

Neurotechnologies

Opportunities, Risks, and Pathways to Responsible Application

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NIRS

MEG
EEG

ECoG

Spikes
LFP

5 mm





LIEBER-HERR-BIRBAUMER-

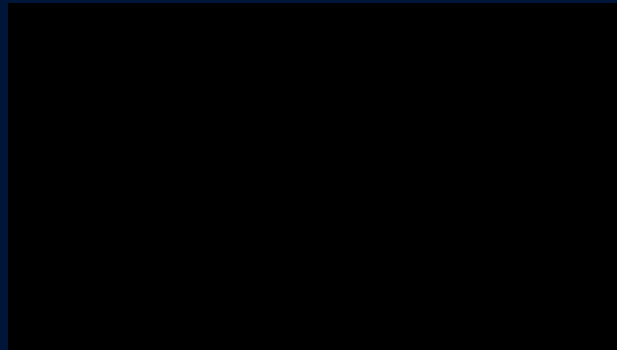
HOFFENTLICH-KOMMEN-SIE-MICH-BESUCHEN,-WENN-DIESER-BRIEF-SIE-ERREICHT-HAT-.ICH-DANKE-IHNEN-UND-IHREM-TEAM-UND-BESONDERS-FRAU-KÜBLER-SEHR-HERZLICH,-DENN-SIE-ALLE-HABEN-MICH-ZUM-ABC-SCHÜTZEN-GEMACHT,-DER-OFT-DIE-RICHTIGEN-BUCHSTABEN-TRIFFT.FRAU-KÜBLER-IST-EINE-MOTIVATIONSKÜNSTLERIN.OHNE-SIE-WÄRE-DIESER-BRIEF-NICHT-ZUSTANDE-GEKOMMEN.-ER-MUSS-GEFEIERT-WERDEN.-DAZU-MÖCHTE-ICH-SIE-UND-IHR-TEAM-HERZLICH-EINLADEN.-EINE-GELEGENHEIT-FINDET-SICH-HOFFENTLICH-BALD.

MIT-BESTEN-GRÜSSEN-
IHR-HANS-PETER-SALZMANN

Birbaumer et al.
1999, *Nature*



John Donoghue Lab,
Brown University 2012



Bolu Ajioboye, Case Western
University, 2018

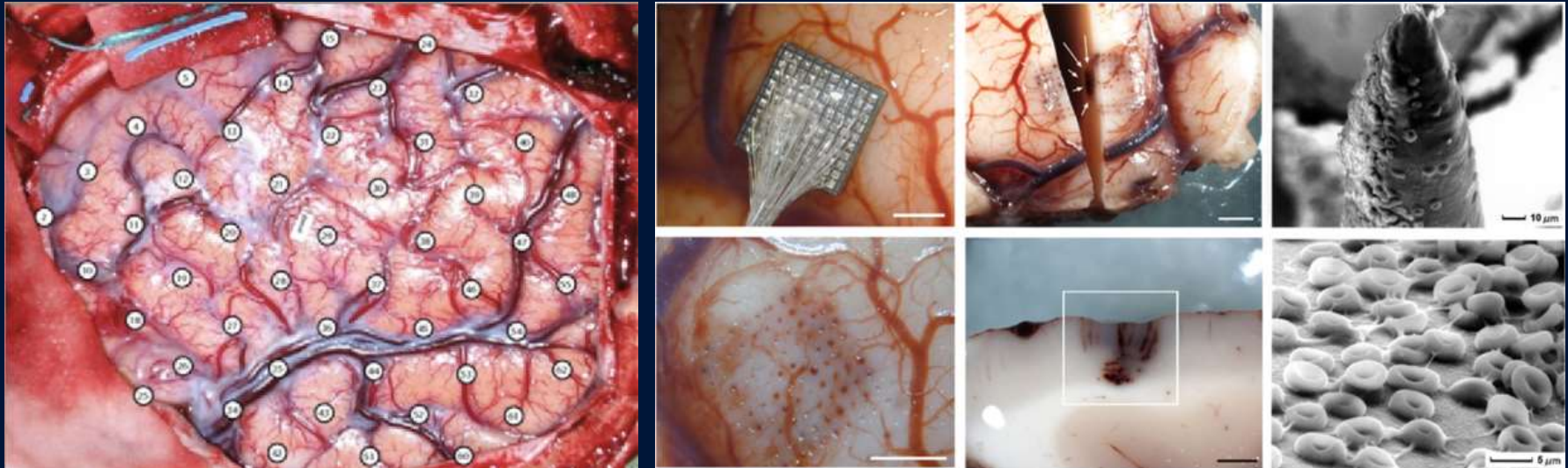


Brock Wester, Johns Hopkins University, 2019

THE LINK



- Involves risks of infections and bleedings
- Removal or repair requires another surgery
- Does not scale
- Mainly interesting for 24/7 assistive BCIs



A man with short grey hair, wearing a light blue short-sleeved button-down shirt and dark shorts, is sitting on a brown leather couch. He is looking off to the side with a thoughtful or concerned expression. His hands are clasped in his lap. The background shows a living room with a framed picture on the wall and a small plant on a shelf.

nature


Abandoned

The human cost of
neurotechnology failure

When the makers of electronic implants abandon their projects, people who rely on the devices have everything to lose.

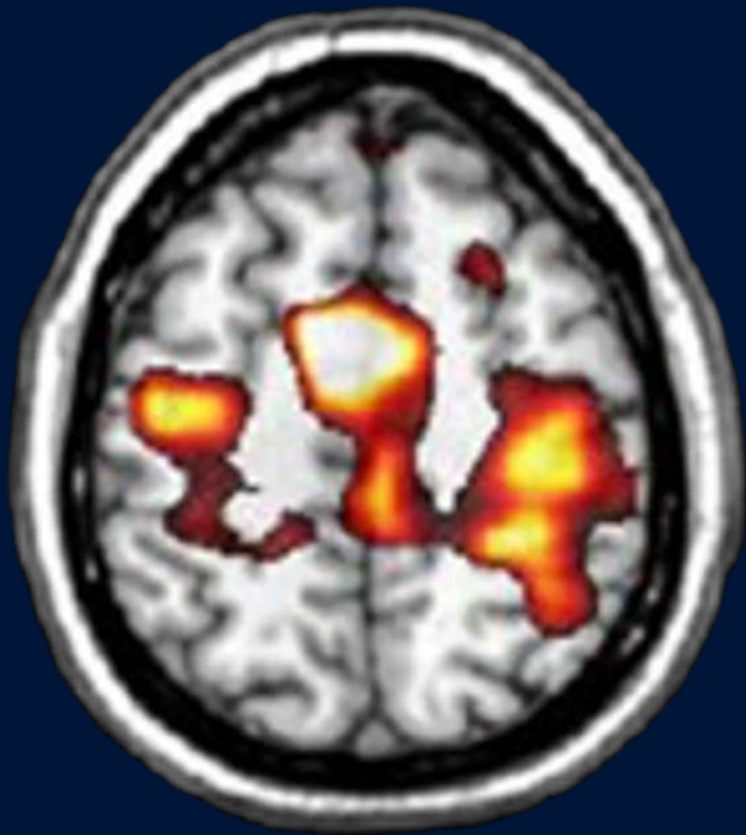
By Liam Drew | 6 December 2022



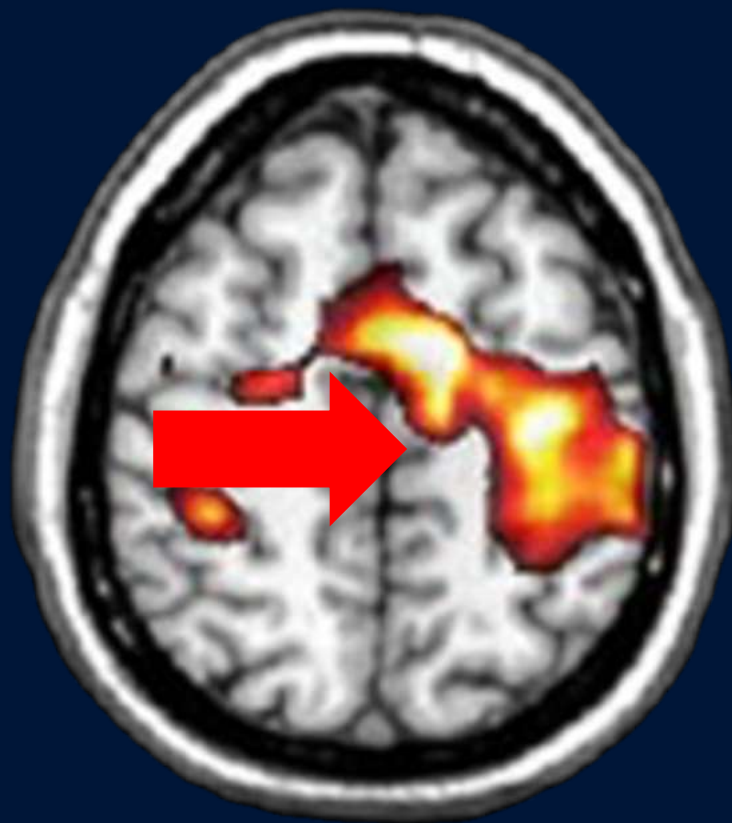
[Home](#)[News](#)[Journals](#)[Topics](#)[Careers](#)[Recent Videos](#)[Latest Podcasts](#)[Photo Galleries](#)[Dance Your Ph.D. Contest](#)[Data Stories Contest](#)A photograph showing a robotic hand, which is orange and black, holding a white ping pong ball. The hand is positioned over a white plate filled with yellow potato chips. In the background, there is a blue cup and a wooden block on a white table. The scene is set in a laboratory or office environment.

Science Robotics releases its inaugural issue!

S. R. Sankaranarayanan et al. / Science
Robotics, 2015



BEFORE



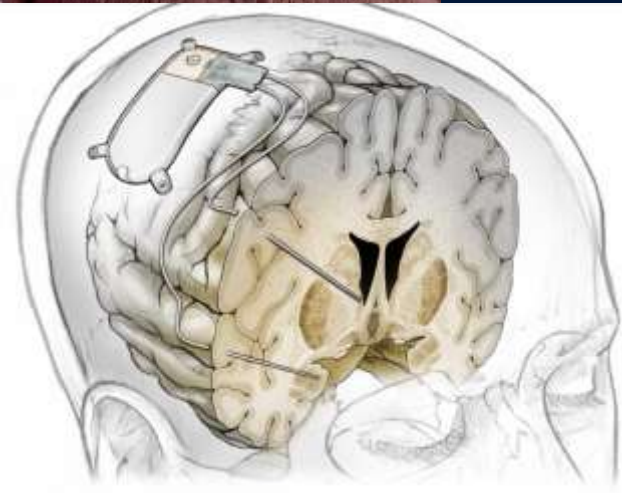
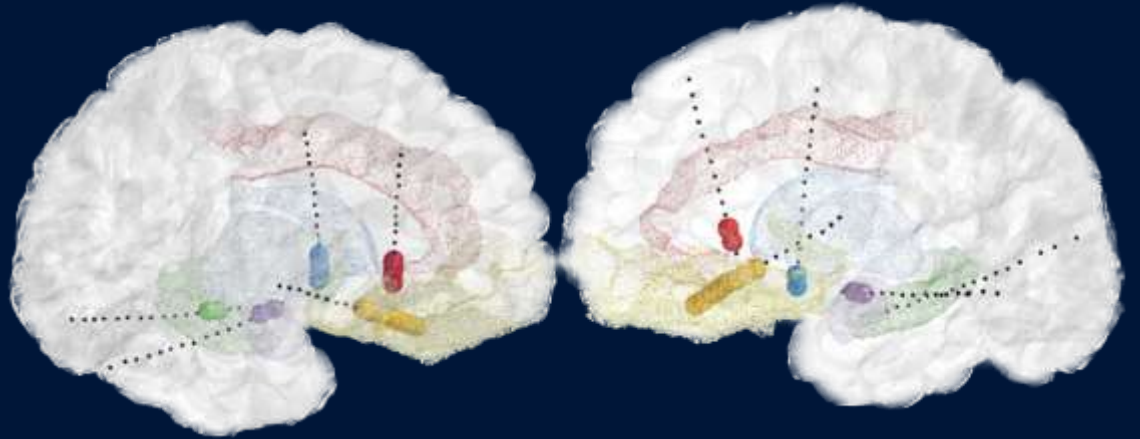
AFTER

Summary I

- Implantable BCIs are relevant for **24/7 assistive systems** in groups that cannot achieve comparable assistance otherwise
- **Repeated use** of brain/neural exoskeletons can lead to **neuroplasticity** triggering neurological recovery
- There's no reason to doubt that such **plasticity extends beyond the motor domain**; it likely also applies to other brain functions, such as **cognitive control** and **emotion regulation**

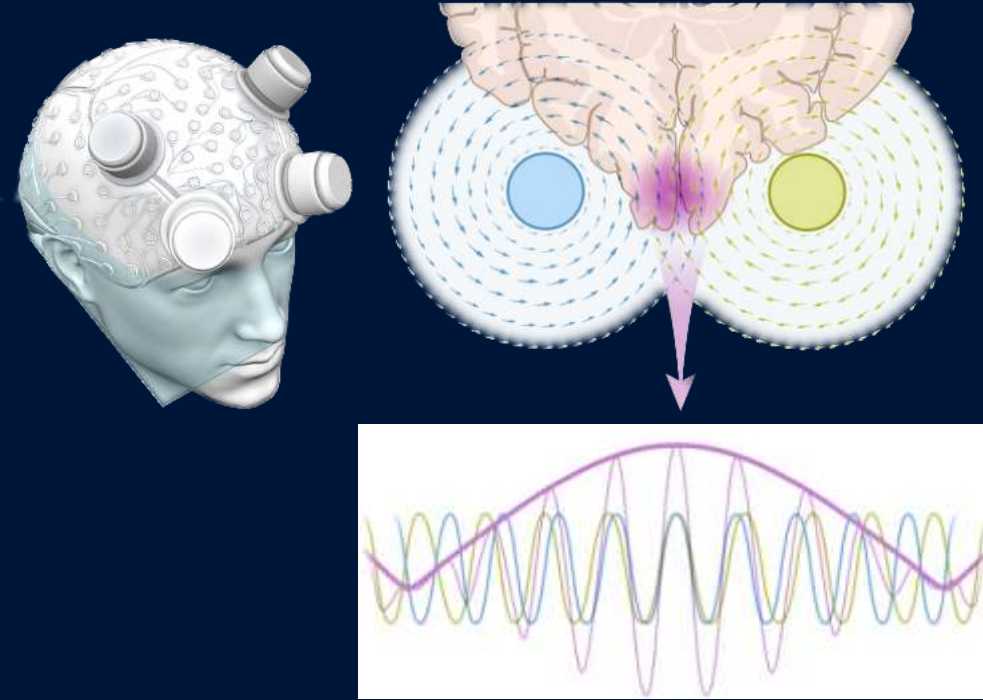


**„(...) the emotions and the darkness
were overwhelming“**



**“At first, within a few weeks, the suicidal
thoughts just disappeared. Then it was just
a gradual process. It was like my lens on the
world changed“**

Temporal Interference Magnetic Stimulation (TIMS)

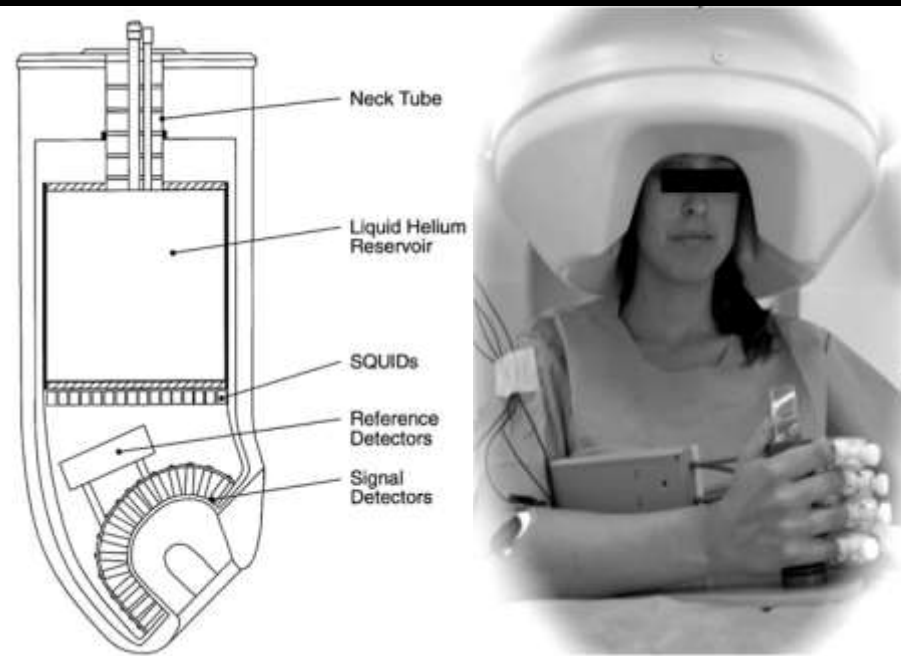


- no implantation
- mm-precise modulation of the deep brain
- flexible targeting
- no sensory confound (muscle/nerve stimulation or clicking)

EEG: very limited spatial precision, 5 - 25 Hz

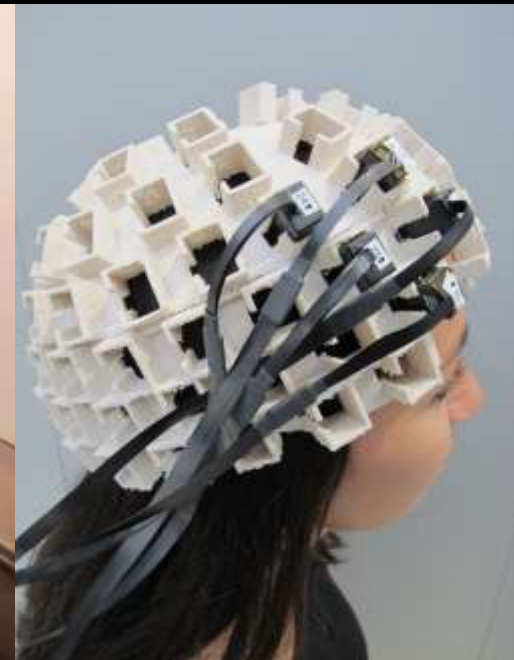
MEG: best noninvasive imaging tool, 0 - 250 Hz

but: helium-cooled, static



Helium-cooled MEG

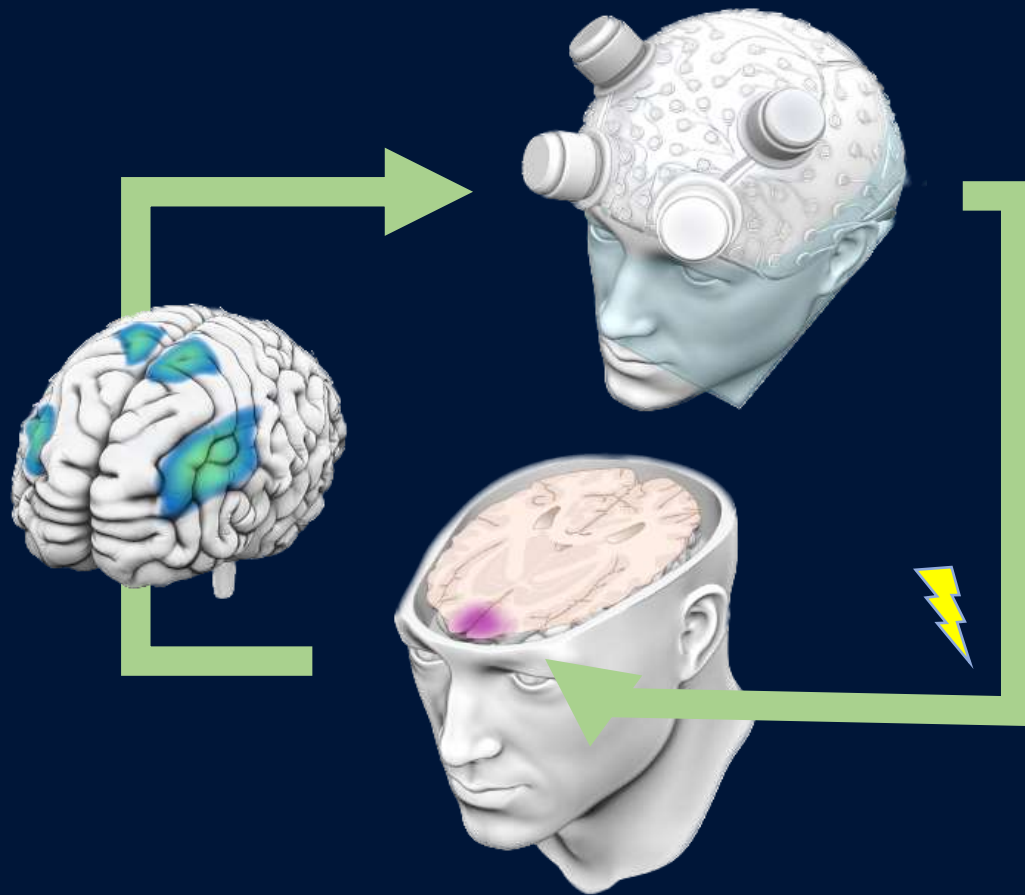
Soekadar et al. 2015, *Cereb Cortex*



Quantum Sensors

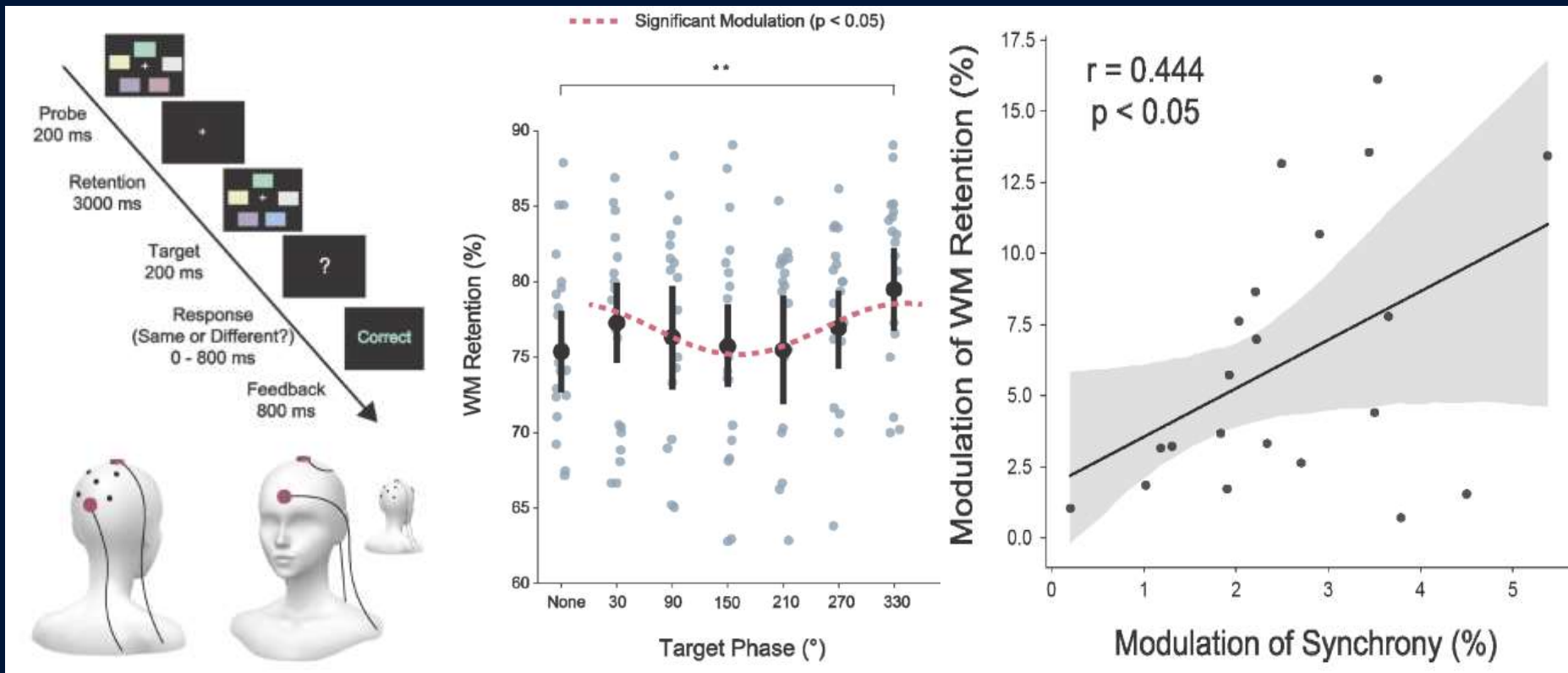
Zerfowski et al. 2021, *ICBEM*

Zerfowski et al. 2022, *BioMag*



BNCI²
Consolidator Grant
2025-2030

Closed-loop tACS to enhance working memory function



Neuroethics und Neurorights



BRAIN-MACHINE INTERFACES

Help, hope and hype: ethical dimensions of neuroprosthetics

Accountability, responsibility, privacy, and security are key.

By Jens Clausen, Elanor Fetz, John Donaghy, Janaki Unitha, Ulrike Späth, Jennifer Chandler, Nils R. Bärnson, Surjo R. Soekadar

Brain-controlled prosthetic robots that restore independent activities of daily living to paralyzed people are about to enter everyday life environments (1). The regained ability to grasp a cup of coffee, hand over a credit card or sign a document with a pen (2) enhances the independence and self-determination of severely paralyzed individuals. However, introducing devices controlled via brain-machine interfaces (BMIs) into everyday environments, possibly

less interactions between mind and machine seem intuitively appealing, creating direct links between a digital machine and our brain may dangerously limit or suspend our capacity to control the interaction between the "inner" personal and outer worlds. For many, such a scenario raises fundamental, even existential fears, including the fear of losing privacy and autonomy, and the basic fear of self-dissolution (as depicted in science fiction movies such as "Star



war and processing could enable more in-depth "mind-reading", i.e., classification of brain states related to specific perceptions, thoughts, emotions or intentions.

RESPONSIBILITY, ACCOUNTABILITY

In some sense BMI-controlled devices might be seen as just another tool (10,11). However, the inclusion of more and more autonomous components into the tools (12) transforms their



New Era of Human-Machine Interaction

before: **Human decides, machine/tool follows**

now: Machine/AI decides autonomously, *or*
Human decides, machine finds best solution
(collaborative interaction)

future: **scenario 1: fusion of brain/mind and machine**
(transhumanism, tech extends and sets the limits)

scenario 2: humanistic augmentation

→ *Technology augments human capabilities, but
remains a tool at service to the human user*

European NeuroTech Innovation Ecosystems

- ❑ **Open Innovation Hub:** Academic-Industrial Partnership & *Clinician Innovators*
- 🔧 **Regulation:** NeuroTech Sherpas & Simplification
- 💰 **Financial Support:** VC-Funds >15 Mio. €
- ❑ **Harmonization:** Simplification of reimbursement across health care systems
- 🎓 **Entrepreneurship:** Education & Support

Summary

- Neurotechnology **improves quality of life** in various conditions (stroke, SCI, ALS etc.)
- For 24/7 assistive and bidirectional BCI technologies, a **Mental Impact Assessment (MIA)** is essential
- The **combination of BCI with neuromodulation and AI** extends applicability towards **mental health**
- NeuroTech innovation ecosystems for **human-centred technological sovereignty**



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