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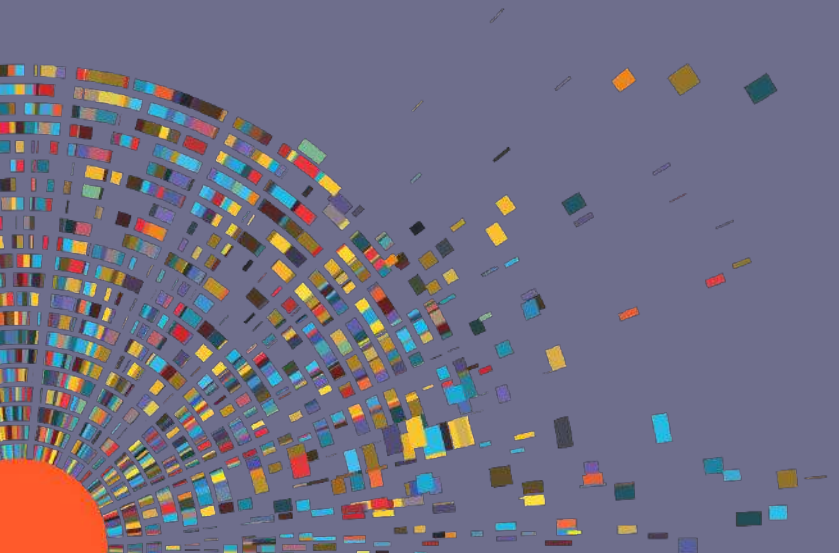
La science pour la santé
From science to health



12e Journée annuelle du Comité d'éthique de l'Inserm

Contrôler ou libérer nos cerveaux ? La tension éthique des neurotechnologies

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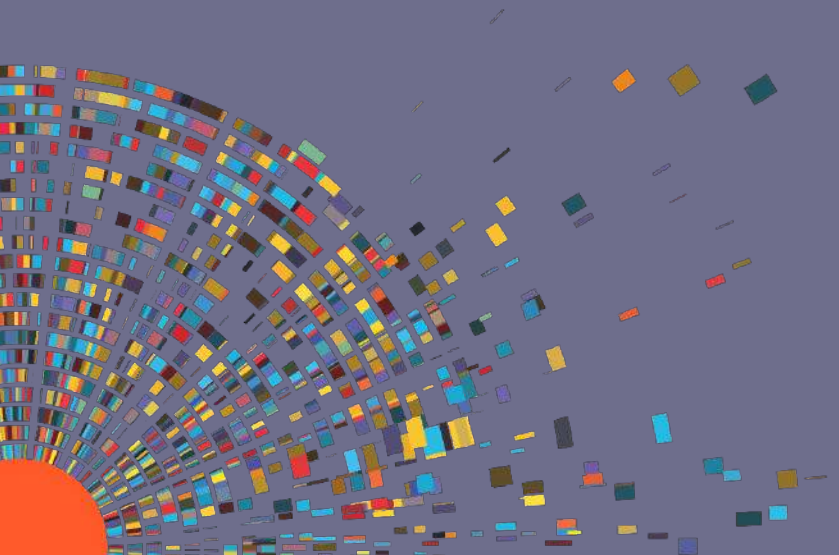


Invasive neurotechnologies and (some) related ethical implications

Blaise Yvert

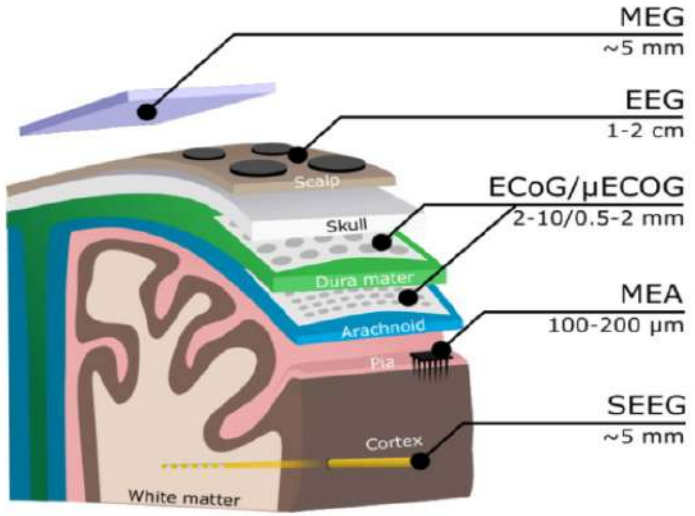
Grenoble Institute of Neuroscience

blaise.yvert@inserm.fr

https://www.neurotech-lab.fr/

Implantable neural interfaces

- Electrocorticography (ECoG)
- Micro-Electrocorticography (µECoG)
- Stereo-Electroencephalography (sEEG)
- Intracortical microelectrode arrays (MEAs)
- Endovascular (Stentrodes)



From Jorfi et al. 2015 and Bocquelet et al. 2017

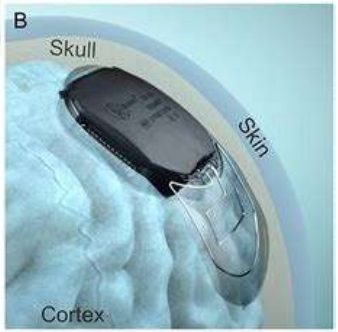
Implantable technologies (endovascular and ECoG)

synchron

WIMAGINE

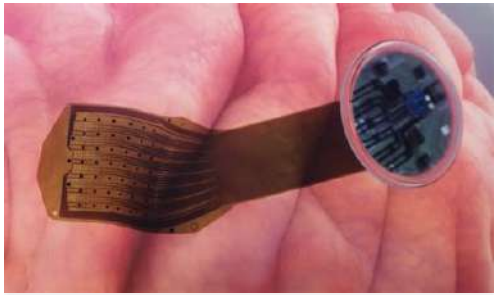
clinatec cea leti

64 elec
wireless

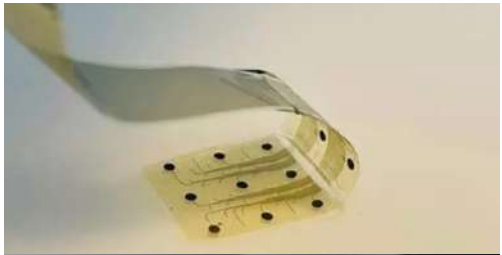


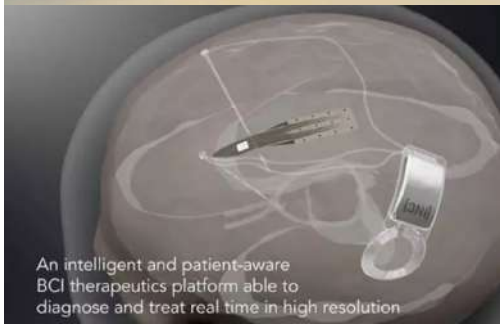
PrecisionNeuroscience

4096 µECoG flex elec/array, wireless



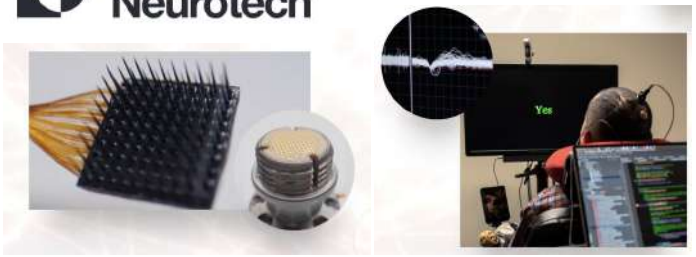
INBRAIN
NEUROELECTRONICS





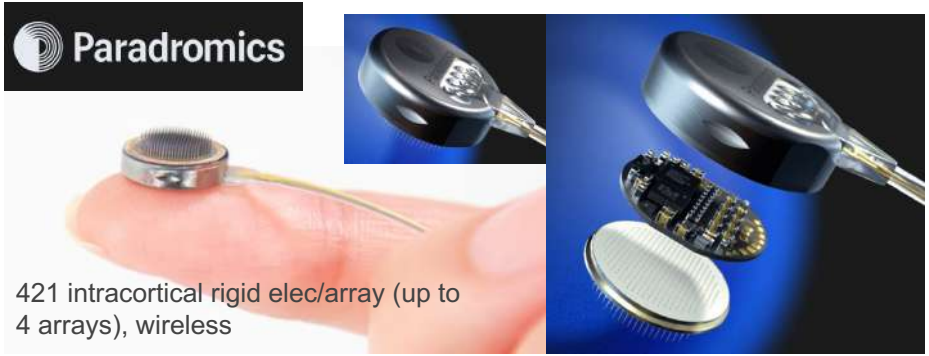
Implantable technologies (intracortical)

Blackrock Neurotech



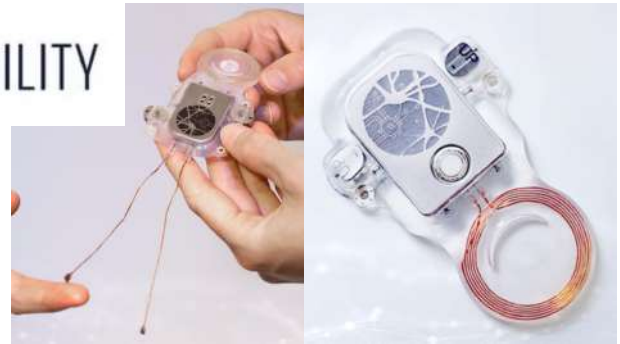
64-96 intracortical rigid elec/array (up to 6 arrays so far), tethered

Paradromics



421 intracortical rigid elec/array (up to 4 arrays), wireless

ABILITY

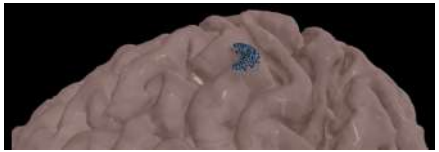


NEURALINK

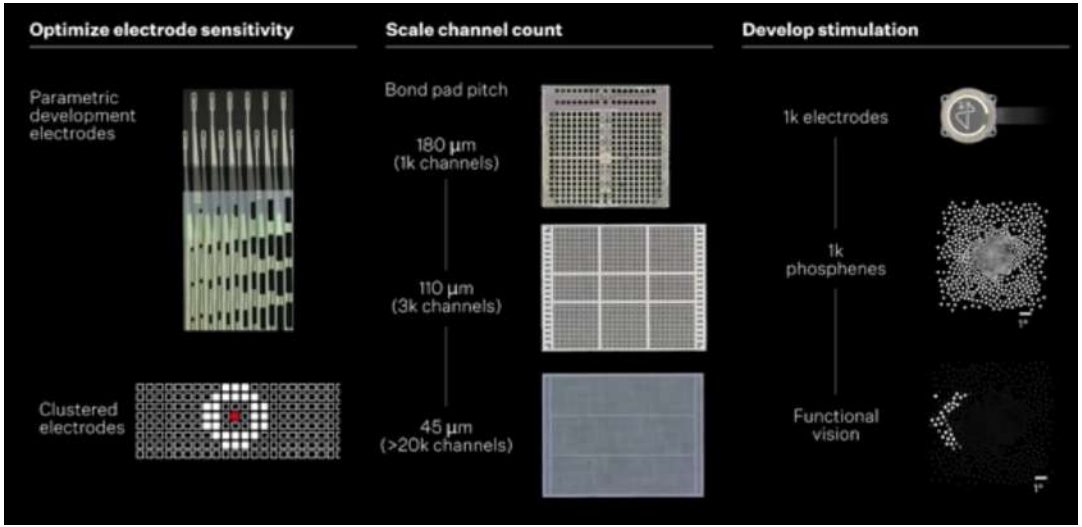
1024 intracortical flex elec/array, robot implantation, wireless

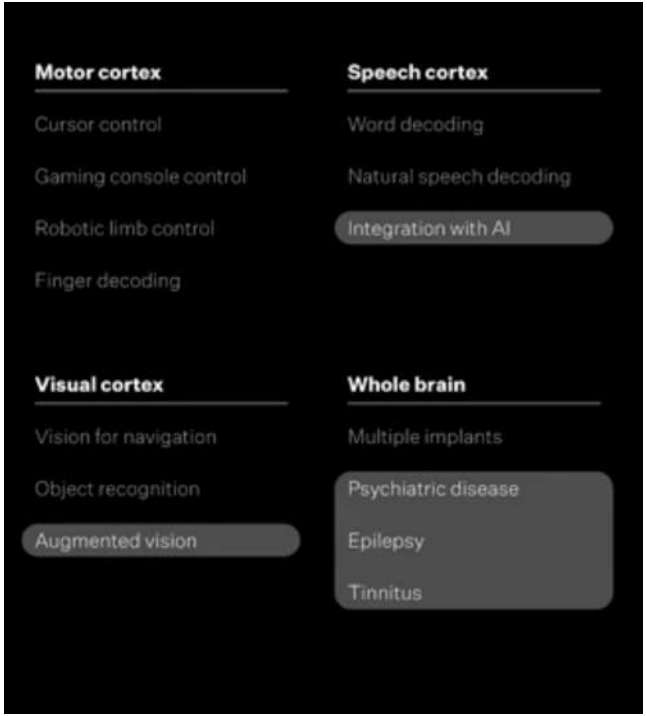
Upcoming implantable technologies

NEURALINK

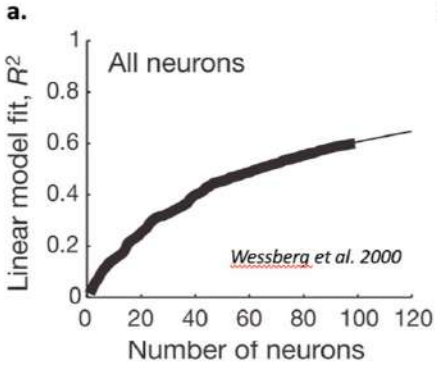


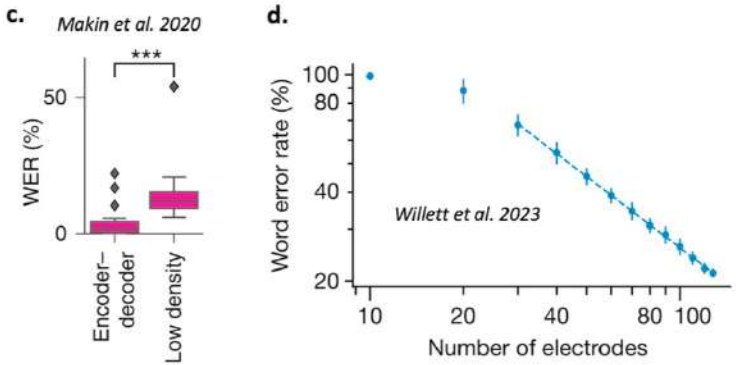
Low-cost



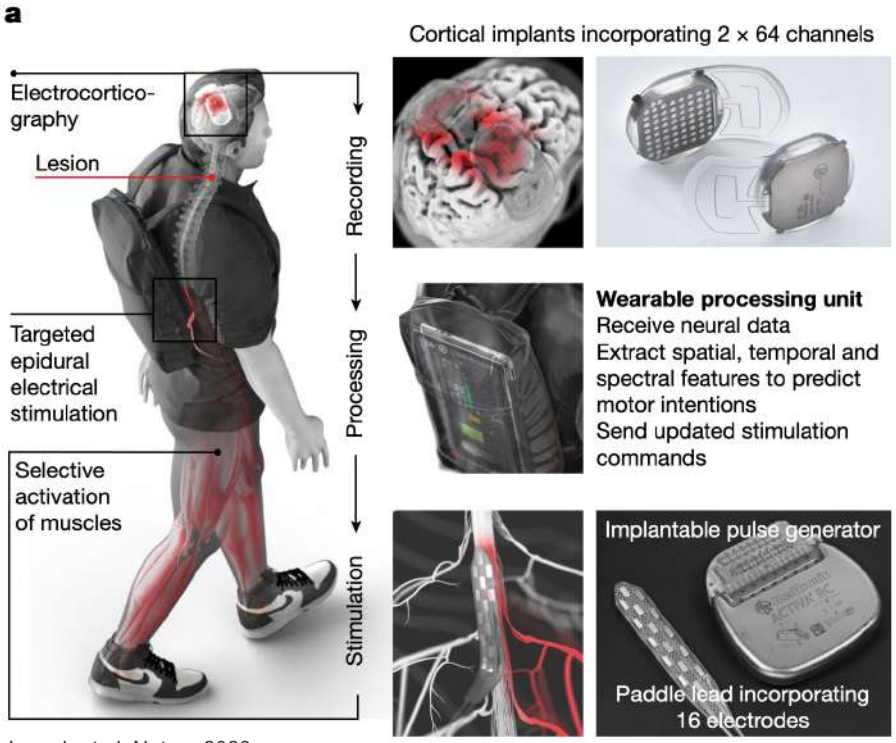


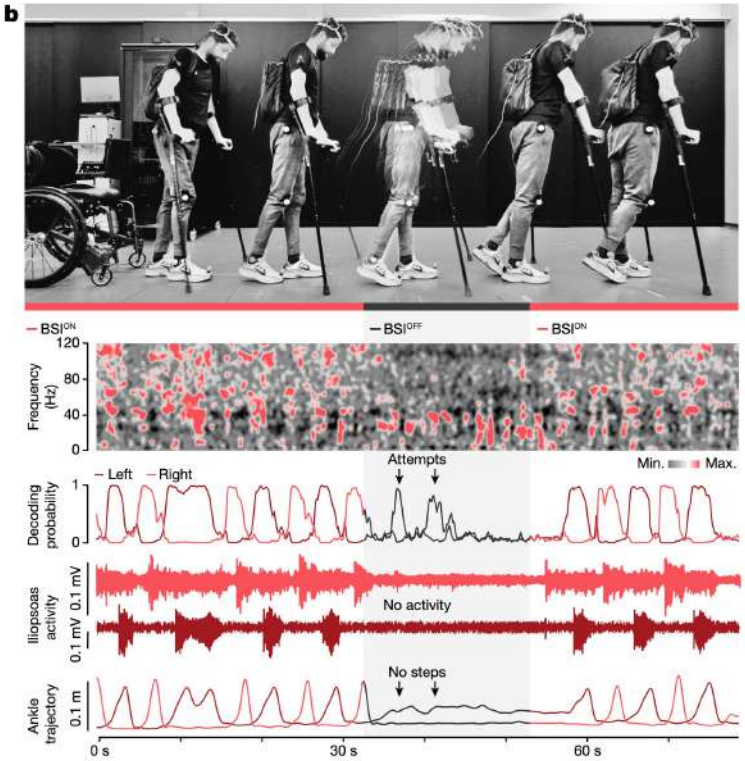
Towards extensive brain interfacing





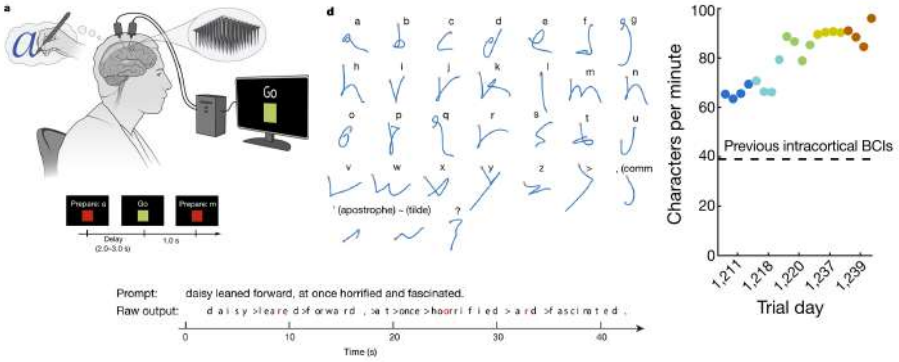
Restoring walking with implantable BCIs



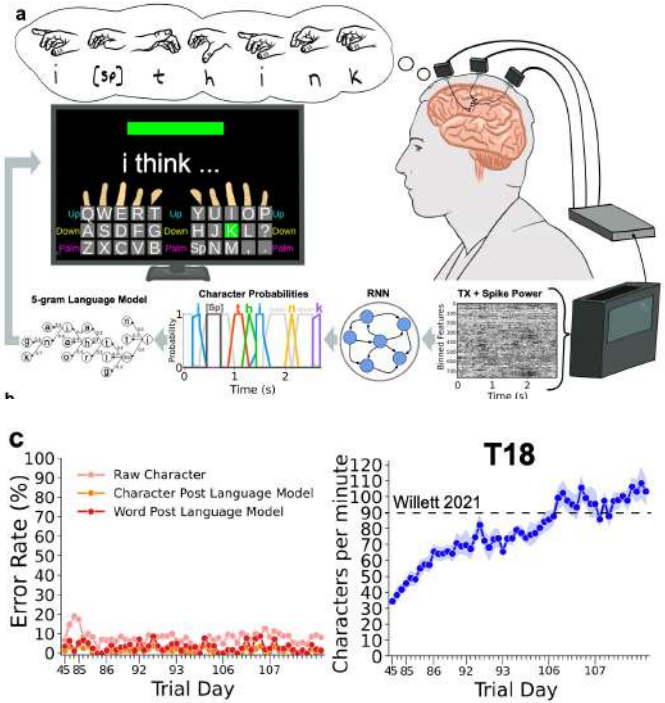


Lorach et al. Nature 2023

Restoring communication with implantable BCIs



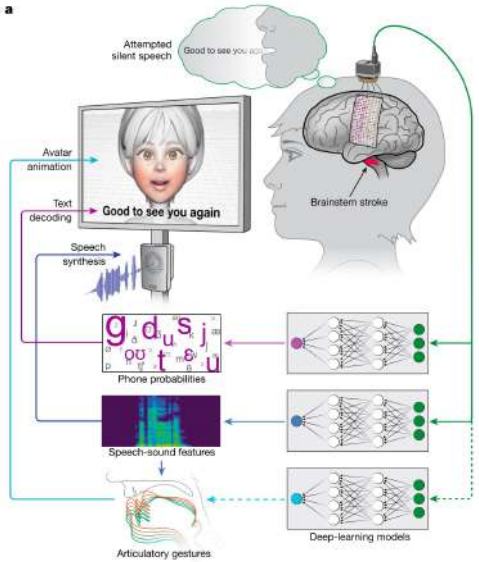
Willett et al., Nature 2021



Jude et al., MedRxiv 2025

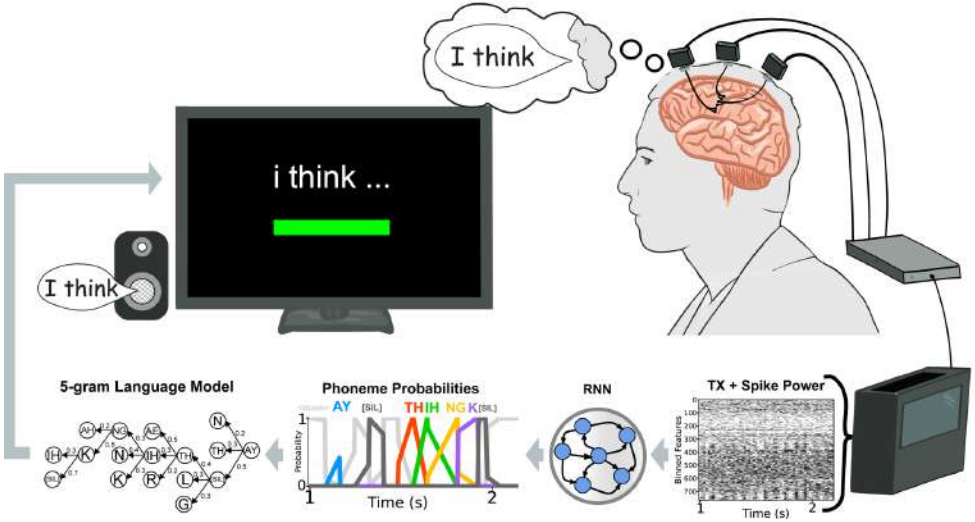
Restoring speech with implantable BCIs

ECoG



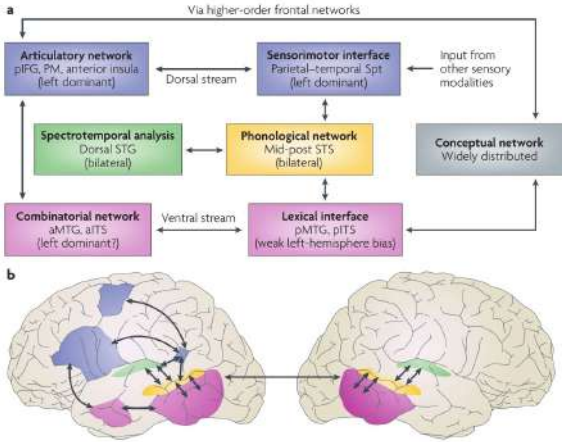
Moses et al., NEJM 2021
Metzger et al., Nature 2023
Luo et al., Adv. Sci. 2023
Littlejohn et al., Nat Neuro 2025

Intracortical



Card et al., NEJM 2024
Jude et al., bioRxiv 2025
Wairagkar et al. Nature 2025
Kunz et al. Cell 2025

Implications: privacy of thoughts with speech BCIs



Hickock and Poeppel, Nature Rev Neurosci, 2007

Article

Neuroprosthetic Speech: The Ethical Significance of Accuracy, Control and Pragmatics

STEPHEN RAINEY, HANNAH MASLEN, PIERRE MÉGEVAND, LUC H. ARNAL, ERIC FOURNERET, and BLAISE YVERT

Cambridge Q Healthc Ethics, 2019

CellPress
OPEN ACCESS

Cell

Article

Inner speech in motor cortex and implications for speech neuroprostheses

Erin M. Kunz,[1,2,18,20,*] Benyamin Abramovich Krasa,[3,18] Foram Kamdar,[4] Donald T. Avansino,[4,5] Nick Hahn,[4] Seonghyun Yoon,[1,6] Akansha Singh,[4] Samuel R. Nason-Tomaszewski,[7] Nicholas S. Card,[8] Justin J. Jude,[11] Brandon G. Jacques,[7] Payton H. Bechefsky,[7] Carrina Iacobacci,[8] Leigh R. Hochberg,[9,10,11] Daniel B. Rubin,[11] Ziv M. Williams,[12,13,14] David M. Brandman,[8] Sergey D. Stavisky,[8] Nicholas AuYong,[7,15,16] Chethan Pandarinath,[7,15] Shaul Druckmann,[1,17] Jaimie M. Henderson,[2,4] and Francis R. Willett[4,5,19]
[1]Department of Electrical Engineering, Stanford University, Stanford, CA, USA
[2]Wu Tsai Neurosciences Institute, Stanford University, Stanford, CA, USA
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https://doi.org/10.1016/j.cell.2025.06.015

SUMMARY

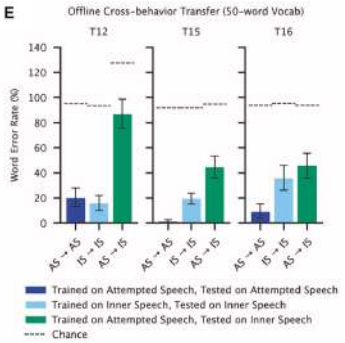
Speech brain-computer interfaces (BCIs) show promise
but have also prompted discussions regarding their pot
ner speech may be a way to bypass the current approac
speech, which is fatiguing and can slow communicatio
we found that inner speech is robustly represented in t
decoded in real time. The representation of inner spe
though we also identified a neural "motor-intent" dim
the possibility of decoding private inner speech and fou
be decoded during sequence recall and counting tasks.
prevent speech BCIs from unintentionally decoding private inner speech.

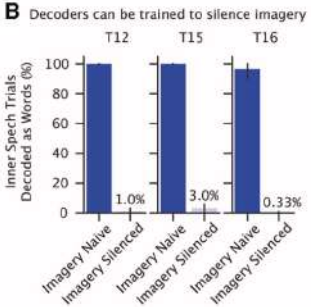
DECLARATION OF INTERESTS

The MGH Translational Research Center has a clinical research support agreement (CRSA) with Axoft, Neuralink, Neurobionics, Paradromics, Precision Neuro, Synchron, and Reach Neuro, for which L.R.H. provides consultative input. L.R.H. is a non-compensated member of the Board of Directors of a nonprofit assistive communication device technology foundation (Speak Your Mind Foundation). Mass General Brigham (MGB) is convening the Implantable Brain-Computer Interface Collaborative Community (iBCI-CC). Charitable gift agreements to MGB, including those received to date from Paradromics, Synchron, Precision Neuro, Neuralink, and Blackrock Neurotech, support the iBCI-CC, for which L.R.H. provides effort.

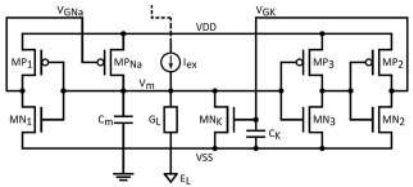
S.D.S. is an inventor on intellectual property licensed by Stanford University to Blackrock Neurotech and Neuralink Corp. He is an advisor to Sonera. He also has equity in Wispr.ai. C.P. is an employee at Meta (Reality Labs). D.M.B. is a surgical consultant for Paradromics Inc. D.M.B. and D.B.R. are principal investigators for the Connexus BCI clinical trial for a Paradromics Inc. clinical product. S.D.S. and D.M.B. are inventors of intellectual property related to speech neuroprostheses owned by the University of California, Davis that has been licensed to a neurotechnology startup.

J.M.H. is a consultant for Paradromics, serves on the Medical Advisory Board of Enspire DBS, and is a shareholder in Maplight Therapeutics. He is also the co-founder of Re-EmergeDBS. He is also an inventor on intellectual property licensed by Stanford University to Blackrock Neurotech and Neuralink Corp. F.R.W. is an inventor on intellectual property licensed by Stanford University to Blackrock Neurotech and Neuralink Corp.





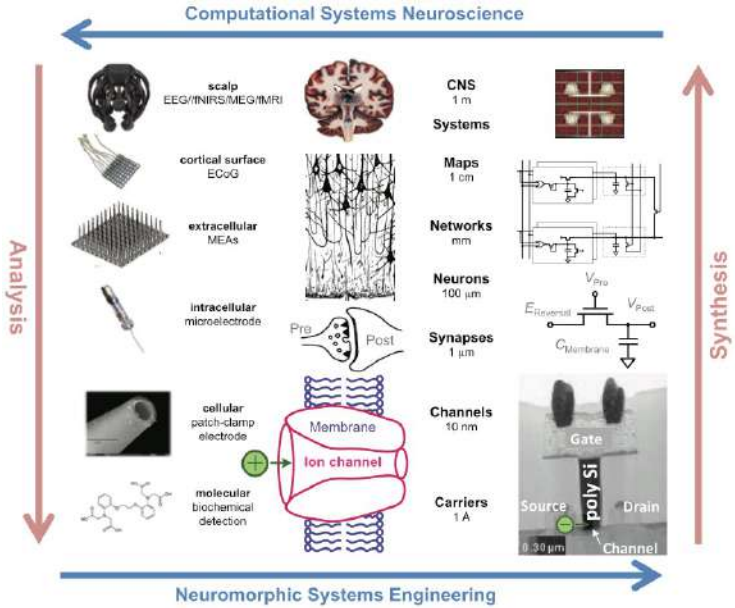
Towards neuromorphic brain interfacing



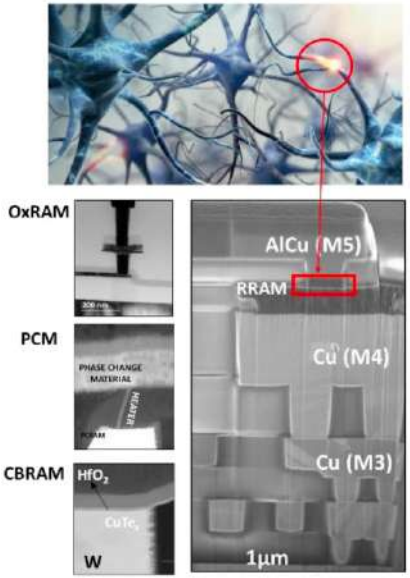
Sourikopoulos et al. Front Neurosci 2017

Goal: low-power automatic signal processing embedded inside brain implants to avoid heavy data transmission

Solution: Spiking Neural Networks (SNNs) compatible with very-low-power neuromorphic hardware

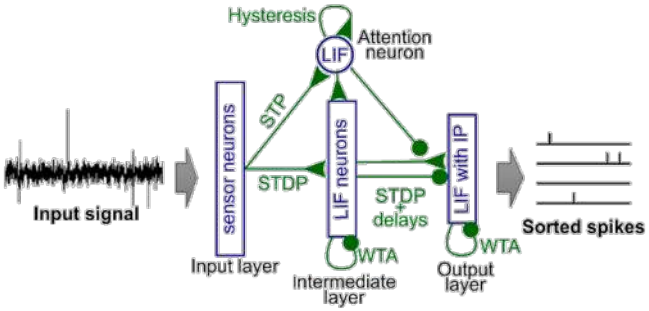


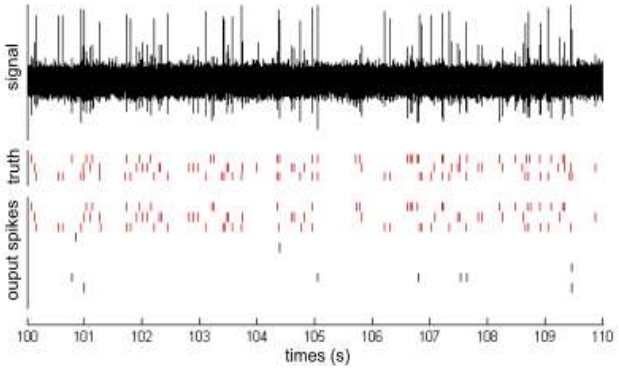
Broccard et al. JNE 2018



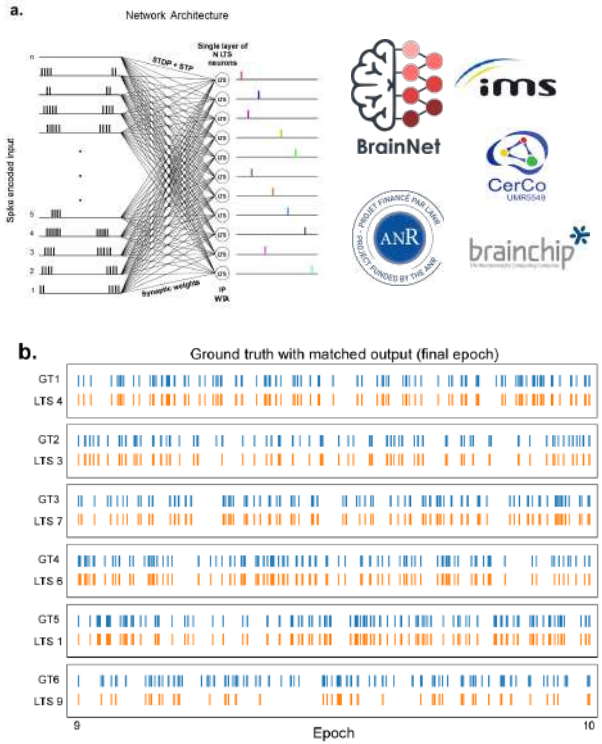
De Salvo, ISSCC 2017

Example : neuromorphic spike sorting algorithms





EN 16 54485
WO2018100325A1
Werner et al., Front Neurosci, 2016
Bernert and Yvert, IJNS, 2019



Pokala et al.,
Nat Comms, in press

Neuromorphic computing hardware

nature communications

Article

https://doi.org/10.1038/s41467-025-61576-6

A neuromorphic processor with on-chip learning for beyond-CMOS device integration

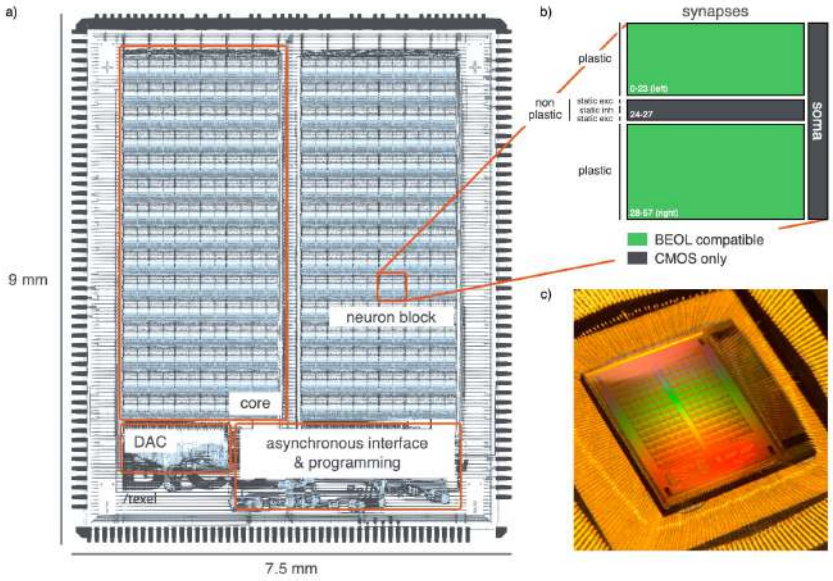
Received: 29 October 2024

Accepted: 24 June 2025

Published online: 11 July 2025

Check for updates

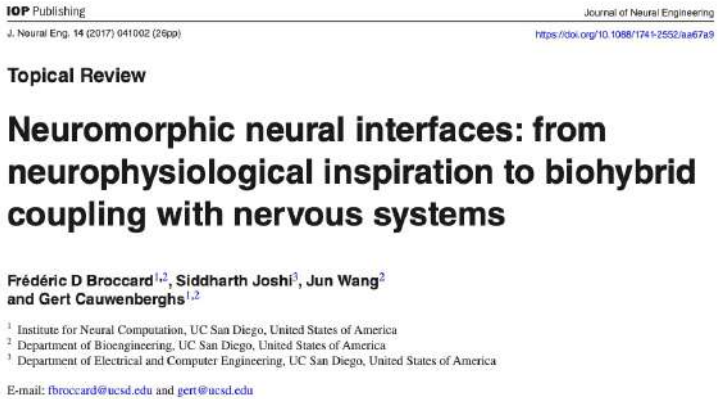
Hugh Greatorex[1,2], Ole Richter[3,4], Michele Mastella[5], Madison Cotteret[1,2,6], Philipp Klein[1,2], Maxime Fabre[1,2,7], Arianna Rubino[8,9], Willian Soares Girão[1,2], Junren Chen[9], Martin Ziegler[10], Laura Bégon-Lours[8], Giacomo Indiveri[9] & Elisabetta Chicca[1,2]



TEXEL chip: 180 neurons, 10,440 plastic synapses

Neuromorphic brain interfacing

Closed-loop coupling between SNNs and cortex



IOP Publishing
J. Neural Eng. 14 (2017) 041002 (26pp)
Journal of Neural Engineering
https://doi.org/10.1088/1741-2552/aa67a9

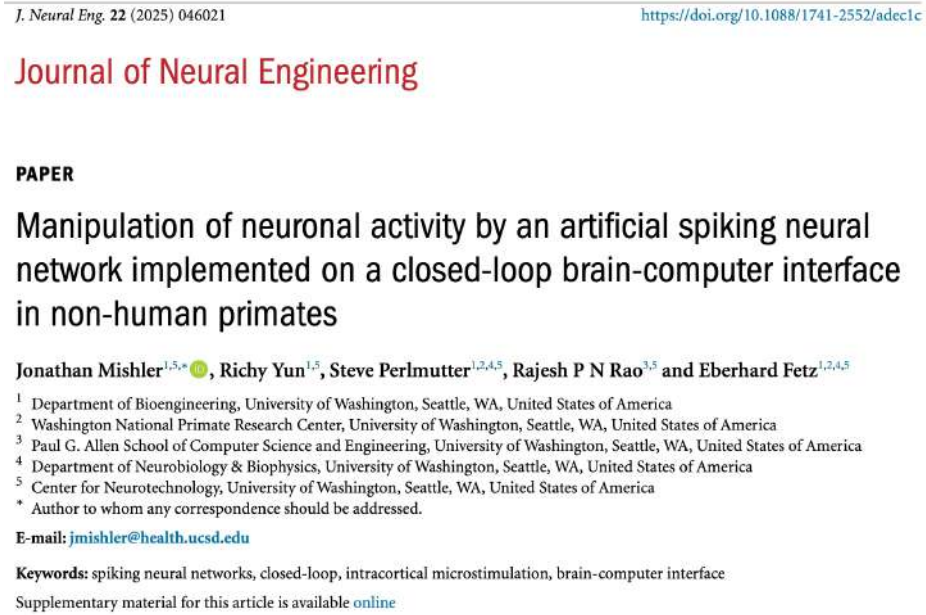
Topical Review

Neuromorphic neural interfaces: from neurophysiological inspiration to biohybrid coupling with nervous systems

Frédéric D Broccard[1,2], Siddharth Joshi[3], Jun Wang[2] and Gert Cauwenberghs[1,2]

[1] Institute for Neural Computation, UC San Diego, United States of America
[2] Department of Bioengineering, UC San Diego, United States of America
[3] Department of Electrical and Computer Engineering, UC San Diego, United States of America

E-mail: fbroccard@ucsd.edu and gert@ucsd.edu



J. Neural Eng. 22 (2025) 046021
https://doi.org/10.1088/1741-2552/adec1c

Journal of Neural Engineering

PAPER

Manipulation of neuronal activity by an artificial spiking neural network implemented on a closed-loop brain-computer interface in non-human primates

Jonathan Mishler[1,5,*], Richy Yun[1,5], Steve Perlmutter[1,2,4,5], Rajesh P N Rao[3,5] and Eberhard Fetz[1,2,4,5]

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[*] Author to whom any correspondence should be addressed.

E-mail: jmishler@health.ucsd.edu

Keywords: spiking neural networks, closed-loop, intracortical microstimulation, brain-computer interface

Supplementary material for this article is available online

Implantable neurotechnologies: Ethical implications

- Answering patients' needs and expectations
- Positive benefit – risk balance
- Affordability / accessibility
- Therapeutics vs. enhancement
- Data safety and privacy
- Dual uses
- Accountability
- Privacy of thoughts with speech BCIs
- Preserving agency and subjectivation
- Coupling with Virtual Reality

➔ **Need for clever regulations**

Article

Neuroprosthetic Speech: The Ethical Significance of Accuracy, Control and Pragmatics

STEPHEN RAINEY, HANNAH MASLEN, PIERRE MÉGEVAND, LUC H. ARNAL, ERIC FOURNERET, and BLAISE YVERT

OPINION
published: 28 April 2020
doi: 10.3389/fnai.2020.00027

Cambridge Quarterly of Healthcare Ethics (2019), Page 1 of 14.
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Digital Normativity: A Challenge for Human Subjectivation

*Eric Fourneret and Blaise Yvert**

Inserm and Univ Grenoble Alpes, BrainTech Lab U1205, Gières, France

Comment

Keywords: artificial intelligence, machine learning, free will (freedom), agency, ethics, education, normativity, governance

https://doi.org/10.1038/s44222-023-00041-9

Neuromorphic brain interfacing and the challenge of human subjectivation

Blaise Yvert & Eric Fourneret

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nature reviews bioengineering

Published online: 22 February 2023

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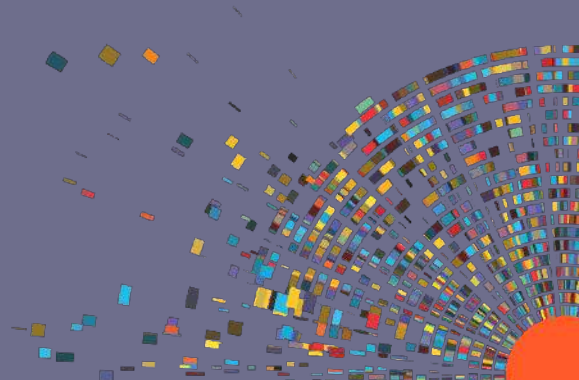
Thank you for your attention



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