on optimised radar imaging algorithms to rapidly analyse the collected data and allow the speedy classification of buried objects. They are using algorithms that allow for the propagation effects of the transmitted electromagnetic waves at the ground surface and other ground information. To create accurate ground radar images, the position of the radar antenna must be determined with extreme precision. When scanning is taking place in the open, the scanning platform needs an inertial navigation capability that is not only highly accurate, but most importantly non-environment-dependent. So the researchers decided to combine sensor systems. Acceleration sensors, video cameras and high-precision millimetre wave radar devices are some of the technologies used.

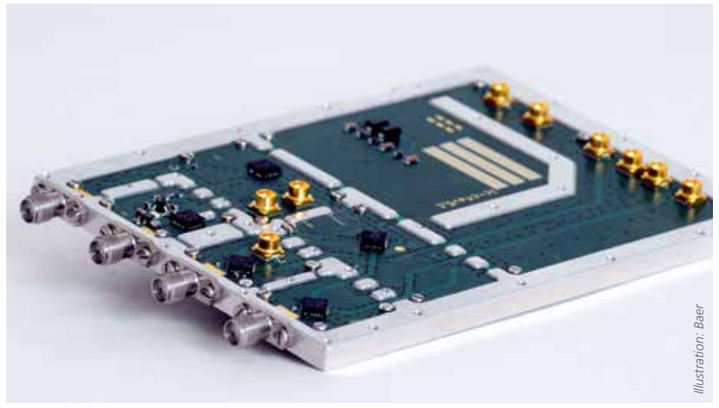


Illustration: Baer

Special hardware components were also used during test scans in Colombia. Here, a component of the radar device developed at TU Ilmenau can be seen.

The development of improved detection and classification algorithms is generally regarded as the most difficult aspect of landmine detection. To investigate the radar response of landmines in the Colombian soil, dummy mines are needed. The electromagnetic characteristics of all the components, for example the explosive used, must be reproduced exactly. Using the measurement data collected by their colleagues in South America and the Colombian military, the German researchers were able to synthesise safe phantom materials. These substances have the same electrical properties as the explosive used in Colombia. A variety of mine designs and environments were also recreated in electromagnetic simulators to better understand the near-surface interaction of the IEDs with the electromagnetic waves.

Peace has been talked about for a long time in Colombia. After decades of bloody civil war and the country's discrediting in the international community, agreement between the fighting groups seemed almost inconceivable. Now, even though the country and some of its representatives are currently dealing with a corruption scandal, the goal of peace seems to be within reach. It is to be hoped that international research cooperations like the landmine detection project can contribute to this peace process. President Santos is not the only one who hopes that the peace process will bring economic growth and stability to the Latin American country. With its wealth of resources, Colombia has enormous potential – but this can only be achieved with effective peace and a day-to-day existence free of landmines.

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www.est.rub.de

Report on the MEDICI project in the RUB research magazine:
http://news.rub.de/wissenschaft/2016-03-18-bodenradar-landminen-mit-neuer-technik-aufspueren

Martin Sommer and Annika Primaßin

Poorly Wired

What happens in your head when the words get stuck? Stuttering can be associated with a high level of psychological strain. New studies, based on modern neurophysiological and MRI examinations, are helping researchers to understand the causes of this disorder in the brain, predict its progress more accurately, and improve stuttering therapy.

Nearly everyone can think of a situation when they have reacted with surprise, helplessness or discomfiture to someone getting stuck with their words. Stuttering is a disruption of the flow of speech which has been known since ancient times and leads to serious communicative impairments. Around 5 percent of all children start to stutter between the ages of two and six, without any recognisable reason. They exhibit "disfluencies" typical of stuttering, which are clearly different from the normal disfluencies of language development: repetition of sounds and syllables (e.g. b-b-b-baby), repetition of monosyllabic words (often with effort and un-rhythmically), prolongation of sounds (ssssssssometimes) and blocks before or within a word (--------monkey).

These "typical disfluencies" are often associated with increased strain and effort while speaking and are perceived by listeners as disrupting or conspicuous. In around 75 percent of affected children stuttering disappears spontaneously, with the result that after puberty only about 1 percent of the total population still experiences stuttering. There are known prognostic factors for a lower probability of remission of stuttering during childhood: a family history of stuttering, being male, and the onset of stuttering after the age of 3½. The following factors have also been observed: no reduction in the frequency and severity of symptoms a year following onset, longer core symptoms with the continuing presence of prolongations and blocks, and below-average development of phonological abilities. Unfortunately, there are currently no other predictors that allow the reliable description of a risk population for persistent stuttering.

After puberty, the spontaneous remission rate for stuttering is very

Left: Stuttering often begins in childhood but also affects adults. Below: Scene from the Oscar-winning film "The King's Speech", with Colin Firth as the stuttering King George VI and Helena Bonham Carter as his wife Elizabeth.

Illustration: Wiki Commons/www.lancashire.gov.uk

Illustration: fotolia/lassedesignen

Illustration: AG Sommer

New medical imaging techniques have revealed that in people who stutter, the white matter in the left hemisphere of the brain is poorly "wired".

low. Stuttering therapies in which patients learn speech techniques to make speech more fluent often have good, though short-term success. In the long term there is a high rate of relapse which often increases the psychological strain caused by difficulties with speech and communication. This can have a profound impact on quality of life and opportunities for personal and career development. In adulthood there are also few predictors for long-term response to stuttering therapy.

The public perception of stuttering is changing. In the past, the media portrayal of people with a stutter tended to be negative and stigmatising (as for example in the film "A Fish Called Wanda"). Now there are films like "The King's Speech", which deal with the real challenges and difficulties experienced by people who stutter. However, there are still plenty of negative stereotypes and disparaging prejudices in our society: people often associate stuttering with lower intelligence, anxiety, nervousness or social reclusiveness. Yet these are unjustified assumptions. People who stutter are raising awareness and taking a proactive approach to the problem to try and build a more realistic picture. Experience and research both prove that, although people who stutter need a little more time to speak and communicate, they are just as intelligent as fluent speakers. They also exhibit no differences in personality traits compared with the average individual. Having been ignored for a long time, stuttering is now seen as an interesting and challenging field of research with a high level of social importance.

The scientific analysis of the causes of stuttering has progressed enormously in the last 20 years through the refinement of imaging techniques and electrophysiological methods in neurology. For example, studies have shown that in people who stutter, the white matter of the brain is poorly wired in the frontal left hemisphere of the brain. This suggests that their speech motor control is less resistant to disruption in the high temporal resolution and complexity required for the speech process.

Methods involving higher temporal resolution (for example using transcranial magnetic stimulation) allow examination of the motor cortex controlling the tongue during the speech preparation phase. They revealed that adults who stutter exhibit a disrupted modulation of the left-hand speech motor cortex, which correlated negatively with speech fluency. Indeed, clinical observation shows that stuttering varies in intensity depending on the situation, being more severe in emotionally stressful situations. Stuttering is also not equally distributed across the articulation of all words, but tends to occur at the beginning of words and in the words that carry the meaning in a sentence. Imaging studies have also revealed a speech-related overactivation in the right hemisphere of the brain, which may be compensatory.

The idea of faulty regulation in the left hemisphere correlates with the observation that people who stutter rarely experience problems when singing – an activity involving mostly right-hemisphere speech motor circuits. With this model, it makes sense that speech is prone to interruptions while singing is unimpeded.

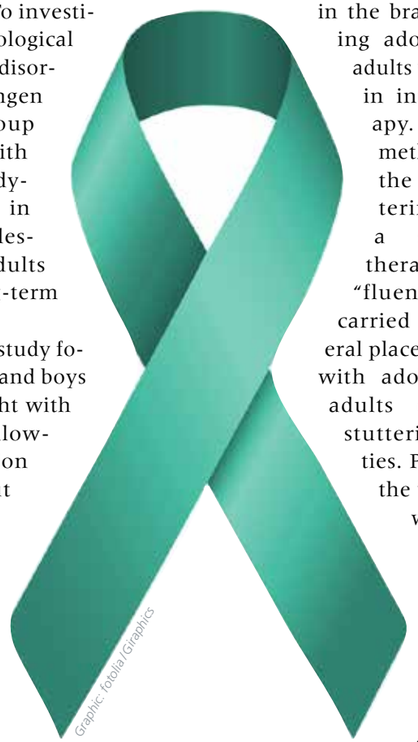
There is still much to be understood about the causative, triggering and sustaining factors

Stuttering therapy for children involves games and on-screen feedback.

Illustrations: AG Sommer

of stuttering. To investigate the neurological origins of the disorder, the Göttingen working group was set up with the aim of studying stuttering in children, adolescents and adults as part of long-term studies.

One recent study focusses on girls and boys aged six to eight with a clinical follow-up observation phase of about one year. The key question is whether an in-depth neurological, paediatric, neuropsychological and imaging investigation makes it possible to identify better predictors for the later progress of stuttering.



Still relatively unknown in Germany, but symbolically significant – the sea-green stuttering awareness ribbon.

What factors suggest that the problem will later become chronic and what makes remission likely? So far it has proved very difficult to recruit participants, so parents of stuttering children are invited to find out more about taking part in the study (details are available on the group's website at www.neurologie.uni-goettingen.de/studie-bildgebung-bei-stotternden-kindern.html).

Another long-term study is investigating neuroplastic changes in the brain in stuttering adolescents and adults who took part in intensive therapy. One of the methods used was the Kassel stuttering therapy, a standardised therapy based on "fluency shaping" carried out in several places in Germany with adolescents and adults experiencing stuttering difficulties. Participants in the "4x5" therapy were also integrated in the study. Participants in both therapy types undergo detailed MRI scans before starting therapy and ten to twelve months later (at the end of the therapy). The aim is to understand the longer-term response to stuttering therapy and detect structural brain changes resulting from the therapy. At the moment, the final scans following completion of therapy are currently being carried out.

The new imaging and neurophysiological techniques developed over the last two decades have contributed to a better understanding of the possible causes and treatability of a disorder which for a long time was very poorly understood. This in turn may lead to predictors for short- and long-term therapy success. With this in mind, the project incorporates interdisciplinary collaboration with imaging specialists on the one hand and speech-language pathologists and phoniatrics experts on the other. Within this interdisciplinary team, we also contributed to the completion of the first S3 guideline on the treatment of stuttering (www.awmf.org/leitlinien/detail/ll/049-013.html). This is designed to support the ongoing scientific evaluation of stuttering diagnosis and therapy in everyday clinical practice in Germany – and to place it on an improved, evidence-based foundation.

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is a consultant at the Göttingen Clinic for Clinical Neurophysiology.

Annika Primaßin, M.Sc.
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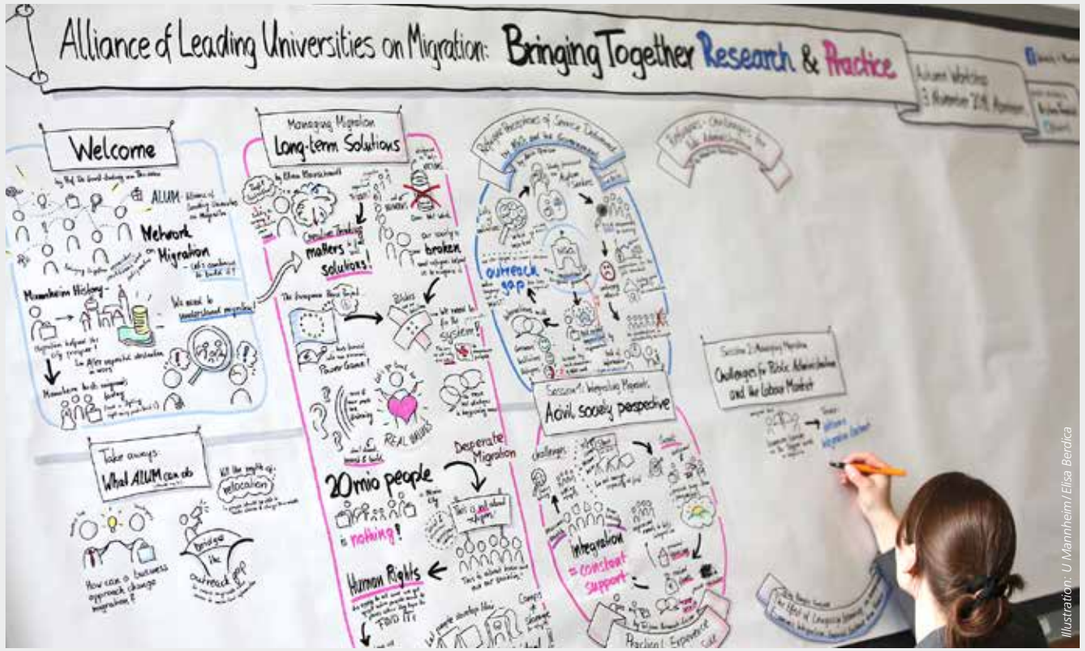
www.neurologie.uni-goettingen.de/stottern-132.html
www.bvss.de

Series: Migration and Refugees / Part 4

Illustration: dpa/Britta Pedersen

Thoughtful, focused, perhaps a little mischievous? The expression of this boy, who has a migration background, speaks volumes – and gives us an opportunity to round off our year-long series exploring research into migration and refugees with a look into the future. Following on from thought patterns in modern populism, the human history of migration and language acquisition as an incentive or barrier to migration, we now turn our attention to young second-generation migrants in four European countries. A comparative study being carried out by sociologists in Mannheim and elsewhere not only provides relevant data, but also reveals a great deal about the stringent demands of a major empirical research project and sets realistic standards for the evaluation of much-discussed social dynamics in European immigration countries.



Work in progress: visually arresting "simultaneous minutes" being taken at a conference of Leading Universities on Migration.

The Litmus Test of Integration

Germany, England, Sweden and the Netherlands: what is life like for second-generation migrants in the Europe of today? What can we say about their lives and attitudes? An interview with Mannheim-based sociologist Frank Kalter, who is leading the German part of a major long-term European project.

german research: Research on integration, employment and education has been carried out at the Mannheim Centre for European Social Research (MZES) for over 25 years. What is the focus of your integration research?

Kalter: At MZES, we're primarily concerned with the structural aspects of integration. This doesn't just relate to the economic environment, but has sound empirical and theoretical underpinnings. Structural variables, such as occupational status, household income and above all education, are generally the key to integration processes. In terms of methods, MZES represents the empirical-analytical paradigm in integration research. In other words, we study integration processes on the basis of extensive high-quality data in a standardised quantitative approach, mostly in collaboration with international colleagues and with a longer-term perspective.

Can you tell us about the context of the "Children of Immigrants" project (see box, right) which you are leading with your colleague Prof. Dr. Irena Kogan?

In 2008, a transnational programme called the NORFACE Research Programme on Migration was launched, and this provided the starting point for conducting comparative projects across Europe. We've been working on education and employment integration issues using national data records for a long time, so we had plenty of experience in this area. Building on that, the key question we asked ourselves was what the situation is like for second-generation migrants in Europe, taking a broad perspective. Without NORFACE, we couldn't have implemented a project of this scope. Using a longitudinal approach, we are analysing complex data on children of migrants in four European countries – Germany, the Netherlands, England and Sweden.

Did you have a template or model on which to base your project?

Yes, in the USA there was a long-term study called the Children of Immigrants Longitudinal Study. This was very influential in migration and integration research.

You examine four European countries, with a focus on central and northern Europe. Isn't that a rather narrow focus?

When you're designing a piece of research, you always have to limit yourself to what's feasible. First of all, we could only study countries that belonged to the NORFACE consortium. That was more of an organisational restriction. The other was that we needed to identify countries with a sufficiently large and diverse second-generation migrant population. This inevitably took us to more traditional immigration countries. We also needed to make our comparisons as strategic as possible within the available financial framework. For example, Germany and the Netherlands have what is known as a "stratified" education system where decisions about a child's education are made early on, whereas England and Sweden operate comprehensive systems. As another example, Sweden and the Netherlands are generally con-

Children of Immigrants Longitudinal Survey in Four European Countries (CILS4EU)

CILS4EU is a long-term empirical research and data infrastructure project for the collection, compilation and analysis of comprehensive data on the lives and attitudes of teenagers and young adults with and without a migration background. The project was launched in 2010 as part of the NORFACE Research Programme on Migration (funded 2009–2013), with representative samples of 14-year-olds in Germany, England, the Netherlands and Sweden. The project employs a comparative approach. As a primary survey, it is the first fully standardised longitudinal study on this topic in Europe, using multilevel and longitudinal data with a large sample size (see table on page 24). The German part of the study (CILS4EUDE) has continued to be funded within the DFG's long-term programme since 2014. The intention is to follow up on the interviewees until early adulthood (around age 25) and continue the project until 2024.

www.mzes.uni-mannheim.de/d7/en/projects/children-of-immigrants-longitudinal-survey-in-four-european-countries-cils4eu


Illustration: MZES/N. Hollermeier

Prof. Dr. Frank Kalter has been Professor of General Sociology at the University of Mannheim since 2009. Between 2014 and 2017, he was director of the Mannheim Centre for European Social Research (MZES), one of the largest university-based institutions for social science research in Germany.

Born in 1964, Kalter studied mathematics and social sciences in Cologne. He earned his doctorate in 1996 in Mannheim, where he also habilitated in 2002. After periods of research abroad, he returned to Germany and was professor of sociology at the University of Leipzig until 2009, when he accepted a professorship in Mannheim. Sociology of migration and integration research are among his key research interests. As an empirical and well-networked integration researcher, he is interested in fundamental questions – and not quick (or over-hasty) answers. This is often a lengthy, even laborious process, which is reflected in the quality of the data underpinning his research, but can hamper the public and media perception of the research findings.

Following in the footsteps of Mannheim sociologist Prof. Dr. Hartmut Esser, Kalter is regarded as a representative of "explanatory sociology". This branch of sociology relies on critical rationalism and seeks to analyse systems and structures in order to understand social dynamics.

However, in this interview with german research, Kalter stressed that "a great deal of research on integration processes has become common knowledge". He comments: "Ten or fifteen years ago, when we reported that the data showed language and education were the key to integration, this was by no means obvious or generally accepted. Some people regarded us as a bit odd. Now the connection has entered into people's general awareness. But we still need continual empirical evidence." **RU**

http://lssw.sowi.uni-mannheim.de/ionas/sowi/lssw/english/People/Prof.%20Dr.%20Frank%20Kalter

sidered to be widely multicultural in their policies, whereas Germany and England are not.

Can you briefly sum up your motivation for doing the study?

When we talk about integration, we're talking about a slow, gradual process. The evidence from many studies shows that it occurs over generations. Seen in this way, the life situation of the second generation is something of a litmus test that provides a good indication as to whether integration will be successful or not.

What different dimensions of integration do you define in your empirical work?

We, as well as other researchers, proceed on the basis of a structural, a social, a cultural and a cognitive-emotional dimension. Obviously, each of these comprises more detailed aspects. We are currently investigating how these different aspects, such as religiosity, manifest in individual migrant groups in different countries and how they can be explained. Why does group X in country Y fare better in the structural dimension than in the cultural dimension? That's the kind of question that interests us, especially the interactions between different dimensions.

Why does the project use school-based samples and collect data from classes, pupils, teachers and parents?

We're using a very complex design. In 2010, we interviewed a representative sample of 14-year-old boys and girls and then followed them up over a period of time. So many crucial developments occur between the ages of 14 and 16 – these are formative years that also include transitions at school, for example from 10th to 11th grade in Germany. We're especially interested in the relative influence of fellow pupils, the general school context and parents.

Can you draw any provisional main conclusions?

In collaboration with our European partners, we have now performed an in-depth evaluation of phase one of the project. What is astonishing is how similar integration processes are for different groups in the various countries. That came as quite a surprise. There would appear to be many very general processes happening in the background, as it were: mechanisms of social inequality, or the transmission of attitudes within families. These play an enormous role in determining whether integration occurs relatively rapidly or not. Perhaps the role of policy is somewhat overestimated overall.

Is the empirical approach a silent muse?

To some extent, certainly. For example, there is quite a lot of good data available on the structural integration of adults, but much less is known about social and cultural integration and the factors affecting it, especially among teenagers. Our project is designed to fill this gap in our knowledge. Through the project we're beginning to see that the long-term success of integration is much more dependent on social background and accompanying cultural processes. Describing these processes is one task, identifying and demonstrating the explanatory mechanisms is another.

The project team in Mannheim and your colleagues in Oxford, Stockholm, Tilburg and Utrecht are particularly interested in the interactions between integration processes. This raises the question of cause and effect. How do you approach the chicken-and-egg problem in empirical integration research?

The basic strategy is obviously the longitudinal design. We're observing processes that occur over time, not taking snapshots. A longitudinal study makes it easier to identify causalities because you can see, for instance, whether social contacts with the majority population already existed prior to success at school or rather were a result of it.

Although the research isn't complete yet, what practical lessons can we draw from the study?

Perhaps the main thing is that you need realistic measurements for successful or failed integration, taking the background processes I mentioned into account. There are some ideas that have little or nothing to do with reality. For example, is it reasonable to expect the same proportion of children of migrants to sit the Abitur as children of German parents? Or is it more realistic to compare them to German children from similar social backgrounds? Part of the reason why programmes aimed at migrants and their children are not always successful could be that the true reasons for inequality lie elsewhere. Above all, we must remember that many processes take time, sometimes multiple generations, and "integration" cannot be achieved by waving a magic wand. Seen from this perspective, successes that have already been achieved are more visible.

The primary data you collected is being added to the GESIS research database, which has an open access commitment. Who has been using the data so far?

The data has quite a lot of users from various disciplines. We also regard our project as a major infrastructure project, so we are also gathering data on variables that lie outside our immediate area of research that could be of interest to other migration and integration researchers – for example on topics like religiosity or xenophobia.

What kind of outlook does your research give us?

Our results show that many aspects of integration are proceeding well. This is certainly underestimated, partly because of the negative examples and bad news that tend to dominate in the public eye and in the media. Compared with what we might have expected, the findings are by no means a cause for pessimism, especially in structural terms. But there are also things that should be examined and analysed in more detail.

In some regards cultural and social integration are lagging behind some people's expectations. For some migrant groups, even in the second generation, certain basic attitudes and orientations still vary significantly from the majority, and in some cases social networks tend to be very closed, ethnically speaking. One important and largely unresolved question is to what extent such cultural and social differences constitute absorbable "horizontal" differentiations, or whether they have longer-term "vertical" consequences, whether they are relevant to social cohesion at a macro level or not.

Interview by Dr. Rembert Unterstell

The Children of Immigrants Longitudinal Survey in Four European Countries uses school-based, representative samples.

Sample size (response rates as %) in individual countries

	England	Germany	Netherlands	Sweden	Total
Schools*	107 (14.7/37.4)	144 (52.7/90.4)	100 (34.9/68.8)	129 (76.8/–)	480
Classes	214 (100.0)	271 (99.6)	222 (94.5)	251 (98.8)	958
Pupils	4315 (80.5)	5013 (80.9)	4363 (91.1)	5025 (86.1)	18716
of which: with migration background	2045	2577	1481	2454	8557
Parents	1588 (36.8)	3909 (78.0)	3248 (74.4)	2955 (58.8)	11700
of which: with migration background	594	1895	827	1217	4533
Teachers	182 (85.0)	248 (91.5)	190 (85.6)	216 (86.1)	836
of which: with migration background	43	19	31	38	131

*Response rates before first replacement / after second replacement. For more information, please refer to the Technical Report (see CILS4EU 2014a).

German Centre for Integration and Migration Research (DeZIM)

DeZIM was founded in summer 2017 on the initiative of the Federal Ministry for Family Affairs, Senior Citizens, Women and Youth. At the formal occasion marking the decision to establish DeZIM on 28 June 2017, Dr. Katarina Barley (SPD), Federal Minister for Family Affairs, Senior Citizens, Women and Youth, announced the intention to establish an institute in Berlin and a nationwide network of research institutions – regarded as the two pillars of DeZIM.

Barley set out a clear vision: "The German Centre for Integration and Migration Research will occupy a unique position in the German research landscape. We will build a long-term research infrastructure, which is needed to fill a gap in existing research and actively contribute to integration. We must counter misinformation and speculation with facts."

Kalter, who is collaborating on the development of DeZIM on behalf of MZES, commenting from the perspective of a basic researcher in this field, noted when speaking to *german research*: "Migration research in Germany is geographically distributed, with different strengths and weaknesses in different areas. In Mannheim, we mostly carry out basic research with a long-term, empirical-analytical approach, usually as part of an international network. Other institutes focus more on policy- and practice-based migration and integration research, with a different methodological emphasis. Recent trends in society are just one reason why it's time for researchers to emerge from their comfort zone to push forward dialogue and cooperation." **RU**

www.bmfsfj.de/bmfsfj/aktuelles/alle-meldungen/auftakt-fuer-deutsches-zentrum-fuer-integrations--und-migrationsforschung-/117074

Moving for the Kids?

Researchers are looking at how educational ambitions, local schools, cultural capital and neighbourhoods create pull or push factors for small-scale mobility.

Sociologists at the University of Bremen are endeavouring to describe and analyse small-scale mobility behaviour among families with and without a migration heritage. Since 2016, as part of the project "Moving for the Kids and the Consequences of Residential Segregation", they have been studying how the perceived quality of schools and neighbourhoods contributes to families' decisions to relocate. Using standardised regional data, the team led by Prof. Dr. Johannes Huinink and Prof. Dr. Michael Windzio aims to test its hypothesis "that young middle-class couples and families take context characteristics of neighbourhoods and schools into account when they decide about their residential location". The team anticipates that: "Context characteristics such as high poverty rates and high concentrations of immigrants in the neighbourhood and the school are perceived as 'push' factors. In addition, we assume that families with a migration heritage orientate their decision also towards the opportunity to preserve their cultural capital, which could possibly countervail the effect of educational motives."

The project in the DFG database GEPRIS:
gepris.dfg.de/gepris/projekt/318053447?language=en

Graphic: Adobe Stock/Christine Wulf

High Ambitions, Low(er) Grades

Examining ethnic educational inequality: understanding mechanisms with data from NEPS.

Although immigrant families often have high educational aspirations, migrants and their descendants tend to have lower educational achievements than their counterparts in the majority population. Sociologists refer to this discrepancy as the aspiration-achievement paradox. A project at the University of Bamberg, which has received DFG funding since 2017, is using empirical data to examine the question of "how high educational aspirations found among immigrant families shape ethnic inequalities throughout educational careers, both in terms of educational achievement and educational transitions". The project is part of the Priority Programme "Education as a Lifelong Process". The team led by sociologist Prof. Dr. Cornelia Kristen is describing and analysing social-structural relationships using data from the German National Educational Panel Study (NEPS). The large samples used in the NEPS will allow them "to draw comparisons with the majority population but also between different immigrant groups and to make distinctions according to generation status".

The project in the DFG database GEPRIS:
gepris.dfg.de/gepris/projekt/390731161?language=en

Transnational Mo bility in Europe

Comparing more than life situations: comparing mobility patterns in the European Union in connection with objective and subjective perceptions of social positions.

Transnational mobility is often perceived as a key factor in improving individual opportunities, both within the European Union and beyond. However, it is also known that not all migrants and migrant groups benefit equally from the opportunities afforded by mobility. Sociological research has revealed an array of differences and possible explanations relating to legal status, gender, ethnicity and class. A sociological project led by Prof. Dr. Thomas Faist at the University of Bielefeld is examining the question of "how mobility patterns and other heterogeneities influence social positions within the transnational social space of the EU". The research team makes a distinction between objective and subjective socioeconomic status. "All these issues will be explored by means of a sequential, mixed-methods research design. Data from the IAB-SOEP Migration Sample, which consists of migrants in Germany, will be analysed to determine typical mobility trajectories and to study the socioeconomic status of mobile people and their level of satisfaction within different life domains."

The project in the DFG database GEPRIS:
gepris.dfg.de/gepris/projekt/318291465?language=en

Newly Arrived in Germany

Focus on recent immigrants: data survey and analysis take account of origin-specific integration trajectories and heterogeneity among origin groups.

Current intra-European and refugee migration to Germany" is the focus of an empirical sociology research project launched in 2017, with a special focus on "immigration processes and early integration trajectories". Led by sociologists Prof. Dr. Claudia Diehl, Konstanz, Prof. Dr. Matthias Koenig, Göttingen, and Prof. Dr. Cornelia Kristen, Bamberg, the research team will collect two waves of panel data "among different groups of recent immigrants in order to adequately describe recent inflows, to answer unsettled questions in immigration and integration research and to provide relevant information for decision makers in the field". The researchers plan to "study recent migrants' immigration and settlement processes and their integration trajectories in the field of their cognitive and structural integration, ethnic and national identities, and acculturation and religiosity" with the aid of a standardised survey among recently arrived Poles, Turks, Romanians, Italians, Syrians and Iraqis in Germany. They are using a research design that enables them to "analyse potential group specific patterns while taking into account origin groups' internal diversity".

The project in the DFG database GEPRIS:
gepris.dfg.de/gepris/projekt/326921298?language=en

Empirical sociologists often rely on questionnaires. Here is an example of a questionnaire from the German part of the CILS4EU project.

Illustration: MZES/Nikolaus Hollermeier

Sabine Kugler, Steffi Deuerling, Daniel Van Opdenbosch and Cordt Zollfrank

Reaching for the Light

In the search for innovative ways of synthesising new materials, researchers are exploring a wide array of technologies and approaches – from sugar-producing single-celled organisms to biotemplates and 3D printing. In one novel technique, scientists are exploiting the sensitivity of microorganisms such as red algae and cyanobacteria.

From kitchens and bathrooms to hospitals and food-processing factories, biofilms – as familiar as they are hazardous – can form and spread quickly. To the human eye, these colonies of single-celled organisms often look like a gleaming, film-like slime. A biofilm is made of polysaccharides which the microbes produce in order to bind water. Because they are released ("excreted") outside the cell membrane, they are referred to as "exopolysaccharides". As the number of individuals in the colony increases, the film turns red or green-blue in colour depending on the organism. By this time, if not before, it's obvious that cleaning is required.

Exopolysaccharides produced by microorganisms are useful for various purposes, for example in the food industry, where they are used to make substances thick, creamy, stable, homogeneous, gel-like or moist. They give yoghurt, non-dairy drinks, syrups and sauces the desired consistency. The benefits of exopolysaccharides are also put

Illustration: Steffi Deuerling

Illustration: AG Zollfrank

Left: an "algae printer" in the centre of a phototaxis lab. Above: A group of microalgae breaks off from a colony in the direction of the light source. The algae prefer to follow the previously formed biofilm.

to good use in the energy sector. Sugar-producing algae are cultivated in reactors with large surfaces exposed to the sun. The sugars are used as the starting material for the synthesis of bioethanol, while the algae themselves can be turned into biodiesel or biogas.

In the production of paints, cosmetics, oil and pharmaceuticals, microbial polysaccharides are valued for their homogeneous long-chain structure as well as their composition, which can be genetically influenced to fit requirements, and the associated properties: solubility in water, biodegradability, bioactivity and biocompatibility. In future, this list of positive attributes might include benefits such as microstructuring, mould-making or prototype manufacturing. But we're getting ahead of ourselves.

3D printing, properly known as computer-controlled additive manufacturing, began in the 1980s with the process of hardening plastics. Since then, it has evolved from an important tool in prototype manufacturing to a universal production routine, used in numerous applications. The key areas of research in 3D printing are the improvement of surface quality and the reduction of the size of individual structures.

Significant progress has been achieved in many applications in recent years, for example in photolithography, which has become a key method in semiconductor and microsystems engineering for the production of integrated circuits and other products. An image is transferred from a photomask to a light-sensitive photoresist by exposing it to light. The exposed areas of the resist are then dissolved, leaving a lithographic mask which can be further processed by means of chemical and physical methods. Using hardened polymers, it was possible to reduce the optical resolution limits, and thus produce additively manufactured three-dimensional structures with features less than 100 nanometres in size.

The equipment used is designed to be compatible with the target materials. Inorganic materials can be manufactured by templating an additively manufactured polymer negative. The cavities of the complete printed structure are filled in and the negative is then removed. A similar procedure has been used for natural materials since the late 1960s.

Manufacturing small three-dimensional structures from a range of materials is the main challenge for researchers in biotemplating, also known as replamineform. The principle, at least, is straightforward. Natural materials have a hierarchical structure, the smallest structural units being no larger than 100 nanometres. These, like the additively manufactured polymers described above, are used as the "templates". In the terminology of material modelling and mould-making, this corresponds to a "lost form". The resulting materials are typically ceramics or metals, whose properties are based on the complex structure

of the template. One example is carbide ceramics templated from wood, which can be freely formed thanks to the prior processing of the template.

Anecdotally, the first artificially produced three-dimensional photonic crystals – structure-based light reflectors with complete band gaps in the visible range – were manufactured with the help of a biotemplating process. Biological reflectors obtained from jewel beetles were then transferred to a ceramic material using this process. Since then, photonic crystals of this type have also been produced with the help of photolithographic processes.

Another example of materials made with biotemplating are linear conducting or semiconducting electronic structural elements. These are templated on biological structures such as polysaccharide or protein strands, or even viruses. Typically, biotemplating uses a liquid to achieve infiltration of the biotemplate.

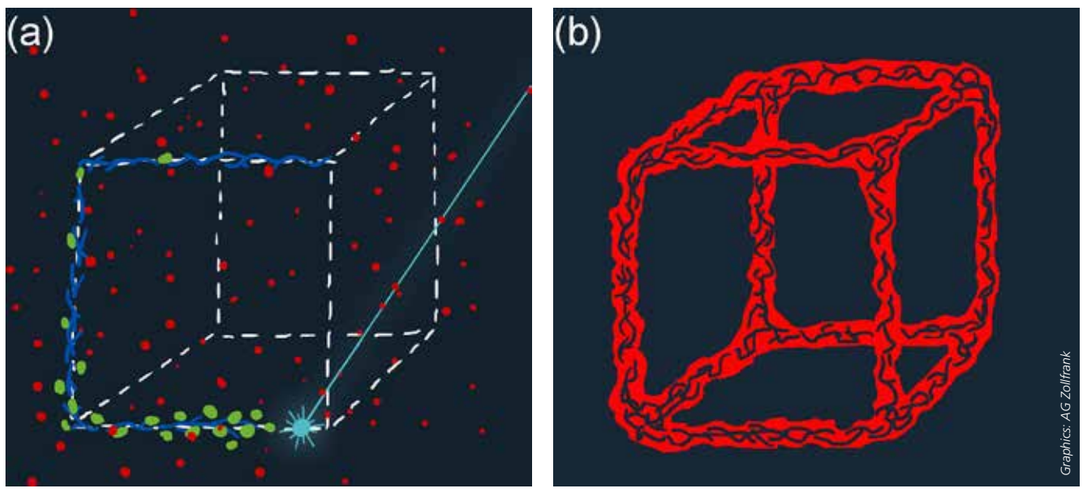
Researchers are currently working to unite these three fields – microbial exopolysaccharide synthesis, additive material structuring and biotemplating – with DFG funding through a Reinhart Koselleck project. The team is exploiting a characteristic of many microorganisms that secrete exopolysaccharides: their capacity for phototaxis. A little explanation is in order. Positive phototaxis refers to movement towards a light source and negative phototaxis to movement away from it.

To maximise photosynthesis, red algae and cyanobacteria possess a combined light sensor and movement apparatus. When just one area of the culture medium is illuminated, the microorganisms gather in the bright area, where they surround themselves with a mantle of newly formed exopolysaccharides. This binds a large amount of water, making it accessible to dissolved substances – the ideal biotemplate.

Exopolysaccharides structured by phototaxis make tailor-made templates. They overcome the limitation to naturally occurring external forms. As an example, it is possible to create an end product consisting of a network of conductive paths by controlling the illumination geometry. Microbes measure a matter of micrometres across and thus form thicker biofilms. To refine the internal structure of a product, it is therefore necessary to use them as mobile "print heads" for exopolysaccharides. The strands left in the wake of a moving microbe have a smaller diameter than the microbe itself.

The research team is currently investigating the ideal way to mobilise individual microbes or groups of microbes using dynamic spot illumination. "Ideal" in this case means rapid, and most importantly reproducible, movement with continuous production of polysaccharides. Depending on the species, microbes have different preferences as to surrounding medium, light quality and quantity, growth cycles and acclimatisation phases. Technical equipment, on the other hand, does not have such delicate sensibilities. In the structuring process currently being used, the equipment is already within a cost framework that could well allow the technique to be economically viable.

Principle of "additive material synthesis", using the polysaccharides (blue) secreted during phototaxis by algae (green): Light spots and simultaneous or subsequent secretion of inorganic material (red) from a solution or suspension (left); right: structure obtained after removal of the algae template.

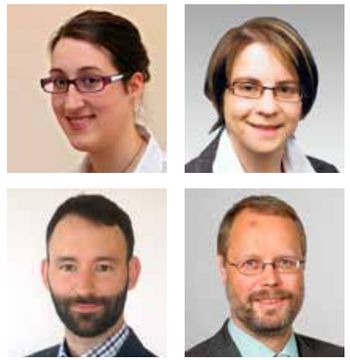


*Light-sensitive red algae (*Rhodophyta*), photographed in Runde, Norway.*

The next step in the refinement of the process is to expand it into three dimensions. While research is currently still limited to the petri dish, future work will involve the confocal illumination and height adjustment of the medium in the vertical plane. Spot illumination allows the light parameters and geometry to be relatively easily controlled and enables targeted phototaxis through rastering of the beam in the medium.

It is anticipated that holographic techniques will significantly speed up the process by allowing light waves to be spatially overlapped while they are temporally controlled as with a single spot of light. The potential advantage of spatial holographic illumination is the possibility of modulating multiple illuminated areas simultaneously.

We are beginning to re-examine the value and potential uses of microorganisms, especially microalgae, for the production of fuels and starting materials for fine chemicals. Researchers are thus turning their attention to a third area, namely the use of microorganisms as structural elements in biotemplating. This will allow further advances on the basis of existing techniques and methods used in the characterisation of microbes and their polysaccharide products. In philosophical terms, the use of single-celled organisms in an engineering process is a tribute to the enormous complexity and utility of nature, even life-forms that are very primitive when seen from the perspective of the whole of Earth's history. Material synthesis is just one area of human endeavour that stands to benefit.



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The Deutsche Forschungsgemeinschaft

The Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) is the central self-governing organisation responsible for promoting research in Germany. According to its statutes, the DFG serves all branches of science and the humanities. The DFG supports and coordinates research projects in all scientific disciplines, in particular in the areas of basic and applied research. Particular attention is paid to promoting early career researchers. Scientists and academics who work at a university or research institution in Germany are eligible to apply for DFG funding. Proposals will be peer reviewed. The final assessment will be carried out by review boards, the members of which are elected by researchers in Germany in their individual subject areas every four years.

The DFG distinguishes between the following programmes for research funding: In the *Individual Grants Programme,* any researcher can apply for financial assistance for an individual research project. *Priority Programmes* allow researchers from various research institutions and laboratories to cooperate within the framework of a set topic or project for a defined period of time, each working at his/her respective research institution. A *Research Unit* is a longer-term collaboration between several researchers who generally work together on a research topic at a single location. In *Central Research Facilities* there is a particular concentration of personnel and equipment that is required to provide scientific and technical services.

Collaborative Research Centres are long-term university research centres in which scientists and academics pursue ambitious joint interdisciplinary research undertakings. They are generally established for a period of twelve years. In addition to the classic Collaborative Research Centres, which are concentrated at one location and open to all subject areas, the DFG also offers several programme variations. *CRC/Transregios* allow various locations to cooperate on one topical focus. *Humanities Centres for Advanced Studies* are designed to support the transition in the humanities to an integrated cultural studies paradigm. *Transfer Projects* serve to transfer the findings of basic research produced by Collaborative Research Centres into the realm of practical application by promoting cooperation between research institutes and users.

DFG Research Centres are an important strategic funding instrument. They concentrate scientific research competence in particularly innovative fields and create temporary, internationally visible research priorities at research universities.

Research Training Groups are university training programmes established for a specific time period to support early career researchers by actively involving them in research work. This focusses on a coherent, topically defined, research and qualification programme. Research Training Groups are designed to promote the early independence of doctoral researchers and intensify international exchange. They are open to international participants. In *International Research Training Groups,* a jointly structured doctoral programme is offered by German and foreign universities. Other funding opportunities for qualified early career researchers are offered by the *Heisenberg Programme* and the *Emmy Noether Programme.* In so-called *Reinhart Koselleck Projects,* the DFG supports especially innovative research undertakings by outstanding scientists and academics.

The *Excellence Initiative* aims to promote top-level research and improve the quality of German universities and research institutions in the long term. Funding is provided for graduate schools, clusters of excellence and institutional strategies.

The DFG also funds and initiates measures to promote scientific libraries, equips computer centres with computing hardware, provides instrumentation for research purposes and conducts peer reviews on proposals for scientific instrumentation. On an international level, the DFG has assumed the role of Scientific Representative to international organisations, coordinates and funds the German contribution towards large-scale international research programmes, and supports international scientific relations.

Another important role of the DFG is to provide policy advice to parliaments and public authorities on scientific issues. A large number of expert commissions and committees provide the scientific background for the passing of new legislation, primarily in the areas of environmental protection and health care.

The legal status of the DFG is that of an association under private law. Its member organisations include research universities, major non-university research institutions, such as the Max Planck Society, the Fraunhofer-Gesellschaft and the Leibniz Association, the Academies of Sciences and Humanities and a number of scientific associations. In order to meet its responsibilities, the DFG receives funding from the German federal government and the federal states, as well as an annual contribution from the Donors' Association for the Promotion of Sciences and Humanities in Germany.

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Paving the way for scientific excellence in Africa: At the end of March, the Next Einstein Forum (NEF) took place in the Rwandan capital Kigali. It was an opportunity for decision-makers from academia, politics, industry and society from nearly every African state to meet with each other and their counterparts from all over the world to discuss the current situation and future development of research in Africa. What is currently the largest pan-African networking event provided numerous opportunities to meet potential cooperation partners. Prior to the event, the DFG, its Rwandan partner organisation NCST and the Science Granting Councils Initiative organised a full-day workshop on "Pan-African Initiatives for Expanding Research Capacities". The workshop participants, who included Rwandan science minister Eugene Mutimura (left) and France A. Córdova, director of the US National Science Foundation (right), discussed the importance of basic research in relation to the region's development goals. DFG President Peter Strohschneider (middle) called for both impact-driven and knowledge-driven research to be regarded as integral components of the research and innovation system.