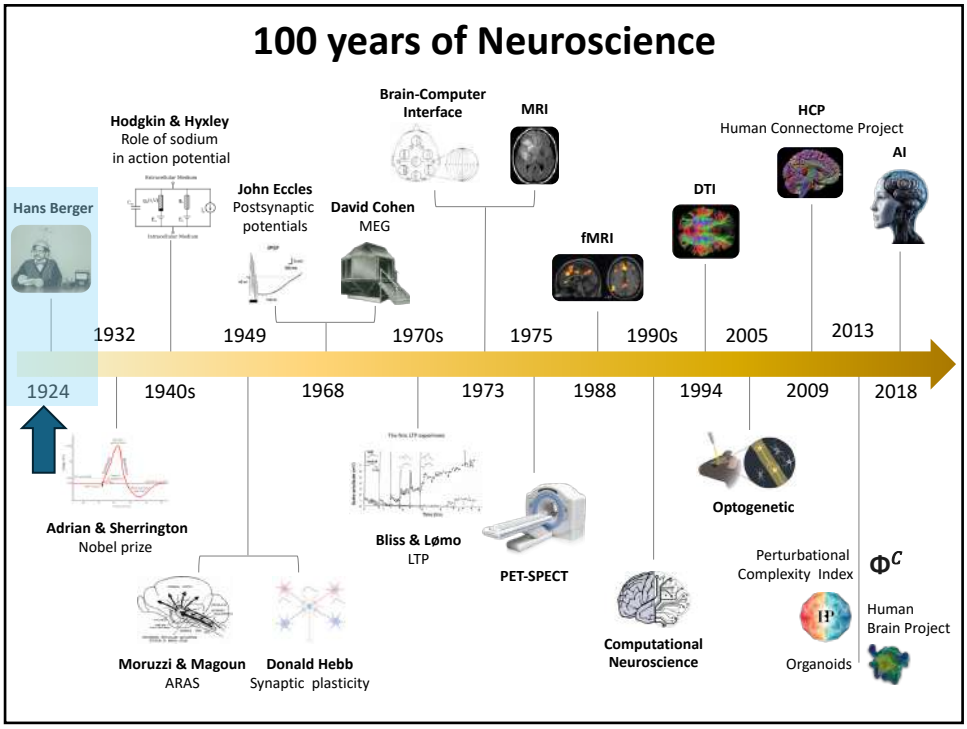

13 GIUGNO 2025
AULA MAGNA U. DINI
WORKSHOP
STANDARDIZATION O BY-DESIGN:
QUALI PROSPETTIVE PER L'HTA
OBIETTIVI FORMATIVI
EEG devices:
evoluzioni e
orizzonti
Angelo Gemignani
WORLD'S BEST HOSPITALS 2024
Newsweek
AZIENDA OSPEDALIERO UNIVERSITARIA PISANA
IN SUPREMÆ DIGNITATIS
1343
angelo.gemignani@unipi.it

1


100 years of Neuroscience
Hans Berger
Hodgkin & Hyxley
Role of sodium
in action potential
John Eccles
Postsynaptic
potentials
David Cohen
MEG
Brain-Computer
Interface
MRI
fMRI
DTI
HCP
Human Connectome Project
AI
1924
1932
1940s
1949
1968
1970s
1973
1975
1988
1990s
1994
2005
2009
2013
2018
Adrian & Sherrington
Nobel prize
Moruzzi & Magoun
ARAS
Donald Hebb
Synaptic plasticity
Bliss & Lømo
LTP
PET-SPECT
Computational
Neuroscience
Optogenetic
Perturbational
Complexity Index
Human
Brain Project
Organoids

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Science, Technology and Culture, 1700–1945

Brainwaves
A Cultural History of Electroencephalography

Cornelius Borck
Translated by Ann M. Hentschel

Figure 10 Berger holding a lecture at the *Psychiatrische Universitätsklinik* in Jena.

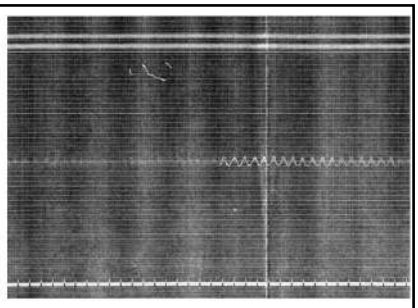


Figure 6 Cerebral current recording from 19 October 1925 generated by the string galvanometer. Bottom: the time signal; center: the brainwaves, redrawn by Berger in white ink on the right half of the image as a regular fluctuation.

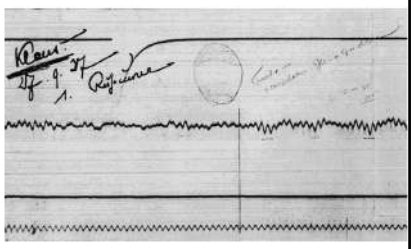


Figure 7 Cerebral current recording dated 27 September 1927 generated by the moving-coil galvanometer, which first recorded black-on-white curves on photographic paper. Center of image: EEG signal; bottom: marking of time as a regular wave. Berger classified the dominant fluctuations on the right half of the image as "waves of first order" (the later alpha waves).

3

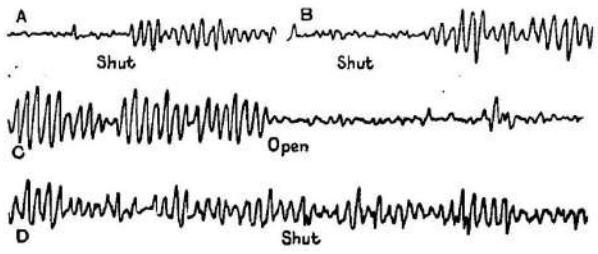
DECEMBER, 1934.

BRAIN.

PART 4, VOL. 57.

THE BERGER RHYTHM: POTENTIAL CHANGES FROM THE OCCIPITAL LOBES IN MAN.

BY E. D. ADRIAN AND B. H. C. MATTHEWS.
(*From the Physiological Laboratory, Cambridge.*)



Adrian & Matthews, 1934

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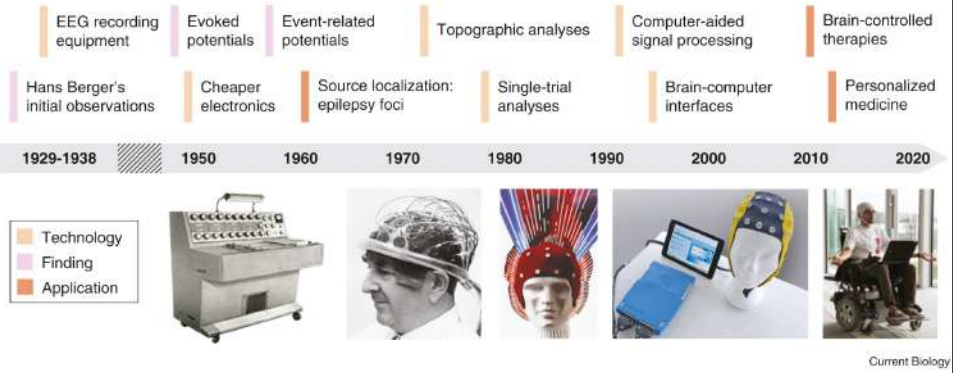
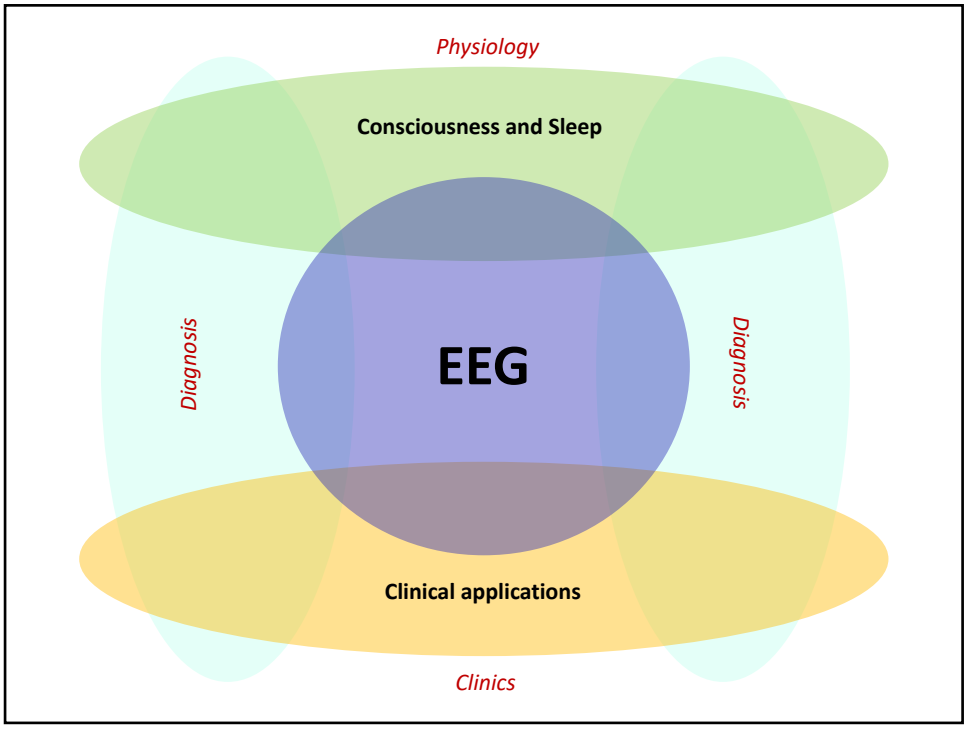
The evolution of human EEG technology and its applications



Biasiucci et al. 2019

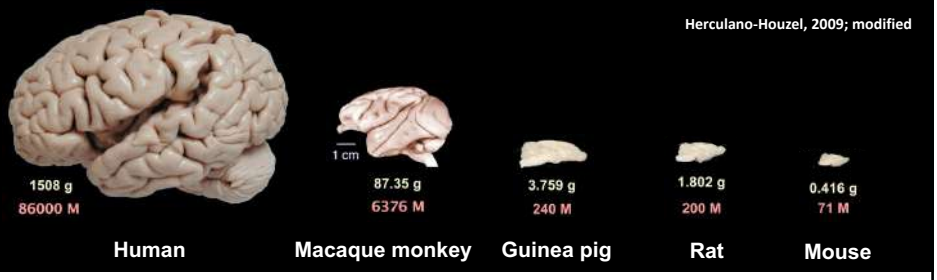
5



6

Brain mass and total number of neurons for the mammalian species

Herculano-Houzel, 2009; modified



NEUROSCIENCE

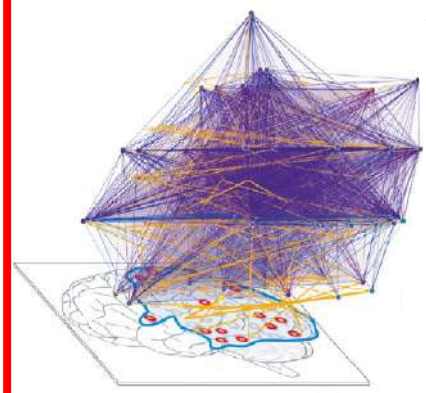
How the Mind Emerges from the Brain's Complex Networks

The new discipline of network neuroscience yields a picture of how mental activity arises from carefully orchestrated interactions among different brain areas

7

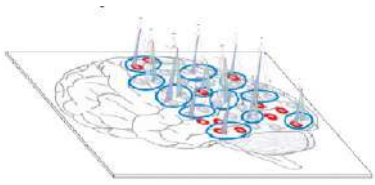
Theories of consciousness

Wakefulness
Dreaming



Neural substrate

Dreamless sleep
(NREM sleep)



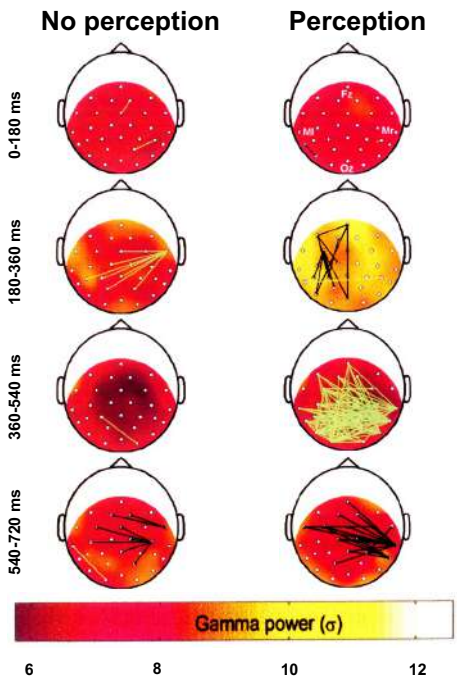
Neural substrate

Storm et al., 2024

8

EEG and functional connectivity

Rodriguez et al, 1999
Nature



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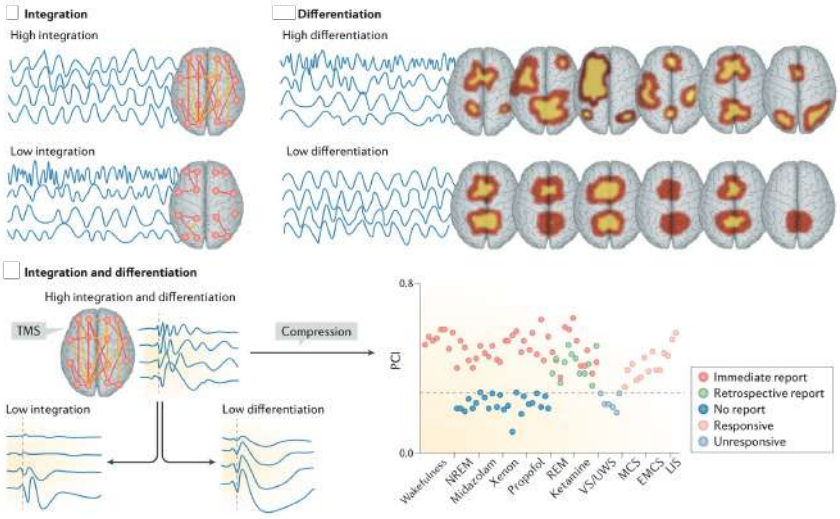
EEG-TMS to detect neural correlate of consciousness

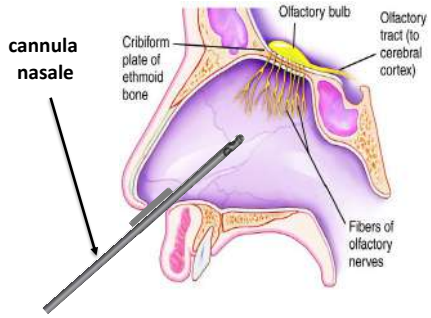


Koch et al. 2016

10

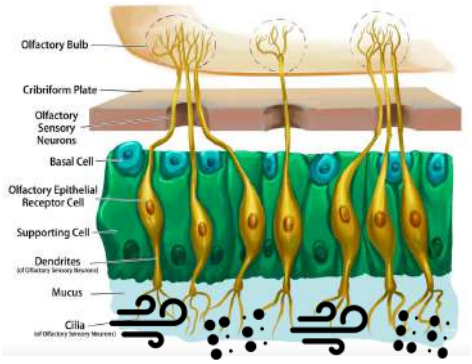
State of consciousness elicited by slow nasal breathing

Artificial slow nasal breathing



Piarulli et al., 2018

Dual function of the olfactory sensory neurons

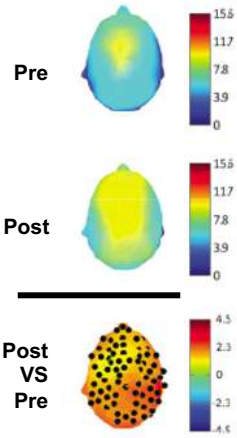


Narayanan et al. 2022

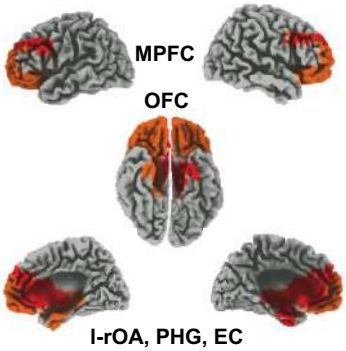
11

State of consciousness elicited by artificial slow nasal breathing

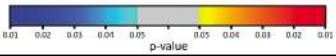
Theta power spectrum density



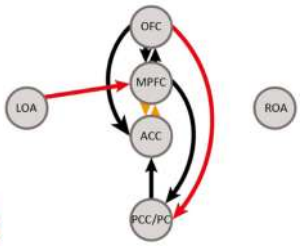
Theta Neurophenomenology



Correlation with altered state of consciousness



Directionality of theta cortical information flow



post > pre, p < 0.05
post > pre, p < 0.01
post > pre, p < 0.001

Piarulli et al., 2018

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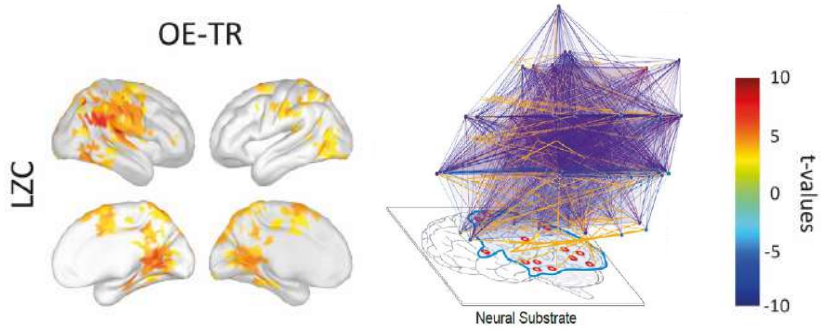
No doubt!!!

Nasal vault artificial stimulation induces increases of neural complexity in the TPO area



Preliminary results

Piarulli et al, in progress

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Science, Technology and Culture, 1700–1945

Brainwaves
A Cultural History of Electroencephalography

Cornelius Borck
Translated by Ann M. Hentschel

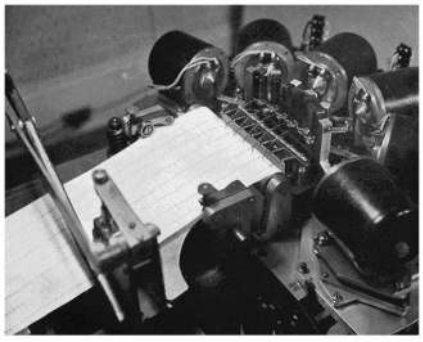

Figure 34 Alfred L. Loomis used high-precision instruments for his EEG experiments in the extravagant setting of his private estate.

were allowed to fall asleep during the ongoing process. As a consequence, in their first *Science* article Loomis and his collaborators were able not only to confirm EEG findings one more time but also to report about the extinction of alpha waves with the onset of sleep and the occurrence of typical spindle-shaped potential waves during sleep.[144] Another article in *Science* two months later already distinguished between three different EEG forms during sleep: alpha waves (10 Hz), sleep spindles (14 Hz for 1–1½ s), and irregular brain activity with slow delta waves (2–5 Hz).[145]

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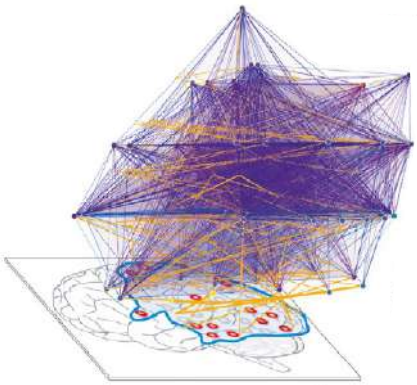
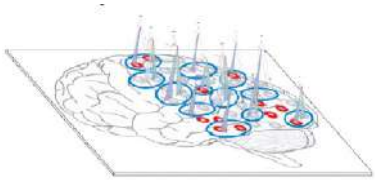
Theories of consciousness

Wakefulness
Dreaming



Neural substrate

Dreamless sleep
(NREM sleep)



Neural substrate

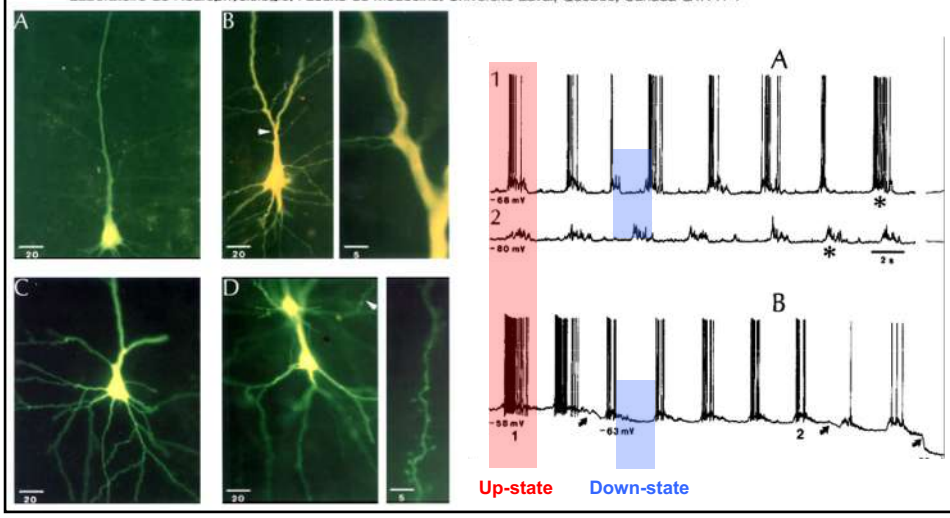
Storm et al., 2024

15

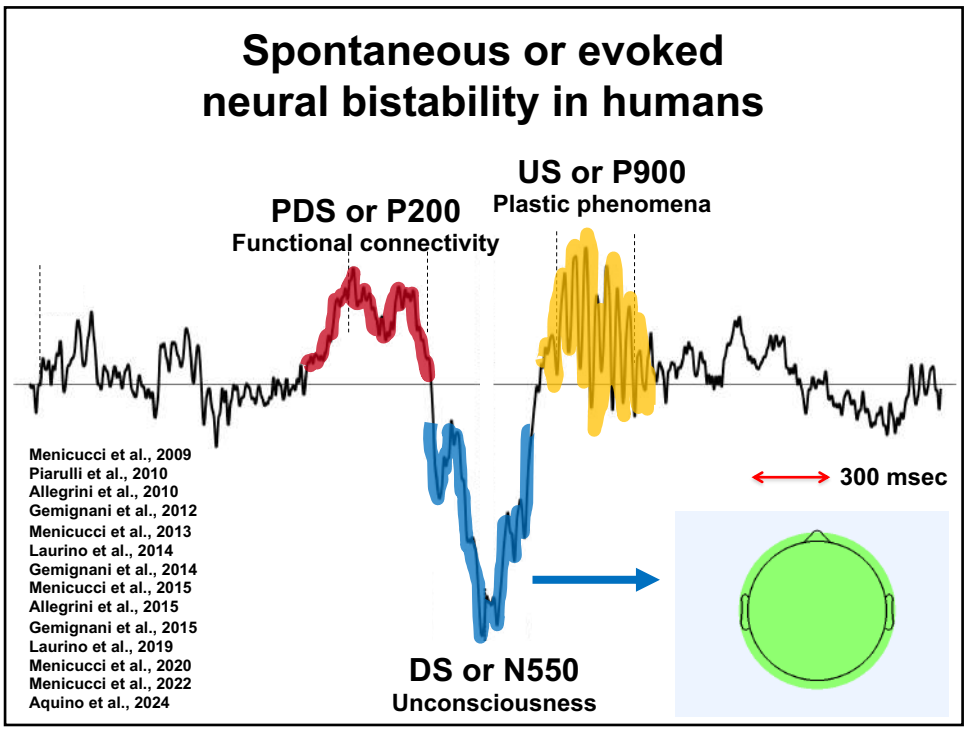
The Journal of Neuroscience, August 1993, 13(8): 3252–3265

A Novel Slow (<1 Hz) Oscillation of Neocortical Neurons *in vivo*: Depolarizing and Hyperpolarizing Components

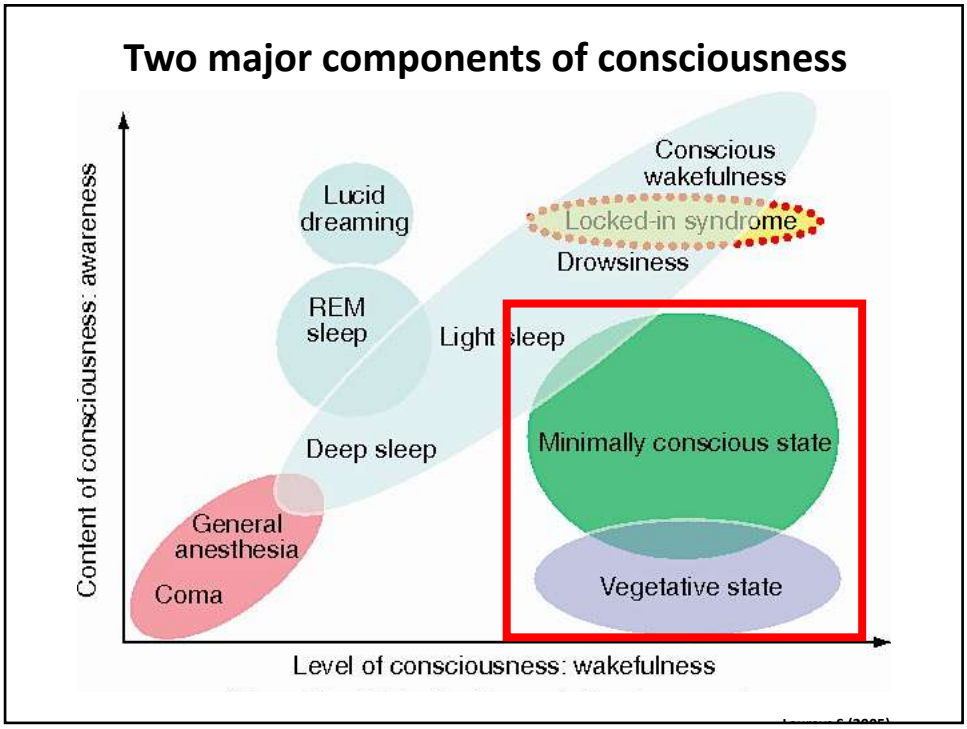
M. Steriade, A. Nuñez, and F. Amzica
Laboratoire de Neurophysiologie, Faculté de Médecine, Université Laval, Quebec, Canada G1K 7P4



16

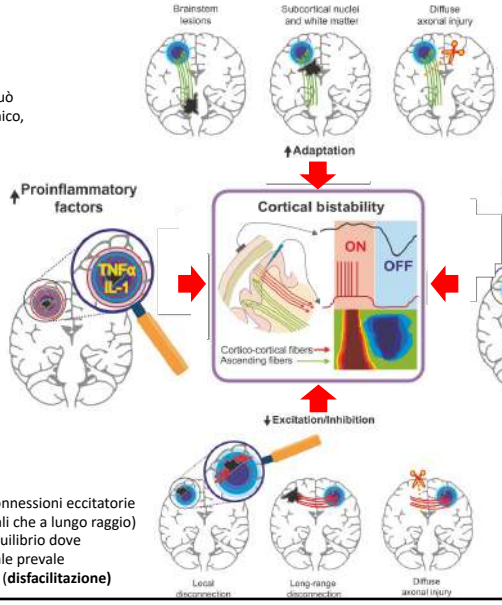

Spontaneous or evoked
neural bistability in humans
US or P900
Plastic phenomena
PDS or P200
Functional connectivity
Menicucci et al., 2009
Piarulli et al., 2010
Allegrini et al., 2010
Gemignani et al., 2012
Menicucci et al., 2013
Laurino et al., 2014
Gemignani et al., 2014
Menicucci et al., 2015
Allegrini et al., 2015
Gemignani et al., 2015
Laurino et al., 2019
Menicucci et al., 2020
Menicucci et al., 2022
Aquino et al., 2024
300 msec
DS or N550
Unconsciousness

17


Two major components of consciousness
Content of consciousness: awareness
Level of consciousness: wakefulness
Lucid dreaming
Conscious wakefulness
Locked-in syndrome
Drowsiness
REM sleep
Light sleep
Deep sleep
Minimally conscious state
General anesthesia
Coma
Vegetative state

18

Slow waves may play a key role in altering functional networks after brain injury



L'accumulo di liquidi può alterare l'equilibrio ionico, bloccando le pompe Na^+/K^+ e facilitando le onde lente (edema).

L'attivazione di microglia e astrociti, accompagnata dall'espressione di citochine proinfiammatori e come IL-1 e TNFα, può favorire l'insorgenza di onde lente

Attivazione di correnti di potassio (K^+) mediate da canali regolati da calcio (Ca^{2+}) e sodio (Na^+). Queste correnti aumentano l'adattamento neuronale, portando a periodi di inattività o **OFF-periods**

Riduzione del rapporto ATP/ADP in seguito a ischemia attiva canali sensibili a K^+-ATP, inducendo iperpolarizzazione e inattività neuronale nelle aree circostanti la lesione

Perdita delle connessioni eccitatorie laterali (sia locali che a lungo raggio) provoca uno squilibrio dove l'inibizione locale prevale sull'eccitazione (**disfacilitazione)**

Massimini et al. 2023

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From Present to Future

Figure 11 The techno-medial practice of the future physician, according to Fritz Kahn. The legend reads: "The physician of the future, who monitors the heart graph, cardiac sounds, blood pressure, respiration curve, and body temperature, of his patients with his remote electrical apparatus from his room."

20

Science, Technology and Culture, 1700–1945

Brainwaves

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Figure 48 Einstein undergoing EEG recording. The EEG was not published.

Thinking processes—especially those of geniuses—may be better understood through studies of brain waves that are under way here at the Massachusetts General Hospital. [. . .] "Brightness and originality, creative and abstractive thinking, might be associated with—or facilitated by—certain different scanning mechanisms," he declared. According to the theory, this scanning mechanism switched from one group of brain cells to another during the thinking process, much like a radar scanner. Very active brains, such as Dr. Einstein's while he was thinking of his theory of relativity, for example, achieved this scanning very rapidly.[63]

21

Brain-to-brain interaction

Specific phenomenon **?** **Aspecific phenomenon**

22

Hyperscanning:
The Future of Social Interactions in Neuroscientific Research

Hyperscanning is a methodology that simultaneously records brain activity from multiple individuals during interactions, enabling the study of dynamic inter-brain connectivity in real-world social contexts.

Proposed by Montague (2002), it is expected to drive future advancements in social, cognitive, and affective neuroscience.

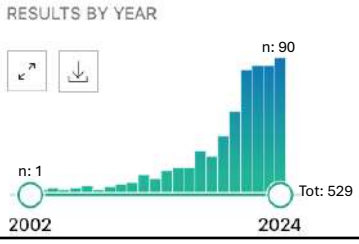
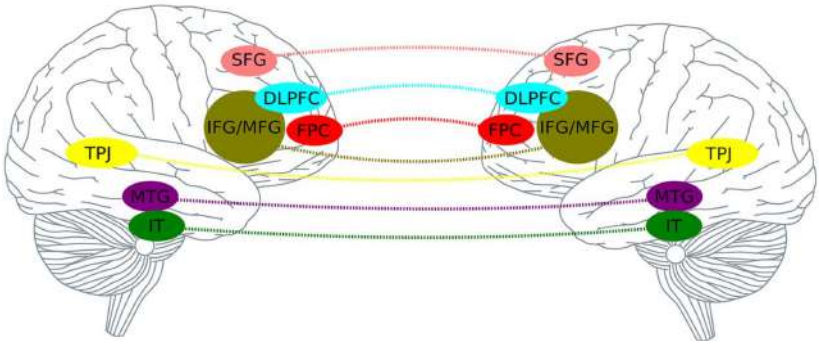


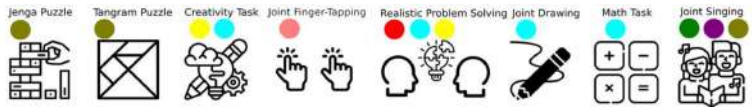
Immagine generata con DALL-E di OpenAI

TenHouten et al. 2022

23

Inter-Brain Synchrony in Prefrontal Cortex and Temporoparietal regions during Cooperative Behavior





Czeszumski et al., 2022

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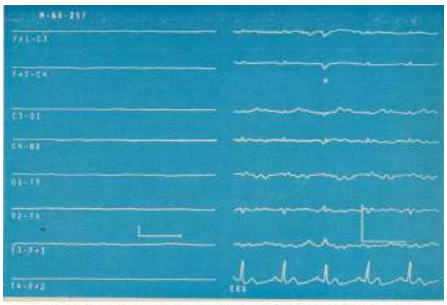
JAMA, Sept 8, 1969 • Vol 209, No 10

Special Contribution

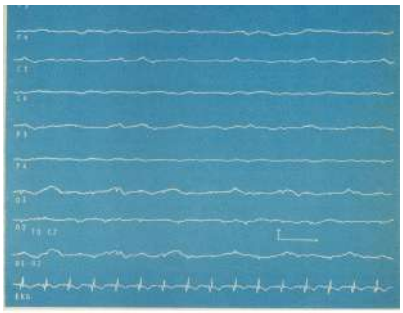
Cerebral Death and the Electroencephalogram

Report of the Ad Hoc Committee of the American Electroencephalographic Society on EEG Criteria for Determination of Cerebral Death

Daniel Silverman, MD; Michael G. Saunders, MD; Robert S. Schwab, MD; and Richard L. Masland, MD



1. *Left*, Apparent electrocerebral silence; some suspicious activity in O1-T3, T3-Fp1. *Right*, With increased gain, activity becomes apparent, higher on left side; X indicates an inspiration artifact. Montages are in International 10-20 System. Calibrations are 50 μv and one second.



3. Low voltage record, not electrocerebral silence, in patient with insulin coma. Montages are in International 10-20 System. Calibrations are 50 μv and one second.

25

What happens to the Brain when We Die?

Ophelia, John Everett Millais
Tate Britain

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PNAS RESEARCH ARTICLE | NEUROSCIENCE OPEN ACCESS

Surge of neurophysiological coupling and connectivity of gamma oscillations in the dying human brain

Gang Xu[a], Temenuzhka Mihaylova[b], Duan Li[c,1], Fangyun Tian[a,2], Peter M. Farrehi[d], Jack M. Parent[b,d,e,f], George A. Mashour[a,g,h], Michael M. Wang[a,b,d,e,f], and Jimo Borjigin[a,b,d,e,h,3]

Edited by Giulio Tononi, University of Wisconsin-Madison, Madison, WI; received September 23, 2022; accepted March 27, 2023 by Editorial Board Member Jeremy Nathans

Is it possible for the human brain to be activated by the dying process?

We addressed this issue by analyzing the electroencephalograms (EEG) of four dying patients before and after the clinical withdrawal of their ventilatory support and found that the resultant global hypoxia markedly stimulated gamma activities in two of the patients.

The surge of gamma connectivity was both local, within the temporo–parieto–occipital (TPO) junctions, and global between the TPO zones and the contralateral prefrontal areas.

While the mechanisms and physiological significance of these findings remain to be fully explored, these data demonstrate that the dying brain can still be active.
They also suggest the need to reevaluate role of the brain during cardiac arrest.

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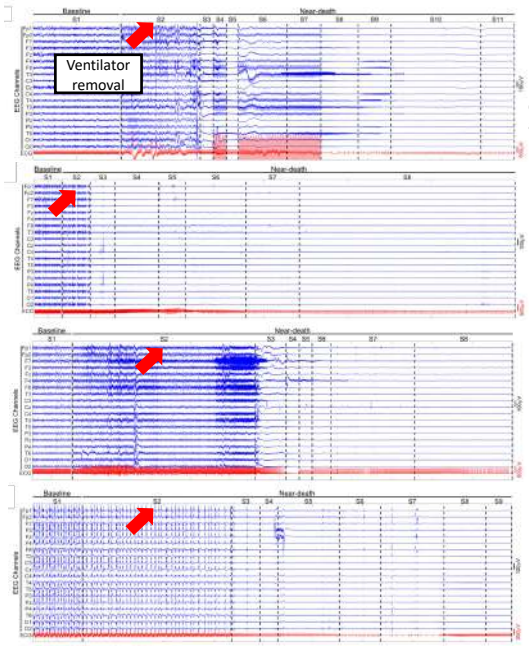
Identification of near death stages in dying patients



Pt1

Cause of death: cardiac arrest-induced anoxic injury

Pt2

Cause of death: cardiac arrest-induced anoxic injury

Pt3

Cause of death: extensive brain hemorrhage

Pt4

Cause of death: cardiac arrest-induced anoxic injury

Xu et al. 2023

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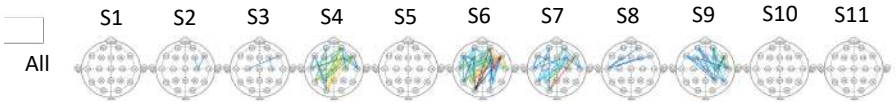
Increase of Cross-Regional Phase-Amplitude Coupling at Near-Death



This study revealed in the dying human brain, the high-frequency activation of the TPO junctions that is also observed in healthy human brain during waking and dreaming and in seizure patients during visual hallucinations and OBE

Xu et al. provide strong evidence that the dying brain is not necessarily the quiet place, electrically speaking, that it was thought to be

Xu et al. 2023

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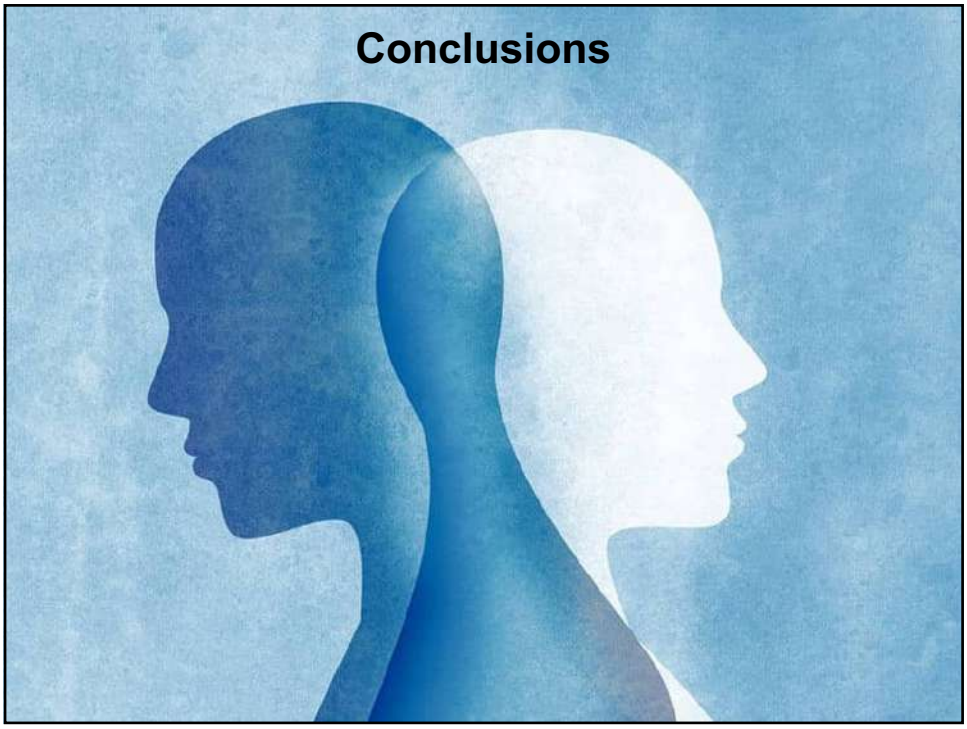
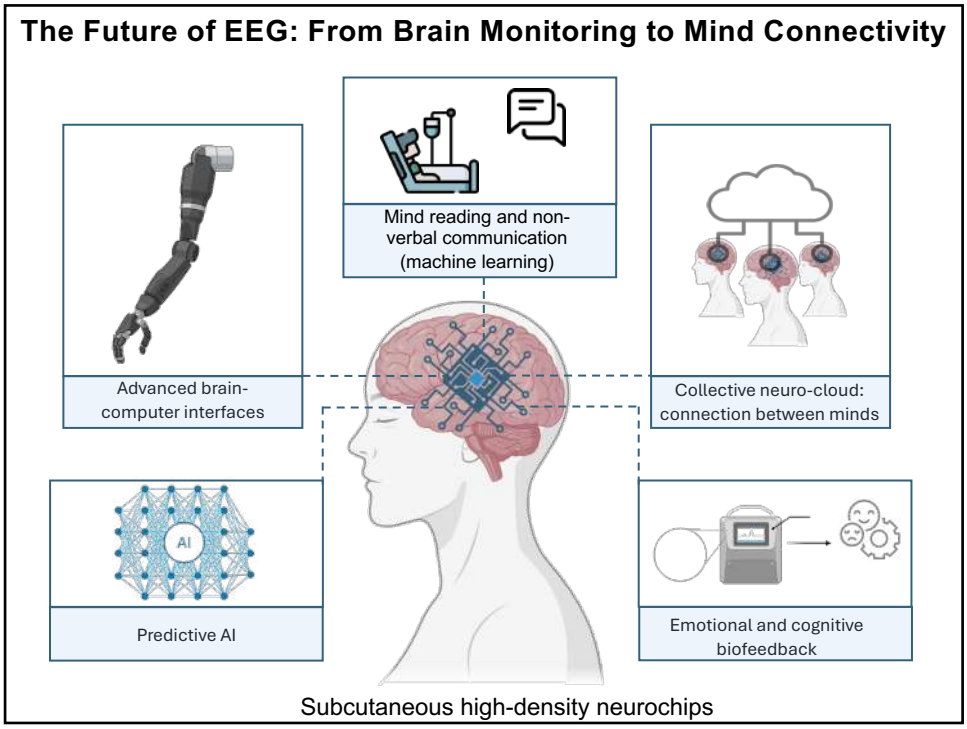
Conclusions



30


The Future of EEG: From Brain Monitoring to Mind Connectivity
Mind reading and non-verbal communication (machine learning)
Advanced brain-computer interfaces
Collective neuro-cloud: connection between minds
AI
Predictive AI
Emotional and cognitive biofeedback
Subcutaneous high-density neurochips

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