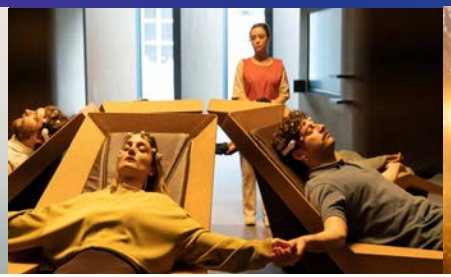
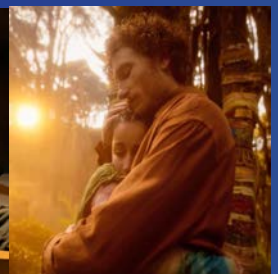
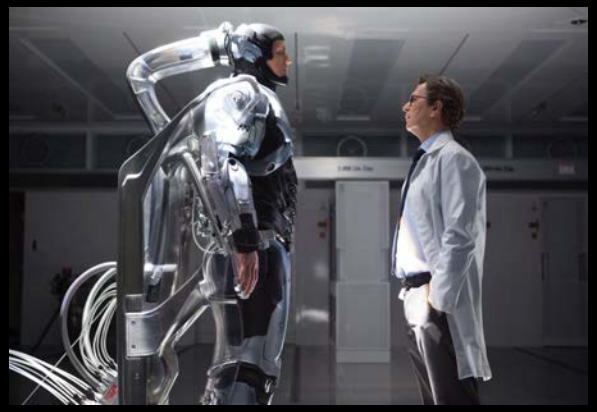
From Restoring Movement to Mental Health: The Next Frontier of Brain-Computer Interfaces

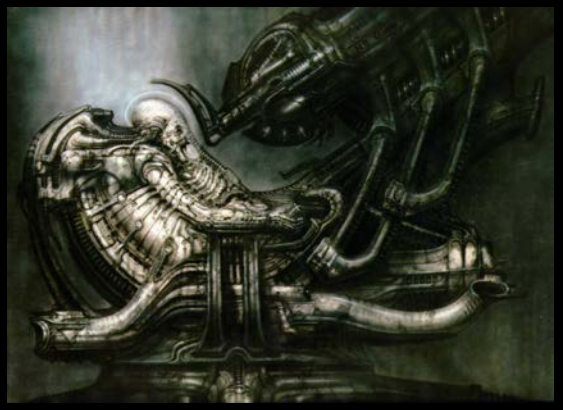
Surjo R. Soekadar
Einstein Professor for Clinical Neurotechnology
Charité – Universitätsmedizin Berlin

environ MENTAL


Morgan Stanley | RESEARCH
October 9, 2024 11:00 AM GMT
Medical Technology | North America
Brain Computer Interfa
Primer: The Ne
Opportu
pment, we think BCIs will soon
iedTech. This technology has the
ningfully improve the lives of millions across
e, suffering from a broad range of conditions. TAM?
$400bn in the US alone, with room for expansion.
400 Billion Reasons To Believe In Brain-Computer Interfaces



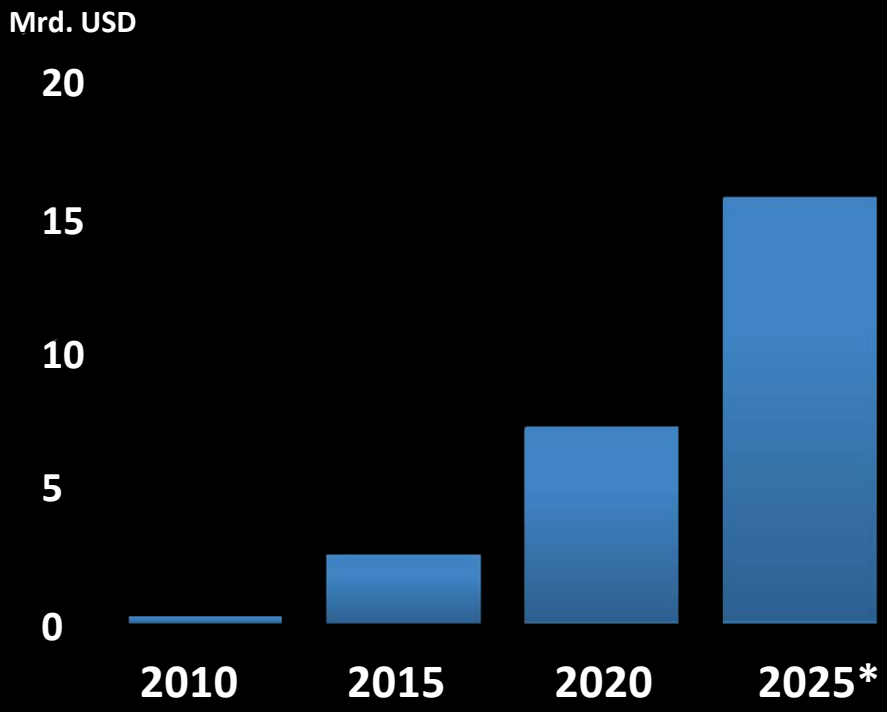


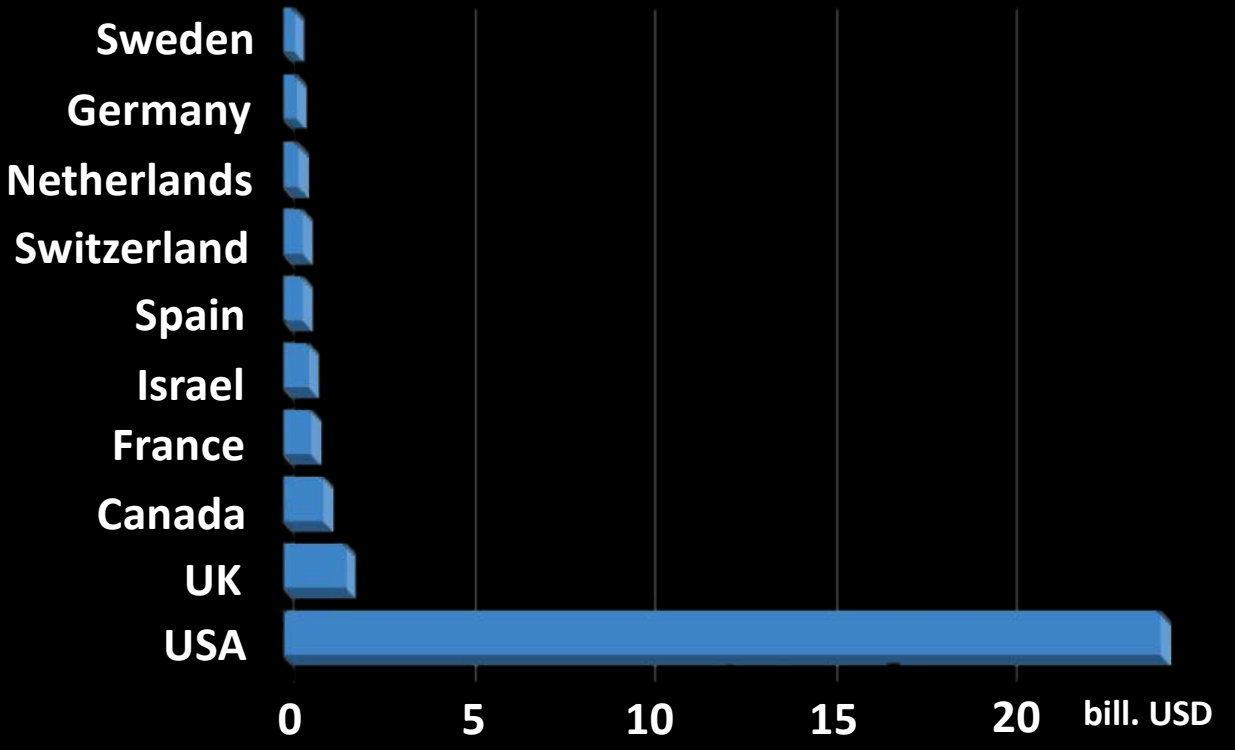

Sony Pictures


TIME
ELON MUSK
LENA DUNHAM
KIMBERLY BLACKWELL
BRYAN CRANSTON
KAI-FU LEE
LINDSEY VONN
SCOOTER BRAUN
HASSAN SHEIK MOHAMMD
ENRIQUE PEÑA NIETO
TRAVIS TYGART
SAM YAGAN
VRINDA GROVER
TADASHI YANAI
IGOR SECHIN
DAVID COLEMAN
PLUS
DEBORAH PERSAUD
HANNAH GAY
KATHERINE LOZOVIAGA
JOAQUIM BARBOSA
REN ZHENGFEI
THE 100
MOST INFLUENTIAL PEOPLE
IN THE WORLD

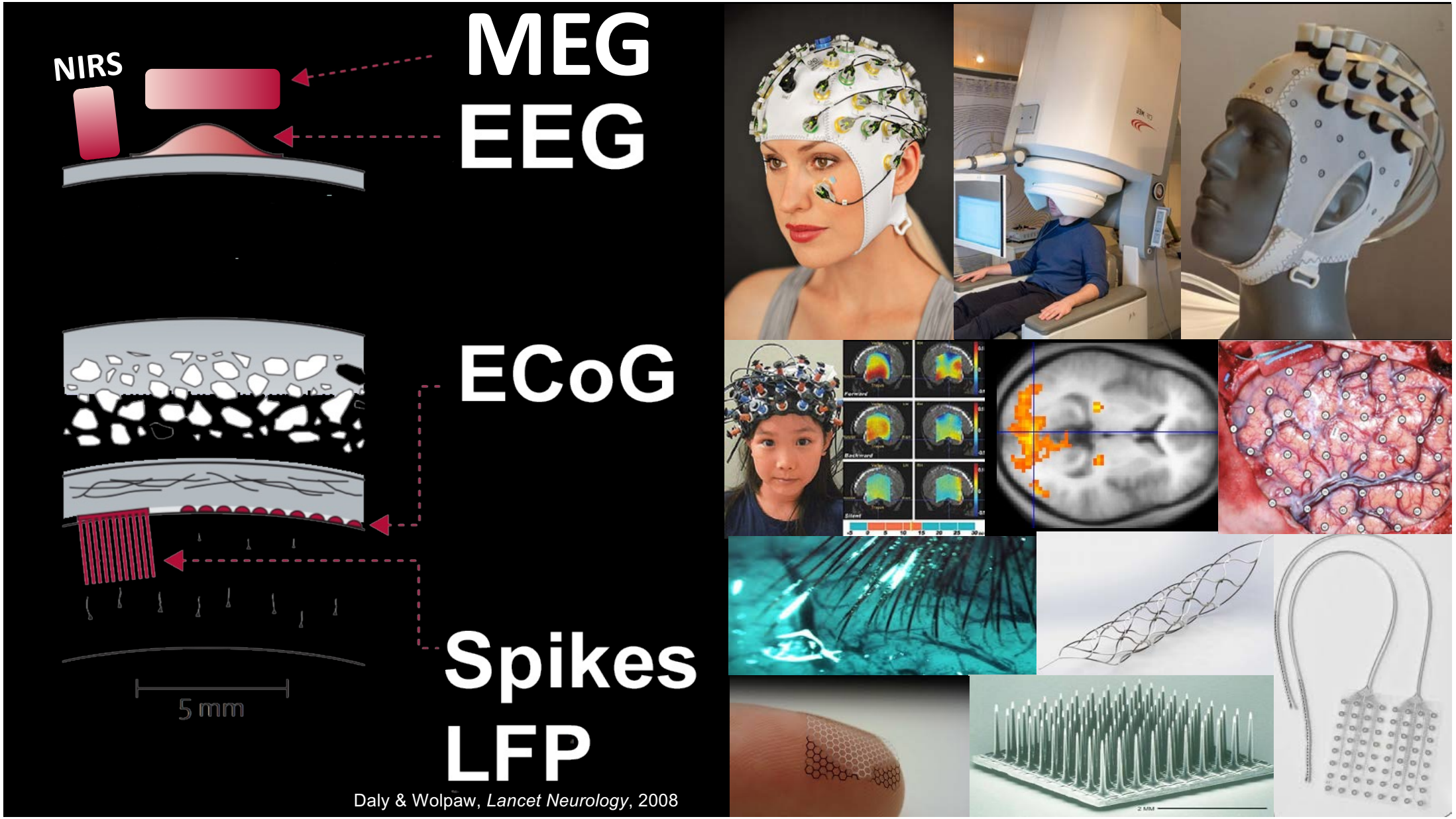

Person of the Year
TIME
Facebook's
Mark
Zuckerberg
THE CONNECTOR

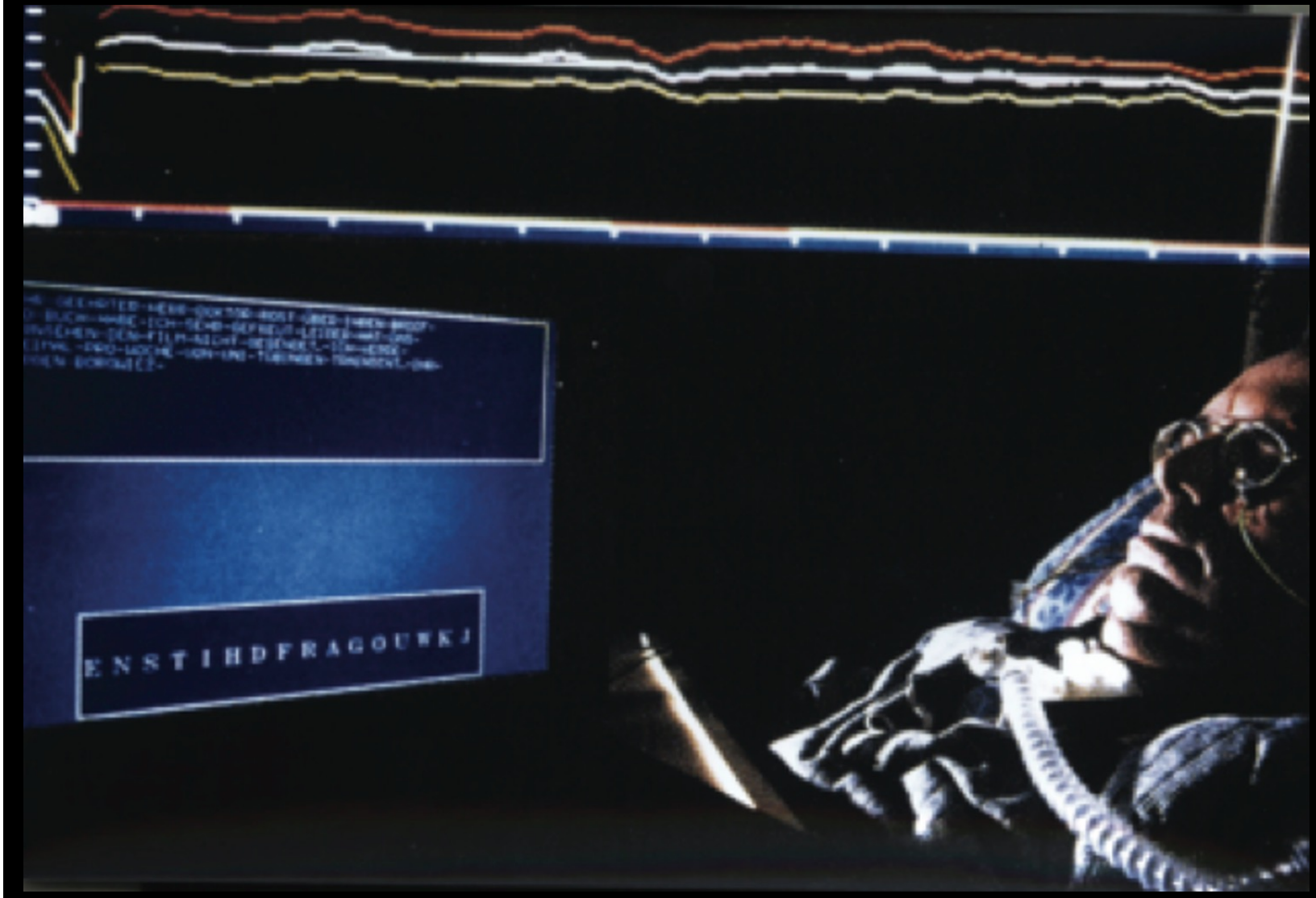
- **500%** more neurotech patents in the last 12 years
- 2026: Market increase by **+75%** to 17.1 billion USD





Global NeuroTech Industry Investment Digest 2021

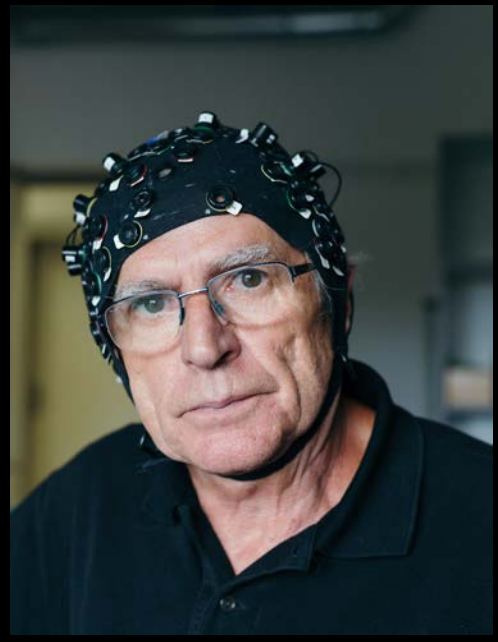

NIRS
MEG
EEG
ECoG
Spikes
LFP
5 mm
Daly & Wolpaw, *Lancet Neurology*, 2008



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***

Andy Schwartz Lab,
University of Pittsburgh 2008

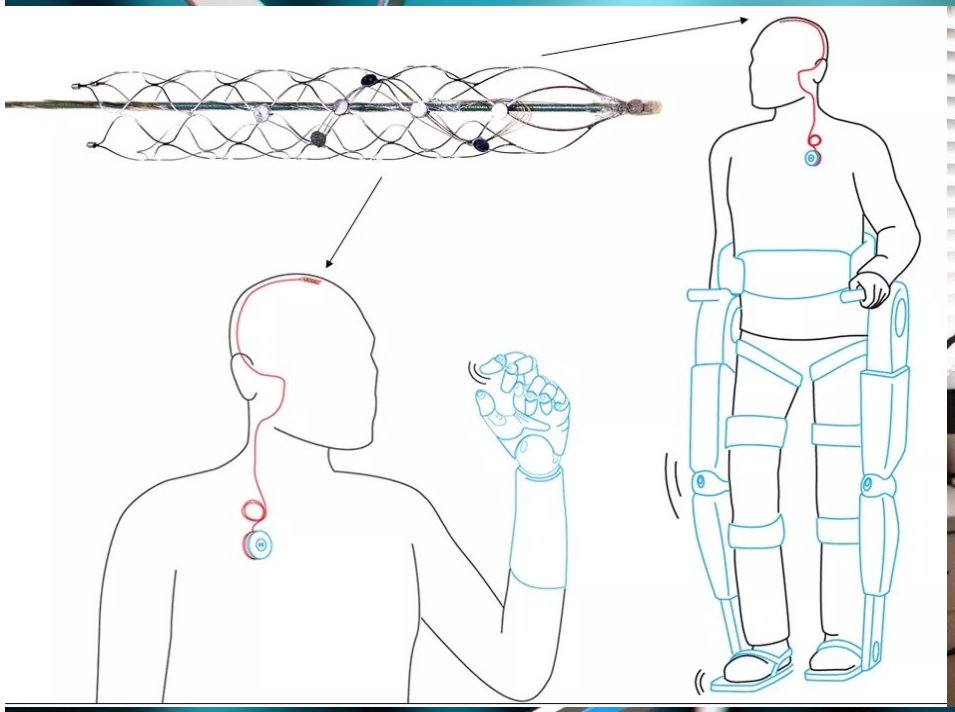
John Donoghue Lab,
Brown University 2012

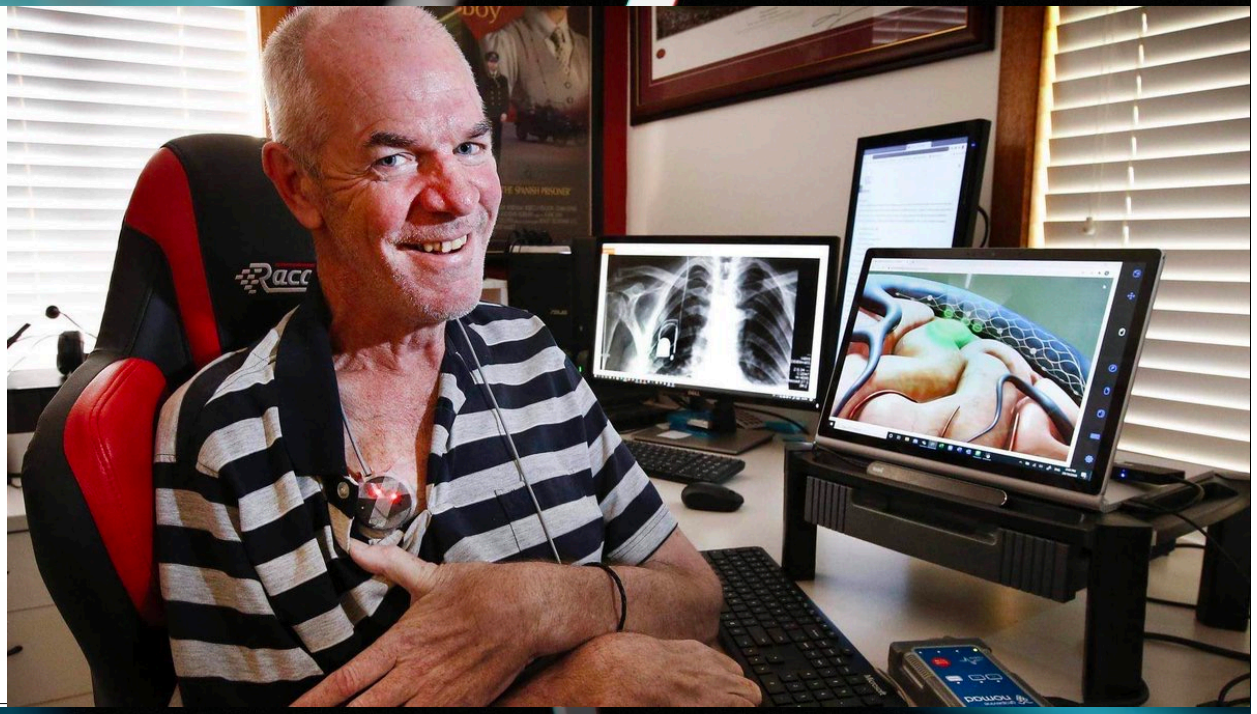
Bolu Ajioboye, Case Western
University, 2018

Brock Wester, Johns Hopkins
University, 2019


9
like > a > soldier > on > a > battlefield, >
stripped > of > ammunition~
lowel felt like a soldi
Willett et al. 2021, *Nature*

THE LINK

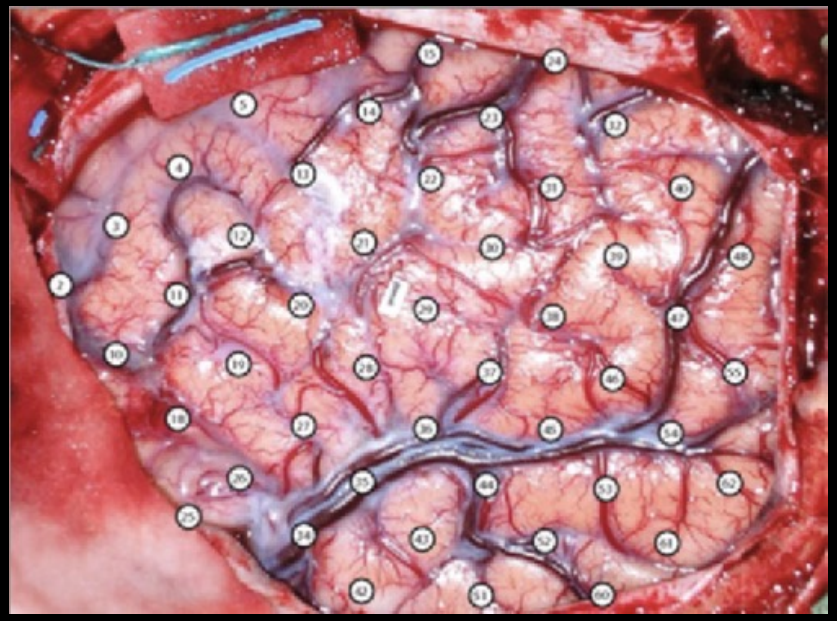


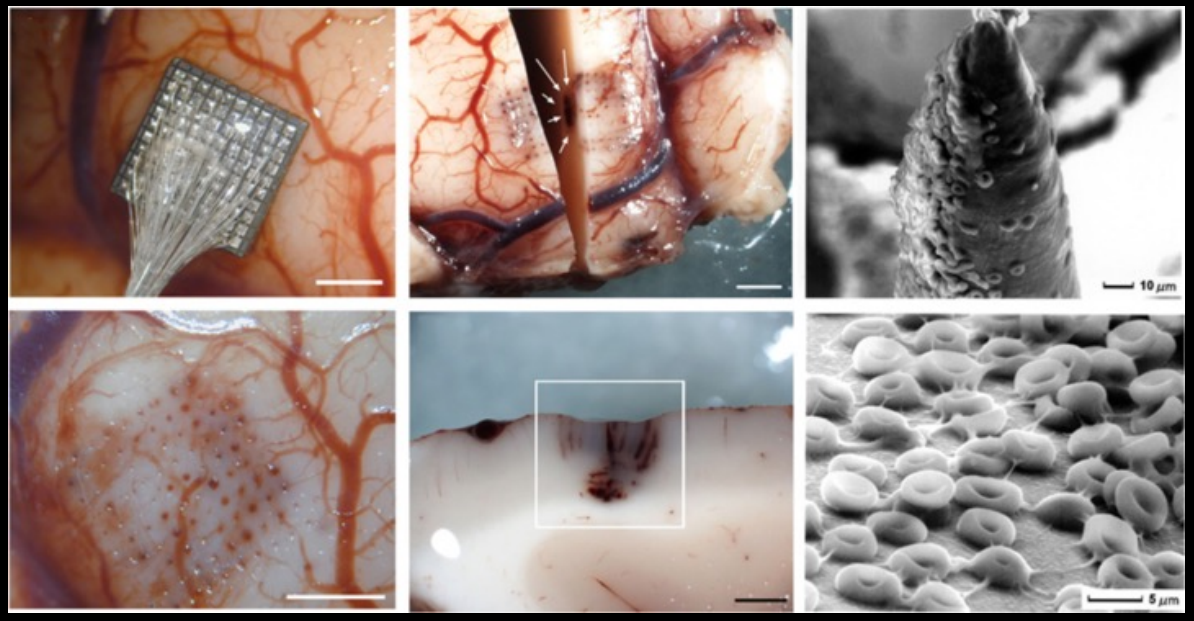


Synchron Inc.


Lorach et al. 2023, *Nature*

- Involves risks of infections and bleedings
- No certification for permanent use
- Cannot be used outside the laboratory
- Removal or repair requires another surgery

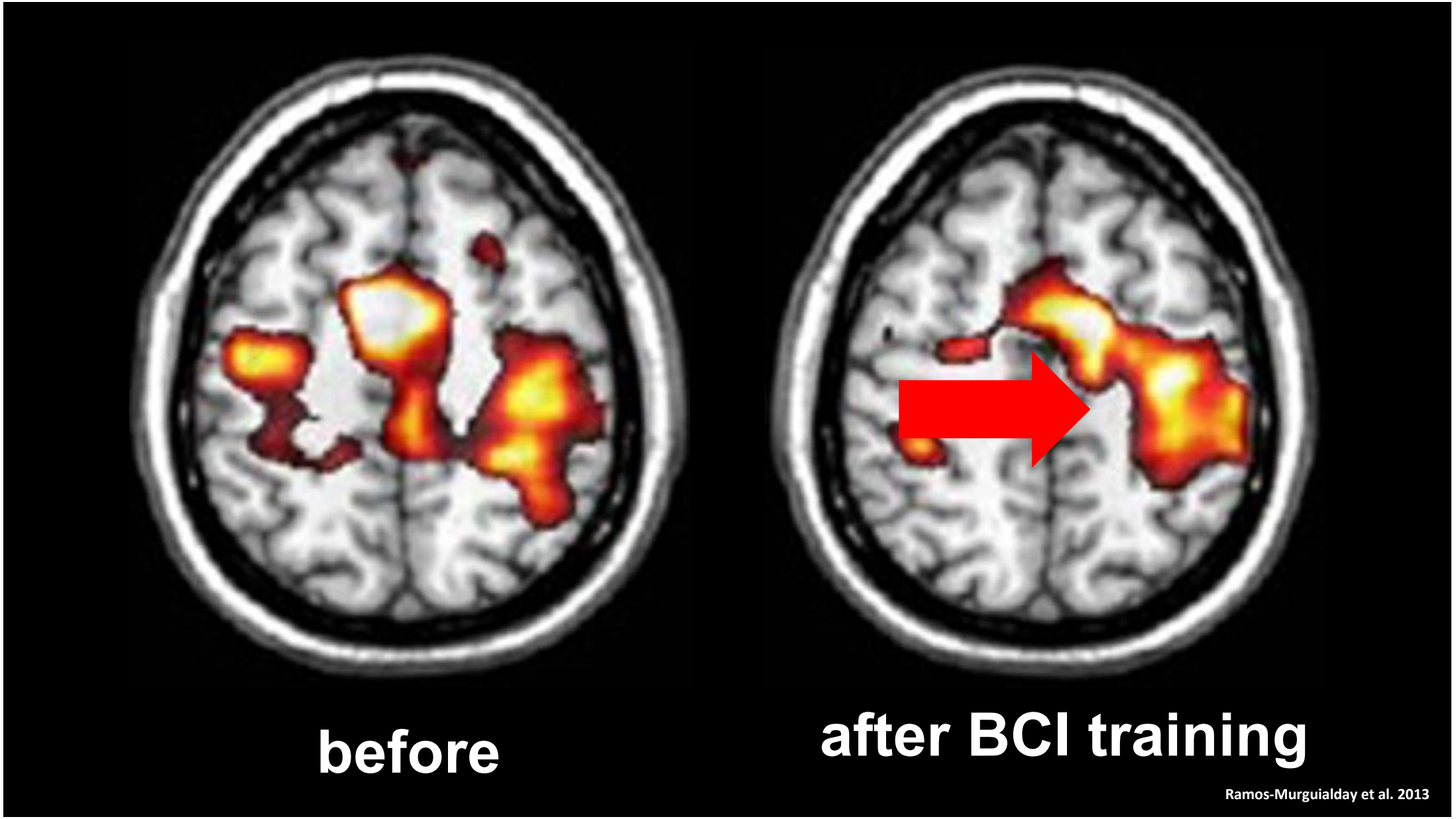


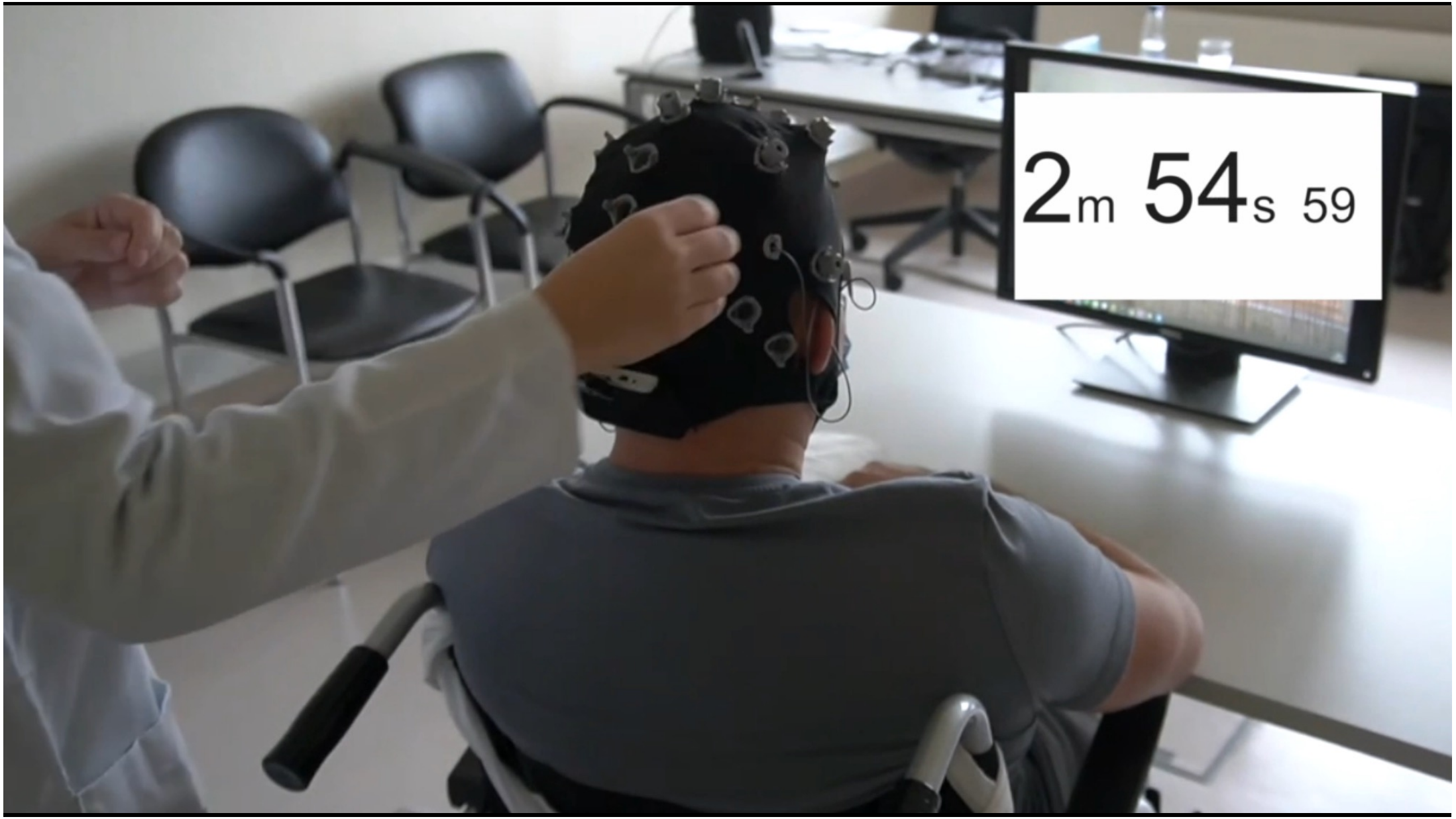


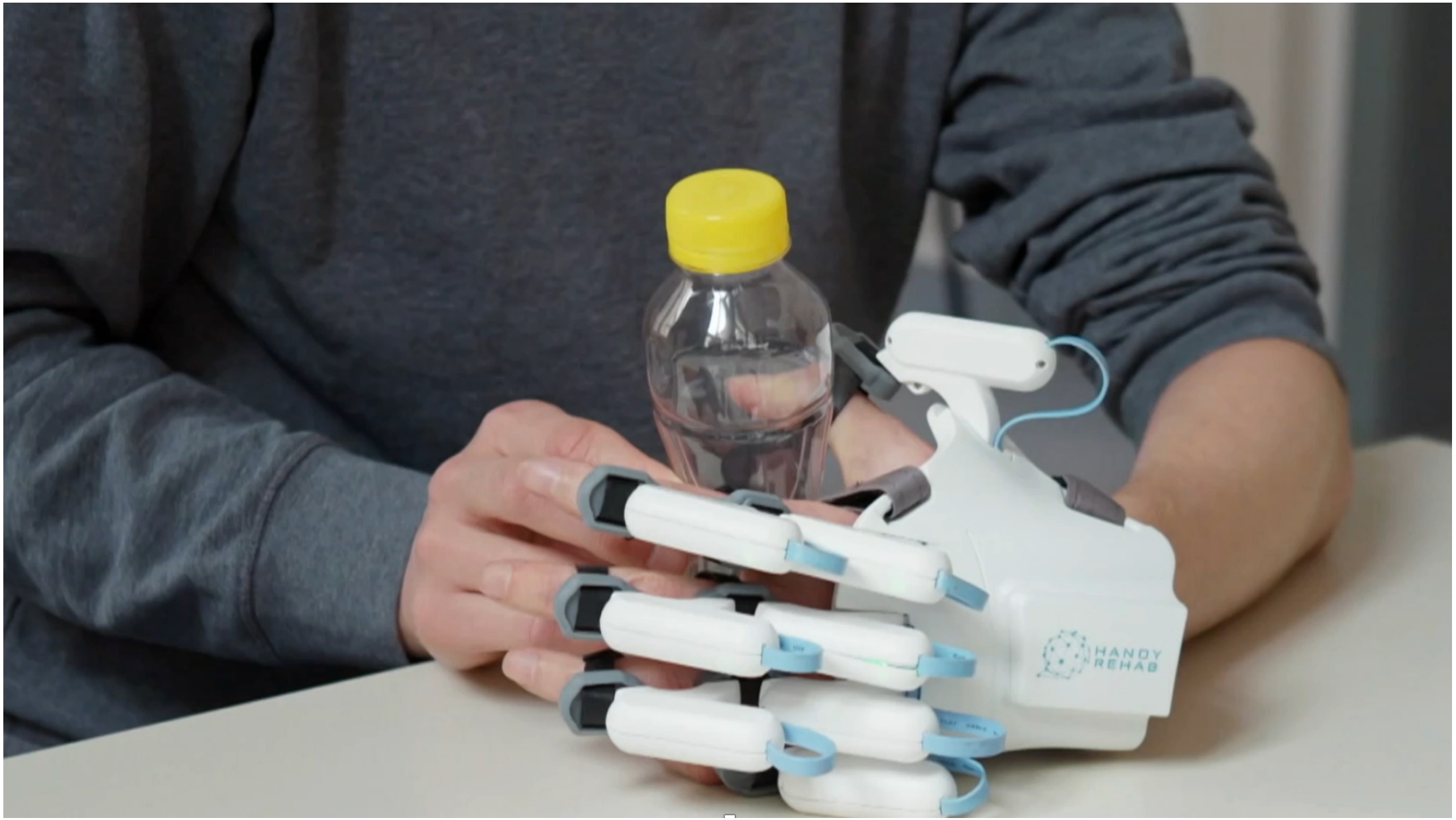
Fernández et al. 2014, *Front Neuroeng*; Bublitz, Gilbert & Soekadar 2023, *Nature Medicine*

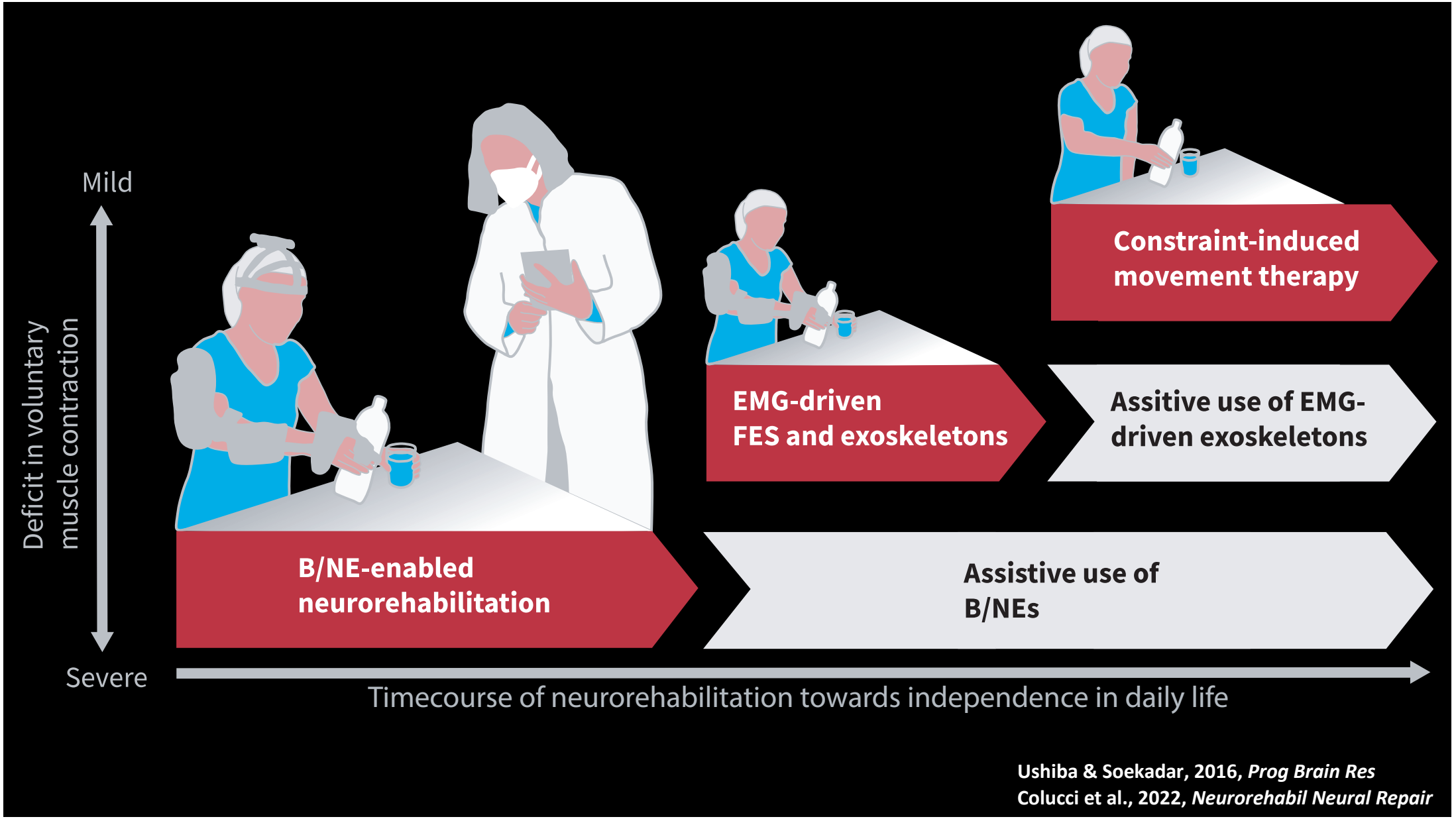
Science Robotics releases its inaugural issue!

Science | Dec. 6, 2016


before
after BCI training
Ramos-Murguialday et al. 2013


2m 54s 59


HANDY
REHAB

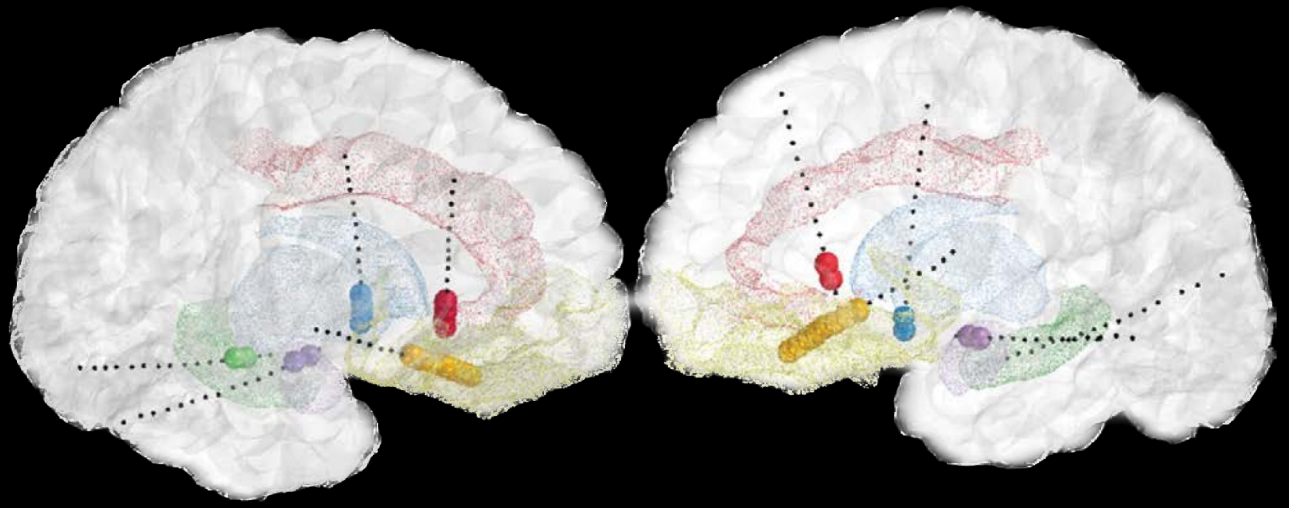


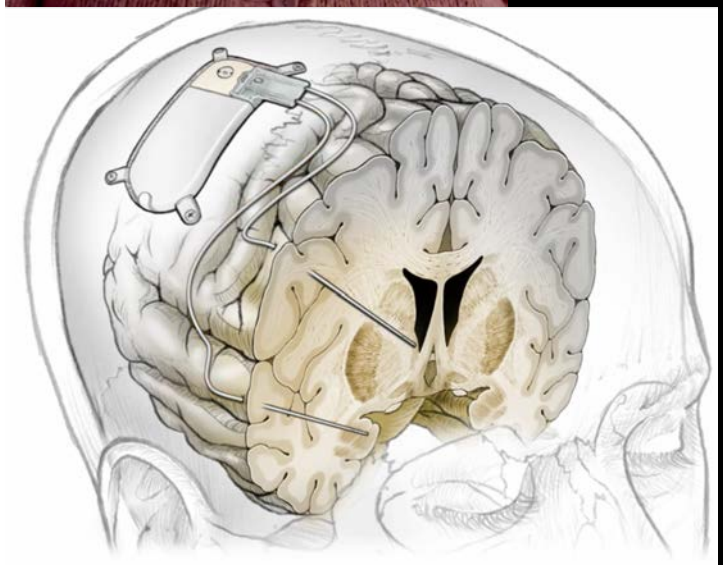
Ushiba & Soekadar, 2016, *Prog Brain Res*
Colucci et al., 2022, *Neurorehabil Neural Repair*

Summary I

- Assistive and restorative neural interfaces are **effective clinical tools** to **improve autonomy** in severe paralysis
- **Repeated use** of brain/neural exoskeletons can lead to **neuroplasticity** triggering neurological recovery
- There's no reason to doubt that such p**lasticity extends beyond the motor domain**; it likely also applies to other areas, such as cognitive control and emotion regulation

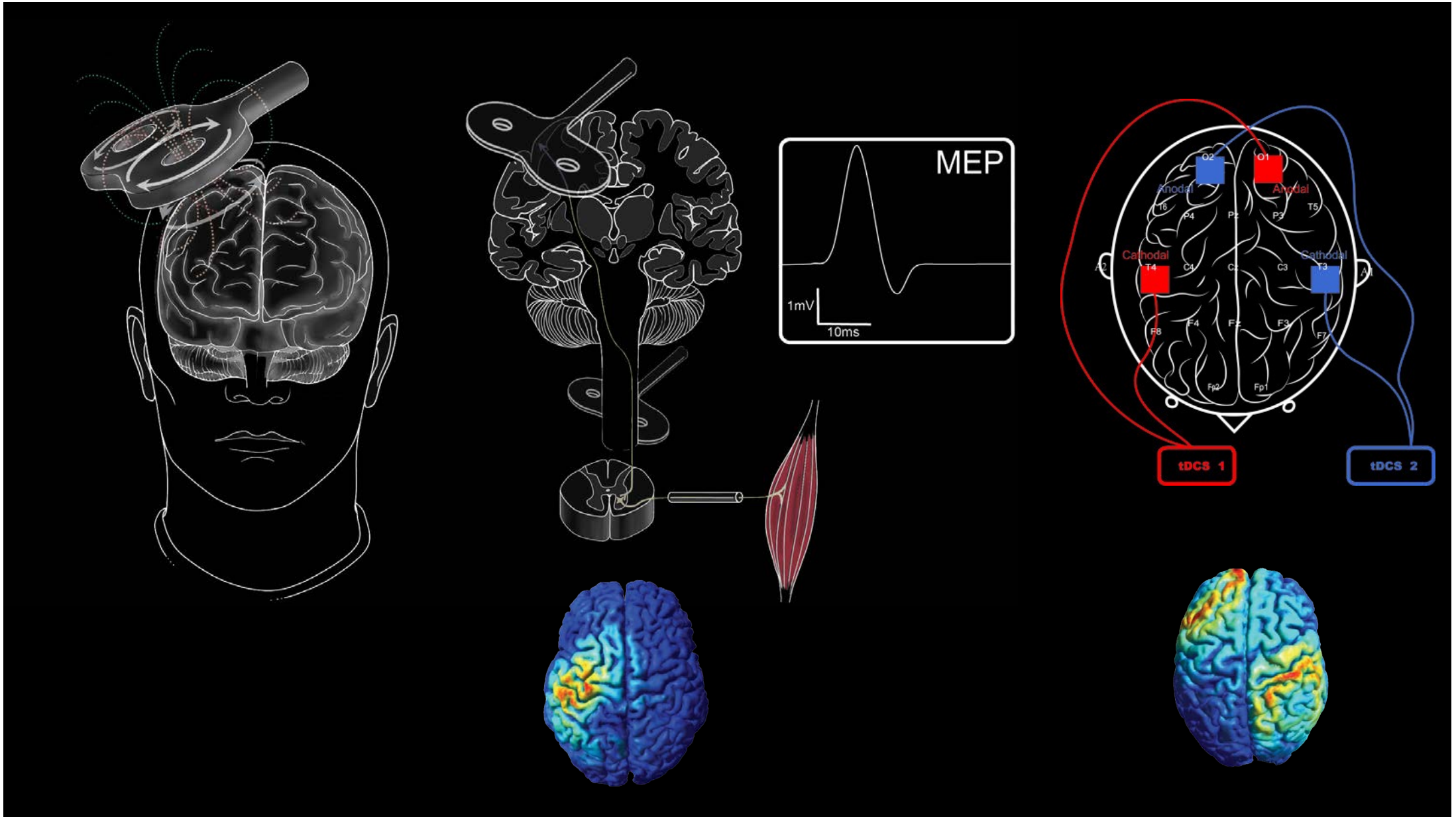
„(…) the emotions and the darkness were overwhelming“

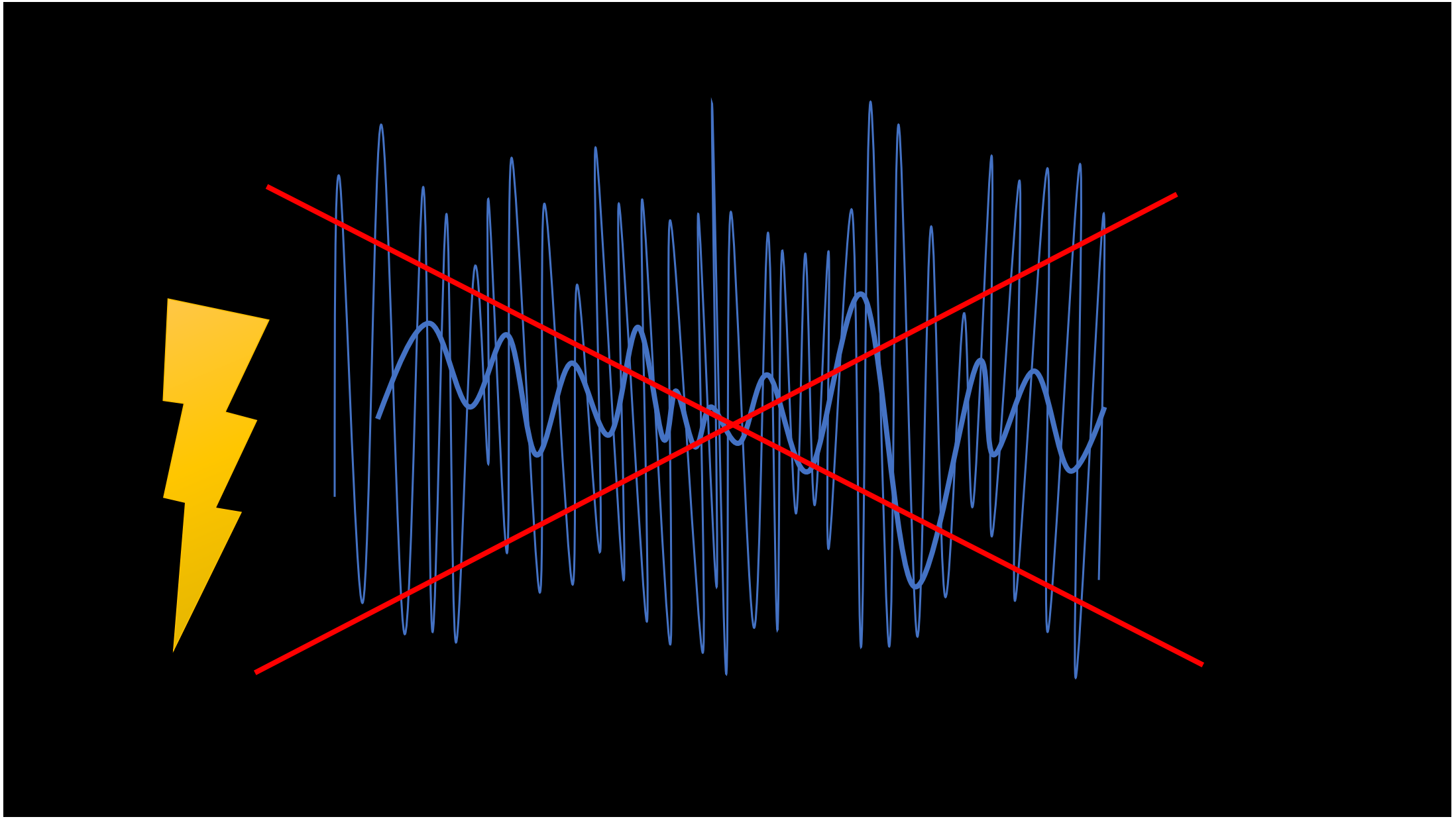


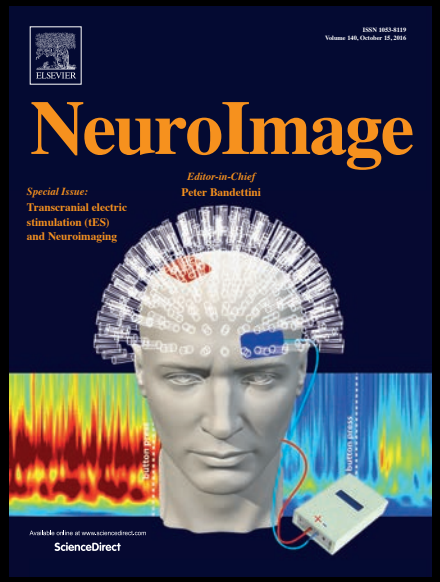


“At first, within a few weeks, the suicidal thoughts just disappeared. Then it was just a gradual process. It was like my lens on the world changed“

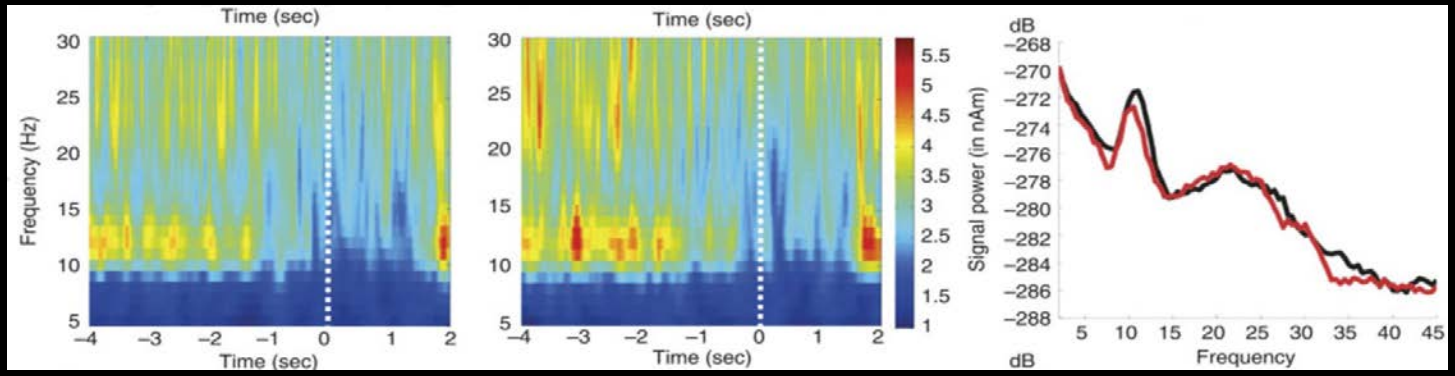
Scangos et al. 2021, *Nature Medicine*


MEP
1mV
10ms
O2
O1
Anodal
Anodal
T6
P4
P2
P3
T5
Cathodal
Cathodal
T4
C4
C2
C3
T3
F8
F4
Fz
F3
F7
Fp2
Fp1
tDCS 1
tDCS 2

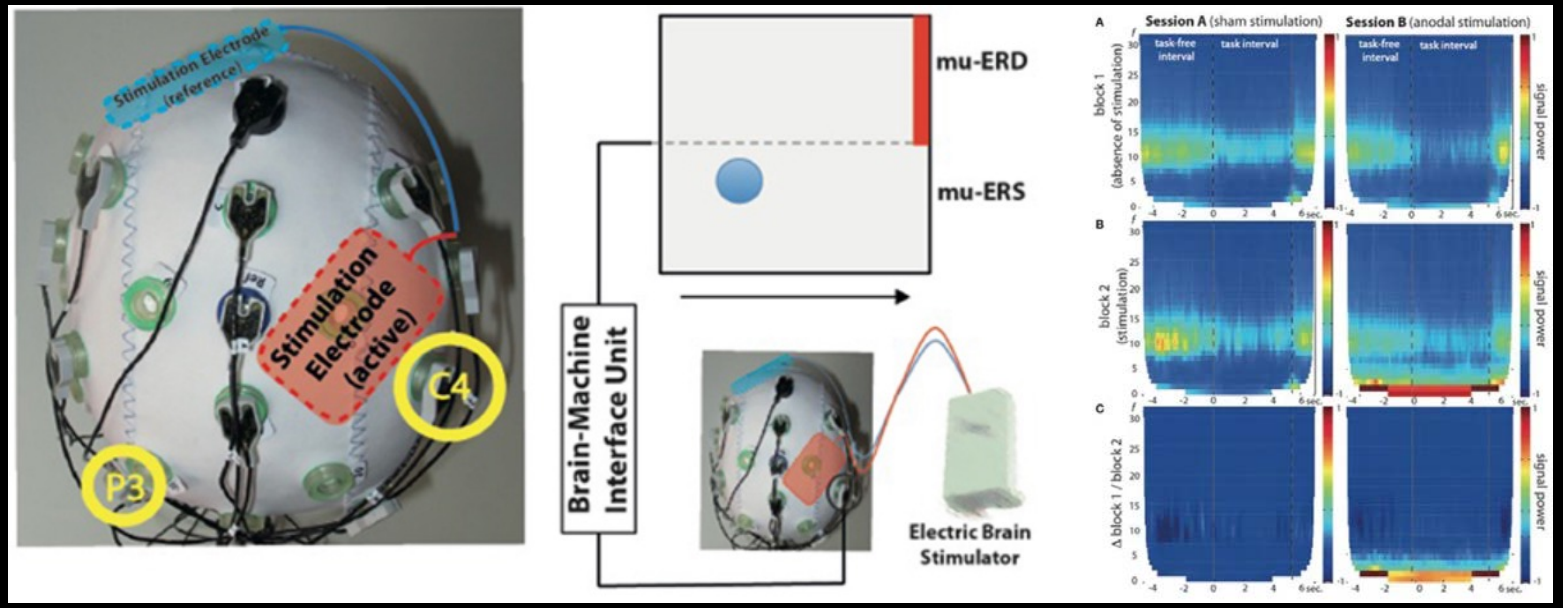




Stimulation OFF Stimulation ON

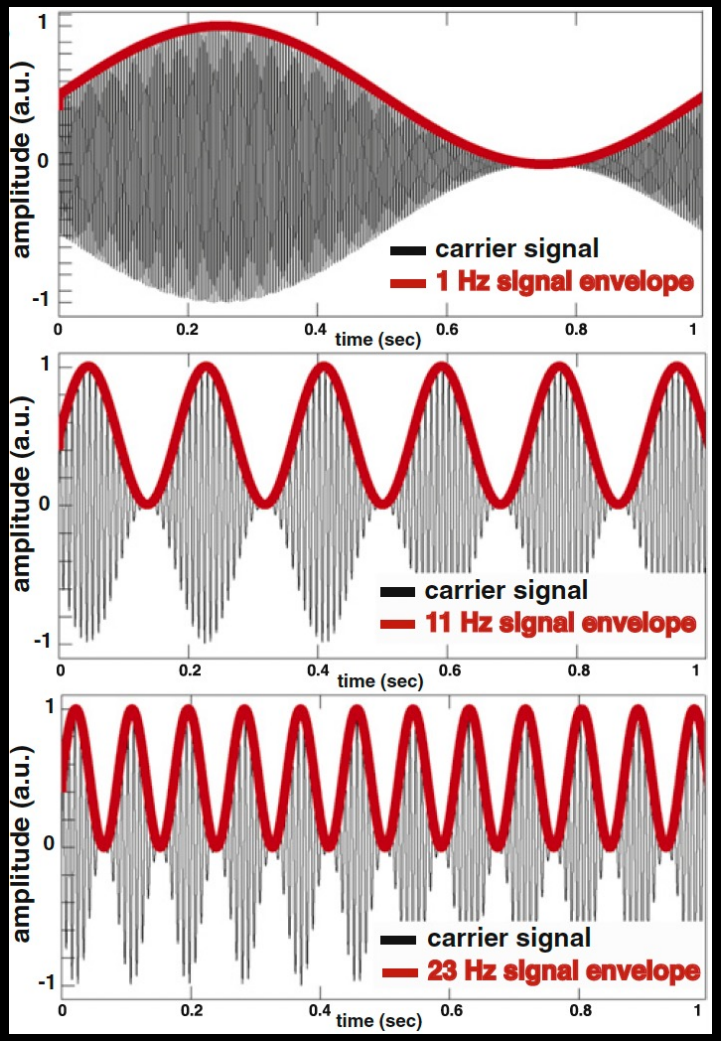


Soekadar et al. 2013, *Nature Communications*

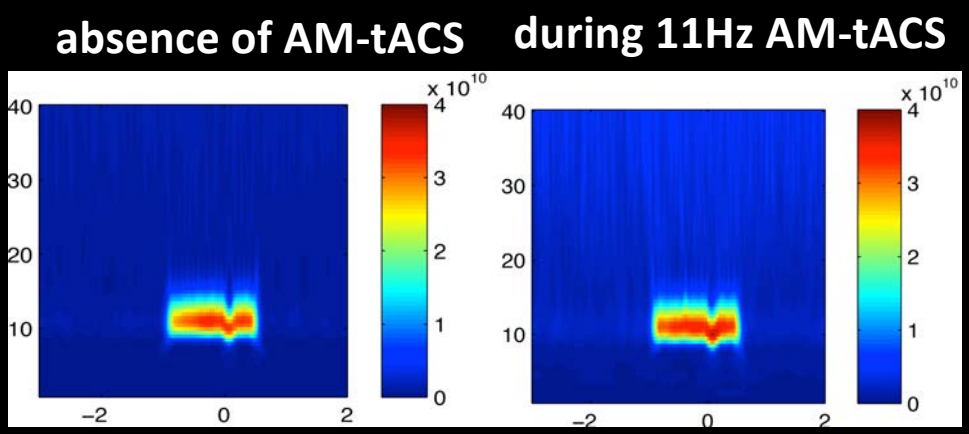


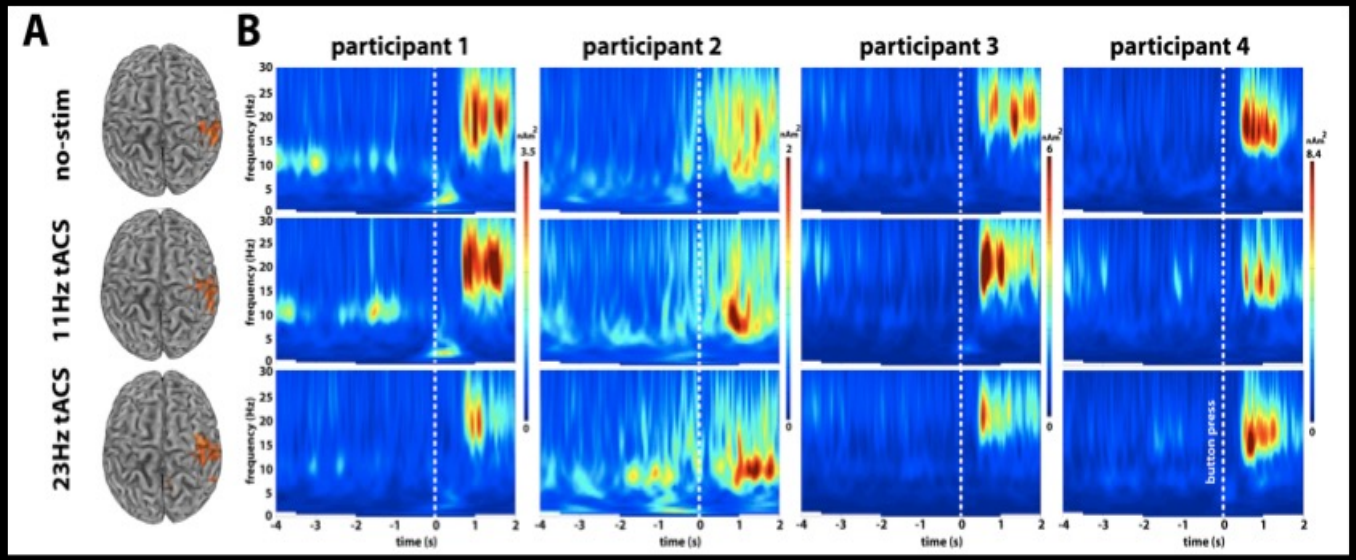
Soekadar et al. 2014, Front Neurosc.

AM-tACS and reconstruction of source activity

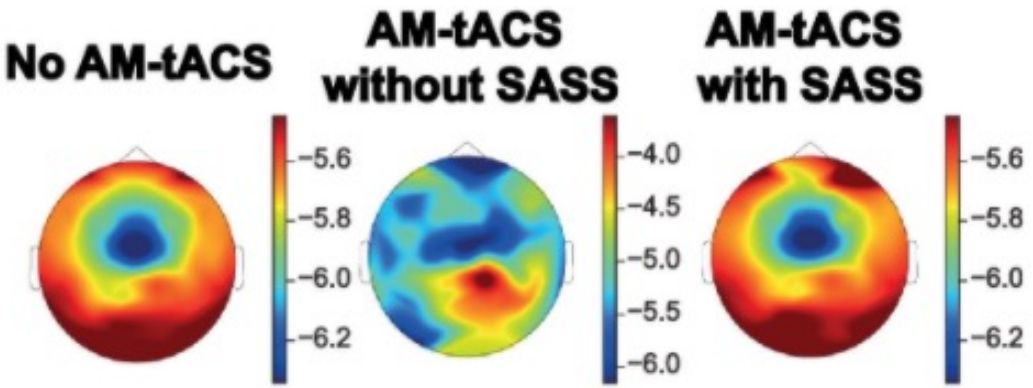


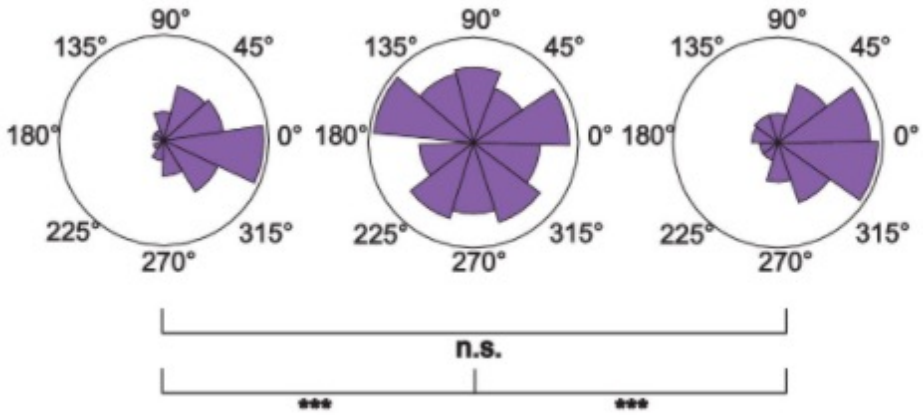
Witkowski et al. 2016, *NeuroImage*



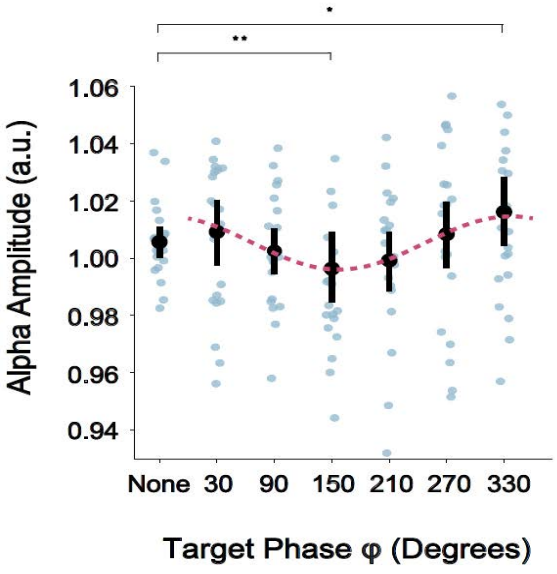


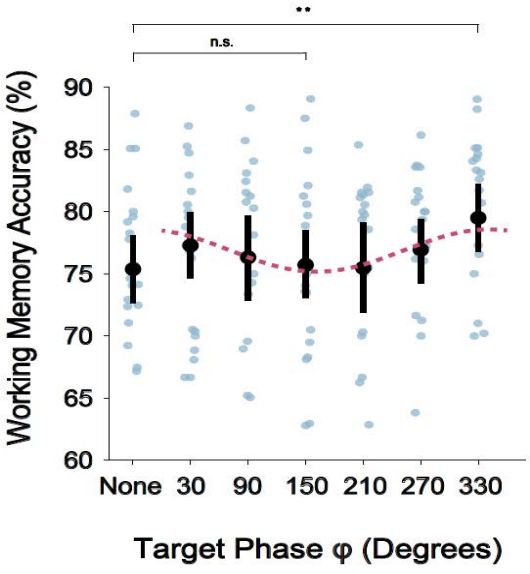
Flicker-EEG phase difference





Haslacher et al. 2021, *Neuroimage*



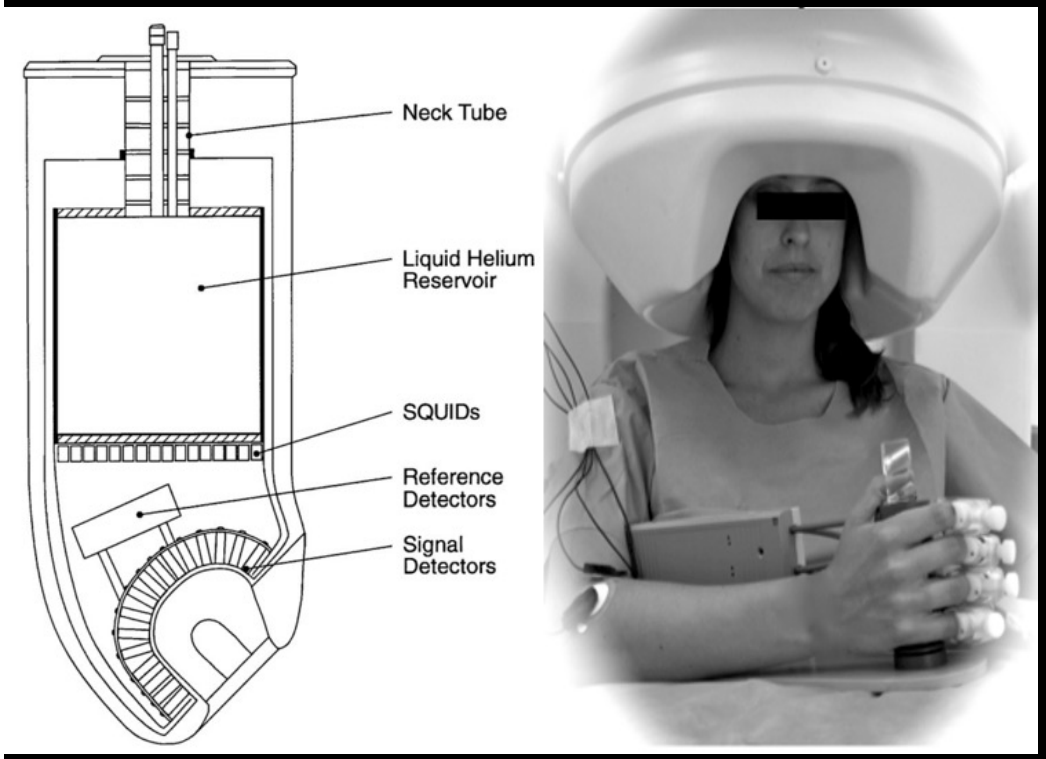


Haslacher et al. 2024, *Brain Stimulation*

EEG: very limited spatial precision, 5 - 25 Hz

MEG: best noninvasive imaging tool, 0 - 250 Hz

but: helium-cooled, static



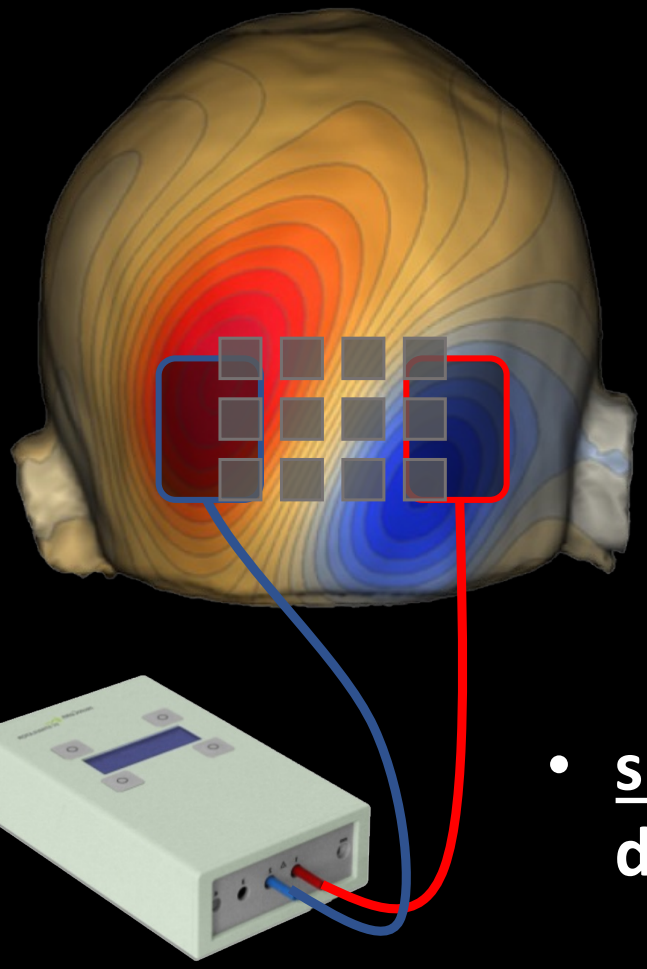
Helium-cooled MEG

Soekadar et al. 2015, *Cereb Cortex*

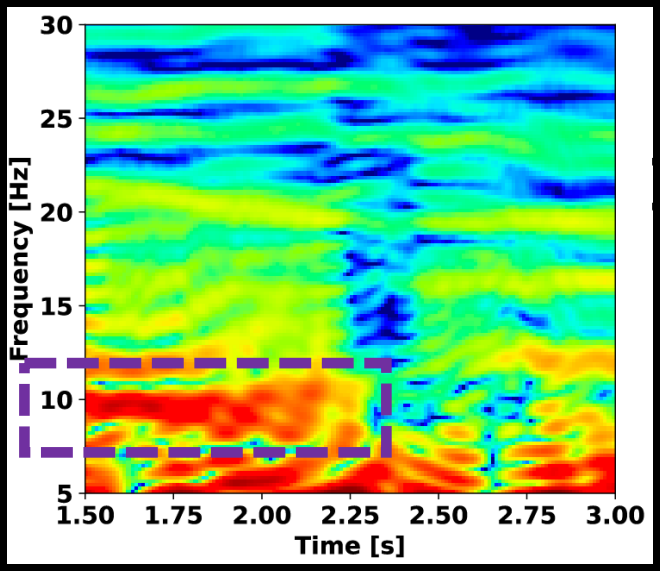
Quantum Sensors

Zerfowski et al. 2021, *ICBEM*

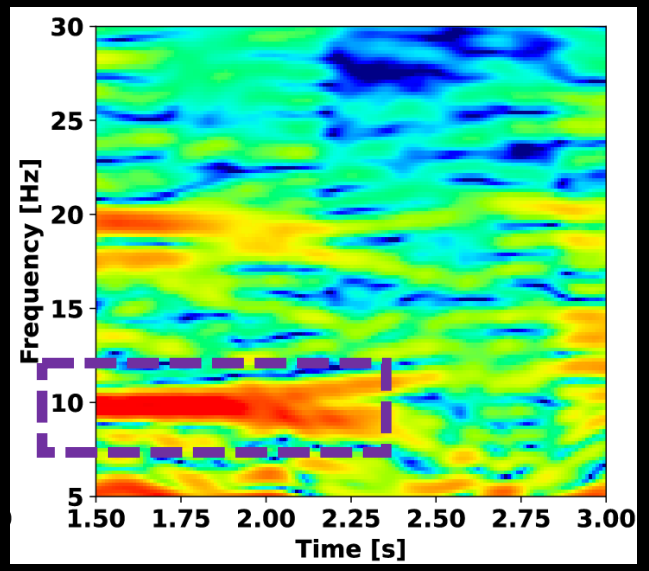
Zerfowski et al. 2022, *BioMag*



Stimulation **OFF**

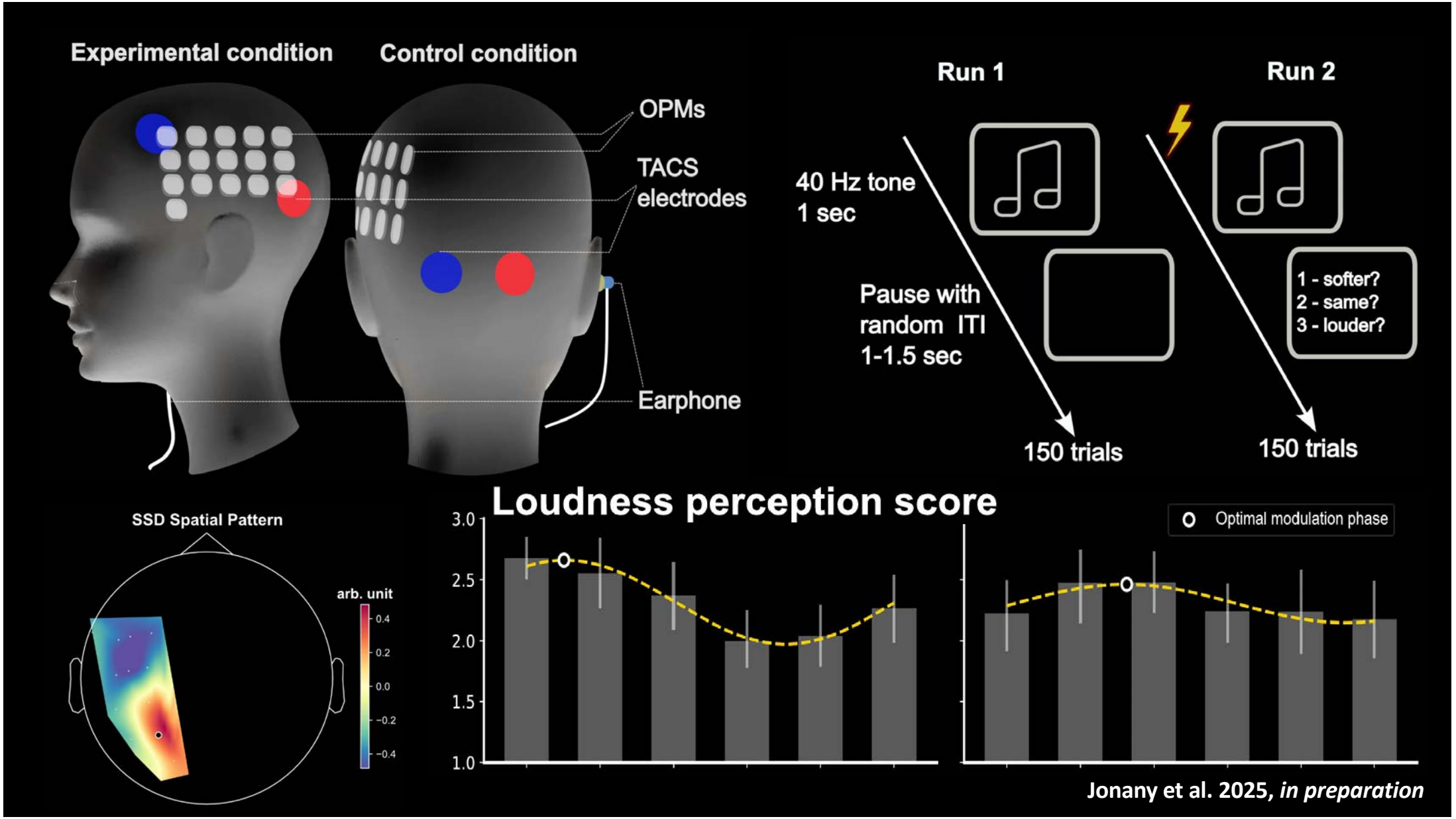


Stimulation **ON**

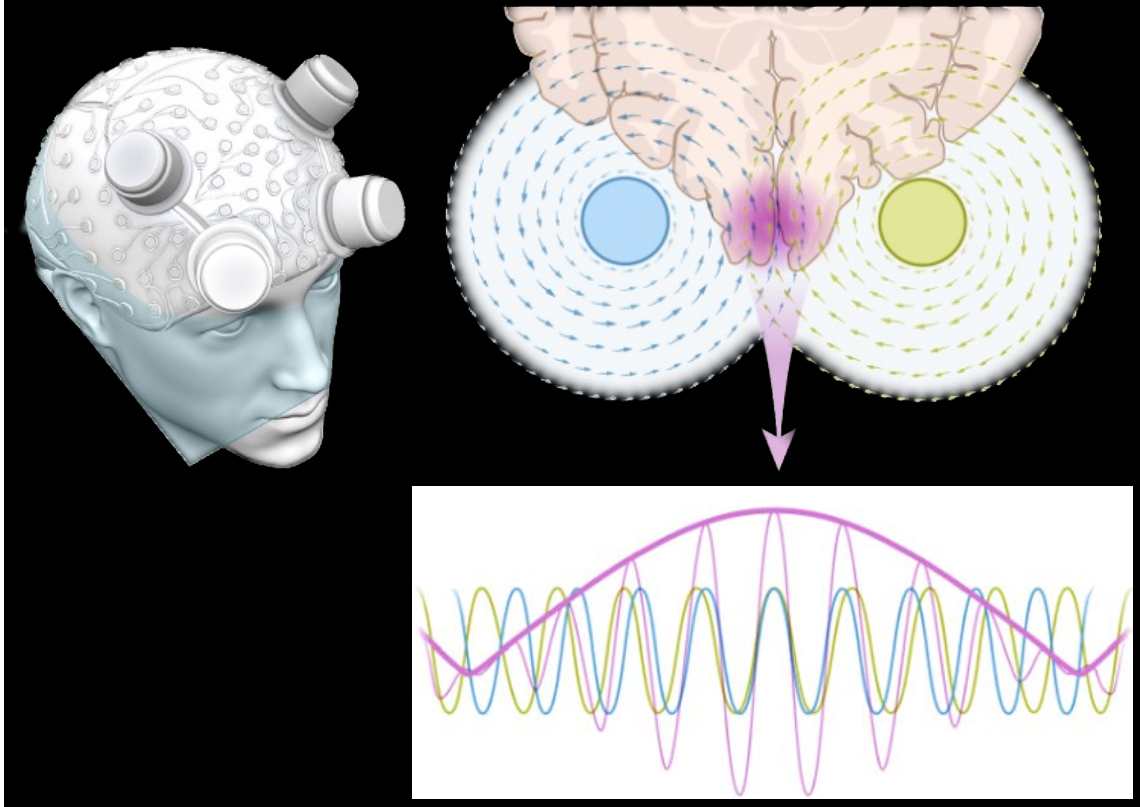


- <u>successful recovery</u> of evoked brain responses during transcranial electric brain stimulation

Jonany et al. 2023, *Brain Stim. Conf. Lisbon*


Experimental condition
Control condition
OPMs
TACS electrodes
Earphone
Run 1
Run 2
40 Hz tone
1 sec
Pause with random ITI 1-1.5 sec
1 - softer?
2 - same?
3 - louder?
150 trials
150 trials
SSD Spatial Pattern
arb. unit
0.4
0.2
0.0
−0.2
−0.4
Loudness perception score
Optimal modulation phase
3.0
2.5
2.0
1.5
1.0
Jonany et al. 2025, *in preparation*

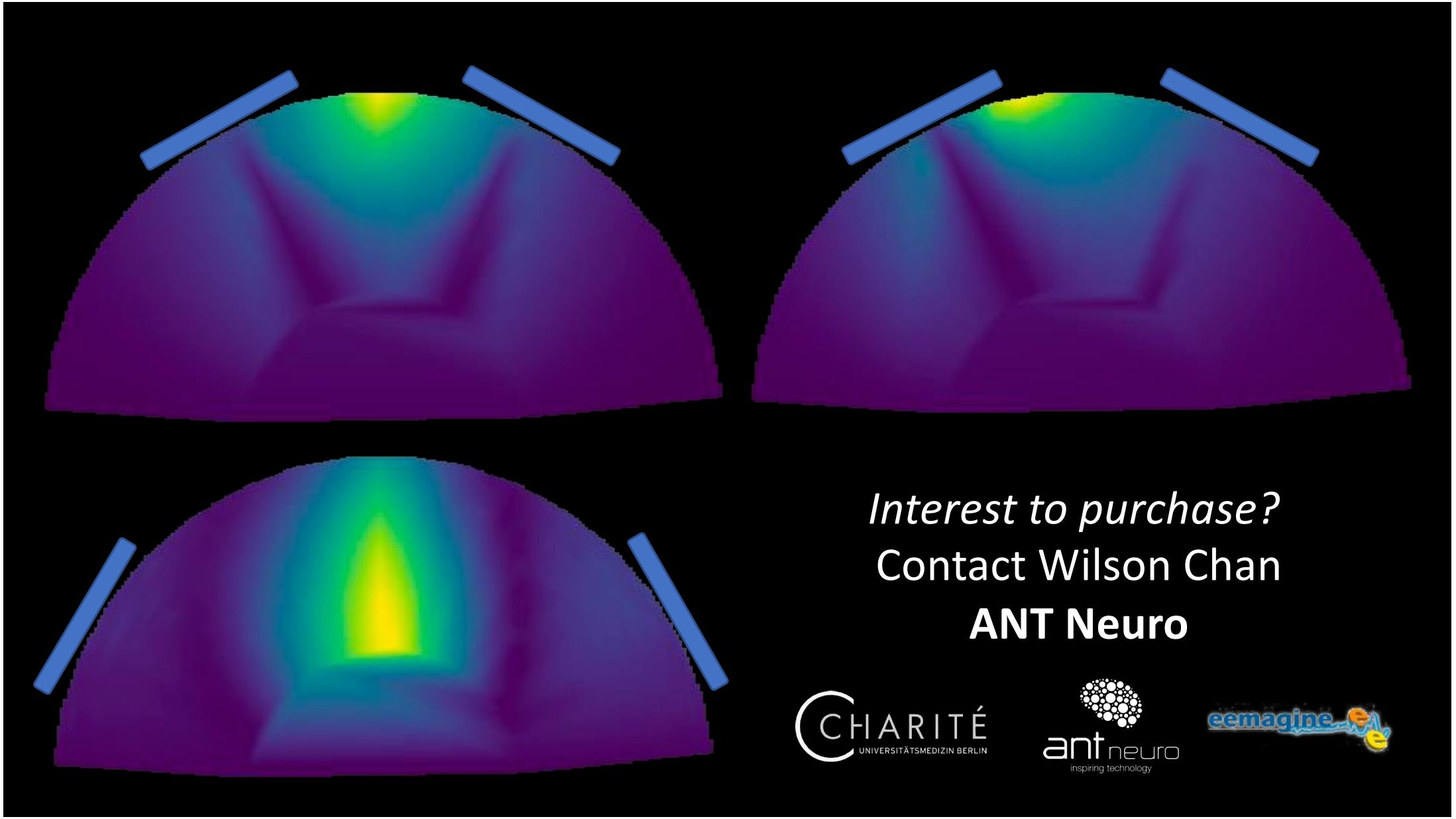
Temporal Interference Magnetic Stimulation (TIMS)



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

SPARK BIH | BIH Innovations
The Technology Transfer Office of BIH and Charité

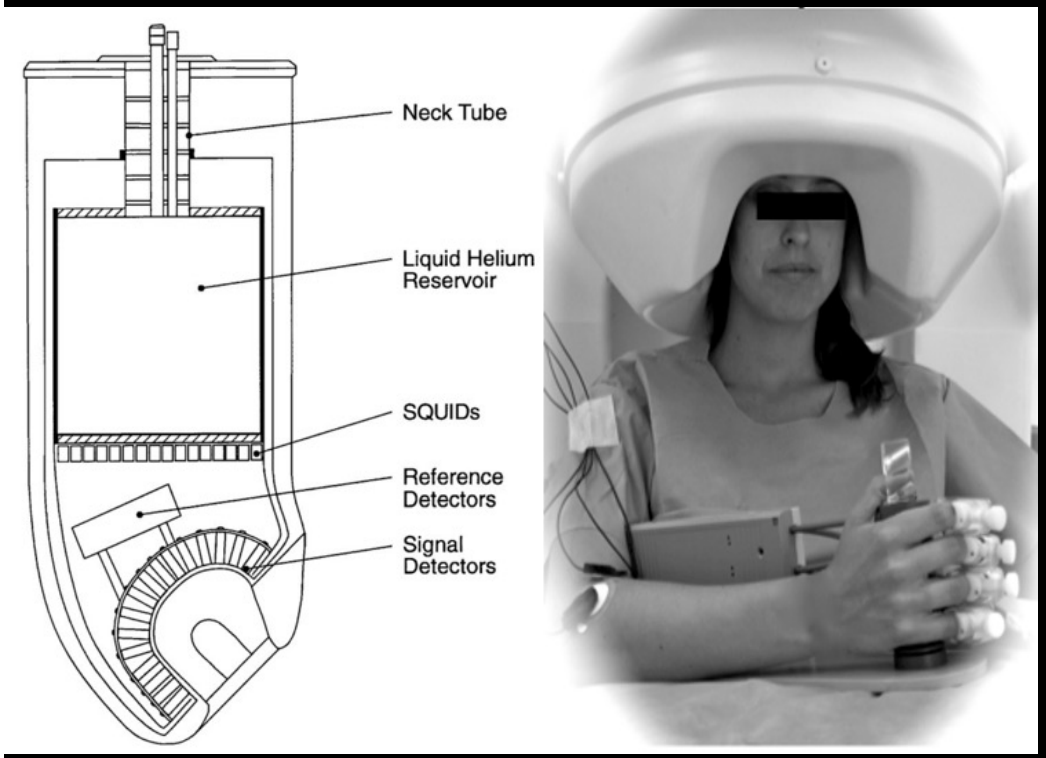
Nasr et al. 2023, *Brain Stim Conf.*


Interest to purchase?
Contact Wilson Chan
ANT Neuro
CHARITÉ
UNIVERSITÄTSMEDIZIN BERLIN
ant neuro
inspiring technology
eemagine

EEG: very limited spatial precision, 5 - 25 Hz

MEG: best noninvasive imaging tool, 0 - 250 Hz

<u>but:</u> helium-cooled, static



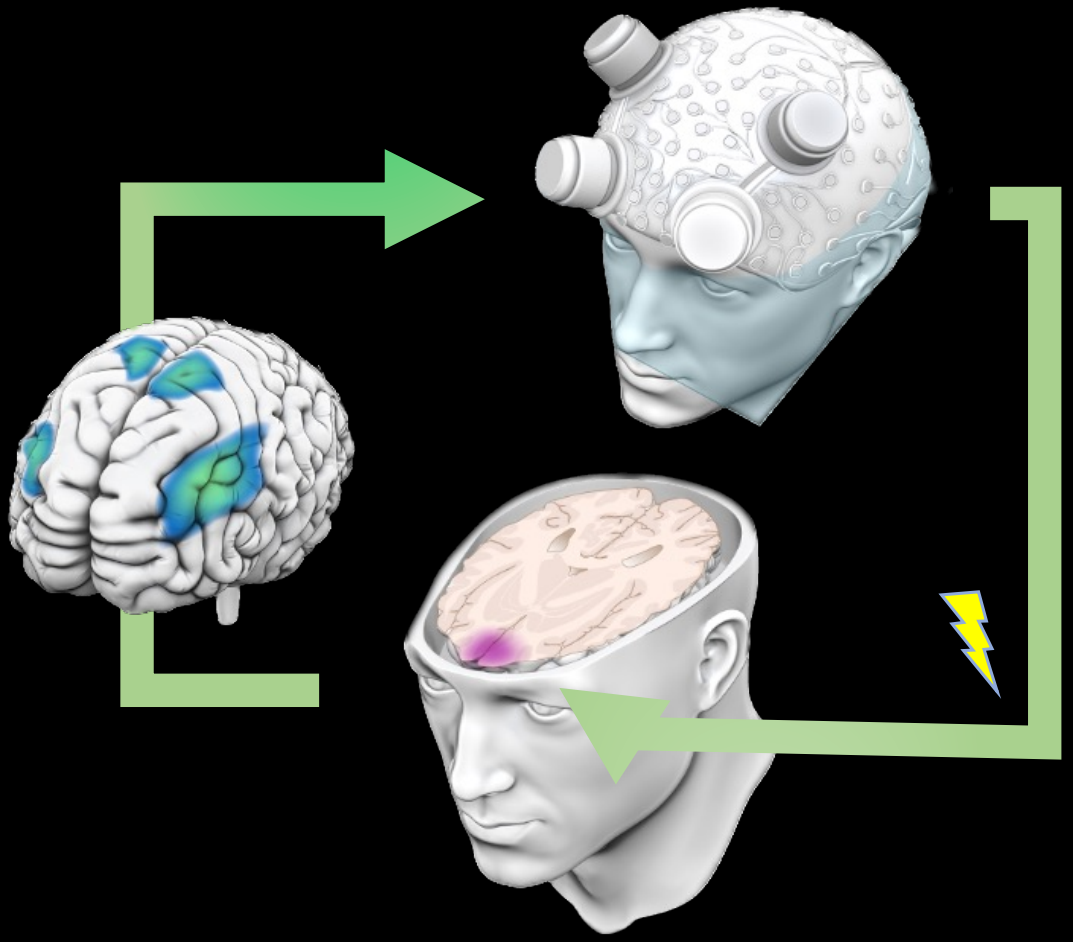
Helium-cooled MEG

Soekadar et al. 2015, *Cereb Cortex*

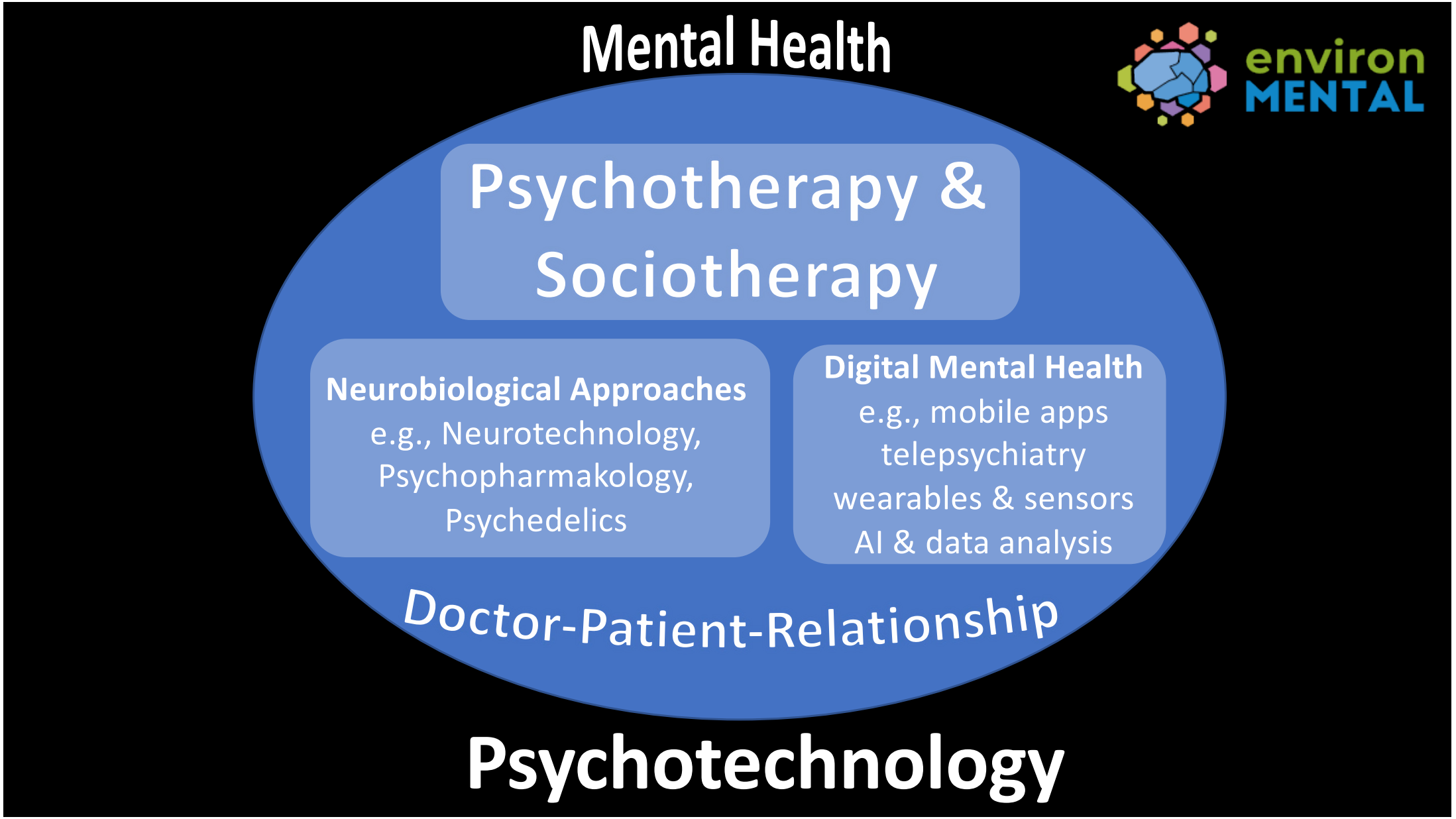
Quantum Sensors

Zerfowski et al. 2021, *ICBEM*

Zerfowski et al. 2022, *BioMag*



BNCI²
Consolidator Grant
2025-2030


Mental Health
environ MENTAL
Psychotherapy & Sociotherapy
Neurobiological Approaches
e.g., Neurotechnology, Psychopharmakology, Psychedelics
Digital Mental Health
e.g., mobile apps
telepsychiatry
wearables & sensors
AI & data analysis
Doctor-Patient-Relationship
Psychotechnology

Neuroethics und Neurorights

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

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, technology sets the limits)

scenario 2: humanistic augmentation
→ *Technology augments human capabilities, but remains a tool at service to the human user*

NeuroTech Innovation Ecosystems

- 🤝 **Open Innovation Hub**: Academic-Industrial Partnership & Clinician Innovators
- 🔧 **Regulation:** NeuroTech Sherpas & Simplification
- 💰 **Financial Support:** VC-Funds >15 Mio. €

Neurotechnology 2040 – human at the center

- human centred & based on ethical principles
- established in prevention, treatment and rehab
- reliable regulatory & ethical framework

Summary

- Neurotechnology **improves quality of life** in various conditions (stroke, SCI, ALS etc.)
- The **combination of neuromodulation and AI** extends applicability towards **mental health**
- **NeuroTech innovation ecosystems** with clinical validation hubs are key





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RESEARCH FOUNDATION
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RESEARCH 19 35 87 years FOR CURES

DFG Deutsche Forschungsgemeinschaft

Bundesministerium
für Bildung
und Forschung

SPARK
BIH

BERLIN
INSTITUTE
OF HEALTH
Charité & Max Delbrück Center

EINSTEIN
Foundation.de

neuron
Network of European
Funding for
Neuroscience Research

CHANSE.

surjo.soekadar@charite.de