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Should we be afraid of NEUROSCIENCE?

OUR GUEST

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THE UNESCO Courier

Editorial

In the field of neuroscience, reality has already surpassed fiction.

Who could have imagined that it would one day be possible to implant false memories in an animal's brain, or to dictate a text to a computer by using thought alone? This is now a reality – and the technological revolution is only just beginning.

These advances are promising when they make it possible to find treatments for mental or neurological pathologies, or when they give a totally paralysed patient the possibility of communicating, or regaining some mobility.

But the ethical questions that neuroscience raises are commensurate with the hopes it generates. This is all the more true as its range of applications extend far beyond the medical sector – to include marketing, education, and even video games.

To the extent that it becomes possible to read and transmit brain data, the issue of the exploitation of this data for commercial or malicious purposes becomes acute. There is a risk that these technologies will be used to monitor, manipulate, or even modify, our most private thoughts.

This is because neuroscience has the particularity of interacting directly with the brain – that is, with the part of ourselves at the very foundation of human identity, freedom of thought, free will, and privacy.

While there are laws to protect privacy and consumer rights, the specific threats related to neuroscience have not been legislated for. Conventions and treaties protecting human rights do not cover particular areas such as the protection of free will or mental privacy. With the exception of some countries – notably Chile and some others – few have begun to strengthen their legal arsenal to protect the "neurorights" of citizens.

It is therefore urgent to establish safeguards to fill these gaps and guarantee the effective protection of citizens against the possible use of their brain data. This is what UNESCO's International Bioethics Committee recommends in its latest report. And it is precisely the purpose of the debate led by UNESCO within the United Nations system to develop a global framework for the governance of neurotechnologies.

Agnès Bardon

Should we be afraid of NEUROSCIENCE?

© Inria - PARIETAL / Photo Kaksonen

A visualization of brain white matter nerve fibres.

Hervé Chneiweiss

Research director at the National Centre for Scientific Research (CNRS), France, and Chairperson of UNESCO's International Bioethics Committee.

Protecting our brain power from being coveted

Dictating a text just by thinking about it? Expanding your memory with brain implants? Creating memories in a mouse's brain? While these innovations are still at the experimental stage, they are no longer in the realm of science fiction. Advances in our understanding of the brain's mechanisms are now making possible what seemed unthinkable only a short while ago. While this progress holds great promise for the treatment of certain diseases, it also raises important ethical questions. In its latest report, UNESCO's International Bioethics Committee warns of the possible infringement of human rights that the use of these new technologies entails.

Traces of healed trepanning [an ancient practice of drilling a hole in the skull] scars show that our ancestors knew that our brains are essential for our survival even in prehistoric times. In many countries, death is now determined by the irreversible cessation of brain activity. Brain activity is the basis of our cognitive state and is unique to each individual – but its principles are shared. By analysing the activity of the brain, we are therefore able to gather information that is inherent to us all – beyond differences in gender, nationality, language, or religion.

Brain activity is central to our idea of human identity, freedom of thought, autonomy, privacy, and our fulfilment as human beings. As a result, the recording ("reading") and/or modulation ("writing") of this activity using neurotechnology has ethical, legal, and societal implications.

The birth of a technology capable of recording brain activity dates back to 1929, when the German neurologist Hans Berger (1873-1941) showed that it was possible to record changes in the electrical potential of the human brain by using an electroencephalography (EEG) machine. This led to important advances, such as the accurate diagnosis and treatment of many forms of epilepsy. Since the 1950s, these techniques have been developed, making it possible to collect the electrical activity in specific regions of the brain, and to stimulate them.

Cracking the brain code

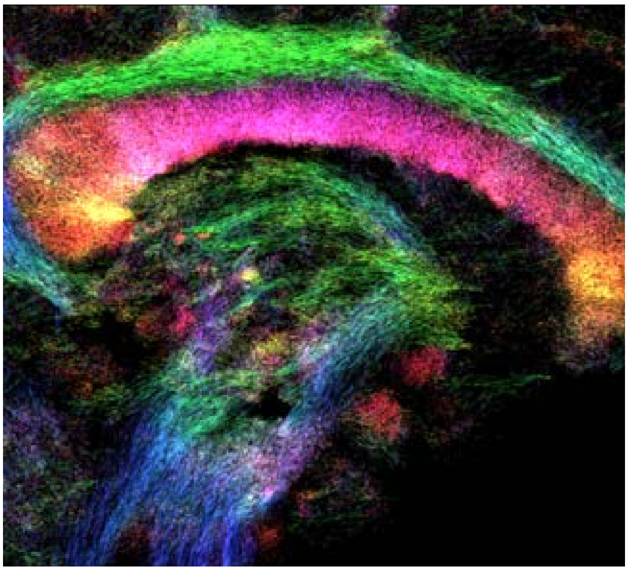
Neurotechnology can be used to identify the properties of nervous system activity, to understand how the brain works, diagnose illnesses, compensate for a faulty neuronal circuit, or control brain activity. Today, it is possible to interact with the nervous system via implants, to modify its activity – to restore hearing, for example. Another advance is the use of deep brain stimulation to treat certain forms of Parkinson's disease.

But the most spectacular developments concern brain-computer interfaces (BCIs), which are designed to record brain signals and "translate" them into commands to control technology. For example, a man who was unable to speak after a stroke ten years earlier, was able to produce sentences using a system that reads the electrical signals from the speech-producing areas of his brain. This type of device combines physical elements (electrodes) with artificial intelligence (AI) algorithms.

Investment in brain research has accelerated in recent years. In 2013, the United States launched the BRAIN Initiative, while the European Union has developed the Human Brain Project. Australia, Canada, China, Japan, and the Republic of Korea have also developed extensive programmes to "crack the brain code". The aim is to better understand the structure of the brain and mental processes, and to develop new technologies to treat certain diseases and compensate for some forms of disability.

A promising market

The stakes are high. Diseases of the nervous system, both neurological and mental, account for a significant part of our health-care expenditure. The annual costs – estimated in 2014 at over 800 billion euros each year across the European Union – are immense. The global annual cost of Alzheimer's disease alone is expected to reach €2 trillion by 2030. Multiple sclerosis is the main cause of disability in young people, thirteen per cent of the population is affected by migraines, and strokes are set to become the leading cause of death. Neurotechnology can offer some solutions to treat these diseases.



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The image shows a sagittal cut of the brain of a young healthy adult. Magnetic resonance imaging (MRI) allows non-invasive, highly accurate brain measurements.

UNESCO's International Bioethics Committee: Recommendations

Neurotechnology is set to play an increasingly important role in our lives. For better, when it comes to providing solutions to treat certain neurological or mental illnesses. And for worse, if it opens the door to the unconsented exploitation of our brain data.

It is precisely these unprecedented ethical and legal issues raised by the advance of neuroscience that have been addressed in the latest report of UNESCO's International Bioethics Committee (IBC). The report makes a series of recommendations, while advocating for the creation of a new set of human rights, called "neurorights".

This is because neurotechnologies, which make it possible to record and transmit neural data, have the potential to open up access to information stored by the brain. The issue is all the more sensitive as this data is increasingly used by the medical sector – but also by industry, marketing, and the gaming industry.

While legal frameworks exist to protect privacy and consumers, there is currently a virtual legal vacuum when it comes to the ethical risks associated with neurotechnology. The human rights protection system itself does not cover all aspects of neuroscience, such as mental privacy or free will. The report, therefore, calls on each country to guarantee the neurorights of its citizens by adopting laws that protect their right to mental privacy and freedom of thought. The IBC stresses the need to pay special attention to children and adolescents, because of the plasticity of their developing brains.

The Committee also calls on technology companies to adhere to a code of conduct for responsible research and innovation, and on researchers to respect the principles of confidentiality, security, and non-discrimination.

The media, the authors of the report point out, also has a specific role to play, in objectively explaining the issues surrounding neurotechnology, so that the public can make informed decisions about what is and is not acceptable.

Finally, the report recommends that UNESCO take the lead to ensure that all humans have a right to the protection of their brain activity, so that the data collected can only be used, published or traded with the informed and explicit consent of individuals.

The Organization is currently leading international discussions to develop a road map that will serve as the basis for a global framework for the governance of neurotechnology.

A market like this whets appetites, and not just in the field of medicine. Recently, more than a billion dollars were invested in Neuralink, entrepreneur Elon Musk's brain-machine interface company, to develop brain implants to improve memory. Ultimately, the project aims to hybridize the brain and AI. And Facebook paid about $1 billion to acquire CTRL-labs, a brain-computing startup working to develop augmented-reality glasses that will be able to transcribe thoughts onto a computer screen without the need for a keyboard.

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The OpenViBE brain-computer interface software – a collaboration between France's National Research Institute for Digital Science and Technology (INRIA) and the National Institute of Health and Medical Research (INSERM) – allows a computer to be controlled by thought.

“The growing non-medical use of brain data poses a challenge for human rights

The fact is that brain data – which contains unique information on the physiology, health and mental status of an identified individual – has become a sought-after commodity that goes far beyond the medical sector. The neurotechnology market is looking to expand into other areas, such as affective computing, which aims to interpret, process, and simulate different human emotional states; and neurogaming, a form of gaming that involves the use of a brain-computer interface, allowing players to interact without the use of a traditional controller. Another area is neuromarketing, which studies the brain mechanisms that may be involved in consumer behaviour. And education is yet another field in which neurotechnology can be applied.

Ethical challenges

This growing non-medical exploitation of brain data poses challenges for ethics and human rights. To the extent that it exposes individuals to intrusion into their most intimate privacy, to the risk of their personal data being hacked, and to a breach of confidentiality and digital surveillance, it requires governance to be put in place.

In its latest report, UNESCO's International Bioethics Committee (IBC) highlights the benefits that may result from the development of neurotechnology. It also warns of the possible infringements of fundamental human rights that these advances may cause – human dignity, through respect for the integrity of each individual's brain; freedom of thought, if devices interfere with our capacity for judgement and decision-making; privacy, in case of bias in the algorithms used; the risk of abusive, unauthorized, or coercive use for malicious purposes; and informed consent. The report also raises the specific question of the interests of the child, since childhood is a crucial period of brain development in the life of the individual.

In view of these challenges, the IBC considers that "neurorights" – intended to protect our brains from the risks to which they are exposed by the development of neurotechnology – encompass some human rights that are already recognized by international law. But given what is at stake, these are sensitive rights that need to be emphasized. These rights are based on the recognition of the fundamental rights of all individuals – including physical and mental integrity, mental privacy, freedom of thought and free will, and the right to enjoy the benefits of scientific progress. The report also stresses the need for people to decide freely and responsibly on issues related the use of neurotechnology, without any form of discrimination, coercion, or violence.

R. Douglas Fields

A fellow of the American Association for the Advancement of Science, and adjunct professor at the University of Maryland, United States. His latest publication is the 2020 book, *Electric Brain: How the New Science of Brainwaves Reads Minds, Tells Us How We Learn, and Helps Us Change for the Better.*

Hacking the brain: More fantasy than reality

Although there has been spectacular progress in neuroscience in recent decades, the possibilities that have been opened up by the development of brain-computer interfaces are not infinite. An extremely complex mechanism, the brain has far from revealed all its secrets.

In 2016, the United States Department of State reported that personnel at the US Embassy in Havana, Cuba, were attacked by a neuroweapon that caused traumatic brain injury. After intensive investigations produced no evidence of any type of direct energy weapon, the reported brain injury, which takes various forms, is now called the "Havana Syndrome".

The prospect of mind control by using electrodes implanted in the brain or by beaming electromagnetic, sonic or laser light through the skull has a long history. Notably in the 1950s and 1960s, advances in electronics enabled neuroscientists to insert stimulating electrodes into the brains of experimental animals and humans to investigate how the brain functions and controls behaviour, both normal and abnormal. Public alarm swelled as leading neuroscientists advocated using radio-controlled brain stimulation to correct deviant behaviour.

During the Cold War period, brainwashing techniques to reprogramme the brain and overwhelm the free will of hapless victims grew out of new research in psychology and psychopharmacology. The scare of brainwashing soon vanished, as it became obvious that the idea of covert mind control was a fantasy.

An Orwellian perspective

Today, stunning advances in brain science and new sophisticated technology to monitor and manipulate brain function are fuelling renewed fear of neuroweapons and mind control. Electroencephalography (EEG), magnetic resonance imaging (MRI) of the functional brain and other methods can be used to reveal a person's thoughts, emotions, and intentions. Brain-computer interfaces (BCI) can enable information to be read out of the brain into computers to control prosthetic limbs, and information can be delivered into the brain through electrodes to generate sensations, emotions, or restore rudimentary vision to the blind.

Recently, it has even been made possible to get two people to play video games "telepathically". Information can be picked up from one person's brain and transmitted over the internet to stimulate the brain of a recipient to enable two people to co-operate over long distances – that is, with their intercepted thoughts and involuntary responses commanded by computers detecting, transmitting, and generating electrical activity in the brain.

These experiments are real. However, the prospect of anything like mind control by electrical stimulation is recognized as being vastly beyond the technical capability and biological feasibility of achieving. "Could a ruthless dictator stand at a master radio transmitter and stimulate the depth of the brains of a mass of hopelessly enslaved people? This Orwellian possibility may provide a good plot for a novel, but fortunately it is beyond the theoretical and practical limits of electrical brain stimulation," José M.R. Delgado (1915-2011), the Spanish neuroscientist, concluded in his 1969 book, *Physical Control of the Mind: Toward a Psychocivilized Society*.

As scientists have learned so much more about how complex the human brain is in the half century since Delgado made that observation, this fact has only become more obvious. Neuroscientists do not understand how information is coded and processed in neural circuits. Therefore, it is impossible to "read out" or "write in" information into and out of the brain as is popularly assumed.

Complex neural circuits

Brain-computer interfaces work by recognizing neural firing patterns accompanying specific functions, much like Amazon algorithms that crunch massive amounts of data to predict what movie or book you might want to purchase next. This read-out and analysis of neural information via implanted electrodes, EEG, or functional MRI, requires prolonged repetition and intense co-operation and practice by the participant to enable the computer programme to recognize that a certain pattern of neuronal firing is associated with, say, an intention to move a finger.

> **"The progress of neuroscience is not in itself a cause for concern. It is the use to which it is put that is the problem**

In this sense, BCIs work much the way we learn to shift gears in an automobile by listening to the sound of the engine. Furthermore, these interfaces require that the brain learn through trial-and-error how to generate those particular neural firing patterns that the computer can use to carry out the intended function.

Likewise, inputting information into the brain is not possible in anything like the way it is popularly assumed and feared. Simply because we don't know how. The neural code is not known. Even if that information code were known, which neuron to stimulate out of the billions in the human brain to evoke an intended function is not known. Scientists can predict which brain region to stimulate, but not which neuron. Moreover, a neuron in a particular spot of one person's brain that controls a specific function will not be the same neuron in another person's brain. Finally, stimulating one neuron would not be adequate to control a person's behaviour, because brain function relies upon the co-ordinated operation of complex neural circuits involving hundreds or thousands of neurons. It is impossible to stimulate large networks of neurons in a co-ordinated way to impose a specific directed behaviour for mind control.

These methods of BCI rely upon intense co-operation, repetition, and learning by the person whose brain is being stimulated. What scientists surmise is that some artificial sensation is evoked in the brain by the stimulation, and that it is the brain's remarkable learning capability and adaptability to begin to recognize that artificial event and then use it in a practical way – for example, to move a robotic arm or interpret flashes of light evoked by stimulating the visual cortex of a blind person. This is a far cry from the fantasy of covert mind control.

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Fear of the unknown

The future is unknowable. Algorithms and artificial intelligence (AI) to mine data are becoming vastly more powerful. Technology and biological understanding will continue to bring us closer to understanding how the human brain operates, and to develop means of modifying its function for medical purposes.

This progress is not in itself a cause for concern. It is the use to which it is put that is the problem. The fact is that nearly every human discovery or invention, from the atom to viruses, is ultimately turned into a weapon by our species. Throughout history, Homo sapiens seems perpetually balanced on the edge of violence and co-operation with its fellow beings. Just as the internet brought tremendous transformations and benefits to society, but also became corrupted to incite violence, there is every reason to believe that the tremendous benefits of advances in neuroscience will, someday if feasible, be subverted for unethical purposes.

For the time being, there is no evidence of mind control, nor any evidence of an attack by a neuroweapon of any kind to explain the "brain fog" and other unexplained medical symptoms of the "Havana Syndrome".

In spite of the fear and sensational press coverage of this supposed neuroweapon, it is important to balance this potential – but presently unsubstantiated – threat with the real threats that we now face. Fear of mind control pales in comparison to existing weapons of war, interrogation, torture, and brutality that are real and present threats. Ours is a species that embraces the prospect of "mutually assured destruction" with atomic weapons as being perfectly logical and justified. That is a dire reality that can be unleashed with the push of a button, not a fantasy-fuelled fear. ■

Interview by **Jenny Dare**
UNESCO

Rafael Yuste: "Let's act before it's too late"

We now know how to induce hallucinations in mice by manipulating their cerebral cortex. What we can do in mice today will be possible to do in humans tomorrow. Neurobiologist Rafael Yuste warns that there is an urgent need to put regulatory frameworks in place to protect the exploitation of our brain activity.

Chair of the NeuroRights Foundation and a professor of Biological Sciences and Neuroscience at Columbia University in New York, Yuste is campaigning for the protection of our "neurorights".

© Boris Séméniako

Your work into the brain began in Madrid, treating patients who had brain disorders, including paranoid schizophrenia. How did that lead to your career in neuroscience?

I was sent to a hospital where the most severely ill patients were being treated. A lot of them were paranoid schizophrenics and we had to interview them with bodyguards present. I was shocked to realize how smart they were. These are not people that are low-functioning, these are people like Sherlock Holmes [the fictional British detective]. In fact, Sherlock Holmes was probably a paranoid schizophrenic. I remember interviewing one of them and it was scary. This person was super-smart, and he threatened me and my family personally. He figured out where I lived from my accent and said, "I'm going to come to your house and kill your father!"

I realized that these people had amazing brains but there was a switch in them that was turned off. They used their intelligence against themselves and against society as opposed to bettering their lives and enhancing their environment. If we could only figure out what's wrong with them, we might be able to flip that switch and send them out back into the world. But we cannot do that, because we don't understand schizophrenia, and we don't understand schizophrenia because we don't understand the brain. That made me step back in my career ambitions and say, 'I really want to have an impact on these patients suffering from mental illnesses, so I'm going to have to understand the basic mechanisms of brain function'. And that's what I did with my career.

Why is it so difficult to understand how the brain works?

The reason we haven't understood the brain yet is because of the sheer number and complexity of the neurons in the brain and the circuits that they build. This is why Santiago Ramón y Cajal, [joint winner of the Nobel Prize in Physiology or Medicine, 1906] one of the founders of neuroscience, compared the brain to an impenetrable jungle where many investigators have been lost.

How does your current research into mice's brains at Columbia University help to understand how the human brain works?

In my opinion, the shortest way to reach the dream of understanding the mind is to figure out the cerebral cortex of mice. Shared by all mammals, the cortex, right under our skull, looks very similar, except for the size. Cortex means 'bark' in Latin and it covers the brain like bark. This thin strip of tissue somehow magically generates everything we are: our perception, our thoughts, our memories, our emotions – everything comes out of the firing of these neurons. We have been using mice for thirty years now, to understand brain circuits of normal mice and of mice that suffer brain diseases – the mouse models of schizophrenia, autism, dementia, Alzheimer's, Parkinson's, epilepsy, etc.

In our work on mice, we've been able to decode and manipulate cortical activity to the point that we can implant hallucinations into mice – so that they behave as if they are seeing something that they are not seeing. Scientists at the Massachusetts Institute of Technology (MIT) in the United States have implanted false memories into mice. This leads to the entire privacy issue of reading not just thoughts, things you are conscious of, but even worse – decoding your subconscious brain activity.

> **"Neurotechnology will lead to a new renaissance in our history**

These types of experiments have made me more and more passionate about the idea behind NeuroRights to protect the human brain, because these methods can change behaviour. We can end up manipulating a mouse as if it were a puppet. What we can do in mice today, we can do in humans tomorrow.

The NeuroRights Foundation, of which you are the Chair, engages the United Nations, technology companies, and the public on the ethical implications of neurotechnology and artificial intelligence (AI). Why should we be concerned about these issues?

In 2017, twenty-five of us met at Columbia University to consider the ethical and societal implications of neurotechnology. We represented The BRAIN (Brain Research Through Advancing Innovative Neurotechnologies) Initiative from the US, and from all the other countries that have brain initiatives and are part of the International Brain Initiative (IBI) – China, Japan, Korea, Australia, Israel, and the European Union. There were experts in building neurotechnology, neurosurgeons and clinicians, neurologists; people that came from AI; from the tech industry; experts in building algorithms; experts in bioethics and the law.

These experts also formed what we named the Morningside Group, to propose ethical guidelines for neurotechnology and AI. The first of these was the development of cerebral rights that we call neurorights. The reason we proposed this is because we think this is a human rights issue – since the brain generates the mind, the mind is what makes us human, so the core of our humanity is our mental ability, our mind. Any technology that patches the tissue that generates those mental and cognitive abilities is going to impact the core of ourselves, our humanity.

In your view, which is the most urgent neuroright that needs to be protected?

Our right to mental privacy, so that the content of our mental activity is not decoded without our consent. This needs to be done now, because neurotechnology is being developed all over the world, proudly set in motion for the benefit of patients. But there are a lot of tech companies and neurotechnology companies that have been created to exploit these methods to record the activity of the brain and link it directly to a computer – like a brain-computer interface (BCI).

The idea is that, instead of having it in your pocket, the iPhone of the future will be wearable on your head, or maybe a chip implanted inside your brain. When this happens, the data that is collected by this BCI technology will become the property of the company, because there is no regulation.

How can we ensure that the UN and governments across the world create the right legal and regulatory frameworks to protect neurorights and mental privacy in the same way that they have laws to protect human rights?

The purpose of the NeuroRights Foundation is to promote the establishment of neurorights, and we're working both with countries and the UN to consider this question of neurotechnology. In *Our Common Agenda,* the UN report [released in September 2021] which addresses the challenges to the Universal Declaration of Human Rights, UN Secretary-General António Guterres specifically mentions neurotechnology as one of the frontier issues that needs to be taken care of in the next six years.

We're also working with countries – Chile may be the best example of this. The Chilean Senate has approved a constitutional amendment that declares cerebral integrity as a basic human right. As soon as the President signs this amendment, the constitution will protect the brains of the citizens from intrusions that are not allowed by the law. That could serve as a model for other countries to follow as they set out ethical guidelines for neurotechnology.

Do you think there's scope for neurotechnology and AI to transform our societies for the better?

Absolutely, yes. I am completely optimistic. I think that neurotechnology will lead to a new renaissance in our history. We have to go full speed ahead – because of the patients, who look us in the eye every day and say 'Will you help me?'– and we have to do it with guard-rails, with intelligence. Technologies are always neutral, but they can be used for good or for bad. The onus is on us to make sure the technology is for the benefit of mankind, not a detriment to our progress.

What key message should we take away?

This is not science fiction. Let's act before it's too late.

Santiago Ramón y Cajal: The first to map the human brain

The Spanish neuroscientist, pathologist, and artist Santiago Ramón y Cajal (1852-1934) was fascinated by the brain. His intricate, beautiful, and accurate illustrations of the inner workings of the brain are still used in neuroscience to demonstrate the neural architecture that underlies memory and human thought.

In 1877, Cajal saved up the money he had earned as a medical officer in the Spanish army to buy himself a microscope. Looking through the lens, he studied and drew – free-hand but with great precision – the tiny structures within the brain, including neurons, or nerve cells.

Cajal based his work on a technique pioneered by the Italian physician Camillo Golgi (1843-1926) in 1903. Using silver nitrate to stain nerve tissue, Golgi was the first to stain neurons black, so they could be distinguished from the surrounding transparent cells.

Cajal perfected this technique, using a gold stain in 1913 to map the central nervous system. He created an extraordinary catalogue of detailed and meticulous drawings, covering different regions of the human brain, and the spinal cords of young animals.

Cajal started from the assumption – which would not be scientifically proven until the 1950s – that neurons in the brain are in touch, but do not touch each other. Known as the neuron doctrine, it states that every neuron in the brain is separate and that neurons communicate across synapses. In 1906, Cajal and Golgi were jointly awarded the Nobel Prize in Physiology or Medicine. Cajal was the first Spanish scientist to be awarded the prize.

In 2017, Cajal's archives – which included scientific manuscripts, drawings, paintings, photos, books, and correspondence – were included in the UNESCO Memory of the World register. Subsequently, there have been calls for Cajal's cultural archive to be given permanent space in a dedicated museum to showcase his discoveries and their influence on neuroscience today.

Meanwhile, Cajal's work continues to bridge science and art. In 2020, volunteers across six countries collaborated to create the Cajal Embroidery Project at the University of Edinburgh's Edinburgh Neuroscience community. The eighty-one exquisite hand-embroidered panels of Cajal's drawings were displayed at the virtual FENS (Federation of European Neuroscience Societies) Forum in 2020, and featured on the front cover of *The Lancet Neurology* in September 2021.

Lorena Guzmán H.

Science journalist, based
in Santiago, Chile.

Chile: Pioneering the protection of neurorights

Chile is set to become the first country in the world to legislate on neurotechnologies and include "brain rights" in its constitution.

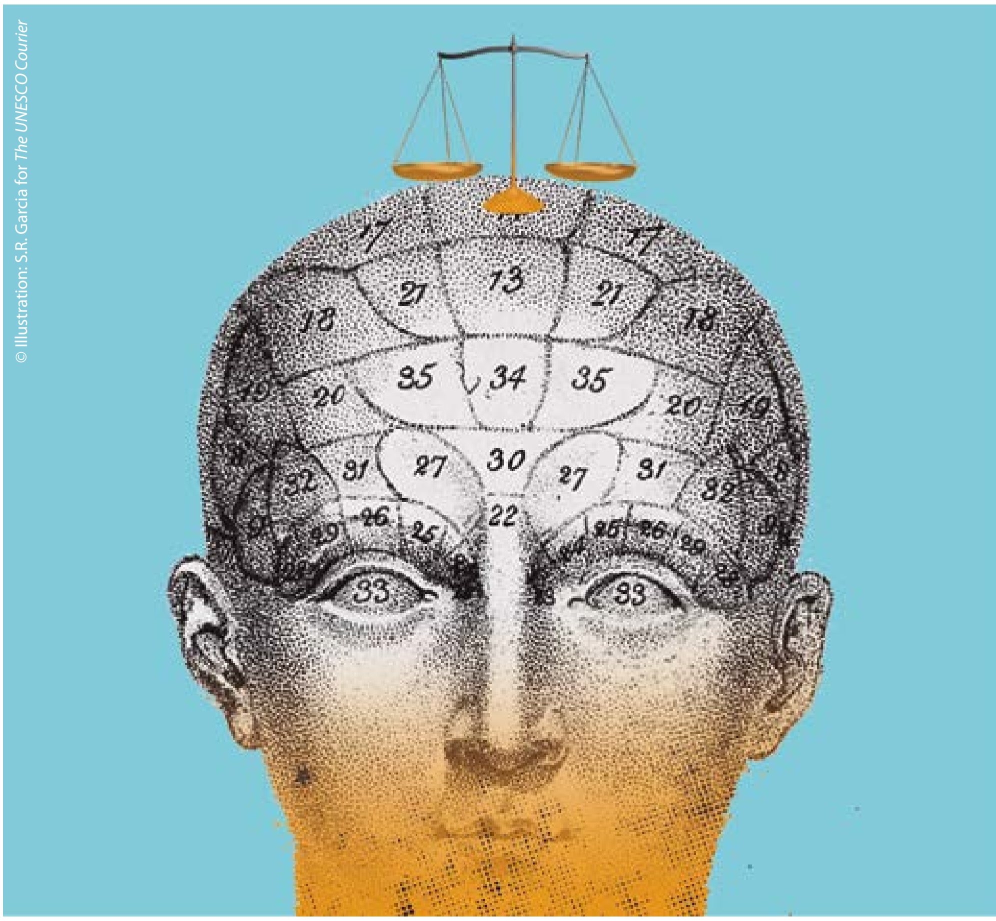
In 2021, Chile's Senate unanimously approved a bill to amend the constitution to protect brain rights or "neurorights". The Chamber of Deputies reviewed and approved the amendment in September that year. It is now expected that the bill will be signed into law by the country's president.

Once the process is completed, Chile will become the world's first country to have legislation to protect mental privacy, free will and non-discrimination in citizens' access to neurotechnology. The aim is to give personal brain data the same status as an organ, so that it cannot be bought or sold, trafficked or manipulated.

At the same time, a constitutional reform to amend Article 19 of the Magna Carta, the country's constitution, is being considered to "protect the integrity and mental indemnity of the brain from the advances and capacities developed by neurotechnologies".

The adoption of such a legal arsenal may seem premature in view of the development of neurotechnologies, which are still limited in their capacity to act on the human brain. But experts are already sounding the alarm and insisting on the need to legislate before intrusive applications become widespread – especially as progress in the field of neurotechnology continues to accelerate.

In April 2021, Neuralink, entrepreneur Elon Musk's brain-machine interface company, released a video of a monkey playing a video game after getting implants. The brain-machine interface technology used to do this is still in its infancy, but it opens the way to an infinite number of applications.



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Dangerous spin-offs

It was precisely this proliferation of technological advances that prompted the Chilean Senate's Future Challenges Commission to take an interest in neurotechnology three years ago. Following a visit by Rafael Yuste – a neurobiologist at Columbia University, New York, and one of the initiators of the BRAIN Initiative, a United States project to map the human brain – the Commission began to be concerned about the risks these advances pose to human security and free will.

While the development of neurotechnology offers hope for many patients – including those with paralysis or degenerative diseases such as Parkinson's or Alzheimer's – it could lead to the manipulation of the human brain.

"Regulations must evolve quickly," warns Guido Girardi, senator and president of the Commission, and one of the initiators of the legislation. "There are already technologies that can directly read the brain, decipher what people are thinking and feeling, but also implant feelings that are not one's own."

More than the technology itself, it is the potential applications that are of most concern. "If we wait for the technology to mature, we may never be able to control it," warns Carlos Amunátegui, professor at the law school of the Pontifical Catholic University of Chile, and one of the experts appointed by the Commission to draft the legislation.

"It would be naive to think that these advances will not translate into commercial applications," says Pablo López-Silva, a psychologist and professor at the University of Valparaiso. "While the development of these technologies is not a problem in itself, it can cross dangerous boundaries if there is no regulation."

Such applications, he explains, could be hacked or contain "neuro cookies" that would allow them to identify a consumer's preferences, and eventually, to implant new ones.

Legal vacuum

Chile is not the only country concerned about the legal vacuum that surrounds neurotechnologies. Spain, US, France, and more recently, Argentina, have begun to study the issue. The United Nations and the Organization of American States have also taken a keen interest in the subject.

But the task is complex. Legislation must be broad enough to be able to adapt to the evolution of new technologies, while ensuring the protection of citizens. "The drafts under discussion do not define what mental activity or neural connections are," says Pedro Maldonado, director of the Department of Neuroscience and associate researcher at the Millennium Institute of Biomedical Neuroscience (BNI) at the University of Chile's Faculty of Medicine.

> **"Legislation must be broad enough to be able to adapt to new technologies, while ensuring the protection of citizens**

The question may seem theoretical, but it is crucial to the extent that neuroscience is at the frontier between brain activity and what creates an individual's own identity. "We are much more than neuronal activity, even though this activity is clearly necessary for us to be the type of person we are," states López-Silva.

The legislation to regulate neuroscience also raises the issue of consent. Before granting permission to an application that uses data on their habits, citizens/consumers must be able to make an informed decision – that is, know exactly how the data will be used. It is therefore essential that this information is really accessible to everyone, López-Silva emphasizes.

Another key issue is access. It is essential that everyone, without discrimination, is able to benefit from the advances generated by neurotechnologies, and that they do not end up being reserved for a minority. This issue remains rather vague, however.

"How can we ensure equitable access to this technology?" Maldonado asks. "The legal texts are not clear enough on this point." ■

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Mahmoud Bukar Maina

Neuroscientist and post-doctoral research fellow at the School of Life Sciences, University of Sussex, in the United Kingdom. His research is focused on understanding the process of degeneration in Alzheimer's disease.

African neuroscience: Desperately seeking diversity

The field of neuroscience remains largely dominated by industrialized countries. Africa could still make a significant contribution to global research, provided that new policies are put in place to stimulate scientific innovation on the continent.

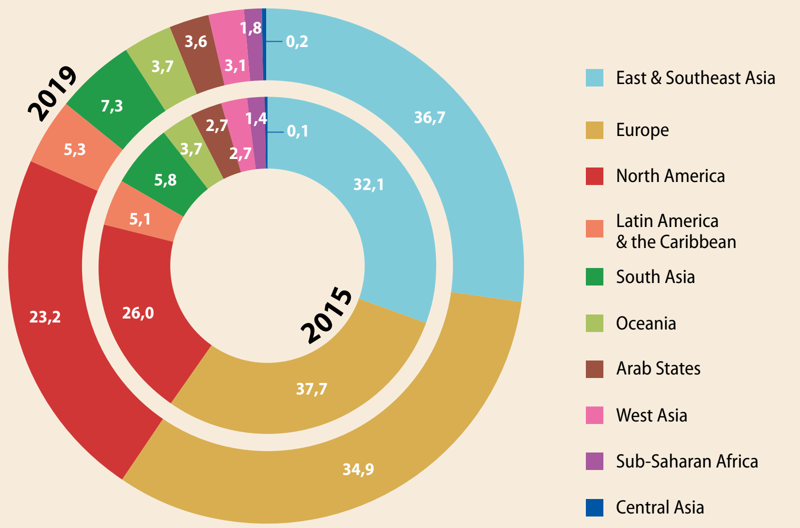
The revolution in neuroscience that is happening today is taking place away from African laboratories. This is all the more regrettable given that Africa is well-placed to participate in global neuroscience research. The continent has the world's greatest genetic diversity – which is crucial to the understanding of the processes governing human health and disease – and significant medicinal plant resources.

Limited access to scientific training, poor funding, and heavy teaching loads on scientists are all obstacles to innovation in Africa. In addition, there is a lack of reliable energy sources and research facilities. This makes it easier to understand why Africa generated only 0.11 per cent of the world's patents in 2013, according to the 2021 *UNESCO Science Report: The race against time for smarter development.*

Recognizing the importance of the global race in the field of brain research, the world's top economies – including Europe, the United States, China, and Japan – have invested in several large-scale projects to study the brain, and to the application of this brain data to accelerate the manufacture of new technologies.

In spite of its strengths, Africa is still lagging behind. To better understand this paradox, and the diversity of African neuroscience, our team analysed 5,219 articles affiliated with African institutions over two decades, and published an extensive study on the subject in June 2021.

Global percentage shares of scientific publications by region, 2015 and 2019



The sum of the percentages indicated for the different regions exceeds the total figure, as joint works by authors from different regions are counted in each of these regions.

© UNESCO Science Report: The Race Against Time for Smarter Development, 2021

South Africa, a driving force

In terms of the number of publications, Egypt and South Africa lead the way – with twenty-eight per cent and twenty-three per cent respectively, followed by Nigeria (eleven per cent), Morocco (eight per cent) and Tunisia (seven per cent). The remaining countries each produced less than three per cent of publications. However, the overall number of publications across all the continent's major geopolitical zones for basic and clinical neuroscience is steadily growing.

Neurodegeneration and brain injury are the main focus of research programmes conducted by African neuroscientists. Investigations into diseases like konzo, dementia, meningitis, stroke, epilepsy, and HIV-related neurological manifestations may reflect a growing awareness among scientists about the prevalence of these conditions and the need for more African-led research into them. By comparison, research on motivation and emotion, motor systems, cognition, and sensory systems is less prevalent.

One key aspect of integration into the global research community comes through international scientific collaborations. Here, the lack of funding and barriers related to visa processes have long made it difficult for many African researchers to engage with colleagues abroad. Even so, intra-African collaborations are not as developed as those in Europe or North America.

Another striking feature is that most collaborations in Africa are with South Africa. While some are based on historical, linguistic and cultural ties, others are primarily influenced by the availability of research resources that are more advanced in South Africa than elsewhere on the continent.

Future efforts to boost African neuroscience must therefore encourage intra-African collaborations and the sharing of resources. At the same time, collaborations with the Global North need to ensure equity so that African partners are not relegated to the sidelines and are given the opportunity to shape projects.

Advanced technologies and medicinal plants

Cutting-edge technologies have been among the major drivers of breakthroughs in neuroscience. Therefore, it is no surprise that countries that have achieved high scientific success to date are those that have access to these state-of-the-art technologies.

However, less than thirty per cent of African neuroscience publications – with the exception of The Gambia – used equipment such as fluorescence and electron microscopy, molecular biology, and cell culture. This indicates that investment in African neuroscience also requires the modernization of research tools.

Another finding specific to Africa: the study of endemic medicinal plants plays an important role in African neuroscience publications. Many of these plants have been used for centuries for the treatment of diseases, but have recently attracted criticism because of false promises by some practitioners – and even proved harmful in some cases. To document the scientific validity of these plants, African researchers, particularly those in West Africa, are investing heavily in this branch of neuroscience, to explore the therapeutic potential of medicinal plants. By contrast, this field of study is generally ignored by countries in the Global North, represented in our study by Australia, the United Kingdom, US, and Japan.

© Amy Maxmen/ACEGID (The African Centre of Excellence for Genomics of Infectious Diseases)

Detection of the Lassa virus in blood samples in Nigeria, using CRISPR, a genome editing tool. Genomic tools like this could enrich neurological research in Africa.

> **"Egypt and South Africa have the highest number of neuroscience publications on the continent**

In addition, our analysis finds the almost total absence of genetically modified model systems in African neuroscience. Due to the close genetic make-up between animals and humans, these models make it easy to enable the modelling of human diseases. The diversity of animal models in the African ecosystem is a strength for African neuroscience, as it can offer a novel perspective into animal and human neuroscience. The promotion of low-cost, genetically tractable model systems – like fruit flies, zebrafish, or the roundworm *Caenorhabditis elegans* – will further strengthen the African neuroscience landscape.

Funding and collaboration

In 2006, the African Union (AU) recommended that its member states invest one per cent of their gross domestic product (GDP) on research. However, no African country currently meets this recommendation. With the exception of Southern Africa, all countries on the continent rely heavily on funding from international sources, mainly from Europe and North America. It is no surprise then that Egypt and South Africa, which have the highest number of neuroscience publications on the continent are the only two countries investing close to the AU's recommendation.

It is clear Africa has the potential to take the lead in neuroscience. Our study highlights the growing number of scientists, scientific contributions, and the impact of neuroscience on the continent. The continent has many philanthropists and charitable organizations that can help fund scientific research to build on its research of medicinal plants and, above all, its genetic diversity. However, local funders need to increase their investments to supplement international funding, boost scientific research infrastructure, and accelerate innovation.

Alla Katsnelson

Freelance science writer and editor based in Northampton, Massachusetts, United States.

Crime: Does brain scan evidence work?

Neurotechnology has made it possible to considerably improve lie detection techniques. Although these devices are becoming increasingly accurate, they raise numerous legal and ethical questions. Evidence derived from the observation of the brain has been ruled inadmissible by most courts around the world.

In the early 1990s, physicians at the Strasbourg University Hospital in France reported the strange case of a 51-year-old man who experienced unusual epileptic seizures. More than a third of the seizures, it seemed, occurred when he lied for business reasons.

The physicians soon determined the cause of the seizures – a tumour pushing against his amygdala, the brain region that regulates emotions such as fear. Researchers think that the fear he experienced when lying, rather than the lie itself, set off the seizures. Presumably, then, similar emotions felt for other reasons would also set off the same electrical cascade in his brain, says Rebecca Wilcoxson, a forensic psychologist at Central Queensland University in Australia.

> **Studies investigating these lie detection techniques have been small**

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There is no single characteristic, in the body or the brain, that appears when and only when someone is lying, Wilcoxson explains. But over the past two decades, neuroscientists have investigated whether tracking different forms of brain activity could provide some level of lie detection to help guide law enforcement agencies.

Contested techniques

They have focused broadly on two technologies. One, called functional magnetic resonance imaging (fMRI), tracks blood flow in the brain to gauge patterns of brain activity. The premise is that telling a lie takes more cognitive load than telling the truth – and that this difference would be detectable by this form of brain imaging. By putting someone in an fMRI scanner, asking them specific questions while imaging their brain, then processing those images, researchers say they can determine the veracity of a person's statements.

The other modality, electro-encephalography (EEG), looks for a blip of electrical activity called the P300, which occurs about 300 milliseconds after a person experiences a stimulus – say, a word or a picture on a screen. The P300 signal isn't lie detection per se, but corresponds to familiarity with a stimulus, explains Robin Palmer, a legal expert on forensics at the University of Canterbury in New Zealand. So, for example, investigators could ask whether a person is familiar with elements of a crime scene or with a murder weapon.

Some studies suggest that when used correctly, these techniques can be highly accurate – significantly more so than a polygraph test. But their use raises many issues. In the United States, brain-based lie detection was presented as evidence in a couple of criminal cases about a decade ago. However, the use of the technology was challenged on appeal and found not to meet the Daubert standard, which determines the admissibility of scientific evidence in court.

Today, these techniques are still considered inadmissible in most countries worldwide. Early on, law enforcement agencies in India and Japan used EEG-based lie detection technology, but they no longer do, says James Giordano, a neuroscientist and ethicist at Georgetown University Medical Center, Washington DC.

© Illustration : François le Loup for *The UNESCO Courier*

Guilty verdict

In 2008, India became the first country to convict someone of a crime relying on evidence from an EEG brain scan. Aditi Sharma, a 24-year old business student from Pune, was convicted of killing her ex-fiancé by poisoning him. The case generated worldwide attention, but the verdict was overturned a year later. In June 2021, Sharma and her new partner were eventually found guilty of the crime, and the veracity of the brain scan was never called into question.

Studies investigating these lie detection techniques have been small, and most participants have mainly been university student volunteers. "We have to show that it works in real life," says Jane Moriarty, a professor of law specializing in neuroscience and scientific evidence at Duquesne University in Pittsburgh, US. "We haven't shown that yet."

The electroencephalogram test is much simpler and cheaper to use, involving just a light portable headset. But its use has been mired in controversy. "Because of insufficient independent corroboration of its accuracy and reliability, it hasn't had much traction," says Palmer. He recently set out to validate the P300 signal, testing it in both university students and in people who were imprisoned for a violent crime. It worked almost perfectly in students, he reports, and slightly less well in imprisoned subjects, who were less co-operative and more impulsive. "We are satisfied that the method of detecting knowledge in the brain using P300 is generally accurate and reliable."

Searching the brain

But even so, Palmer cautions, ethical and legal issues surrounding its use abound. For example, if police believe someone has insider knowledge about a crime, can they force the person to take the test? "Is it possible to get a search warrant for somebody's brain?" he asks. He plans to work with police in New Zealand to trial the technology with paid informants, who would volunteer to take the test.

Another issue is how these tools interact with memory, explains Moriarty. Suppose you're shown a photo of a suspect, but the person looks very much like a close friend. Would your brain show a P300 signal? Similarly, an object central to a criminal case might coincidentally look like something a person is familiar with in a different context. "Those are some of the concerns I have," she says. "First, does mistaken recognition look like recognition, and second, how do you know the person doesn't recognize something in a non-inculpatory fashion?" What's more, she adds, "people taking the tests may be able to intentionally confound their own results."

There's also the danger of misuse by authorities, notes Palmer. Imagine that police arrest someone they suspect stole an object. If an officer shows it to the suspect, the person will appear guilty when tested. "That's why it can never be entrusted to police units to do this," he says. "It's got to be independent units who do the testing."

It's hard to gauge the extent to which government agencies are using such technology, experts say. The Pentagon, which houses the US Department of Defence, has supported research into high-tech lie detection, including the use of fMRI. But they are commercially available. For example, Brainwave Science, a company based in Massachusetts, US, says on its website that it has developed a P300 testing system which measures brainwaves to help law enforcement agencies in areas including national security, counter-terrorism, criminal justice, and immigration control.

> **"No brain technology on its own is sufficient to be able to make legal conclusions**

The complexity and sophistication of brain-based technologies are evolving, Giordano states. Today, no brain technology on its own is "to the point where it is sufficient as a stand-alone metric to be able to make legal conclusions as regards guilt," he adds.

But that time may not be far away. Scientists are increasingly using machine learning and artificial intelligence to pull out cleaner signals from brain data. "The 800-pound gorilla in the room is that we simply do not know how 'mind' actually occurs in 'brain'," he concludes. "What the technology is allowing us to do is to gain insights."

Florian Bayer

Freelance journalist based in Vienna, covering politics, human rights, and civil society.

Neuroscience in schools: Between a mirage and a miracle

In the 2000s, educational neuroscience was regarded by some as a tool capable of revolutionizing schools. Twenty years later, the field may not have lived up to all its promises, but it remains a relevant resource for providing scientific validation to some educational practices.

When children start attending school, they are eager to learn, to explore, and curious about their surroundings. But as they progress through school, this motivation tends to erode, and can even turn into frustration. One of the major challenges facing teachers is how to maintain, or generate, this interest beyond early childhood.

Around the year 2000, educational neuroscience was one of the most promising approaches on how to reform our school systems. Scientific research on learning mechanisms seemed to open the way to new methods that could improve concentration, develop motivation, or promote memorization in pupils. But twenty years later, the results are mixed. Although the work of researchers has led to the introduction of some promising learning devices, the revolution that was announced has not really taken place.

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Measuring the brain activity of a six-month-old baby using an electroencephalogram at the Babylab of the Integrative Neuroscience and Cognition Centre, the French National Centre for Scientific Research (INCC/CNRS) and the University of Paris. The laboratory studies the acquisition of language and the cognitive capacities of infants.

Involving students is key

When neurosciences are applied to education, they show that it is important to involve pupils in order to stimulate their attention; that it is advisable to alternate learning and testing phases; or that reactivating knowledge several times during the year enables it to be stored in long-term memory. They also point to the role of emotion and pleasure in learning, and thus question the usefulness of punishment or marking – which is often stigmatizing and not very effective. Researchers have also emphasized the value of rituals to prepare children for a work session. These conclusions are often in line with the practice of teachers.

"I teach mathematics and physics, which is why neurological explanations and evidence appeal to me," says Gerald Stachl, headmaster at a high school in Wiener Neustadt, about fifty kilometres from the Austrian capital. "We have experienced many of the findings of neuroscience empirically in the classroom, but it is good to have scientific confirmation of this," he says. For example, studies have shown that the division of lessons into fifty-minute segments is poorly suited to the learning pace of students.

From theory to practice

While some of the work of neuroscientists raises interesting issues, it is difficult to transfer laboratory data into the classroom. The centralization of the education system, regulations, and curricula leave little room for experimentation. What's more, we are only just beginning to understand

Teachers are divided about the value of using cognitive science in the classroom

© UNICEF / Bobby Shing

Neuroscience confirms the importance of participation in stimulating the attention of students. Children participate in a group work session at a school in Port Vila, the capital of Vanuatu, in 2020.

the complex mechanisms of learning. Brain scans can show which regions of the brain are activated when performing a given task. But they don't explain the psychological mechanisms at hand, which may play an even more important role. Also, each individual learns at a different pace and in different ways.

Teachers are divided about the value of using cognitive science in the classroom. "I do not see much usefulness or direct consequences of neurological research on teaching practices," says Nicole Vidal, professor at the Freiburg Advanced Center of Education in Germany. "After the initial hype, it turned out that deriving educational applications from brain functionality is not as easy as was first thought."

Stefan Hopmann, professor of education at the University of Vienna, is also sceptical about neuroscience in education. He sees only a little potential in the field, adding that there are some publications on the subject that lack scientific rigour. "A lot of common-sense pedagogical knowledge is inflated to more than what it actually is," he observes.

Instead of revolutionizing the way we teach, educational neuroscience might help us to overcome specific problems and learning disorders such as dyslexia or attention deficit, Vidal concurs.

The sacredness of grades

"The hype about educational neuroscience has ended, unfortunately," declares Thomas Mohrs, an education scientist at the University of Education, Upper Austria (PHOÖ), in Linz. He is convinced that neurodidactics is the scientific proof of what supporters of progressive education have been practising for many decades.

In particular, Mohrs criticizes the sacredness of grades and the negative effects on students of the race for performance during exams. "Fear is the number-one killer of creativity," he insists. Instead of condemning kids for "failing", teachers should encourage them to make mistakes – and learn from them. Studies in educational neuroscience confirm this again and again, he says.

"One of the most fundamental scientific principles is 'trial and error'. It is essential for any scientific progress," Mohrs adds. Only by being allowed to make mistakes can we learn from ourselves and get better, according to him. Yet schools are not geared to helping students learn from their mistakes, but rather to condemning them.

However, while pressure can be destabilizing, it also acts as a stimulus. "With no pressure at all, certain incentives might be missing," Stachl explains. The problem is that even modest pressure applied to students to ensure they pass their yearly exams almost inevitably results in kids and teachers focusing on their weaknesses instead of their strengths. The entire class then runs the risk of falling into "the trap of the average", as Austrian geneticist Markus Hengstschläger points out in *Die Durchschnittsfalle*, his bestselling book published in 2012.

Neurosciences point to the role of emotion and pleasure in learning

Stachl agrees with this point of view. "We should certainly avoid having lessons only with the entire class present," he says. To some extent, of course, better pupils can help, by being peer mentors to those who struggle. But when this is applied too often, the more advanced pupils do not get challenged enough, he argues. This is why he advocates separate learning settings in smaller groups with similarly skilled pupils. This not instead, but in addition to, the regular lessons with the entire class. Educational neuroscience supports this approach, he points out.

"The school system clearly needs reforms, but in recent years these are almost never evidence-based," says Vidal. In the absence of an overall strategy, there is a tendency to "shop around" in educational neuroscience. "This has nothing to do with actual empirical research," she claims. She also warns of commercial interests, which are often involved.

In fact, although most teachers are open to neuroscience data, no Austrian school has systematically integrated neurodidactic approaches in their teaching.

Although educational neuroscience is not the miracle cure hoped for by some, it does appear to be an additional resource for teachers, which can help them to identify practices that have proved effective. But it is important that teachers are aware of the results of this relatively new and evolving field – which is often not the case. ■

In China, new hope for the "children of the stars"

Advances in neuroscience combined with the neurochemical powers of acupuncture offer new hope for treating autistic children in China, referred to as "children of the stars".

Zhang Rong and Han Ji-sheng

Associate professor at the Neuroscience Research Institute, Peking University, Beijing, **Zhang** is a co-founder of the Autism Research Center of the Peking University Health Science Center.

Founder of the Neuroscience Research Institute and an academician of the Chinese Academy of Sciences, **Han**, a leading expert on acupuncture, holds several other distinguished positions.

As early as in the seventh century, what we now call autism had already been recorded in China. During the Sui Dynasty (581-618), Chao Yuanfang, an imperial physician, wrote in *Zhubing Yuanhou Lun* (On the Etiology of Diseases), of the so-called *hun se* (muddle-headed), *yu chi* (language delay) phenotype, saying it was "clinically manifested in a child's lack of speech and neurodevelopmental retardation".

© Tian Tian

It was not until 1943 – when the child psychiatrist Leo Kanner at the Johns Hopkins Hospital in Baltimore, in the United States, described and coined the term "early infantile autism" – that the disorder was clearly defined in medical history.

The 1988 film *Rain Man*, directed by Barry Levinson, was one of the first on-screen depictions of autism and brought sensational awareness of the condition onto the international radar – even if the view it presents is reductive.

In 2007, the United Nations General Assembly unanimously approved April 2 as World Autism Awareness Day (WAAD) to improve the public's attention to autism.

An increasing number of children across the world are being diagnosed with autism spectrum disorder (ASD), a complex developmental disorder with an early onset, with core symptoms including social interaction and communication deficits and stereotyped repetitive behaviours. About 1 in 160 children has an ASD worldwide, according to the World Health Organization (WHO).

Like in most countries around the world, families in China have been affected by autism, financially and emotionally, with no specific medical cures available in clinics.

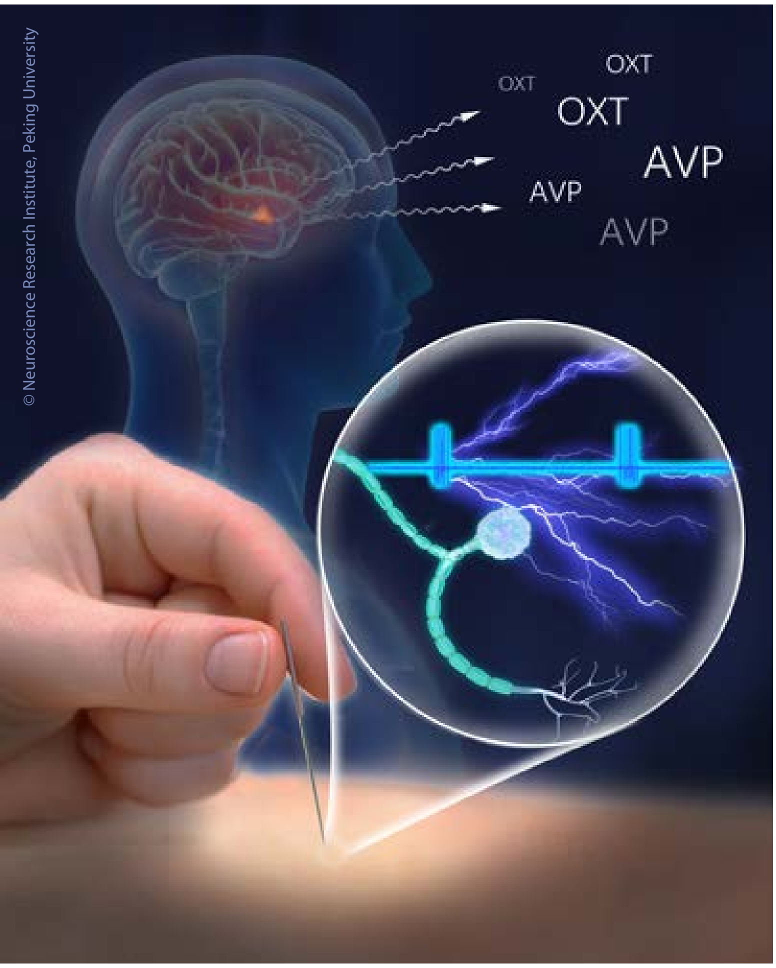
An increased awareness

Since 1982, when the concept of autism was first recorded in medical literature by Tao Guotai, a psychiatrist at the Nanjing Brain Hospital, awareness of the condition has increased considerably in China.

The diagnosis of the condition has also evolved. Government support has enabled affected families to receive better care. At the same time, research has made significant progress. Experts in the fields of child psychiatry, rehabilitation, genetics, cognitive psychology, and neuroscience, have carried out independent research while learning from the best practices of other countries.

◥ Peach Blossoms, *painted by Tian Tian, an 18- year- old Chinese boy with autism.*

© Neuroscience Research Institute, Peking University



◥ *Acupuncture can cause the release of substances that play a key role in the regulation of social behaviour.*

> **"Clinical practices have shown the efficacy of acupuncture as an alternative therapy for autism**

More recently, rapid advances in genetics have identified more than 200 genes as likely causes of ASD. A number of environmental risk factors have also been determined. These complex etiologies lead to structural and functional brain-wide alterations, which in turn lead to the behavioural phenotypes in ASD.

A promising alternative

In the absence of any real medication available for effectively treating ASD currently, and adverse reactions to existing drug therapies, early behaviour rehabilitation has long been regarded as the only effective option.

But clinical practices have shown the efficacy of acupuncture as an alternative therapy for autism. China is spearheading medical research to study this traditional Chinese medical technique, used for millennia to treat pain and other functional diseases.

Headed by Han Ji-sheng [co-author of this article], a research group at the Beijing medical school has been doing basic and clinical research on acupuncture analgesia since 1965. Recognized worldwide for its role in inducing analgesia by stimulating the release of endogenous opioid peptides, we were keen to find out whether acupuncture could also alleviate the symptoms of autistic children.

In 1997, Zhang Suikang, a well-known traditional Chinese medicine doctor from Jiangsu Province, first reported that acupuncture was effective for treating children with autism. In 1998, studies identified the association between ASD and oxytocin (OXT).

Oxytocin was first reported to be involved in maternal behaviour and mother-infant bonds in sheep by our collaborator Keith Kendrick in 1987. Subsequently, OXT and another closely related nona-peptide arginine vasopressin (AVP) have been reported to enhance socially relevant recognition, cognition, memory, reward, empathy, trust and attachment behaviours by acting on its receptors distributed in many different brain regions regulating social behaviour.

Our decade-long research on acupuncture mechanisms demonstrated that peripheral electric stimulation can induce the release of a host of neurotransmitters and neuropeptides in the central nervous system, including OXT and AVP.

In our study – which started in 2008 – we applied an acupuncture-derived technique, transcutaneous electrical acupoint stimulation (TEAS), to treat children with ASD for three months. A total of 246 children with ASD have participated in the study, from which the preliminary data has been encouraging.

The results showed that this method, combined with rehabilitation, has a satisfactory treatment effect in improving deficits in social communication and interaction, sensation, intelligence, food aversion, and even anxiety, in children with ASD compared with rehabilitation intervention.

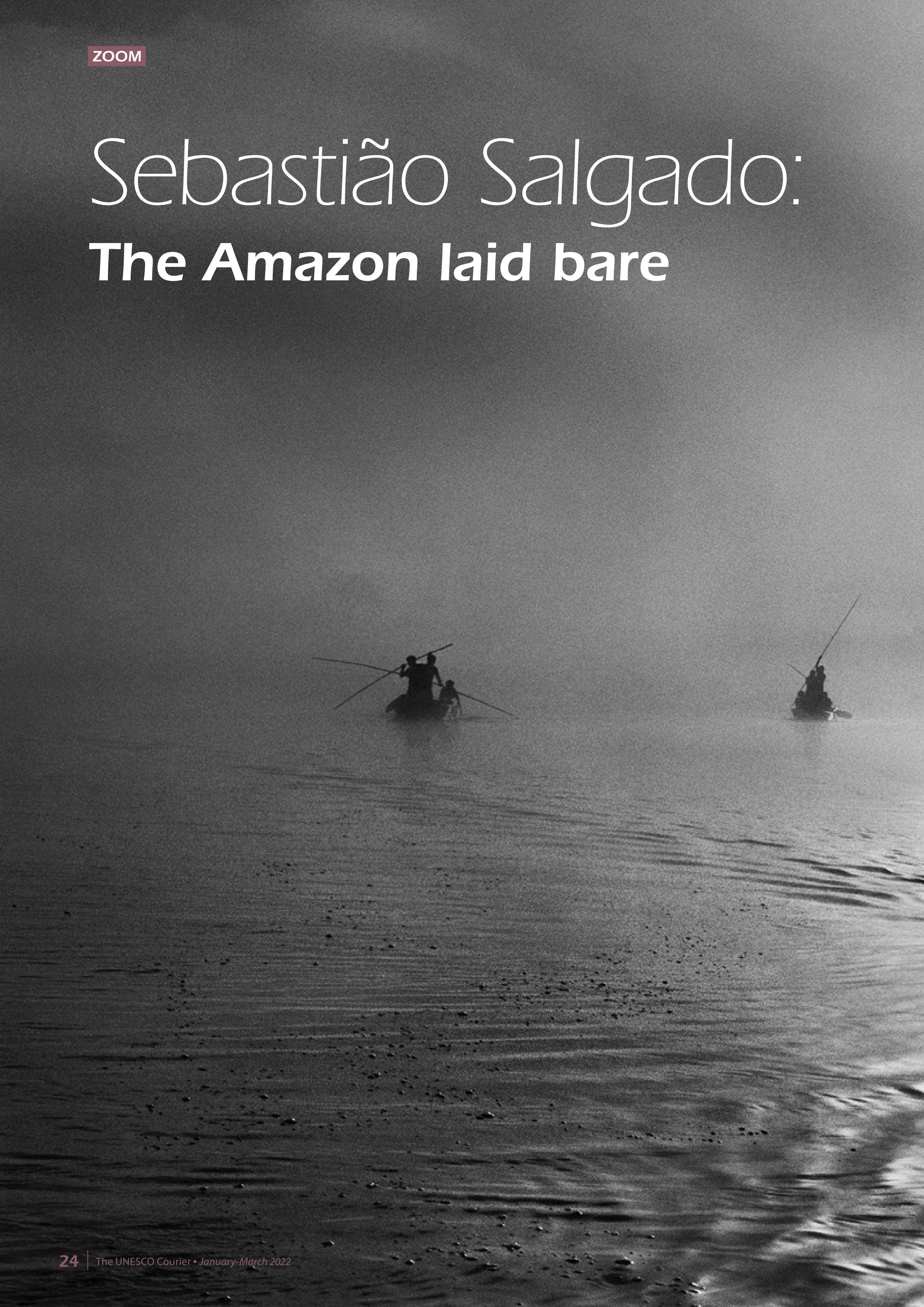
Acupuncture has been established as a safe, inexpensive, and effective means for treating functional diseases. However, there is still much more to be done to verify and understand its application in treating autism. In particular, we need to improve our knowledge of how acupuncture signals affect the brain's social interaction control centre and decode the circuits and mechanisms underlying social behaviour.

The Chinese government launched its Brain Science and Brain-Inspired Intelligence project in 2021. The project was set up to explore the neurological basis of human cognition, and to tackle major brain diseases.

The effort is significant, especially for understanding behavioural diversity. As we respect differences, and appreciate autistic communities, we hope the "children of the stars" are fully accepted as an integral part of our human family. ■

> **"About one in 160 children worldwide has an ASD, according to the WHO**

Sebastião Salgado:
The Amazon laid bare



Photos: Sebastião Salgado

Text: Katerina Markelova
UNESCO

Pages 24-25: The Indigenous Territory of Xingu, in the state of Mato Grosso, is inhabited by 6,000 people from sixteen different communities, Brazil, 2005.

Above: The Marauiá mountain range, Yanomami Indigenous Territory, municipality of São Gabriel da Cachoeira, Amazonas state, Brazil, 2018. One of the most diverse ecosystems on the planet, the Amazon is home to 16,000 species of trees.

Skies filled with inky clouds, forest-dwellers captured in the intimacy of their daily lives, mountains emerging from the vegetation. The Amazon that Sebastião Salgado shows us is not one of clichés – all luxuriance and vivid colours, with variations of bright green foliage, purple earth, and rivers irrigating the forest. On the contrary, Salgado's images portray a world in chiaroscuro, grandiose, complex. Fragile too.

For the Amazon – home to 370,000 Indian indigenous peoples, and a carbon sink that absorbs almost ten per cent of the world's CO_2 – is under threat. According to a November 2021 estimate by Brazil's National Institute for Space Research (INPE), deforestation, much of it illegal, has increased by almost twenty-two per cent in one year – with more than 13,000 new square kilometres of forest felled.

With his book, *Amazônia*, published in 2021, the Brazilian photojournalist pays tribute to the beauty of the Amazon rainforest, which he believes is still not too late to save. "My wish, with all my heart, with all my energy, with all the passion I possess, is that in

fifty years' time, this book will not resemble a record of a lost world," Salgado says. "Amazônia must live on."

In 1998, Salgado and his wife, Lélia, founded Instituto Terra, located on the photographer's family farm, in the Rio Doce river valley. To restore this land which had been degraded by erosion, the couple established a reforestation programme in Minas Gerais state, planting three million trees in twenty years.

"All the biodiversity has returned, even the jaguars, which were thought to be extinct in our region," enthuses the photographer. The Institute, which is part of the UNESCO Mata Atlântica biosphere reserve, also has an educational vocation, raising awareness about the environment. These are all objectives of UNESCO's Man and the Biosphere (MAB) programme – which celebrated its 50th anniversary in 2021, and with which Salgado is actively involved. ■

Above: A Yanomami shaman, Amazonas state, Brazil, 2014. The 40,000-strong Yanomami peoples, who inhabit Brazil and Venezuela, form the largest indigenous group in the Amazon.

Amazônia is also a photography exhibition. After Paris, Rome and London, it travels to São Paulo, Rio de Janeiro, and Manchester in 2022. Sebastião Salgado's images were also exhibited at UNESCO's 75th anniversary celebrations in November 2021.

Above: Aldeni and Josane, Yanomami Indigenous Territory, Amazonas state, Brazil, 2014. Their survival threatened by the incursions of illegal gold prospectors, the Yanomami lands, spanning 9.6 million hectares, were recognized as a protected Indigenous Territory in 1992.

Opposite, above: The inhabitants of Watoriki walk past the sacred Ceiba pentandra, a gigantic tree at the entrance to the village. Yanomami Indigenous Territory, Amazonas state, Brazil, 2014.

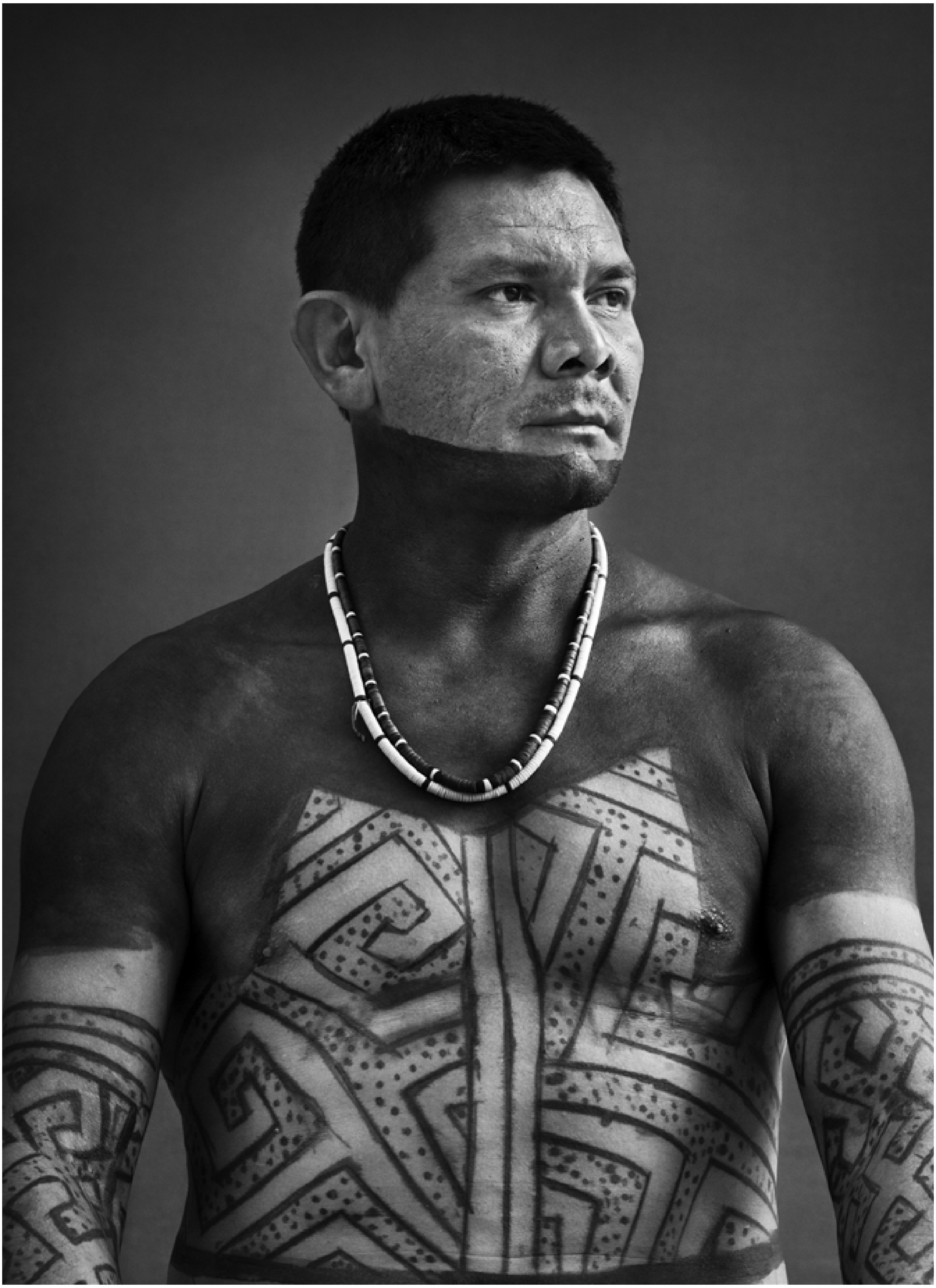
Opposite, below: Heavy rains over the Juruá River, Amazonas state, Brazil, 2009. About 1,000 litres of water evaporate daily from each large tree. These billions of trees generate a flow of moisture into the air – far greater than the Amazon rivers themselves.

Pages 30-31: The Mariuá River archipelago, Rio Negro, Amazonas state, Brazil, 2019.

Above: Manitzi Asháninka (right) and his son Tchari, or Davizinho (left), Kampa do Rio Amônea Indigenous Territory, Acre state, Brazil, 2016. An indigenous group with one of the longest-known histories, the Asháninka can trace back their economic and cultural relations with the Inca Empire to the fifteenth century.

Opposite, above: A cluster of jauari palm trees, on the banks of the Jaú River, Jaú National Park, in Amazonas state, Brazil, 2019. The spiny palm is widespread in the Amazon rainforest.

Opposite, below: Marubo Indians in the Javari Valley, Amazonas state, Brazil, 1998. As is the case with other peoples of the far west of the Amazon, the mythology of the Marubo is strongly influenced by the memory of their relationship with the Inca Empire.



Opposite: A Marubo Indian, his body painted with genipap juice, in the village of Maronal, Amazonas state, 2018. With population numbers just over 2,000, the Marubo inhabit the Indigenous Territory of the Javari Valley, one of the largest in Brazil, spanning 8.5 million hectares.

Above: Manda Yawanawá, the daughter of Jeré Yawanawá, from the village of Escondido, Rio Gregório Indigenous Territory, state of Acre, Brazil, 2016. The Yawanawá community, which had only 120 members in the 1970s, has been able to rebuild itself and reconnect with the knowledge of the elders.

Ethical fashion:

© Katie Aird

From the series Collection*, by photographer Katie Aird, who worked with designer Mabel Tallulah to create a collection made from recycled denim and velvet. Made by printing over receipts, the images by the two British artists draw attention to the waste and pollution generated by clothes that are only worn once.*

Olivia Pinnock

Fashion journalist and lecturer based in London, with a special interest in sustainability.

A rising trend or empty rhetoric?

Driven by the awareness of a growing number of consumers, the fashion industry is trying, with varying degrees of sincerity, to be more virtuous and more sustainable. But in spite of initiatives to improve recycling, promote exchanges, and the range of rental options on offer, progress to make this highly polluting sector go green remains modest.

Go into almost any high-street clothing store today and you'll find items proudly labelled "organic", "vegan" and "recycled". This would have been a rare sight even five years ago. But behind the declared desire to make fashion sustainable and more eco-responsible, the actions taken to make this happen remain limited in scope.

The figures speak for themselves. A 2020 report by Global Fashion Agenda, an industry forum on sustainability, and McKinsey, the management consulting firm, found that if the industry continues with its existing decarbonization initiatives, emissions will be capped at 2.1 billion tons a year by 2030. That's the same level the report estimates the industry emitted in 2018, accounting for four per cent of the world's total emissions.

Some countries are beginning to take initiatives to reduce the environmental impact of the industry, with relative success. For example, in the United Kingdom, Europe's largest consumer of fashion, the Sustainable Clothing Action Plan was launched in 2012. The industry-led action plan brought together ninety UK brands which make up almost fifty per cent of clothing sales in the country. They collectively set targets to reduce their waste footprint by 3.5 per cent, and the amount of clothing in household waste by fifteen per cent by 2020. However, according to its final report, released in October 2021, they reduced the waste footprint by only 2.1% and the share of clothing in household waste by only 4%.

Yet, consumers are increasingly sensitive to the ethical argument, especially since the Covid-19 pandemic. The time spent reflecting on the interconnected nature of the world, our values, and how we can build a better future, has only reinforced this trend. A global survey of readers of the fashion magazine *Vogue,* found that the number of respondents who say sustainability is an important factor when making a fashion purchase rose to sixty-nine per cent in May 2021, from sixty-five per cent in October 2020.

> **"The number of people who said sustainability was an important factor when purchasing clothes rose to sixty-nine per cent in 2021**

If fashion brands are taking steps to clean up their businesses and the majority of fashion shoppers are keen to support it, why isn't fashion doing better at shaking off its reputation as one of the world's most polluting industries? It boils down to one simple truth – the way we currently make, consume, and discard fashion items is fundamentally flawed.

Self-esteem and our desire to belong

Clothing is an essential human need, so it's no wonder that consumption has increased along with global population figures. However, clothes also tap into deeper human needs. Our desire to belong is shown outwardly by dressing in a similar manner to our peers. Our self-esteem and confidence are intrinsically linked to dressing in ways that make us feel good, and we might even attempt to garner respect from others through the labels we wear. The act of getting dressed can also be a form of self-expression and creativity for some. It's these needs which the fashion industry has manipulated to sell us more and more, sending production skyrocketing in recent decades.

Changes in the geopolitical landscape and technology have also supported this growth. In the 1980s and 1990s, fashion brands in the West gradually began to →

offshore their production to Asia, where the cost of labour is cheaper. Cheaper clothes meant more purchases, and lower quality became more acceptable to consumers as it became easier to replace items at low cost. With the advent of internet shopping in the 2000s, fashion-lovers were able to shop around the clock from a wider choice of stores. And the rise of social media and smartphones in the 2010s has provided a 24/7 marketing machine for brands to advertise products.

Between 2000 and 2014, clothing production doubled, and the number of garments purchased per person increased by around sixty per cent, according to McKinsey. The pace at which fashion collections are renewed has definitely accelerated. Fashion stores, which used to release two collections a year, now offer new lines every week. And ultra-fast, online fashion retailers aimed at Generation Z consumers, can put up thousands of new products on their sites every day.

This staggering increase in production has put enormous strain on natural resources such as cotton, including the land and water required to grow it, and on fossil fuels that are used to produce polyester. At the same time, it has increased waste in both the supply chain and at the end-of-life stage, and accelerated carbon emissions.

Jeans for rent

But there is another, more virtuous approach that rethinks the way we produce and consume products from the textile industry.

Thus, clothing recycling is easy to implement, provided that the infrastructure for collecting used clothing and transforming it into new clothing is improved.

While recycling textiles is easily doable, the infrastructure to collect old clothes and transform them into new clothes needs to be improved. As such, brands who use recycled materials are running their own take-back schemes for clothes and accessories.

Among the most innovative of these is MUD Jeans, based in the Netherlands. Their leasing model allows customers to pay a monthly fee of €9.95 over twelve months for their jeans, making high-quality, sustainably-made fashion more economically accessible. At the end of that period, customers can keep the jeans, send them back, or start leasing a new pair, enabling them to scratch the itch for a new fashion fix. Any jeans sent back are then recycled into new jeans to be sold, or leased, by the brand.

SPIN, a global community platform created by Lablaco, a company based in Italy, enables members of the public to explore options to extend the wear and life of items in their wardrobe. They can swap, rent or sell back to brands – giving them access to other people's wardrobes around the world.

> **"The production of clothing worldwide doubled between 2000 and 2014**

Post-pandemic fashion

Sales of second-hand fashion are also on the rise. Brands which traditionally only sell brand-new items are embracing it to boost their sustainability credentials while making money.

Reflaunt, a company based in Singapore, has created software that fashion brands can plug into their websites to allow customers to offer their unwanted items from the label through them. Listed on multiple second-hand marketplaces, customers receive cash or store credits once the items are sold. The platform's clients include luxury French fashion house Balenciaga and the Swedish premium high-street label Cos.

Many of these ideas are not new. Rental has long been used in the men's formal wear sector, while thrift stores have been the traditional avenue for those seeking second-hand wares. However, technology is enabling these ideas to happen more widely and more easily. And the involvement of those with fashion experience is making them appealing to a style-conscious audience. Post-pandemic fashion will not just be about what we wear – it will be a seismic shift in our relationship with it. It needs to be a relationship where business success is not dependent on churning out more and more products, and where old clothes become a resource, instead of waste. This movement also requires a more responsible and sober attitude from consumers. That is the price to be paid for a transition towards fashion that is more virtuous and sustainable. ■

© Bente Stachowske / Greenpeace

◥ *An activist disguised as a Trash Queen promotes "Buy Nothing Day" on Black Friday in Hamburg, Germany, 2016, as part of a Greenpeace campaign to reduce overconsumption.*

"

The way we currently make, consume, and discard fashion items is fundamentally flawed

Sergey Zimov:

"Thawing permafrost is a direct threat to the climate"

© Sergey Zimov

Interview by
Katerina Markelova

UNESCO

Beyond the Arctic Circle, in the heart of northern Siberia, Russian scientist Sergey Zimov has created Pleistocene Park – to reconstitute the ecosystem of the Ice Age by reintroducing large herbivore species into the former Mammoth steppe, where the soil had become severely depleted. Restoring these ecosystems could also help halt the thawing of the permafrost, a gigantic layer of glacial ice that traps billions of tons of organic carbon. As it melts, the microbes that dwell here quickly convert formerly frozen organic matter into carbon dioxide and methane. The release of these greenhouse gases as a result of climate change is a threat that has long been ignored.

● ***Why has the permafrost started to thaw?***

The release of greenhouse gases into the atmosphere is warming the planet. To date, its temperature has risen by more than 1 °C. In the northern hemisphere, in Russia for example, the warming observed is even more than 3 °C. This is because the land is warming faster than the ocean. And the land area is larger in the northern hemisphere.

But the temperature of the permafrost is not just dictated by the air temperature – it also depends on the thickness of the snow cover. When there is a lot of snow, the ground and the permafrost do not get much colder in winter. Today, the snow cover is one and a half times greater than it was several decades ago. With global warming, more water is evaporating from the ocean, and clouds are producing more snow than before. As a result, the ground temperature in Russia has risen by 5 °C to 7 °C.

Permafrost temperatures used to range between -6 °C and -8 °C in the north of Siberia and between -2 °C and -3 °C in the south. Now, almost half of Siberia is melting – the southern part of the region, but also the lower Kolyma, an area of continuous permafrost on the edge of the Arctic Ocean. Near my home, the permafrost has thawed by more than four metres in some places. In the large coastal plains of Kolyma, this phenomenon began three years ago.

Sergey Zimov, the Russian geophysicist and ecologist, founded the Northeast Science Station in Cherskii, northern Siberia, which serves as an open-air laboratory today. He is also one of the research directors of the Pacific Geographical Institute of the Far Eastern Branch of the Russian Academy of Sciences.

Zimov initiated the first experiments to reintroduce mammals into the Kolyma River basin in 1988, and created Pleistocene Park in 1996. Its mission is to restore an ecosystem comparable to the Mammoth steppe which was dominant in Eurasia in the late Pleistocene epoch – between 2.58 million years and 11,700 years ago.

● ***What are the dangers associated with melting permafrost?***

Permafrost covers 11 million square kilometres of Russian territory. These are rich soils that are full of organic matter and dormant bacteria. When the soil thaws, the old microorganisms wake up and attack what they have not had time to consume – releasing carbon dioxide when the soil is dry, and methane when it is saturated with water.

There is twice as much organic matter in our permafrost as there is in all the flora of the planet. Most of it, equivalent to 1,000 gigatons, is concentrated in the first three metres. And three metres thaw very quickly – it only takes three to five years. This is why the thawing of the permafrost is a direct threat to the global climate today. It produces greenhouse gases, and the resulting global warming in turn accelerates the thawing of the permafrost. It's very difficult to stop this process.

Under these conditions, the goals of the Paris Agreement – adopted in 2015 to move to a low-carbon economy on a global scale – become meaningless. The reduction of greenhouse gas emissions that could be achieved through the Agreement and renewable energy represents only a small part of the permafrost emissions.

→

● ***The methane released by permafrost is far more dangerous than carbon dioxide…***

If it were only carbon dioxide that was released from the melting, permafrost emissions would be equivalent to those generated by humans. But some of the gas released into the atmosphere, about ten per cent to twenty per cent, is methane. And since the greenhouse effect of methane is eighty times more powerful than that of CO_2 over short periods of time, the climatic consequences of the release of this gas can be up to four times greater than those resulting from the emission of carbon dioxide.

During the first year and a half of the Covid-19 epidemic, anthropogenic greenhouse gas emissions slowed down significantly. One might have expected the overall concentration of greenhouse gases in the atmosphere to decrease. Instead, there has been a historic increase in the concentration of methane. I regularly observe the appearance of new small springs where methane is bubbling up. I cannot see any other explanation for this high concentration.

● ***Why is the thawing of the permafrost not taken into account in the analyses and forecasts of the Intergovernmental Panel on Climate Change (IPCC)?***

Thirty years ago, the scientific community thought it knew the carbon cycle well. Nobody thought about permafrost. When I started talking about the effects of melting, it became clear that all the equations had to be rewritten. In the early years, many scientists disputed my conclusions, refusing to believe that the permafrost was melting. Permafrost has long been treated like an unwanted child in the scientific family. According to the latest estimates, it will have shrunk by ten per cent to twenty per cent by the end of the century. Awareness about it will probably come only this year, thanks to the observation of the significant increase in global greenhouse gas concentrations.

● ***Twenty years ago, you created Pleistocene Park, not imagining that it would one day contribute to climate protection. Could you tell us about it?***

I created Pleistocene Park to observe how quickly animals could transform the moss tundra into productive grassland. My main objective at the time was to solve a scientific mystery – why had the natural

© Chris Linden

Ice-filled Siberian permafrost soil revealed in a slump along the banks of the Kolyma River in the Arctic. The thick layer of underground ice is made up of ancient soils rich in organic matter. It is covered by a layer of soil that thaws in summer and allows vegetation to grow.

© The Zimov Hypothesis/Arturo Mio

A cross-section of the Duvanny Yar on the right bank of the Kolyma River – three hours by boat from Cherskii – provides a lateral view of the thawing permafrost.

As the permafrost melts, the goals of the Paris Agreement become meaningless

environment, which had known so many grasslands, horses, bison, mammoths, become so poor?

The park occupies part of the Kolyma River basin, where the vegetation is rich, and the surrounding hills are covered with larch and shrub forests, marshes and mosses. We have fenced off a portion of this land and introduced various animals: bison, musk oxen, reindeer, yaks, Yakutian horses. Today there is a 200-hectare area with a high density and another 2,000 hectares that have not yet been fully populated. In twenty years, the peat bogs have been trampled, the shrubs broken, and the amount of grass – which dries out the marshes – has increased significantly.

Our park is located in a fairly typical region of Siberia, and shows that it is possible to replace peat bogs and sparse forests everywhere with productive grasslands on dry, dense land. Most of the animals that used to live here can adapt to this environment again.

● *Why have the ecosystems of the Mammoth steppe disappeared?*

Mainly because of humans. The preservation of diverse grassland ecosystems requires a lot of effort. Moss and trees grow everywhere, and it is very difficult for grasses to resist. The maintenance of grasslands requires a lot of "gardeners". When humans began to colonize Siberia or America, they reduced the number of animals everywhere. They didn't kill them all, of course, but if there are only half as many animals, trees, shrubs and mosses will invade the grassland. Through excessive hunting, humans have destroyed these large ecosystems.

● *Your research in Pleistocene Park has shown that grassland ecosystems can slow down the thawing of the permafrost.*

Our measurements have not shown anything that is not already known. Take albedo, for example. Scientists have known for a long time that dark forests absorb the sun's rays, while the lighter, snow-covered grasslands reflect them in winter.

It is also well-established that the thickness of the snow cover has a significant influence on ground and permafrost temperatures. The specialist literature indicates that an additional ten centimetres of snow increases these temperatures by more than 1 °C.

In the grassland ecosystem, everything that grew during the summer had to be consumed in the winter. The only way to →

access the grass during the cold season is to dig through the snow. Our animals dig in the snow all winter long. This contributes greatly to the cooling of the soil.

● ***How many animals does it take to make an ecosystem like this work?***

It takes tens of millions of animals to affect the climate, about ten tons per square kilometre. Maybe even fifteen tons, with global warming. What do ten tons of animals per square kilometre represent, when a horse weighs 400 kilos and a bison 500 kilos? That's about ten animals.

© Sergey Zimov

◥ *Bison bones, sealed in the permafrost since the Ice Age, are now rising to the surface. Such finds have been common in recent years in Yakutia, particularly near rivers where the water erodes the banks.*

"

Within a decade, we could populate the Siberian ecosystems with herbivores, and have a significant impact on the climate

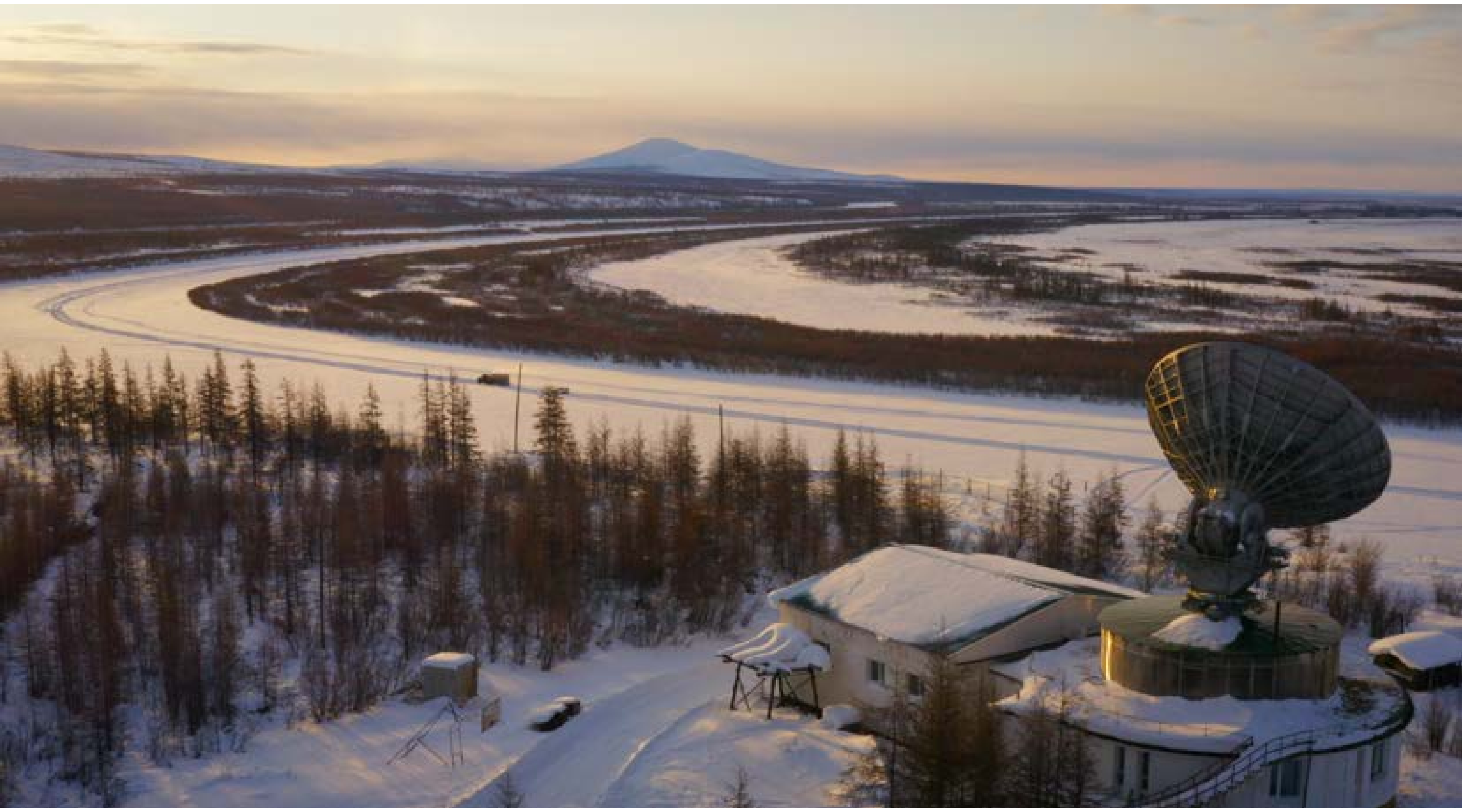
Before the arrival of humans, horses and bison accounted for sixty per cent to seventy per cent of the zoo mass, and reindeer and mammoths, for ten per cent each. The other animals made up the remaining ten per cent. Similar proportions, in fact, are found in the African savannah. Until recently, the population there consisted mainly of zebras, wildebeest, elephants, and gazelles. Our goal is to give all surviving species a chance, to help them at the beginning. Then we will let them manage their own relationships – with each other, and with their predators.

● ***Where will we find all these animals?***

First of all, you should know that even large animals reproduce relatively quickly. They can multiply a hundred times over every twenty-five years. Today in Russia, there are several million reindeer, half a million Yakutian horses, thousands of musk oxen and snow sheep. It would therefore be easy to obtain tens of millions of animals in Siberia within five to ten years, and their number could reach several hundred million in twenty-five or thirty years. In other words, within a decade, we could

© Sergey Zimov

◥ *Experiments at Pleistocene Park show that it is possible to reconstruct an ecosystem comparable to that of the Mammoth steppe – that was dominant in Eurasia at the end of the Pleistocene – across Siberia.*



© *The Zimov Hypothesis*/Arturo Mio

The Northeast Science Station in Cherskii, northern Siberia.

populate the Siberian ecosystems with herbivores, and have a significant impact on the climate.

Our family has created two parks [the second, Wild Field, is located in the Tula region, about 250 kilometres south of Moscow] on a small scale, without any state funding. We use expensive means of transportation, we move a few animals, we face many administrative problems related to health regulations and customs – and yet we have succeeded. If one family of scientists could do it, large states could easily do it through international co-operation.

● *At Harvard Medical School in the United States, a team of scientists led by geneticist George Church is working on genetically resurrecting woolly mammoths thousands of years after they went extinct. What links do they have with Pleistocene Park?*

Grassland ecosystems have all had elephants – the African elephant, the Asian elephant, mastodons, steppe mammoths, or mammoths in general. I believe that the main function of the elephant in the Mammoth steppe was to provide water sources. The streams and rivers often dry up in the summer, and the animals have to look for water several dozen kilometres away. Elephants and mammoths can dig holes to collect water in ditches. After they have drunk, other animals can also take advantage of this.

In winter, the animals eat snow and do not need water. But in Siberia, autumn is often cold, and the rivers and lakes freeze over before the first snow. At this time, animals risk dying of thirst. Mammoths could break through any ice, drink, and allow other animals to drink. In our case, we could imagine an Asian elephant with longer hair and increased fat reserves. This is what the Harvard scientists are working on. I plan to experiment this year with the adaptation of Asian elephants to our climate.

● *Which regions of the planet should be occupied by mammoth steppe ecosystems to stop the permafrost from melting?*

The entire extent of the permafrost. With the help of animals, the permafrost could be cooled by 4 °C. This would give humanity a chance to adapt to global warming. These ecosystems must be reconstituted not only where there is permafrost, but more generally, everywhere in Russia, where the territory is not exploited. It is not just permafrost that threatens the climate, but also all the land in the north that is rich in organic matter. The rate of decomposition of organic matter in the soil depends mainly on its temperature. The only way to force the soil to retain carbon is to cool it down.

We must create parks right now in many parts of Siberia – besides expanding our own, we should open parks in the Indigirka River basin; in Central Yakutia; south of the Taimyr Peninsula; in the northern Urals – and introduce animals in these parks. Then it will be necessary to expand these parks and introduce animals accustomed to the climate, and to each other, into new territories.

Forest fires in Siberia and the melting permafrost are destroying ecosystems. Every year there are more and more places where grass can grow. These are all ready-made grasslands. If we created wildernesses in these areas, nature would continue to develop on its own. Animals could then, without human intervention, help regulate climate change. ■

IN DEPTH

Linda Klaassen
and Mila Ibrahimova

UNESCO

African film: A booming industry

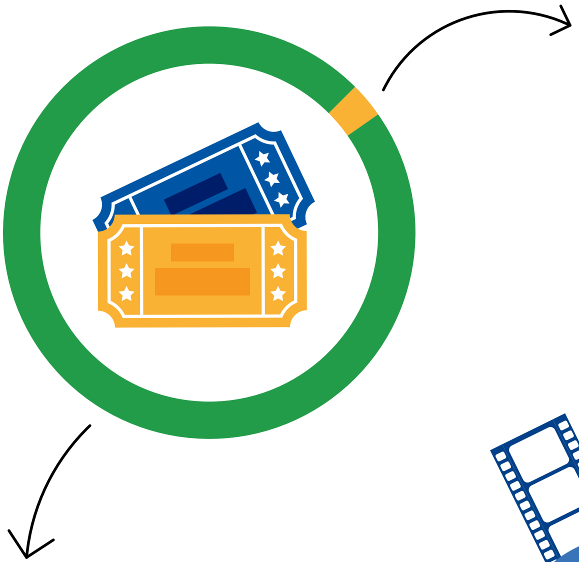
The widespread use of new technologies, the affordability of digital film equipment, and the rise of online platforms are enabling a new generation of African filmmakers to emerge. The UNESCO report, *The African Film Industry: Trends, Challenges and Opportunities for Growth*, released on 5 October 2021, reflects the vitality of African cinema, driven by digital technologies.

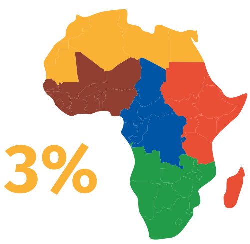
Also known as "Nollywood", the Nigerian film industry – which produces around 2,500 films a year – is emblematic of this growth. It has enabled the emergence of a local production and distribution industry with its own economic model. The real game-changer is the ongoing digital revolution, which started some twenty years ago and was accelerated by the Covid-19 pandemic.

Across most of the continent, however, the economic potential of the film and audiovisual sectors remains largely untapped, with the film industry continuing to be structurally underfunded, underdeveloped and undervalued. According to the Pan African Federation of Filmmakers (FEPACI), the industry generates $5 billion in annual revenue out of a potential $20 billion.

There are also challenges that persist in areas such as gender equality and freedom of expression. According to the UNESCO study, eighty-seven per cent of respondents said that there are explicit or self-imposed limitations to what can be shown or addressed on-screen. ■

Source: *The African Film Industry: Trends, Challenges and Opportunities for Growth*, UNESCO, 2021.





However, **AFRICA AND THE MIDDLE EAST** represent only about **3%** ($58 billion) of this global trade.

THE FILM AND AUDIOVISUAL INDUSTRIES account for $5 BILLION of the GDP in Africa, employing an estimated 5 MILLION PEOPLE.

Globally, cultural and creative industries (CCIs) are estimated to generate about **$2.25 TRILLION ANNUALLY** (3% of global GDP) and to employ 30 MILLION PEOPLE WORLDWIDE

The film and audiovisual industries has the potential to create OVER **20 MILLION JOBS** and generate **$20 BILLION** IN REVENUES PER YEAR.

Population And Countries

Number of cinema screens per region

209.1 MILLION	Central Africa	Burundi, Cameroon, Central African Republic, Chad, Congo, Equatorial Guinea, Democratic Republic of the Congo, Gabon, Sao Tome and Principe	24 Screens
494 MILLION	Eastern Africa	Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Rwanda, Seychelles, Somalia, South Sudan, Sudan, United Republic of Tanzania, Uganda	249 Screens
238.5 MILLION	Northern Africa	Algeria, Egypt, Libya, Mauritania, Morocco, Tunisia	285 Screens
228.1 MILLION	Southern Africa	Angola, Botswana, Eswatini, Lesotho, Malawi, Mozambique, Namibia, South Africa, Zambia, Zimbabwe	803 Screens
501.7 MILLION	Western Africa	Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo	292 Screens

Source: *The African Film Industry*, UNESCO, 2021

AFRICA'S CINEMA NETWORK IS THE LEAST DEVELOPED IN THE WORLD,
WITH A TOTAL OF ABOUT 1,653 SCREENS – ONE PER 787,402 PEOPLE.
This can be compared to one screen per 19,043 people in China and one screen per 215,900 people in India.

Africa's largest cinema markets

Number of screens / population coverage

		1 screen per
South Africa	663 screens	88,325 people
Nigeria	237 screens	843,881 people
Ethiopia	127 screens	882,677 people
Egypt	80 screens	1.25M people
Morocco	77 screens	473,636 people

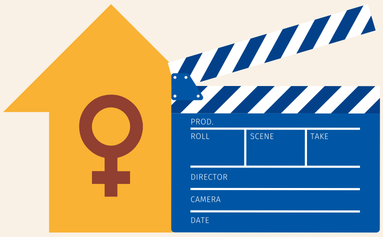
Top producing African countries in volume

Estimated number of local films produced per year

Nigeria	2,599*	Tunisia	185
Ghana	600	Ethiopia	140
Kenya	500	Zambia	105
Tanzania	500	Liberia	100
Uganda	200	Egypt	60

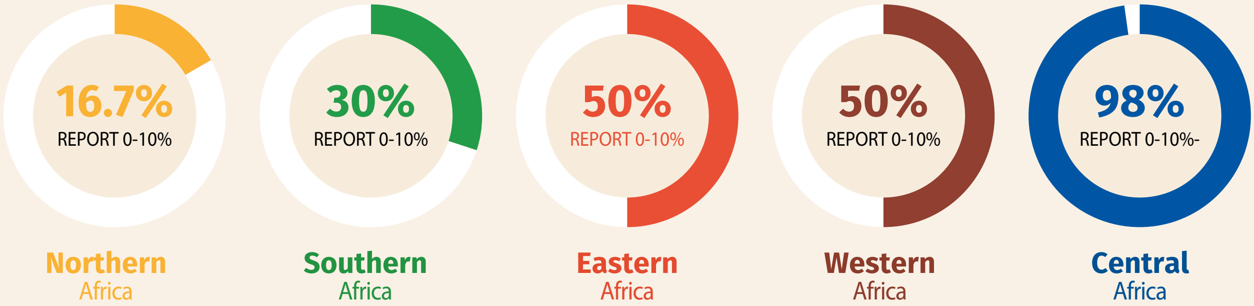
Note:
These figures were reported by practitioners and include films on DVD and VOD.
**Source: National Bureau of Statistics, Nigeria*

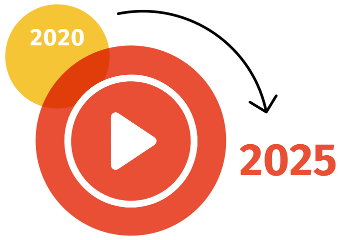
Source: *The African Film Industry*, UNESCO, 2021



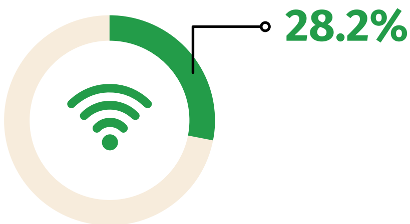
Proportion of women in the film industry

Several Arabic-speaking and English-speaking countries – including Tunisia, Morocco, Nigeria, Kenya, South Africa, Rwanda, and Zimbabwe – show encouraging dynamics, **WITH 30% OR MORE WOMEN IN FRONT OF AND BEHIND THE CAMERA.**

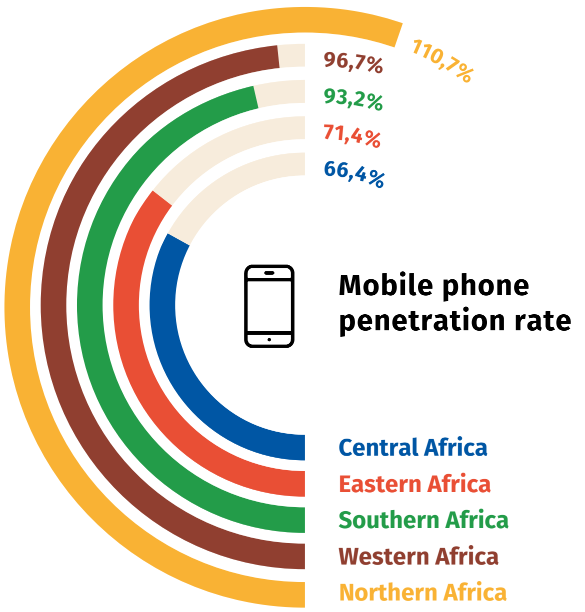


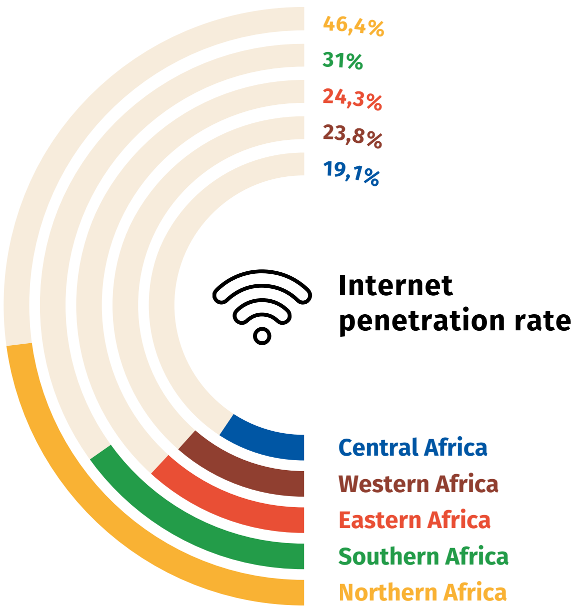


The African video-on-demand (VOD) sector is growing rapidly, with subscriptions poised to grow **FROM 3.9 MILLION IN 2020 TO 13 MILLION IN 2025,** according to business intelligence provider Digital TV Research.



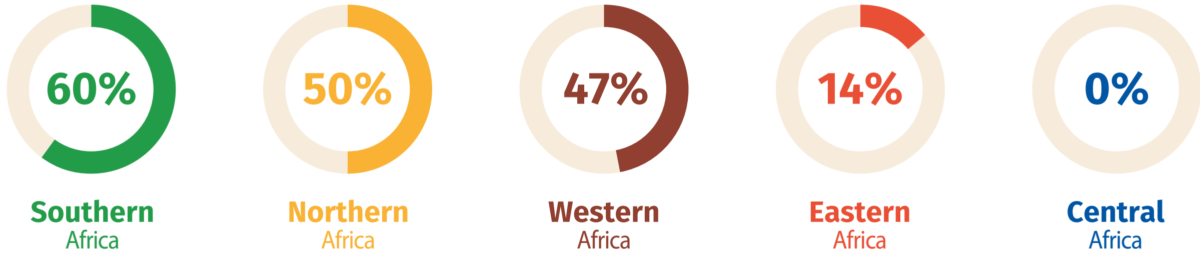
The continent remains the **WORLD'S LEAST CONNECTED REGION,** with about 28.2% of internet users.





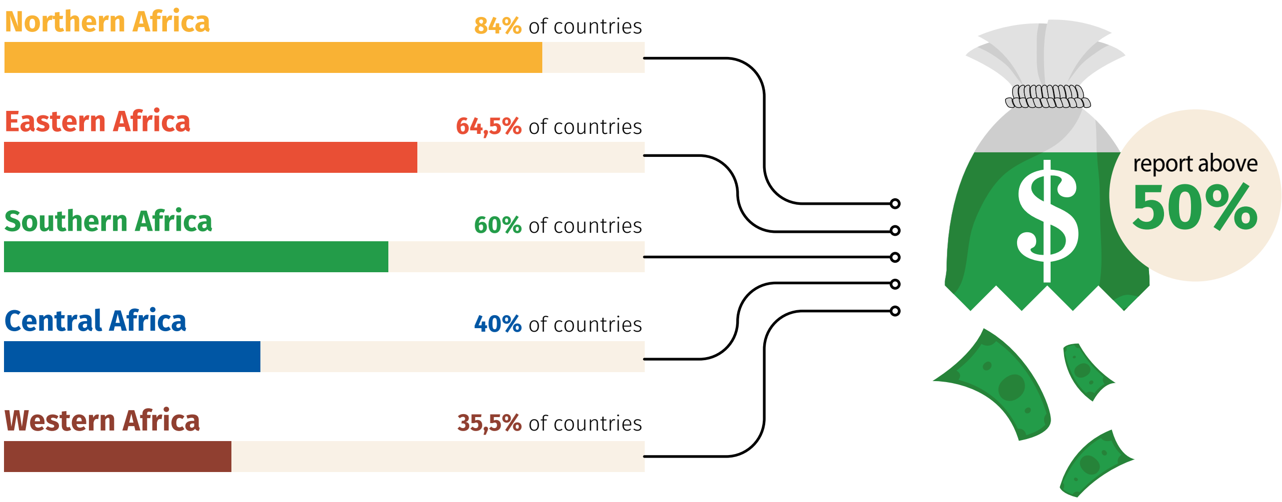
PUBLIC FUNDING FOR FILMS

According to the research conducted in the framework of UNESCO's report, **only 19 countries out of 54 (35.2%) offer financial support to filmmakers** – most often in the form of grants or subsidies.

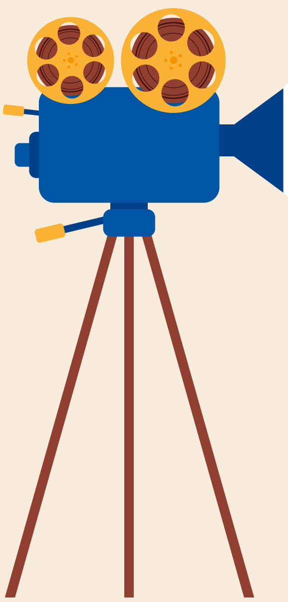


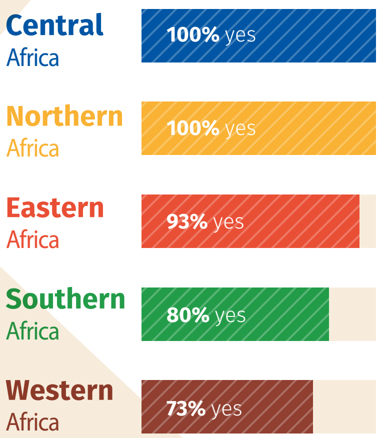
SHARE OF REVENUES LOST TO PIRACY

Two-thirds of countries estimated that more than 50% of total revenue is lost due to piracy, with one-third of countries estimating that these losses amount to more than 75%. The numbers are based more on perceptions than facts.



LIMITS TO FREEDOM OF EXPRESSION





Practitioners from at least 47 countries (87%) report **SOME TYPE OF LIMITATION TO THE TOPICS THEY ARE ALLOWED TO ADDRESS** in their work.

At least 37 countries (68.5%) **HAVE AN OFFICIAL CENSORSHIP BOARD** or a classification board charged with vetting projects before they can be released to the public.

Note: *A detailed online quantitative questionnaire was shared with governments and stakeholders in 54 African States. Responses were received from 43 countries, including 36 official responses from governments. When official data was not available, stakeholders were encouraged to provide their best estimate, compiled from various sources.*

Source: *The African Film Industry*, UNESCO, 2021

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ISSN 1020-4202
EAN 3059630111003
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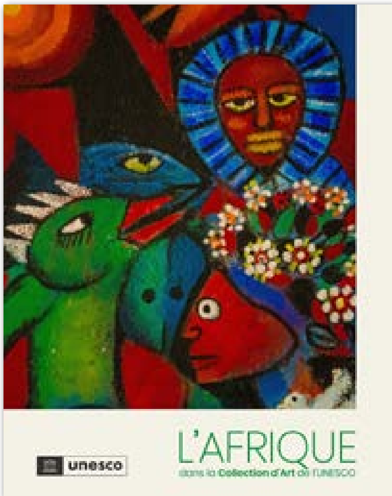

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