Rafael Yuste: “Because it accesses the centre of our mental activity, neurotechnology bypasses all of the filters that exist in the body

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Rafael Yuste studied Medicine at the Autonomous University of Madrid. He went to the United States to write his thesis and has now lived there for 36 years. He had to abandon his musical studies at Madrid Royal Conservatory because the time came when the disciplines of science and music each demanded 150% of his time. He set music to one side and devoted his life to science. He is currently Director of the NeuroTechnology Centre (NTC) at Columbia University, New York. Yuste is one of the proponents of the BRAIN Initiative project. His work focusses on understanding how perception and memories work, and he has experimentally altered “perceptions” in laboratory animals.

- ***The BRAIN Initiative: A map of the brain***

In September 2011, we sent the Obama Administration a proposal to conduct a project similar to the human genome one, but about the brain, on a large scale, with a 15-year duration and funding similar to or larger than that of the Human Genome Project. The aim was to develop techniques to measure and map brain activity. And the same day that we sent the proposal, they read it and sent it back. They loved it!

Obama chose this project as the Administration’s star science project, he presented it to Congress and managed to convince them two years later, in 2013, with the goal of developing methods to advance our understanding brain function and progressing both in the clinical context and also in economic terms. The latter aspect is what convinced Congress.

- ***What do we really know about the brain? Do we have a map?***

We don’t even have a draft. The brain is a very complex organ with more types of cell than the rest of the body. We don’t know exactly, but we estimate around 100,000 million neurons, each connected at a minimum with around another 100,000 neurons. The complexity of the brain network is three times greater than all of the internet on Earth. Which means that inside our heads there are three internets.

This tangle of connections, what **Santiago Ramón y Cajal** called the impenetrable jungle, is where thoughts, memory, imagination, behaviour, identity and awareness arise. And that is the greatest question in neuroscience, which remains unanswered. How does what we are —humanity, our mind— arise from the brain activity of all of these connections?

We are not talking about any organ of the body, like the liver, lungs or heart. This is the organ that generates the human mind, and it is there to be discovered. Neurobiologists have been pondering this for over 100 years. And the idea we presented to Obama is that we lack technology. We won’t progress in this field if we don’t construct the techniques to enter the brain and map what is going on, so as to be able to change it and help patients.

And that is the central goal of the BRAIN Initiative: develop the methods to record brain activity and change it. The American project has inspired similar projects in many countries: China, Japan, South Korea, Australia and Europe, Israel, Canada. In 2017, we created an international network, the International Brain Initiative, similar to that of the human genome.

We are halfway there, we’re gradually developing techniques and the first major results are being seen: the brain activity of small animals has been mapped, but not yet decoded. It’s like the genome: one thing is sequencing, and another is understanding what is written there.

- ***So, having the map does not mean we understand what is going on in the brain?***

First you need to have it. That is the prerequisite to understanding what is happening. It’s what they call “necessary but insufficient”. It’s the same as with the genome, it was sequenced, and we are still trying to decode what is happening. It’s such a complex system that we neurobiologists have tackled

it from the outside, but still haven't got inside. And that is what these techniques allow us to do. It's not just about recording. First, we map and then we modify.

- ***Your training was in Medicine. How did that influence you when it came to research?***

One of the things I remember is the care given to schizophrenia patients when I was doing a clinical rotation in psychiatry at the Lafora Hospital in Madrid. At that time, we had bodyguards to interview some of the patients who were dangerous. For me, that was a shocking experience because I remember one of the patients I interviewed was highly intelligent, and instead of helping society, contributing to progress, he was a self-destructive being. And I wondered if we could have entered his brain and seen what was going on, would it have been possible to turn a switch on or off and suddenly make all of that creativity and intelligence serve another purpose and improve his life.

I realised that intervention is not possible until we can see what happens inside the brain. To understand pathophysiology, first we have to understand the physiology of the organ

- ***At the turn of the 21st century there was talk of the "brain decade". And now we are in 2023.***

More and more progress is being made. This is a taste of things to come. I completely agree that, in the same way that genetics and molecular biology represented a leap for biology in the 20th century, the 21st century will belong to neuroscience. We are talking about an organ of the body that generates the human mind and identity, the essence of who we are. We'll know ourselves from the inside for the first time.

It will be a revolution for **humankind**; I compare it to a new Renaissance. Knowing ourselves began in the Renaissance. And the repercussions will be of all kinds, in medicine of course, but also the human and economic spheres.

To give an example: in the last 15-20 years mobile phones have revolutionised the world. What do smart phones do? They connect us to a network. They have changed our lives. Now, a phone is an accessory that forms part of our identity, and we access it with our fingers. But the next generation will be able to do all that with an interface.

These interfaces are now being tested for people with spinal **cord injuries or ALS** so that they can move their limbs or communicate by means of the interface.

The interfaces that spinal cord injury patients have are invasive. A lot of the neurotechnology being developed is not invasive. For instance, one of the goals of many companies is being able to write mentally without using our fingers. This would lead to an increase in cognitive capacities.

- ***Isn't all of this available information a double-edged sword?***

Here, we come up against ethical and social problems, which are very important, and many researchers like us, who are involved in the field, see them coming. There's no escaping them. Technologies are neutral: you can use them to cure a tetraplegic or to give someone access to what you are thinking. As we develop technology and support initiatives like that of the USA, we must develop ethical rules. We believe it is a question of human rights that protect the essence of what it is to be human, which is generated by the brain.

It's a rule of three: if the brain generates all mental and cognitive activities, and you can record and change brain activity with techniques, it follows that you can record and change cognitive activities. And that is not science fiction, we have done it in animals. In fact, at my laboratory we are specialists in recording, decoding and manipulating brain activity in mice. And we do this not because we want to enslave them, but to cure Alzheimer's or schizophrenia by understanding how the brain works in

animals.

What can be done in a mouse today, will be possible in human beings in the future, which is why, before that happens, we have to protect human brain activity as a basic human right.

- ***Yet again, science is a step ahead of the law.***

The clearest example is what happened with nuclear power. It was the physicists who made the nuclear reactor that warned the humans who were in danger. And that's why the Atomic Energy Commission was created in Vienna. Something similar will happen with neurotechnology. We are going to become a different type of human being, and we need to think about that carefully and define what type of human beings we want to be. We have to protect basic rights before 'getting the car on the road'.

- ***Will we have to add new rights to human rights?***

If humankind progresses, why would human rights not progress too? The truth is that we are always changing. We have to improve, not only in medical techniques, but also in social rules, and in this case human rights.

- ***What do we mean by neurorights?***

The concept of neurorights refers to rights in the cerebral and mental domain. Current human rights refer to the body's need to eat, to a dwelling, etc.

Now we are talking about brain activity. We propose the right to mental privacy so that the content of brain activity cannot be decoded without consent; the right to personal identity and free will, so that brain activity cannot be modulated, because the essence and freedom of choice are going to change; and the right to equal access to sensory and cognitive augmentation technologies so that we don't end up with a two-speed human race: those that have neurotechnology and those who don't.

We scientists are working closely with experts in human rights, in cases of torture, disappearances, racial discrimination, protection of minors, etc.

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- ***Methods to modify our conduct already exist, like social media, internet…***

That's true, but that's just a taste of things to come. For instance, I can tell you what we do with mice, which is to modify their visual perception based on neurotechnology that stimulates the neurons in the visual cortex of the brain responsible for vision. And the animal behaves as if it were seeing things that we put into its brain. And we have proved that there is no difference in animal behaviour if the information comes from inside or outside. In fact, the animal interprets them as its own.

As it accesses the centre of our mental activity, neurotechnology bypasses all of the filters we have in our bodies; for instance, if we read information on internet that may be biased, although we believe it, we always know it is external. If we put it directly into the brain, we will believe it's what we think.

That's why it is so important to protect ourselves. There must be a red line that is not crossed. We have reached the essence of what it is to be human, and we can change it. It sounds like science fiction, but we are already doing it in laboratories.

We have the example of Chile, where a constitutional amendment was unanimously approved to protect brain activity as a fundamental right of all Chilean citizens, so that brain activity cannot be altered or decoded without consent. The idea is that the United Nations should champion this legislation and spread it worldwide so that brain activity is sacrosanct and cannot be touched.

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- ***Do we see what we think we see?***

One of the few things we know about the brain is that we are seeing that the world we live in is generated internally. That is related to what Plato and Kant said, that the reason the human mind fits in with the world is not because it is a refection of the world but the opposite: the world is a reflection of our minds. What we believe we see we already have in our brain. That is what we are beginning to find in mice.

And I believe it fits in with many of the discoveries that are being made now in neuroscience, which say that we have a machine that is generating a kind of virtual reality that is no other than the world we live in.

- ***That would explain, for instance, how millions of people see a single fact in many different ways?***

That predicts that each of us lives in an isolated universe, which is the universe of our mind. But the brain has 700 million years of evolution behind it, and it has evolved as a machine to predict the future.

And we perceive all of this through our senses —the systems of sight, smell, touch— which are fantastic. With that, the virtual model adapts to the world and it's so good that it makes us believe that it is the world.

A human being is no more than that: **the human mind, what it knows, everything it is, thoughts, memories, emotions. It must be protected because if you don't, yours might be decoded or altered**.

I am optimistic, I think that this type of technology and knowledge will take us to a better and fairer society. Historically, that is what has always happened: science shines a light, long-held prejudices disappear and ignorance ends.

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- ***Does it mean we will be able to communicate with people who suffer cognitive deterioration like Alzheimer's or ALS?***

That's one example of the benefits of neurotechnology. One of the things they are starting to do with implanted interfaces is precisely that; to decode the mental activity of patients who cannot communicate.

My colleagues at Stanford University and the University of California San Francisco (USA) have been able to decode speech through internal brain sensors. So, it is possible that Alzheimer's or ALS patients could establish two-way communication.

One of my first medical experiences at Madrid's Fundación Jiménez Díaz was with an ALS patient. It was there that I perceived the importance of being able to help these patients communicate,

because one of the last things that stops working is the brain. Patients with ALS are locked in their own body, which is paralysed, but they can't communicate. Neurotechnology could represent a route to freedom for them. In the future, assisted neurotechnology will enable control of robotic equipment, prostheses of legs and arms, or even living without that death sentence.

That is one example of the benefits. But the same technology can be used on a normal person to find out what they are thinking. For instance, in a police interrogation.

That is why rights must be protected.

- ***And they aren't?***

Not yet. In the proposal we sent to the Obama government in 2011, we highlighted the importance of tackling the ethical and social issues of neurotechnology and the need for regulation. And that aspect still lags behind the technological developments.

Sometimes we speak about setting up guide rails so that this technology develops within an ethical system that is compatible, but also strict so there are no deviations.

- ***What is the role of private business?***

Private business plays an important role because it can be the driving force behind neurotechnology and bring benefit to patients and humankind in general. But it has to understand that certain rules must be followed. We are collaborating and working with many private companies, **IBM, Google, Facebook, etc.**, and they understand that this is a field of interest to them which should be developed within an ethical framework.

The idea is that this new human rights platform should also receive support from the private sector.

- **Rafael Yuste gave the seminar "The neural code: emergent properties of neural circuits" at the invitation of Jorge Alegre-Cebollada**

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