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Pacemakers for the Brain

Brain-computer interfaces can read neural signals and influence brain activity. We spoke with Pascal Fries about how this technology can benefit people with neurological and psychiatric conditions, future developments, and his views on ethical boundaries.

Brain-computer interfaces have been making headlines in recent years. But for most people, the technology remains something of a mystery. What is a brain-computer interface, in simple terms?

At its core, a brain-computer interface connects a computer to the central nervous system—that is, to the brain or the spinal cord. This allows neural activity to be read, influenced—or both at once. Ideally, the two go hand in hand: the system first measures the current state to then respond by stimulating the brain. The stimulation can be designed to either enhance or inhibit neural activity.

What signals does a brain-computer interface actually read?

The primary currency of brain-computer interfaces is electrical signals. Different methods vary in both their resolution and how invasive they are, ranging from electroencephalography, which picks up electrical oscillations from outside the skull, to surgically implanted electrodes capable of detecting signals from individual neurons.

You mentioned systems that both measure and stimulate. They are relatively new; do they represent a major leap forward?

Older systems stimulate regardless of what the brain is doing at any given moment. Take classic deep brain stimulation for Parkinson's, for example. It delivers continuous stimulation while the patient is awake. This is similar to early pacemakers, which operated on the same principle, setting a fixed rhythm regardless of heart rate. Later, the approach shifted to making stimulation dependent on the pulse. This principle has been applied to Parkinson's therapy with brain-computer interfaces: So-called closed-loop systems only spring into action when the beta rhythm of brain waves is too pronounced—the pattern that triggers the muscle rigidity typical of Parkinson's disease. While such closed-loop systems enable smarter therapies, they are still rare in clinical applications.

In which other clinical applications are brain-computer interfaces close to a breakthrough?

Development is quite advanced in the field of epilepsy. Two companies working on this technology are, for example, NeuroPace in the U.S. and Precisis in Heidelberg. Both aim to identify the early warning signs of an epileptic seizure and prevent it through targeted counter-stimulation.

Some startups are planning to use brain-computer interfaces to treat depression. How exactly is that supposed to work?

That's right; two companies in this field are Inner Cosmos and Motif Neurotech. To my knowledge, both aim to activate the left dorsolateral prefrontal cortex.

Let's slow down there — can you explain what that means?

To put it very simply: Our prefrontal cortex constantly simulates the near-future consequences of our actions: "What would happen if I did this or that, or if I didn't do it?" A specific brain region, known as the left dorsolateral prefrontal cortex (or left DLPFC for short), appears to perform a kind of "best-case scenario" simulation. For example, if a person thinks, "If I do this, things will go well, and I will feel joy," the left DLPFC is active. People with depression often find it difficult to imagine anything bringing them joy, and this appears to be linked to relative inactivity in the left DLPFC. Therefore, stimulating the left DLPFC can help them.

That sounds like it could also be relevant for other psychiatric disorders.

Yes, for example, anxiety disorders. In simple terms: The right DLPFC—the counterpart to the left one—is responsible for worst-case scenarios: "If I do this, something could go wrong, so I should probably leave it alone; otherwise, I'll end up regretting it." In anxiety disorders, this activity is too pronounced, so the right DLPFC is an obvious target for inhibition.

We’ve talked at length about the clinical applications of brain-computer interfaces. But could they one day be used to enhance the healthy brain beyond its natural capabilities?

Technically, this is possible, and some key players in this field want to do just that. For example, Elon Musk argues that artificial intelligence could threaten humanity, and that we would need to connect to computers via broadband links to keep up. Moreover, some have military applications in mind; interfaces with several thousand electrode contacts in the brain could undoubtedly be used to efficiently control robots. And some people simply aspire to have superhuman abilities or desire other forms of augmentation to feel better or be more productive.

But would that be something we should want? Where are the ethical boundaries?

Personally, I draw a clear ethical line here. I consider medically indicated brain-computer interfaces to be highly relevant and an important addition to the therapeutic portfolio. To gauge their potential impact, consider pacemakers: They have been developed over decades and now provide more than three million people with vital, often life-saving, medical assistance. What’s more, non-invasive brain-computer interfaces could be beneficial for people with subclinical depressive moods. However, I consider the implantation of brain-computer interfaces in or on the brain without a medical indication to be ethically questionable, if not unjustifiable.

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