Brains and evolution of culture

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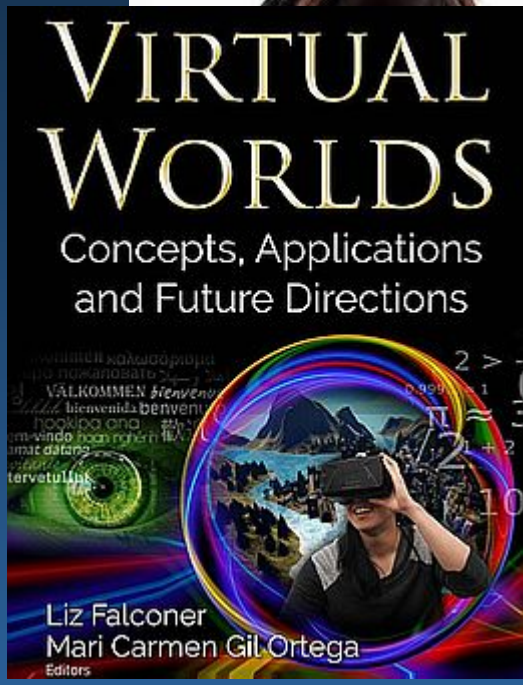
Google: Wlodzislaw Duch

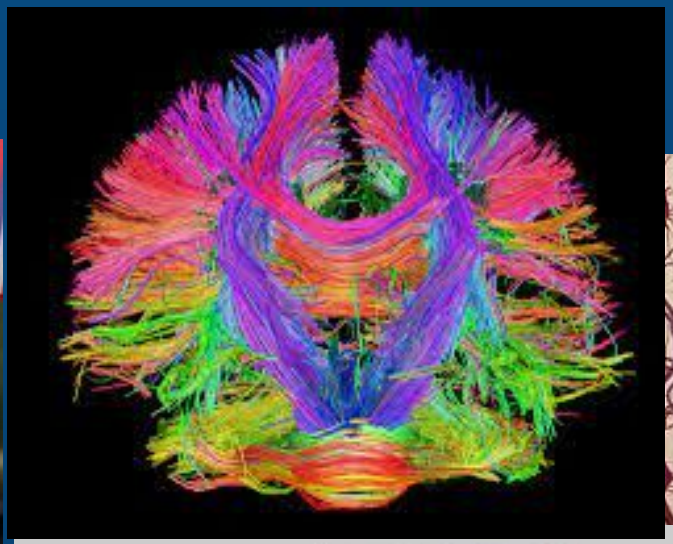
Seminaria "Paradygmat ewolucji w naukach społecznych", Poznań 24/11/2022

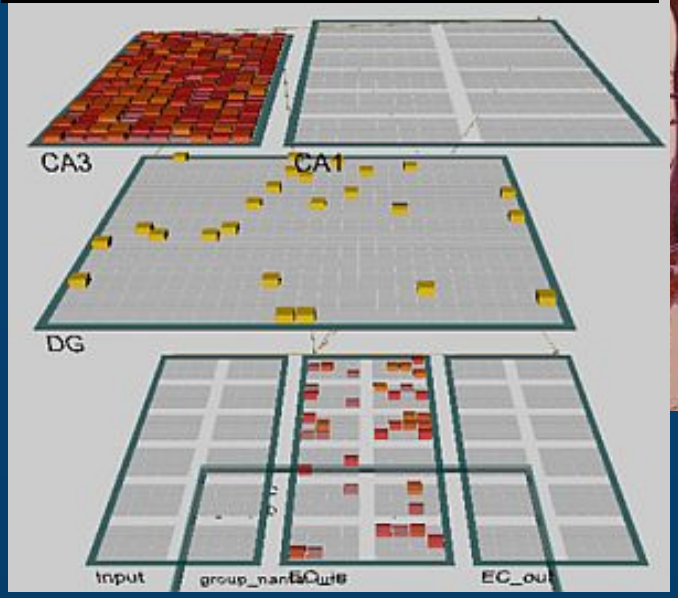
- Understanding culture ⇔ deep understanding of human behavior, brain processes.
- Phenomics: foundations of our minds.
- Brain states and memory.
- Neuroplasticity and conspiracies.
- Wonders of equilibria: from genes to culture.
- Future: brain-machine interfaces, neurotechnologies, cyborgization, artificial intelligence and transhumanism.

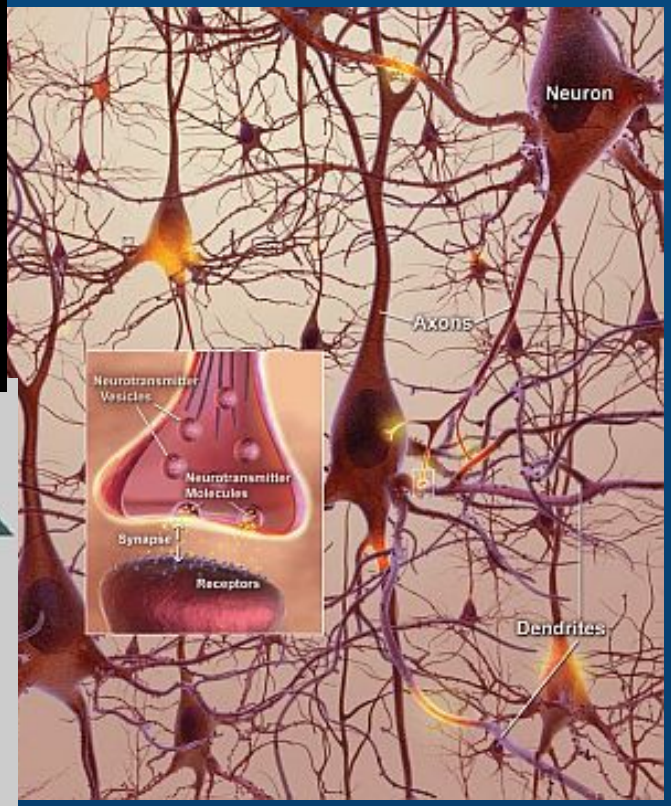


Duch W. (2021). *Memetics and Neural Models of Conspiracy Theories*. Patterns 2(11), 2-13.
More papers on these topics.

From Behavior to Neurons

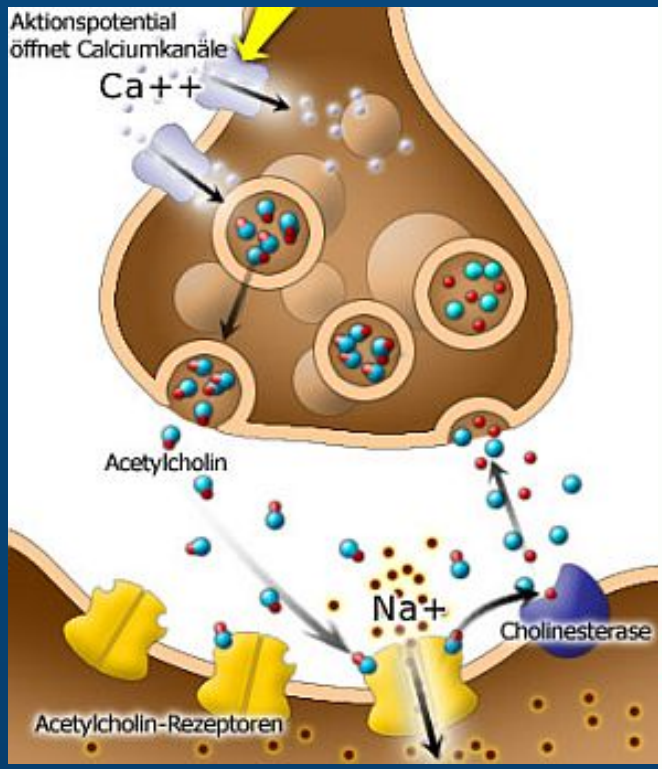


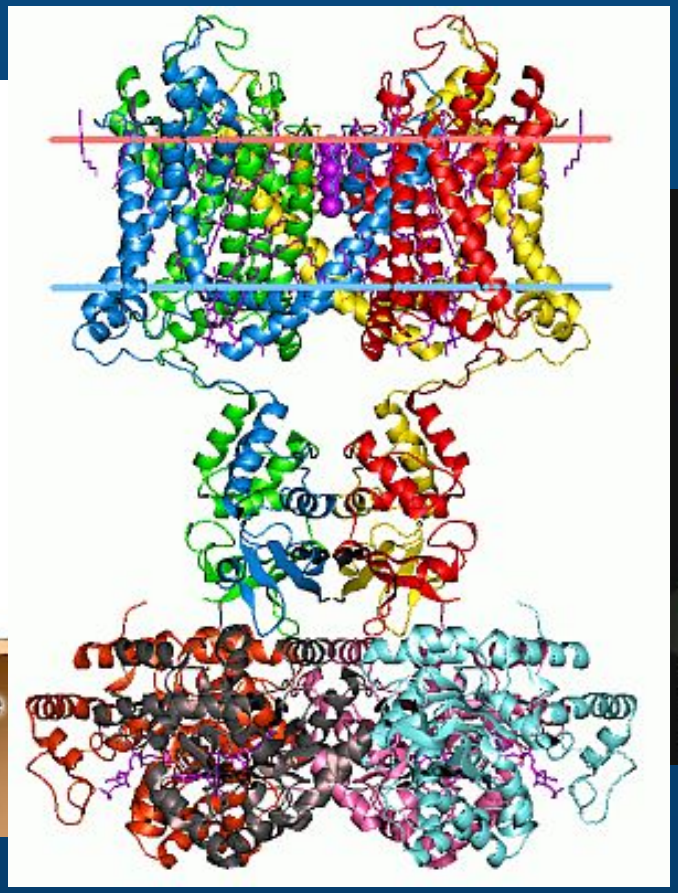


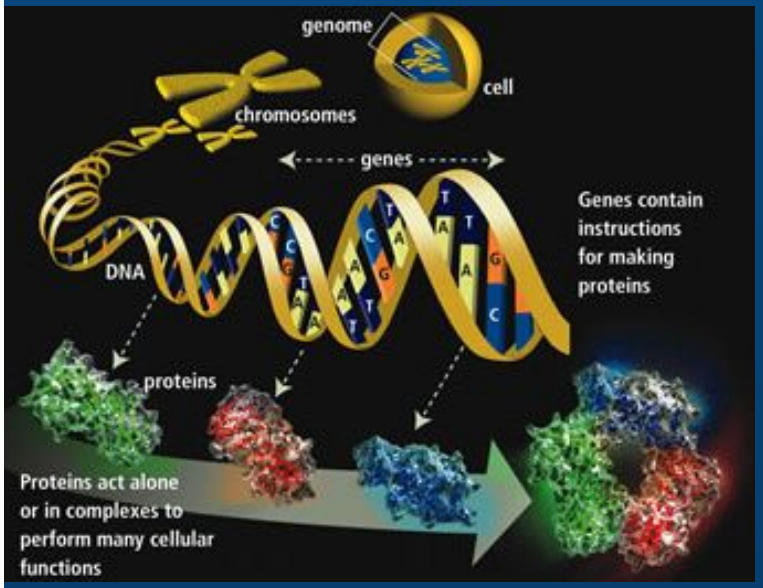


Cognitive phenotypes ↔ behavior ↔ conspiracies ↔ memory, memes
↔ **neurodynamics** ↔network structure ↔ connectome ↔ neuron properties

From Neurons to Genes

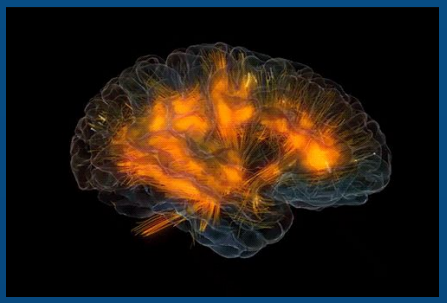






↔ **neurodynamics** ↔network structure ↔ connectome ↔ neuron properties ↔ synapses ↔ receptors, ion channels ↔ neurochemicals, proteins ↔ genes.

Explaining behavior



Seconds

Minutes

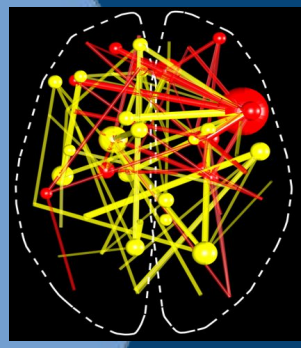
Days

Month

Years

Millenia

Eras/Eons



Cognitive phenomics, fast/slow: neurodynamics, hormones, education, culture, infancy, gestation and evolution.

Genes and brains

Large-scale programs to link genes with behavior.

Worm (C. Elegans)

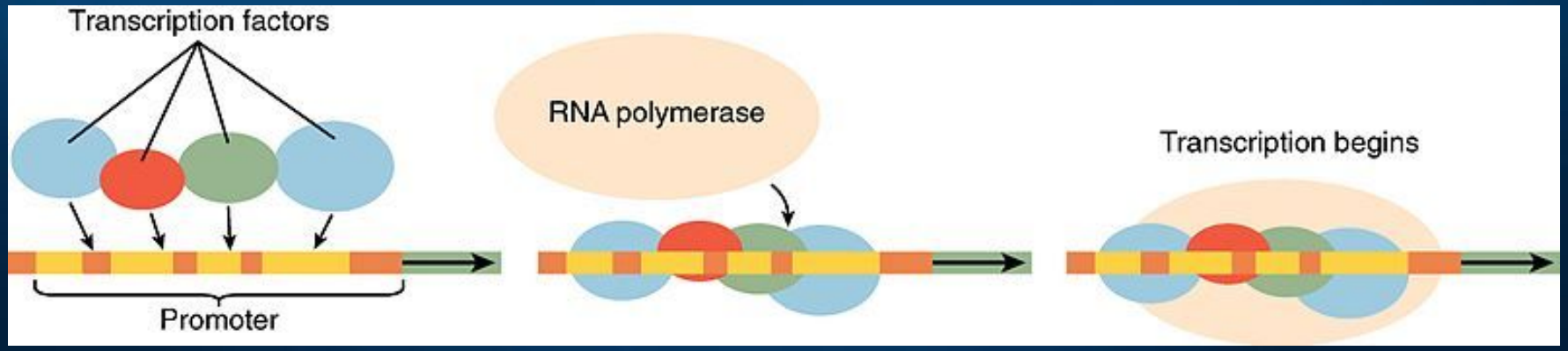
19 000 genes
302 neurons
7 800 synapses

Human

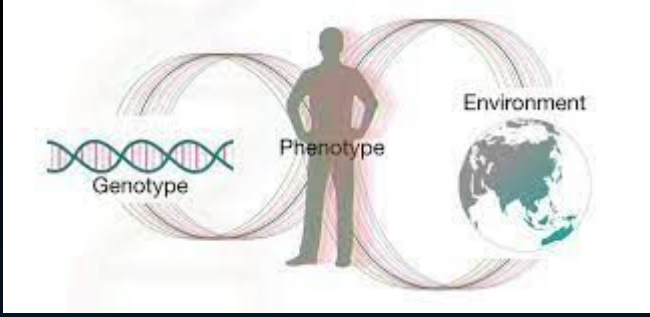
~ 19 000 genes
~ 100 B neurons (10^{11})
~ 10^{14} – 10^{15} synapses

Epigenetics: environment turns genes on/off via transcription factors.

Genes do not control our behavior, but provide a substrate for cognition & behavior.
Genetics limits of human potential is very rarely closely approached.



Genes: big lie!



Genes or nature? Are we at mercy of our genes?

New York Times (11.03.2008): genes are responsible for roughly
60 percent of intelligence, 60 percent of personality, 40–66 percent of motor skills,
21 percent of creativity. These estimations were based on early research:

Wright, L. (1999). Twins: And What They Tell Us About Who We Are. Wiley.

But … "The models suggest that in impoverished families, 60% of the variance in IQ is accounted for by the shared environment, and the contributions of genes is close to zero; in affluent families, the result is almost exactly the reverse."

Turkheimer, E. et al. (2003). Socioeconomic Status Modifies Heritability of IQ in Young Children. Psychological Science, 14(6), 623–628

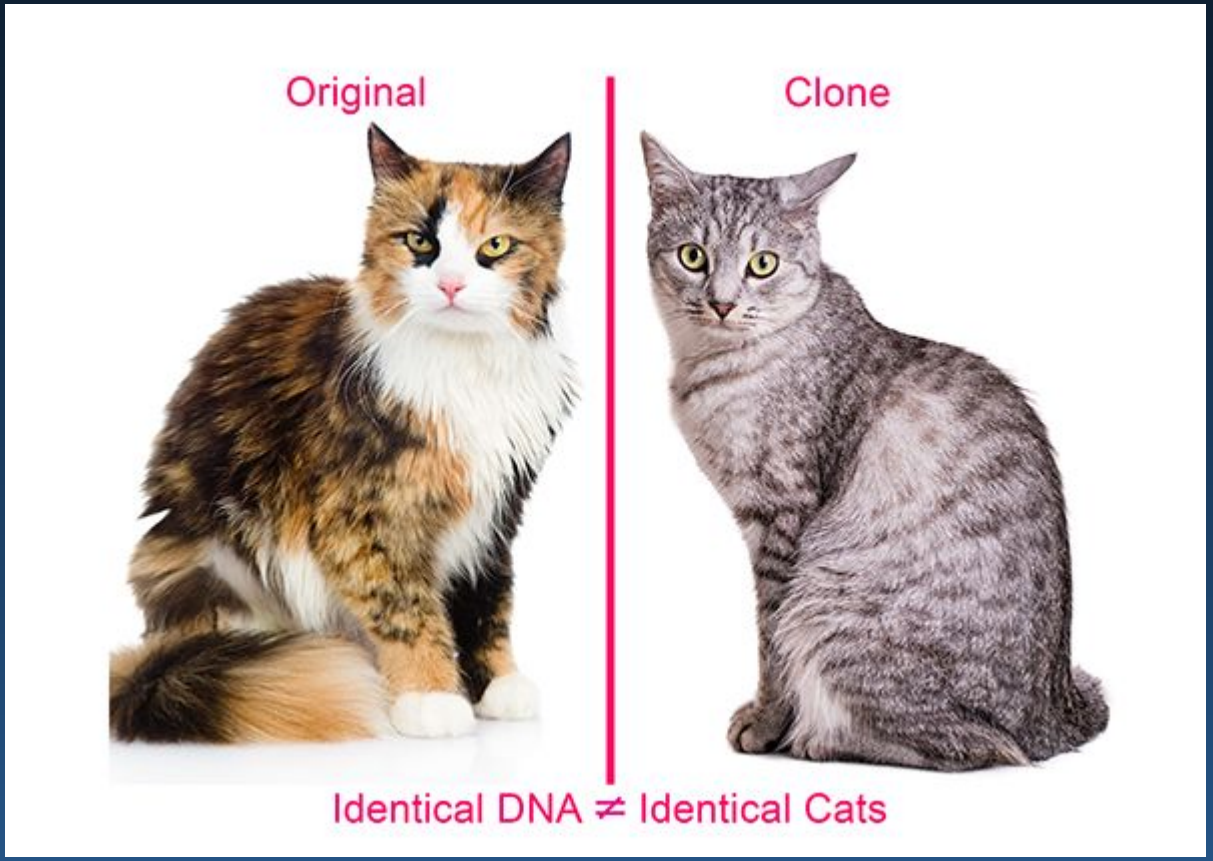
It all depends on the developmental processes, there is no fixed value for traits that genes encode in human population.
In 1957 it was found, that Japanese children raised in California were on average 12cm taller than Japanese children raised in Japan in the same time period.
Same gene pool, different environment = radically different stature.

Recipes are not yet food ...

Genetic cloning

In 2001 Rainbow cat was successfully cloned. Her clone Cc, created and verified by geneticists at Texas A&M University, shares exactly the same nuclear DNA.

The two cats are quite different. Rainbow has several colors (brown, black, white, and gold), her clone Cc is white and gray! Also their characters are quite different.



Genes/molecules

Nano/millisecond scale incredible complexity!

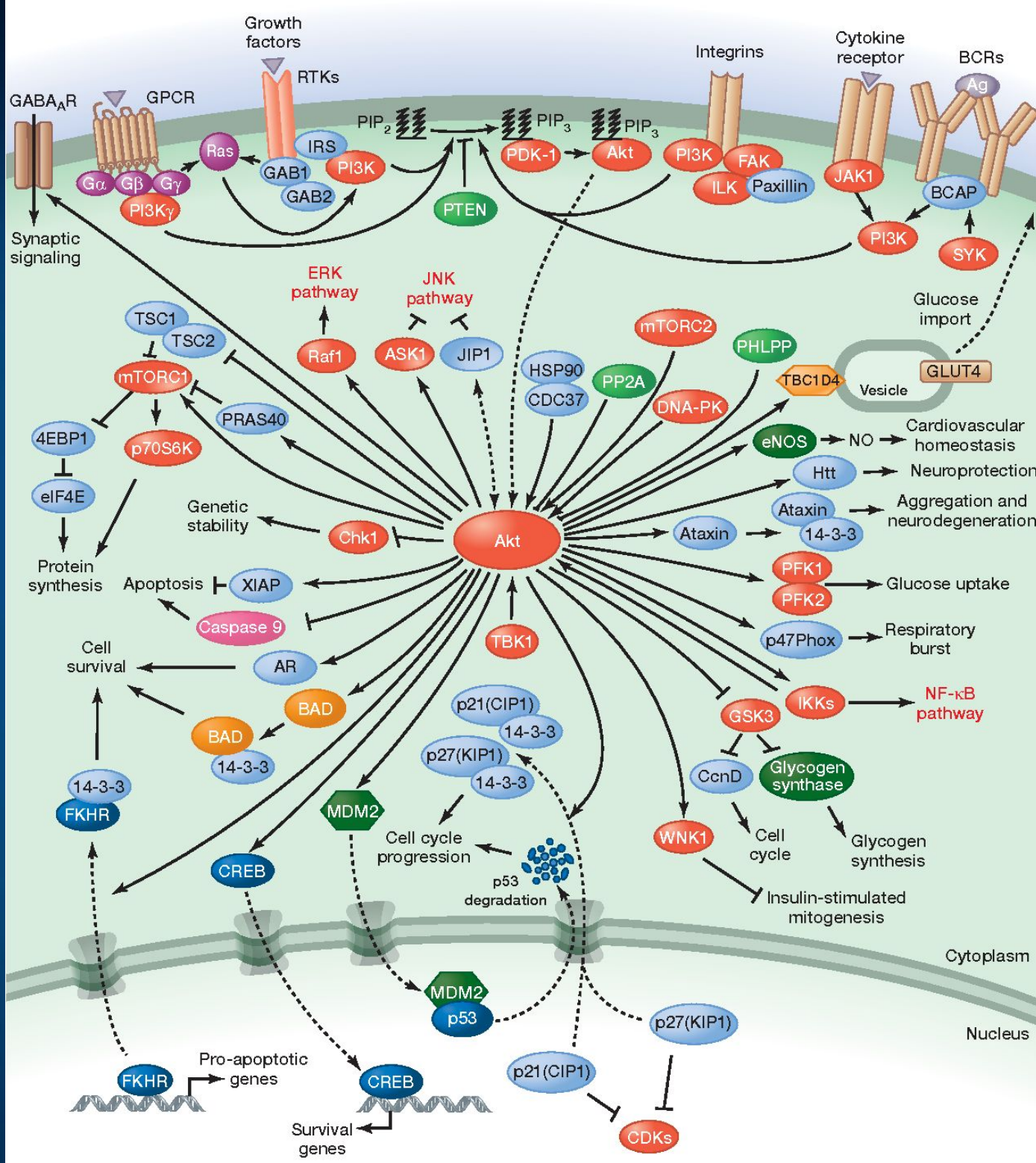
Dscam gene has 38 000 variants of proteins!

Total length of our DNA in $50x10^{12}$cells is $100x10^{9}$ km, or about 666 times the distance to the Sun.

Flow of 100 mln ions/sec through single ion channel.

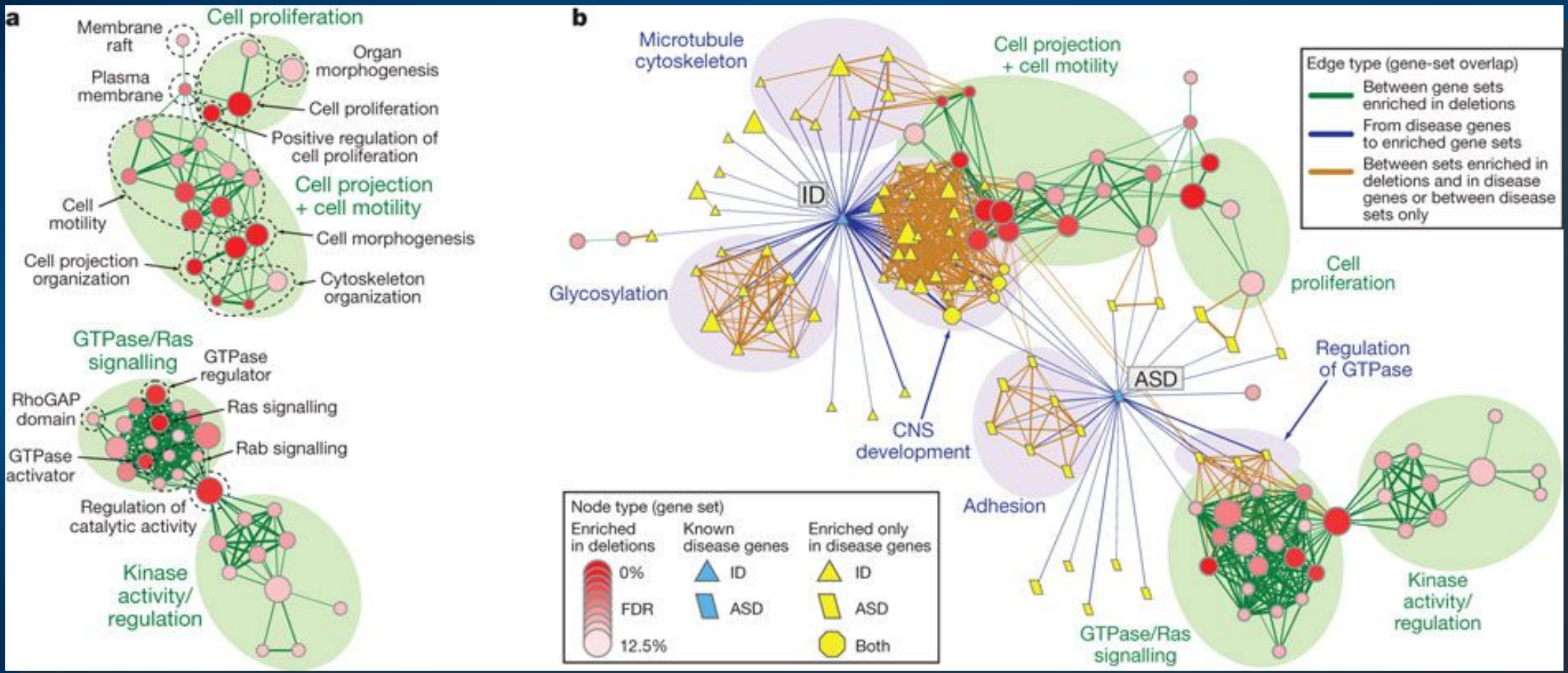
Neuron has 10 000 ion channels, billions of ions flow in each second.

Simple loops => infinite complexity (ex. fractals).



Genes & functions

Pinto, D. + 180 coauthors ... (2010). Functional impact of global rare copy number variation in autism spectrum disorders. *Nature* **466**, 368–372 (2010)



ASD heritability is ~90%, SFARI Human Gene Module database in 9/2021 listed 1028 ASD genes, implicated in 10-20% of cases, single genes in less than 1%.

Genetic variants ⇔ educational attainment: 126,559 subjects, 180 authors, most predictive genetic variant (SNP) accounted for 0.02%, all genes 2% of total variance.

GxE

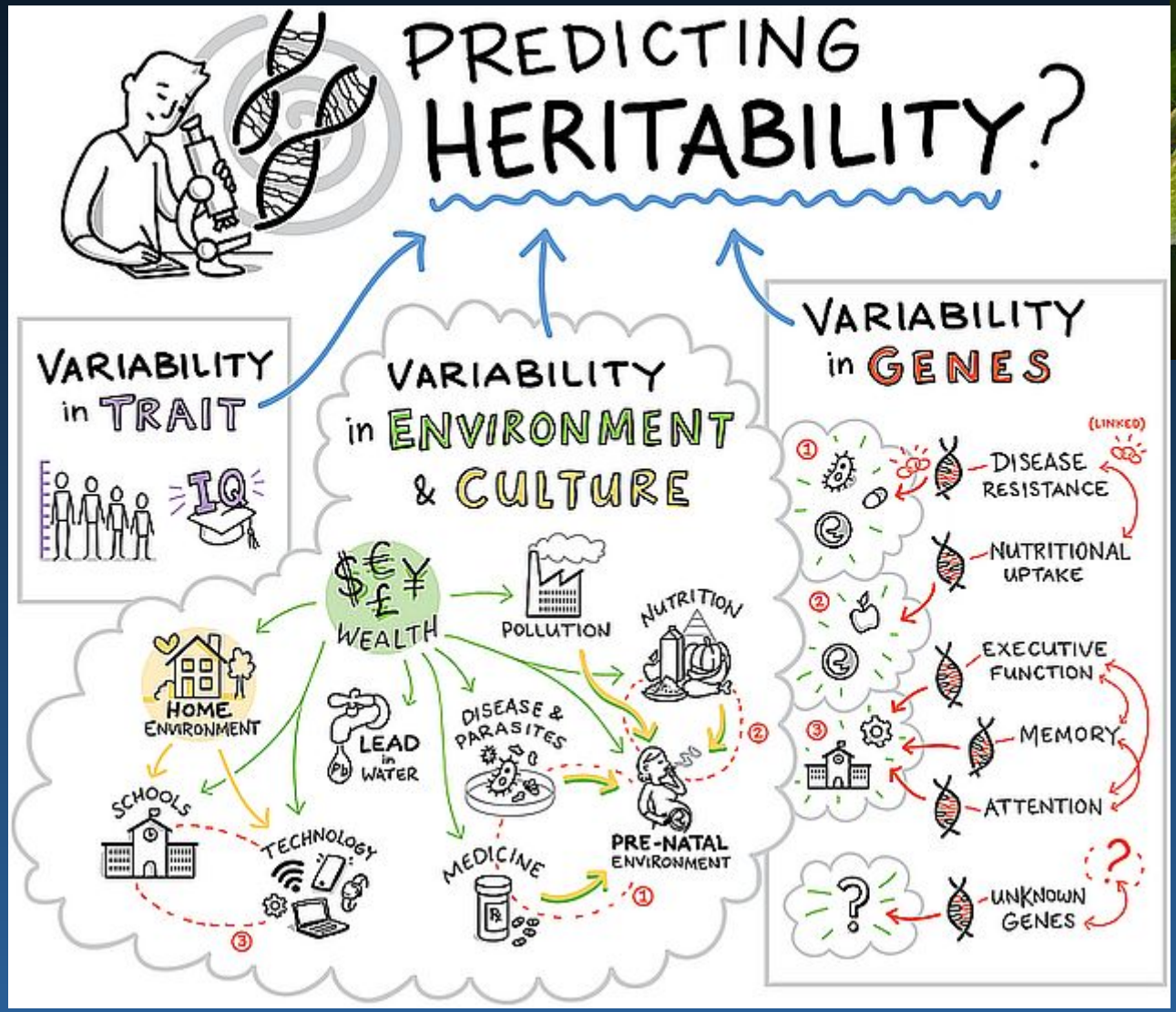
Reification of our intelligence, personality, selves and fears is wrong.
We are processes, not static objects.

Developmental processes and environment always interact with genes.

Physical matter is a substrate for biological processes.

Brain matter is a substrate for mental processes.

Data flow selects direction.



Phenomics => behavior

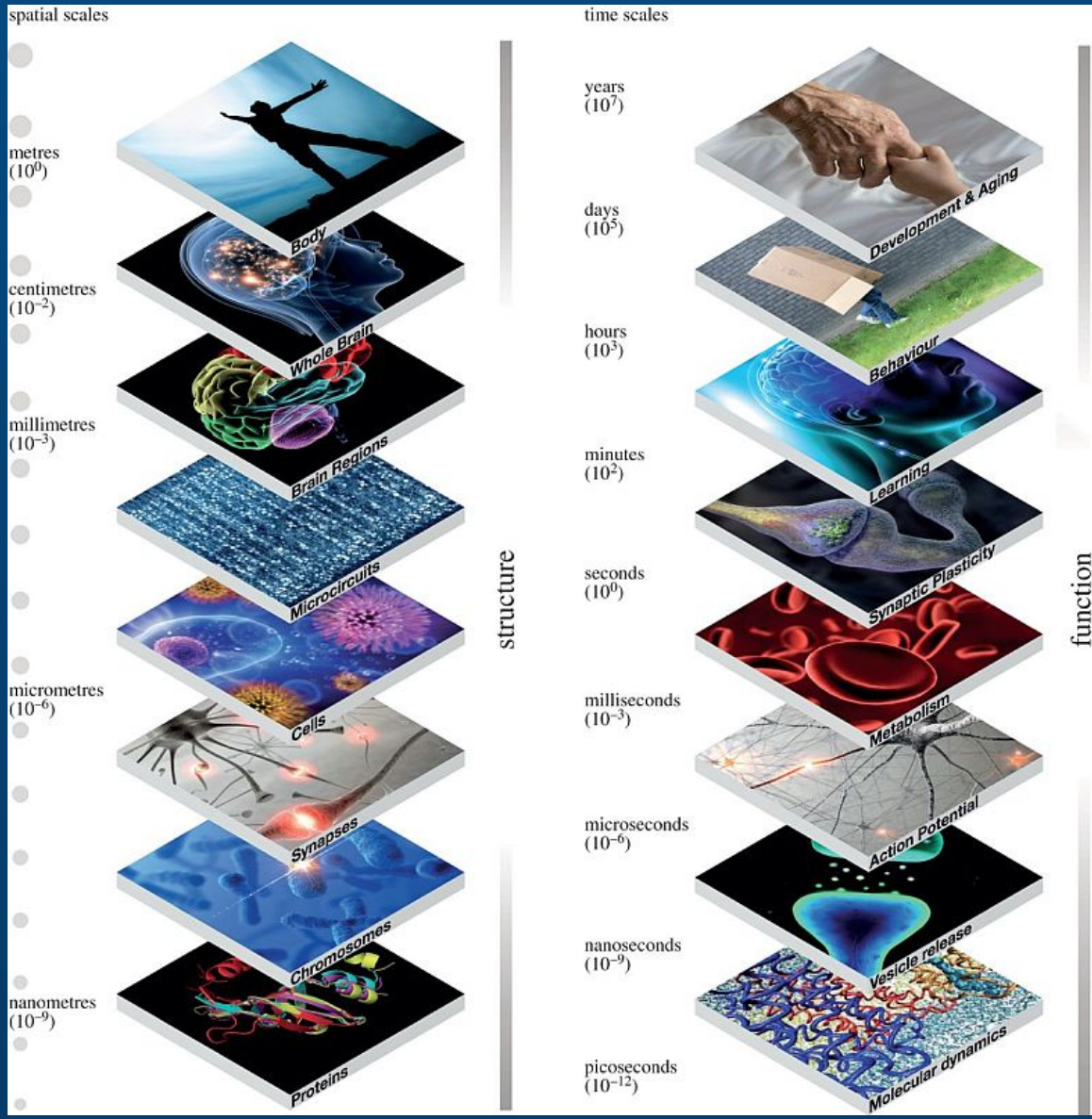
The Consortium for Neuropsychiatric Phenomics (2008).

"… categories, based upon presenting signs and symptoms, may not capture fundamental underlying mechanisms of dysfunction" (Insel et al., 2010).

New approach: RDOC NIMH.

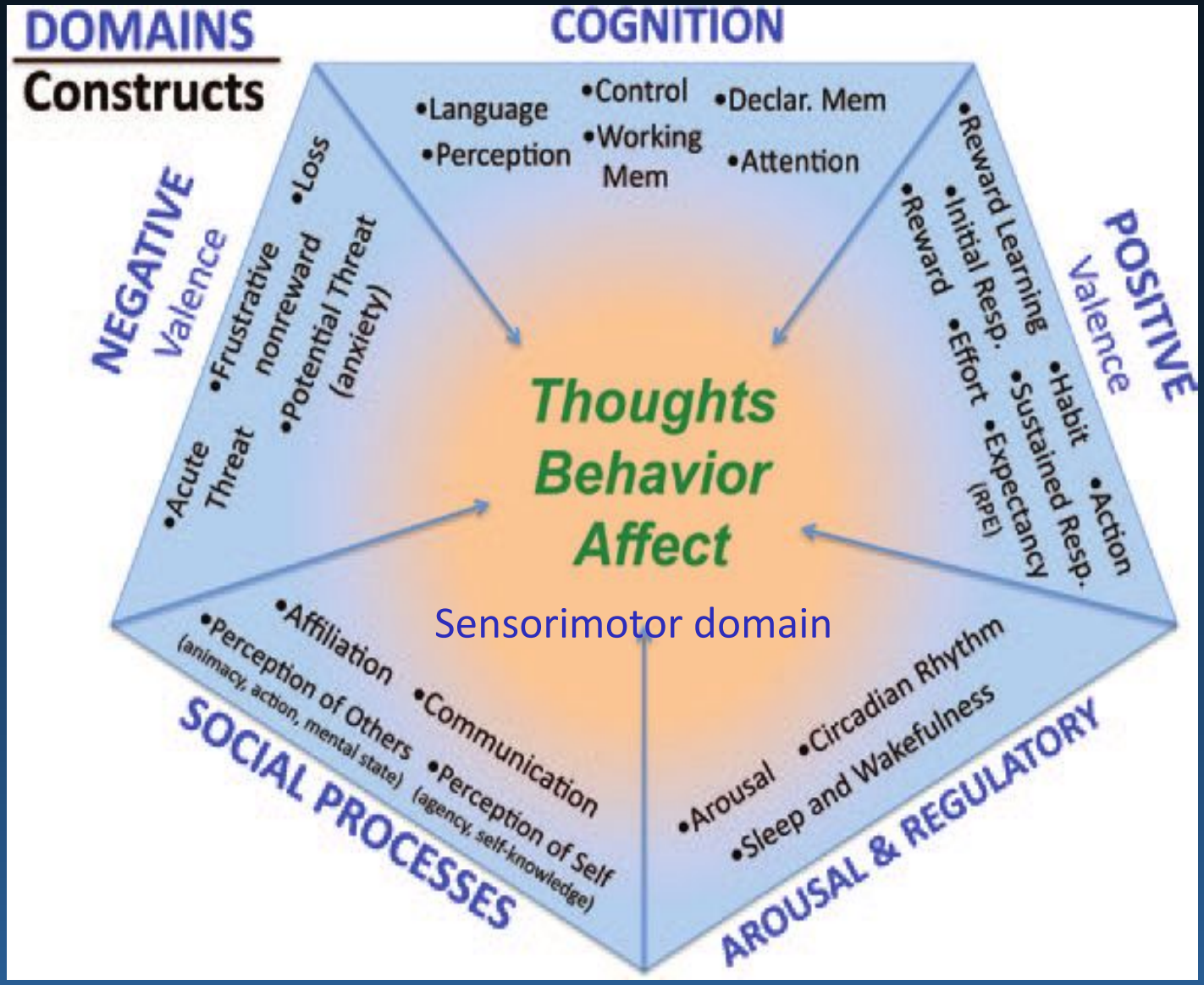
Description of organisms at different levels will help to answer different types of questions.

Network level is in the middle and can be connected to the mental level via computational models.



RDoC
Research Domain Criteria Initiative

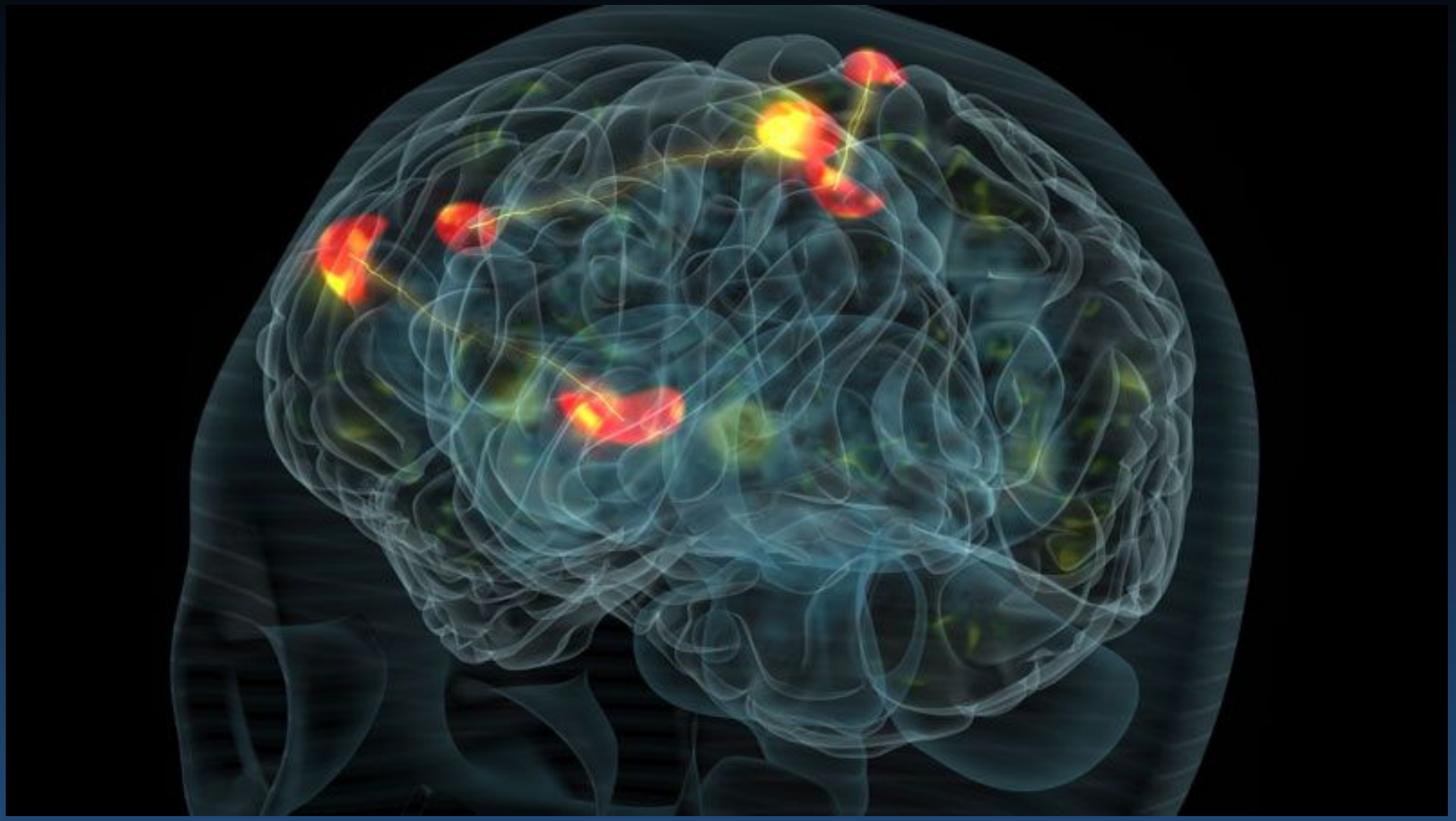
NIMH RDoC Matrix for deregulation of 6 large brain systems.



RDoC Matrix for „cognitive domain”

Construct/Subconstruct		Genes	Molecules	Cells	Circuits	Physiology	Behavior	Self-Report	Paradigms
Attention		Elements	Elements	Elements	Elements	Elements	Elements		Elements
Perception	Visual Perception	Elements	Elements	Elements	Elements	Elements	Elements	Elements	Elements
	Auditory Perception	Elements	Elements	Elements	Elements	Elements	Elements	Elements	Elements
	Olfactory/Somatosensory/Multimodal/Perception								Elements
Declarative Memory		Elements	Elements	Elements	Elements	Elements	Elements	Elements	Elements
Language		Elements			Elements	Elements	Elements	Elements	Elements
Cognitive Control	Goal Selection; Updating, Representation, and Maintenance ⇒ Focus 1 of 2 ⇒ Goal Selection				Elements			Elements	Elements
	Goal Selection; Updating, Representation, and Maintenance ⇒ Focus 2 of 2 ⇒ Updating, Representation, and Maintenance	Elements	Elements	Elements	Elements	Elements	Elements	Elements	Elements
	Response Selection; Inhibition/Suppression ⇒ Focus 1 of 2 ⇒ Response Selection	Elements	Elements	Elements	Elements	Elements	Elements	Elements	Elements
	Response Selection; Inhibition/Suppression ⇒ Focus 2 of 2 ⇒ Inhibition/Suppression	Elements	Elements	Elements	Elements	Elements	Elements	Elements	Elements
	Performance Monitoring	Elements	Elements		Elements	Elements	Elements	Elements	Elements
Working Memory	Active Maintenance	Elements	Elements	Elements	Elements	Elements			Elements
	Flexible Updating	Elements	Elements	Elements	Elements	Elements			Elements
	Limited Capacity	Elements	Elements		Elements	Elements			Elements
	Interference Control	Elements	Elements	Elements	Elements	Elements			Elements

Mental states: strong, consistent activations

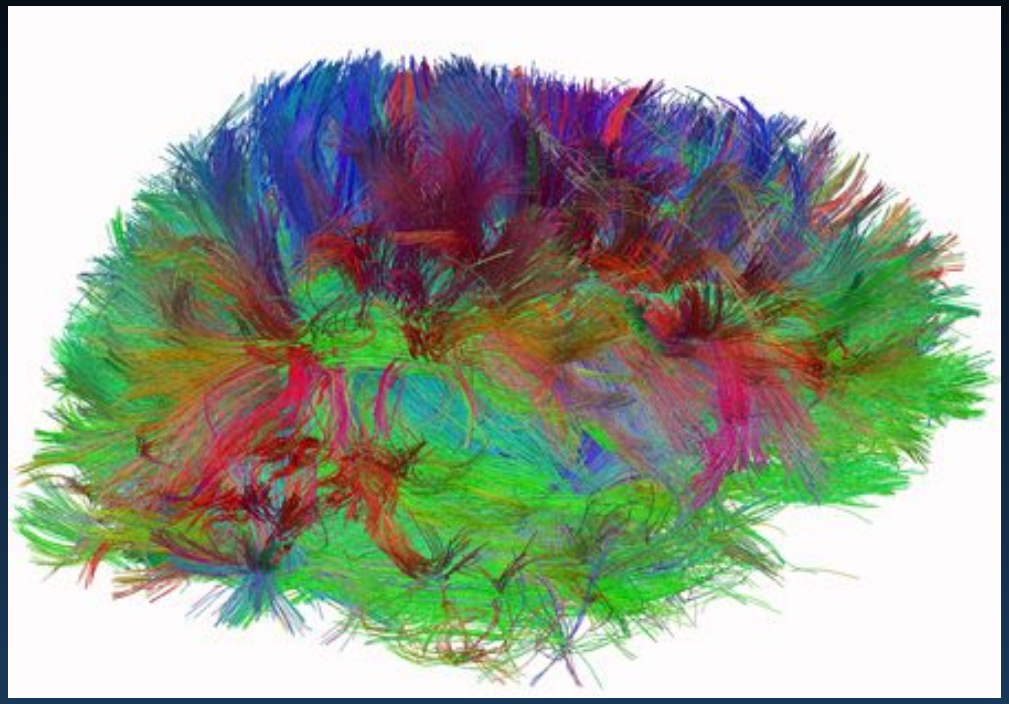


Large number of neuronal processes is going on in the brain at each moment.

Numerous neuronal networks excite and compete with each other.
Only the strongest processes that can be clearly distinguished from the noise (signal detection theory), will be expressed as action, speech, thought, or percept.

Consciousness is the perception of what is going on in one's own mind (J. Locke, 1689).

Neuronal determinism



Genetic determinism imposes general constraints on the efficiency of brains, it is better to have numerous "wrinkles" and "hairy" brains than smooth and combed.

Neural activity (neurodynamics) determines what comes to mind.
Neuronal determinism: brain shaped by life experiences, upbringing, education, forms associations, thoughts, emotions. Connectome and neural properties are the key.

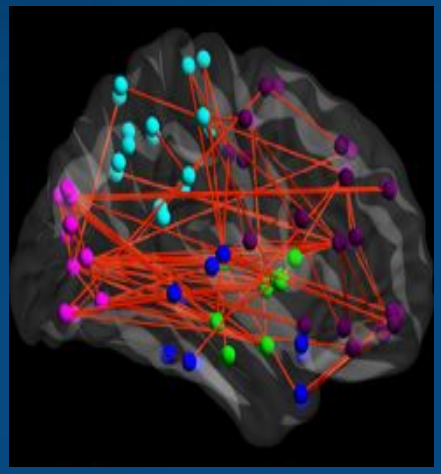
Genes ⇔ Brain/body
⇑⇔ Environment ⇔⇓

Metaphor: mind is a shadow of brain activity (neurodynamics).

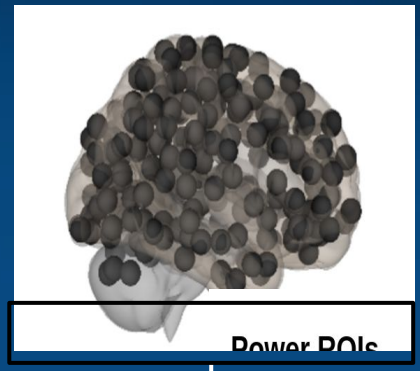
Human connectome and MRI/fMRI

Structural connectivity

Functional connectivity

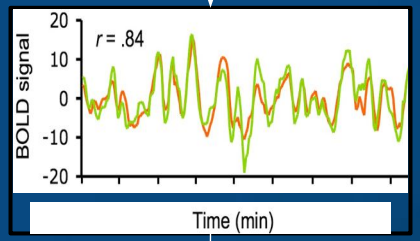


Node definition (parcelation)

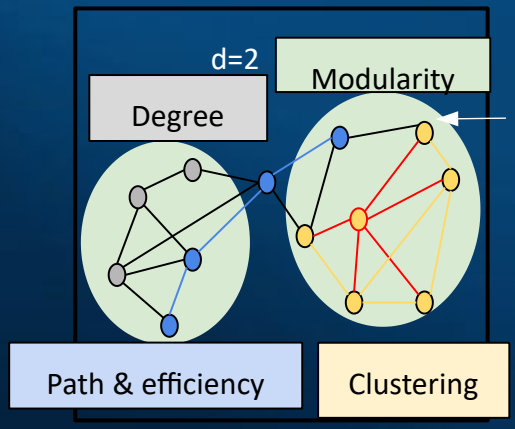


Signal extraction

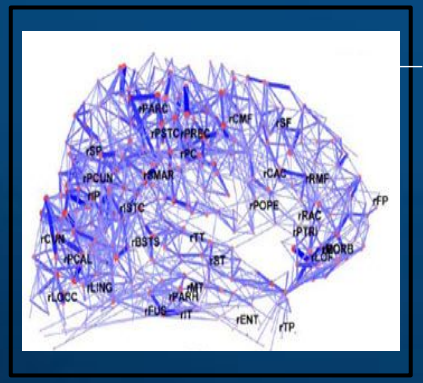
Correlation calculation



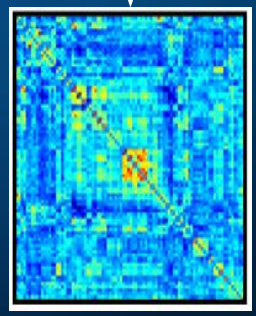
Graph theory



Whole-brain graph



Binary matrix

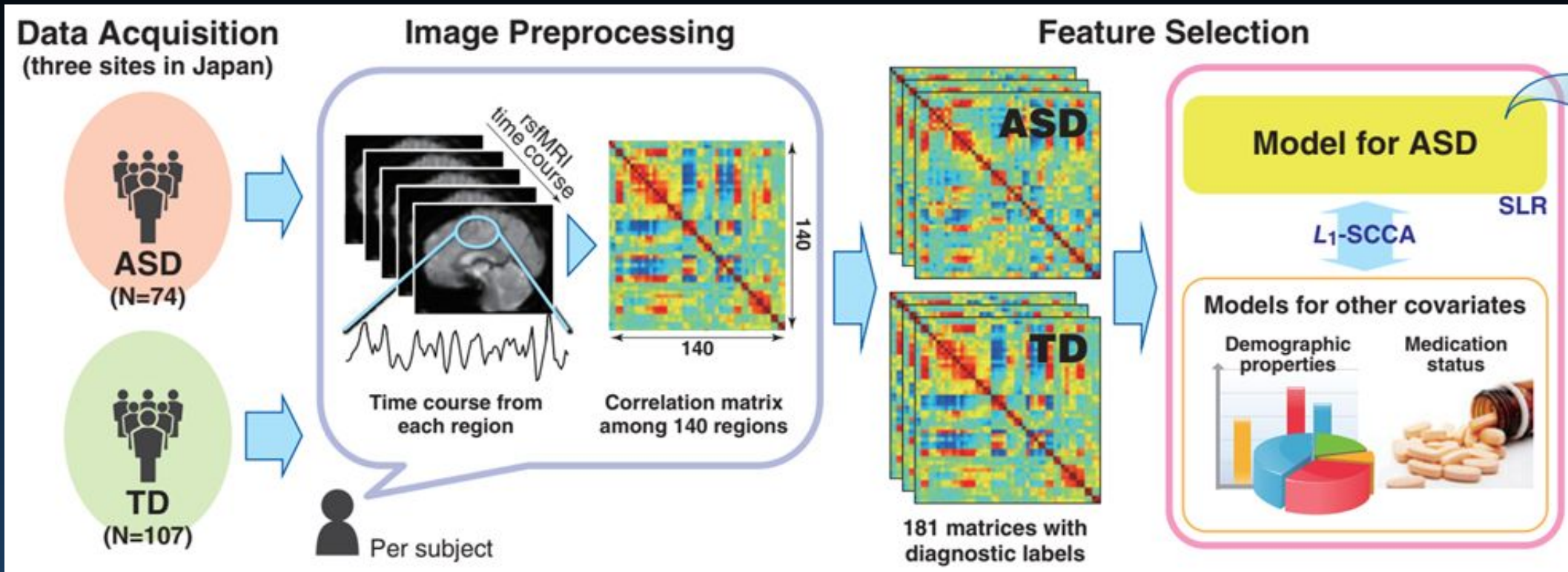


Correlation matrix

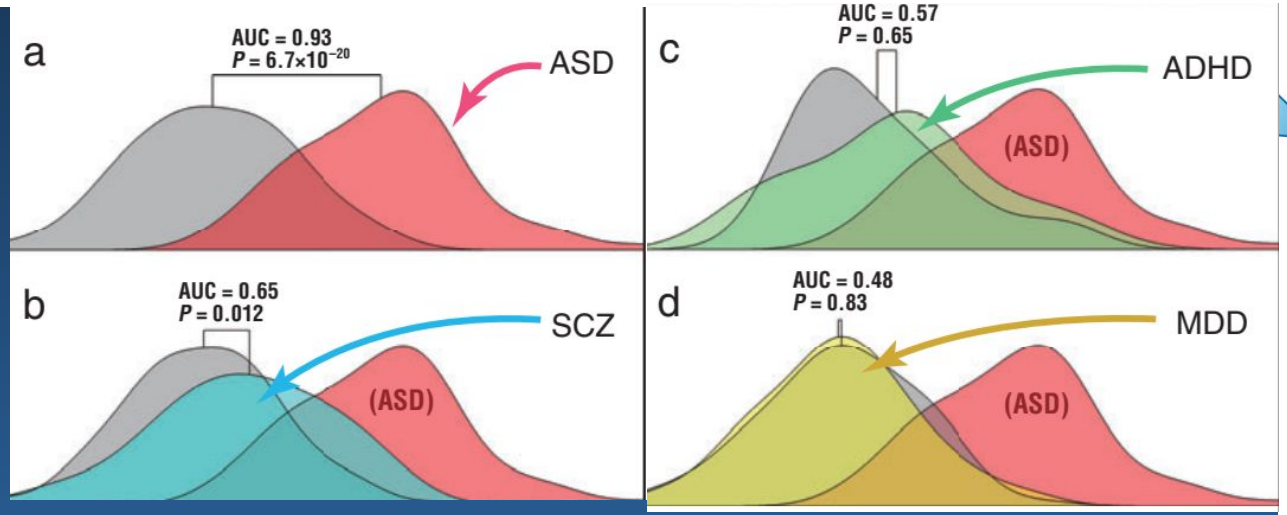
Many toolboxes are available for such analysis.

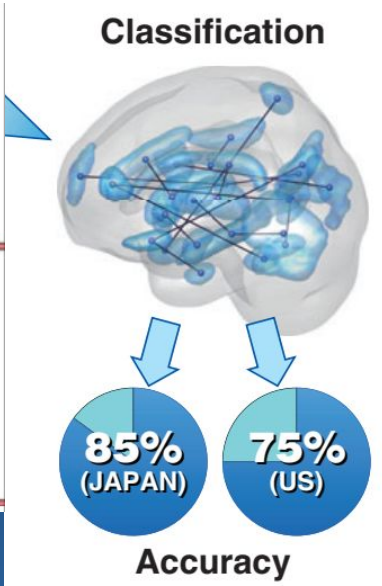
Bullmore & Sporns (2009)

Biomarkers from neuroimaging



Functional connections in brains of people with different disorders have diagnostic value.





N. Yahata et al, *Psychiatry and Clinical Neurosciences* 2017: **71**

Brains and culture

(Neuro)education

Training changes our body, but brain is much easier to change!

All experience is changing brains thanks to neuroplasticity.

We create connections in the brain, activation pathways are "grooved" by our experience, peers, family, teachers.

Result: many cultures, beliefs, values, languages, arts …

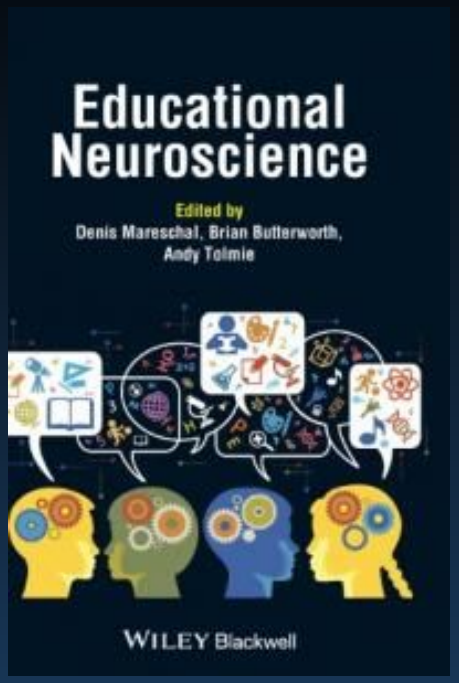
Education is sculpting the physical structure of the brain.

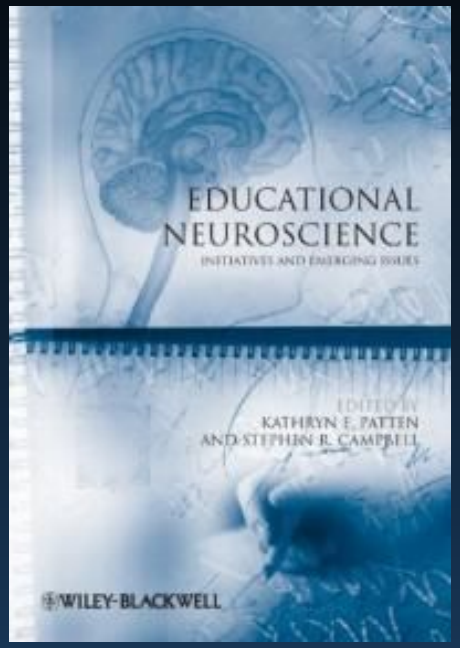
Neuroeducation: an interdisciplinary field combining the results of neuroscience, psychology and pedagogy in order to develop more effective teaching methods.

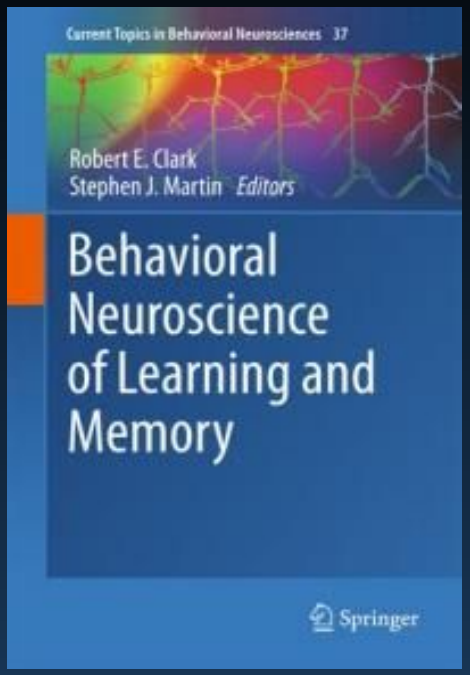
Neurologist Henry Herbert Donaldson (1857–1938):
„The Growth of the Brain: A Study of the Nervous System in Relation to Education", 1895!

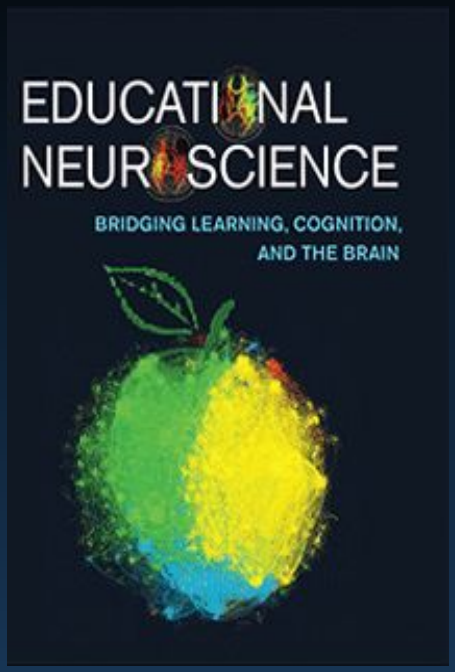
Educator Reuben Halleck (1859–1936):
„The Education of the Central Nervous System: A Study of Foundations, Especially of Sensory and Motor Training", 1896!

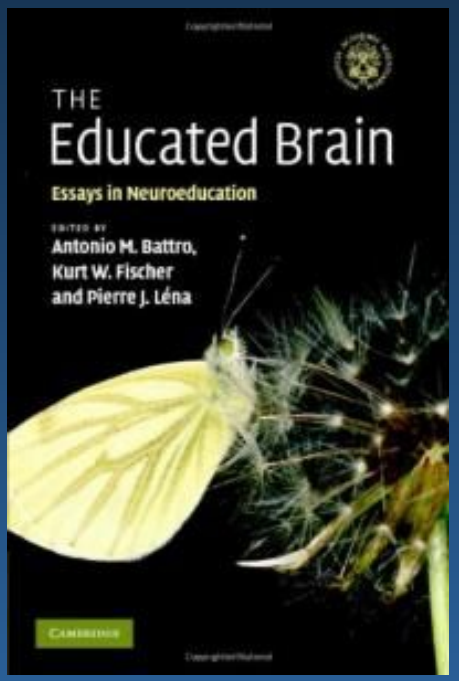
Books on neuro-education

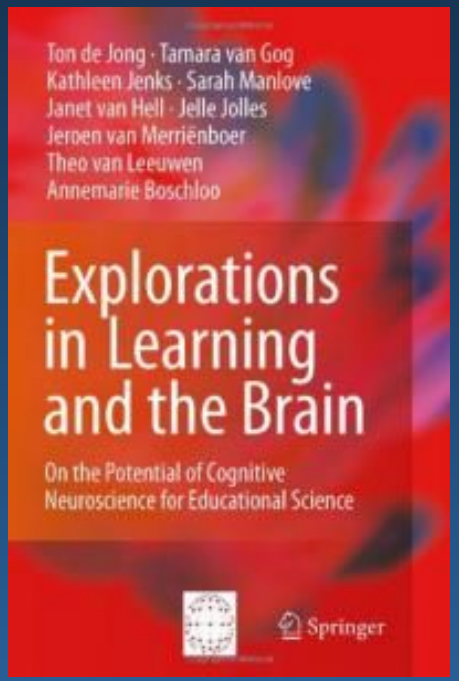


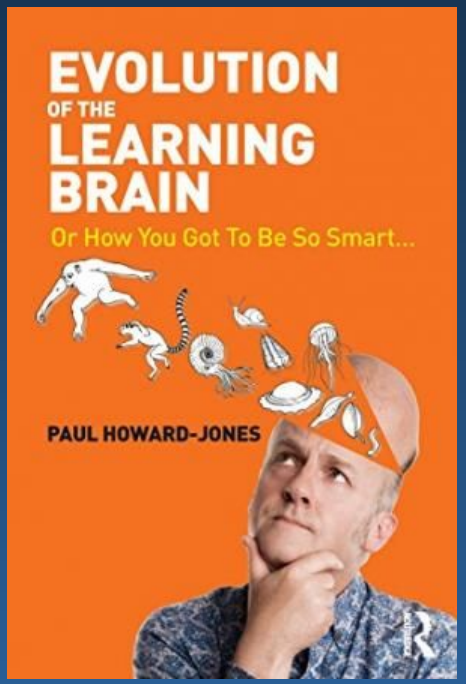


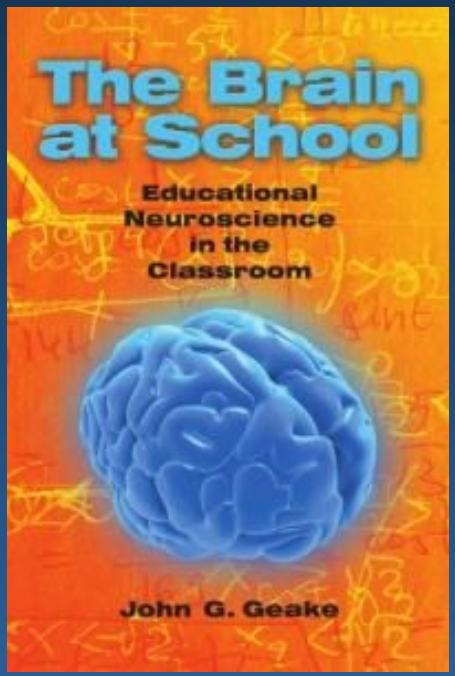












Report „Neuroscience and Education”

Paul Howard-Jones, Neuroscience and Education: A Review of Educational Interventions and Approaches Informed by Neuroscience. Full Report and Executive Summary. Polish translation K. Cipora, A. Bereś, E. Międzobrodzka, J. Płachetka. Education Endowment Foundation.

18 topics, summary of scientific discoveries and educational applications of these discoveries. Report in English and in Polish (updated).

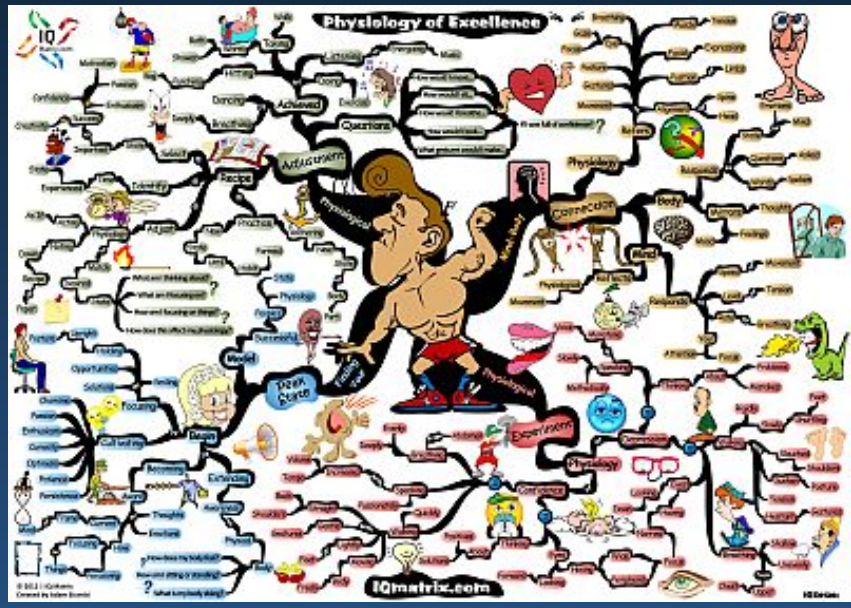
Conceptual space

What comes to my mind? Culture and experience provides shared conceptual space, necessary for communication, understanding, reading and writing with comprehension.

Since 1986 Core Knowledge Foundation has been working in the US and UK trying to define this common cultural code, from kindergarten to the end of elementary school.

Communication space: how do we understand concepts, what chains of associations the invoke, what resonance do they create in different brains?

That depends on the conceptual grid in our brain.



Words, concepts that activate the brain enable segmentation of experience. Without words there would be a constant flow of states, very limited planning and associative processes.

Natural language models reflect brain processes. OpenAI GPT-3, Google Switch Transformer (1600 billion parameters, in 2048 domains) are trained on general knowledge, trillions of words, and then used to create models in a specialized domains.

Conceptual framework, "mind space" (WD, 1994).

IQmatrix.com and hundreds of mind maps on any topic.

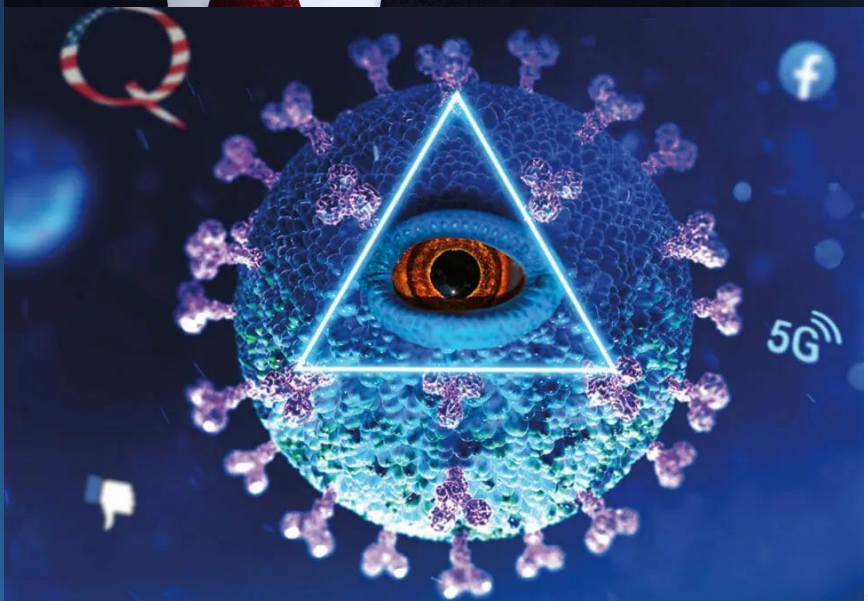

5G
DOES NOT
SPREAD
COVID-19
STOP
5G

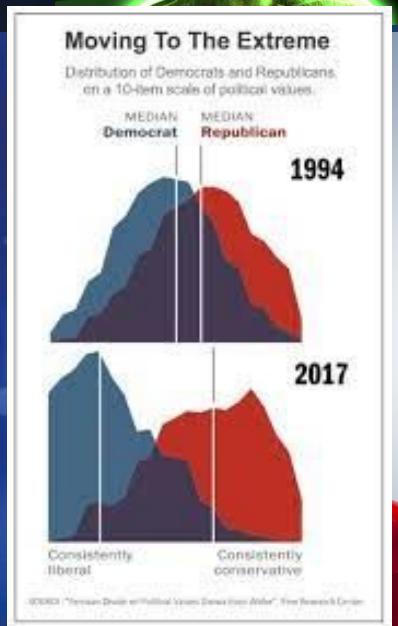

INVESTIGATE
COVID
AND 5G!


I WANT TO
WE COME IN PEACE
Believe

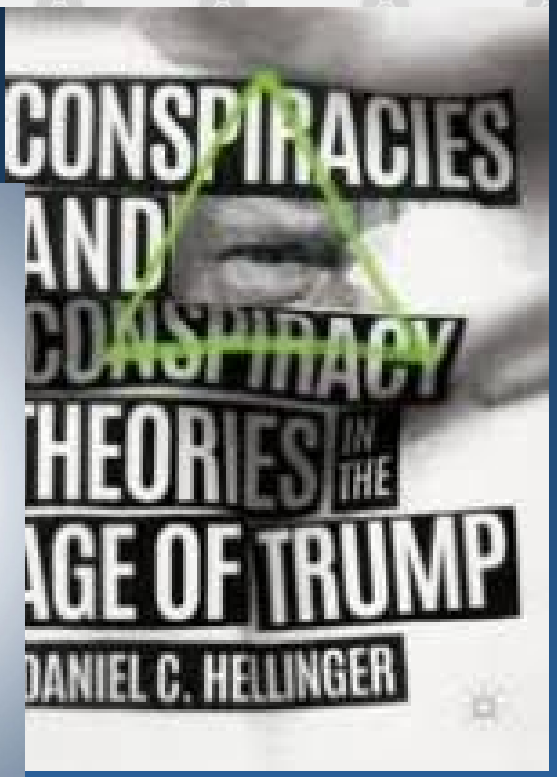

CNN
CNN SPECIAL REPORT
DONALD TRUMP'S
CONSPIRACY
THEORIES
MONDAY 9P ET/PT

THE TRUTH
BEHIND
AREA 51


Q
5G


Moving To The Extreme
Distribution of Democrats and Republicans on a 10-item scale of political values
MEDIAN Democrat
MEDIAN Republican
1994
2017
Consistently liberal
Consistently conservative


COVID-19


CONSPIRACIES
AND
CONSPIRACY
THEORIES IN THE
AGE OF TRUMP
DANIEL C. HELLINGER

The Cognitive Bias Codex

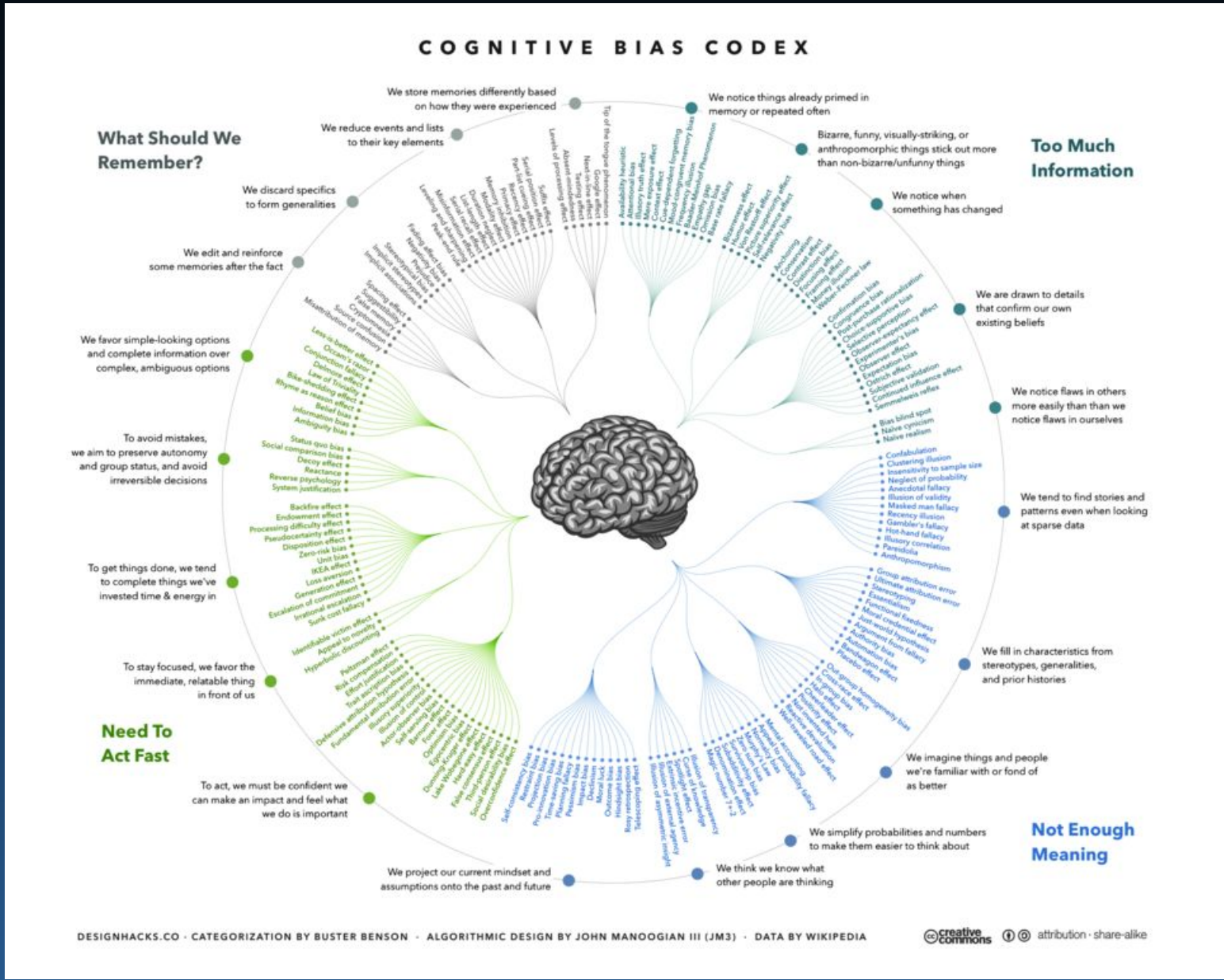
Cognitive biases are systematic patterns of deviation from rationality in judgment, studied in psychology, sociology, behavioral economics.

Over 180 biases …

Nobel 2002 in Economic Sciences

Daniel Kahneman, Bounded Rationality

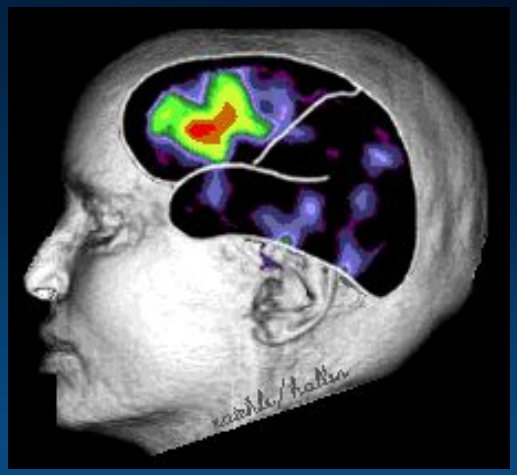
Nobel 2017, **Richard H. Thaler**, decision making.



Source: Wikimedia commons

Brain states and memory

Brains ⇔ Minds

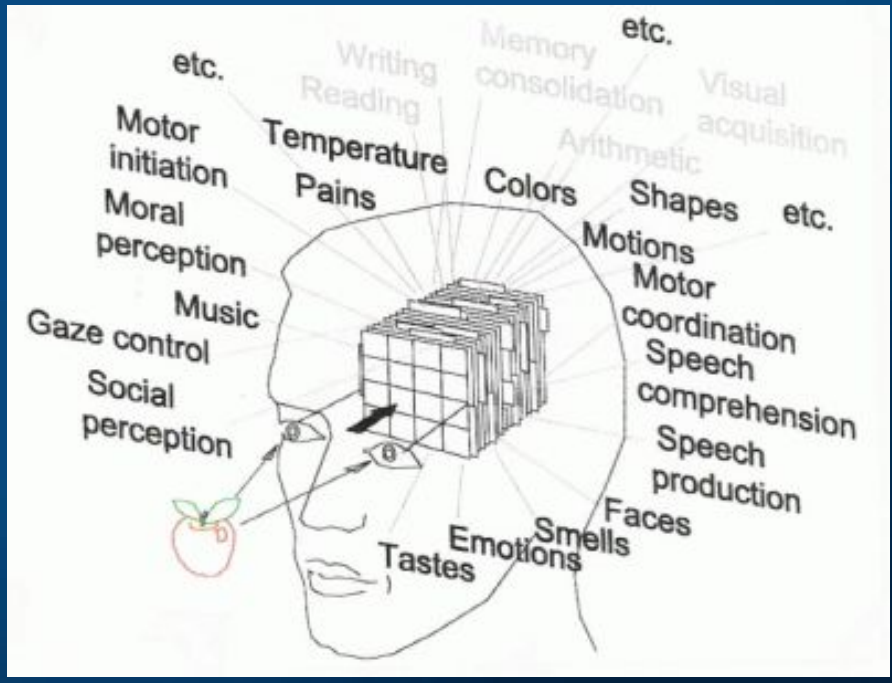


Define mapping S(M)⇔S(B). BCI: intentions => actions.
How do we describe the state of mind?

Verbal description is not sufficient unless words are represented in a space with dimensions that measure different aspects of experience.

Stream of mental states, movement of thoughts ⇔ trajectories in psychological spaces.

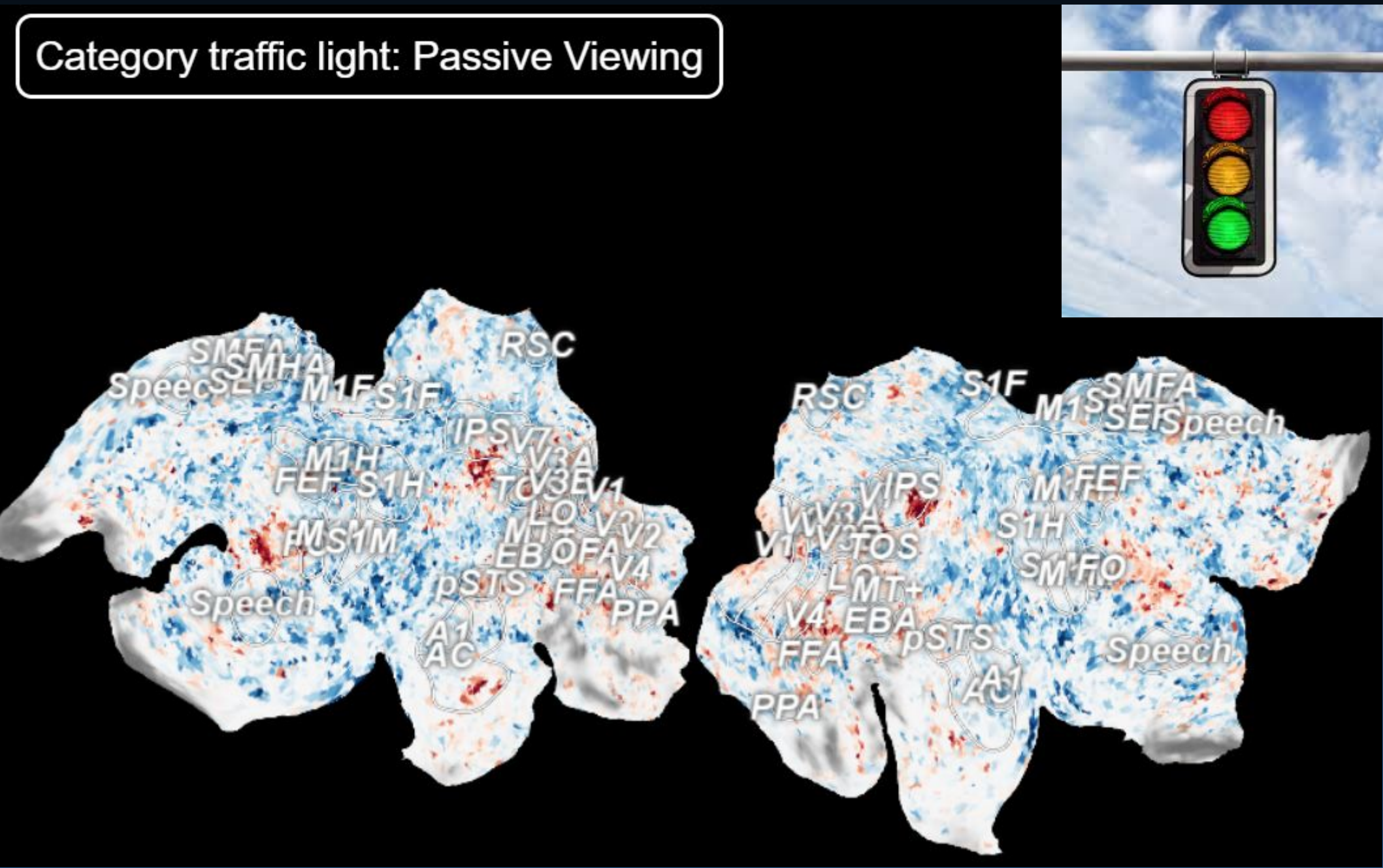
Two problems: discretization of continuous processes for explainable, symbolic models, and lack of good phenomenology – we are not able to describe our mental states.



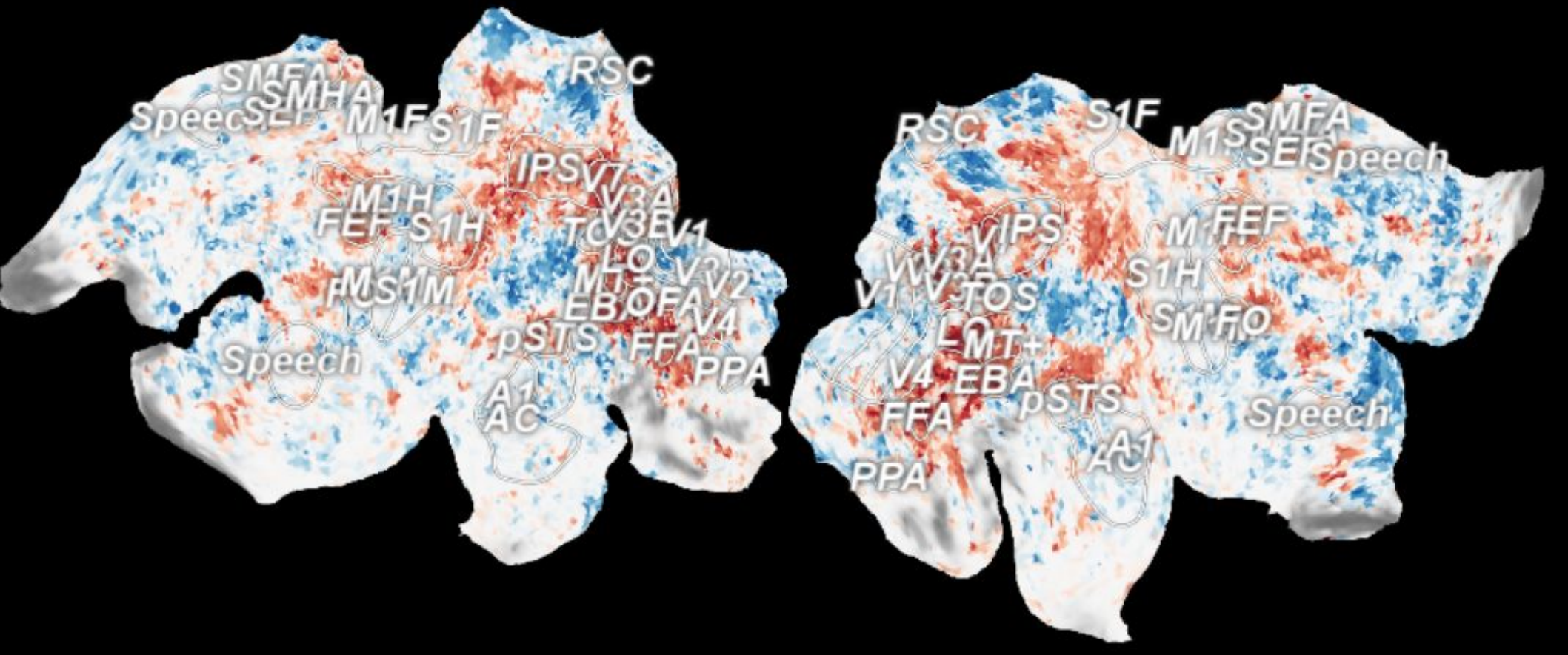
Neurodynamics: bioelectrical activity of the brain, neural activity measured using
EEG, MEG, NIRS-OT, PET, fMRI ...

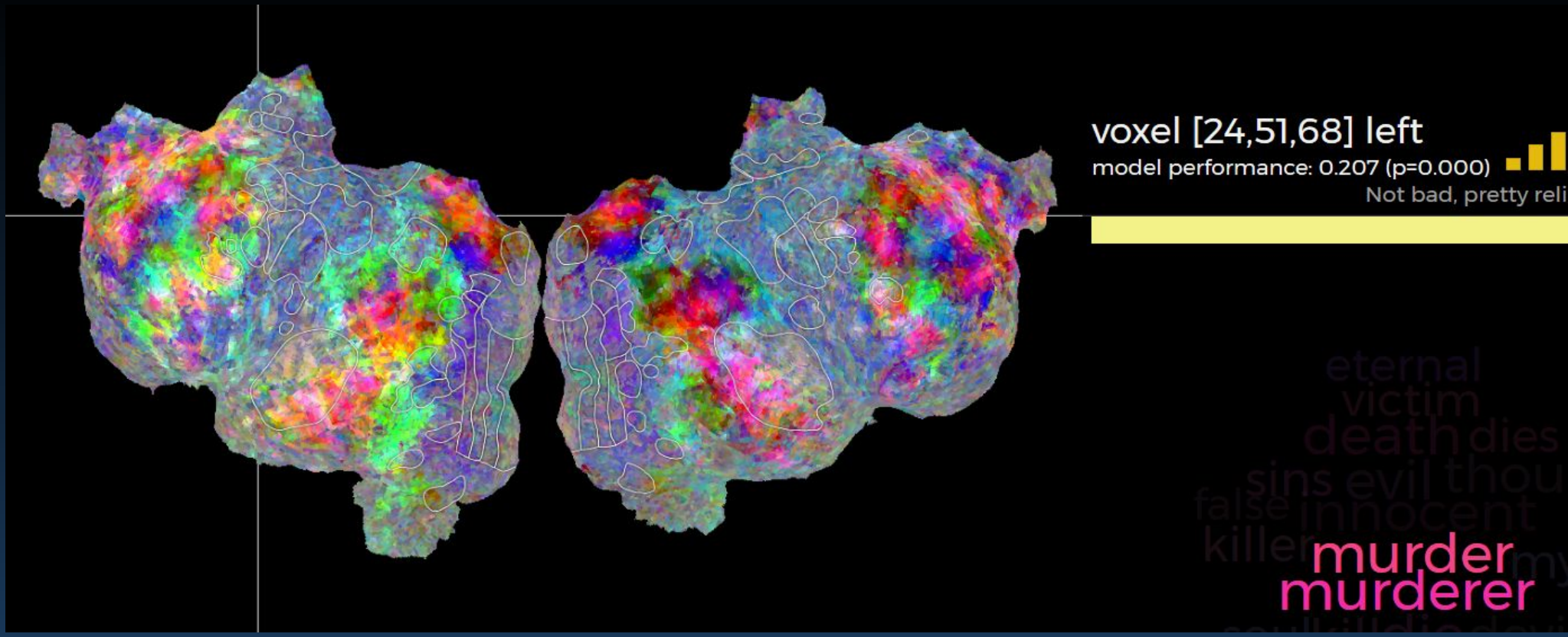
E. Schwitzgabel, Perplexities of Consciousness. MIT Press 2011.

Interpretation for simple objects is easy: IPS – visual attention, V4 – color, AC – object recogniton.



Category zebra: Passive Viewing





Whole fMRI activity map for the word “murder” shown on the flattened cortex.

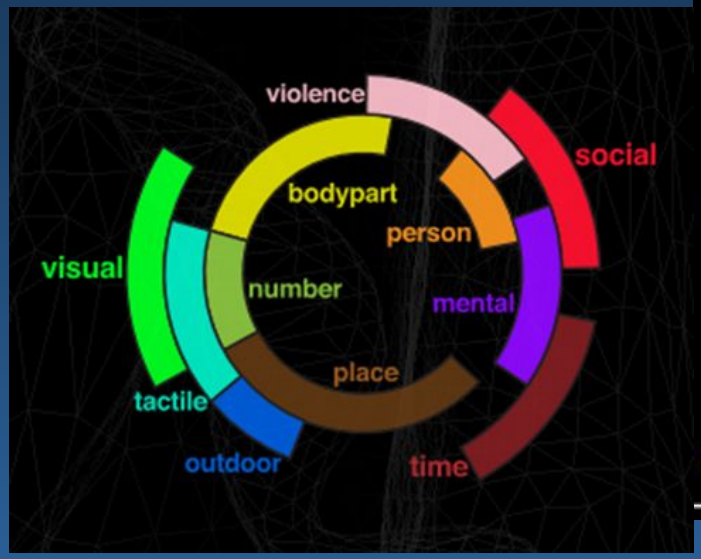
Each word activates a whole map of activity in the brain, depending on sensory features, motor actions and affective components associated with this word.
Why such activity patterns arise? Brain subnetworks connect active areas.

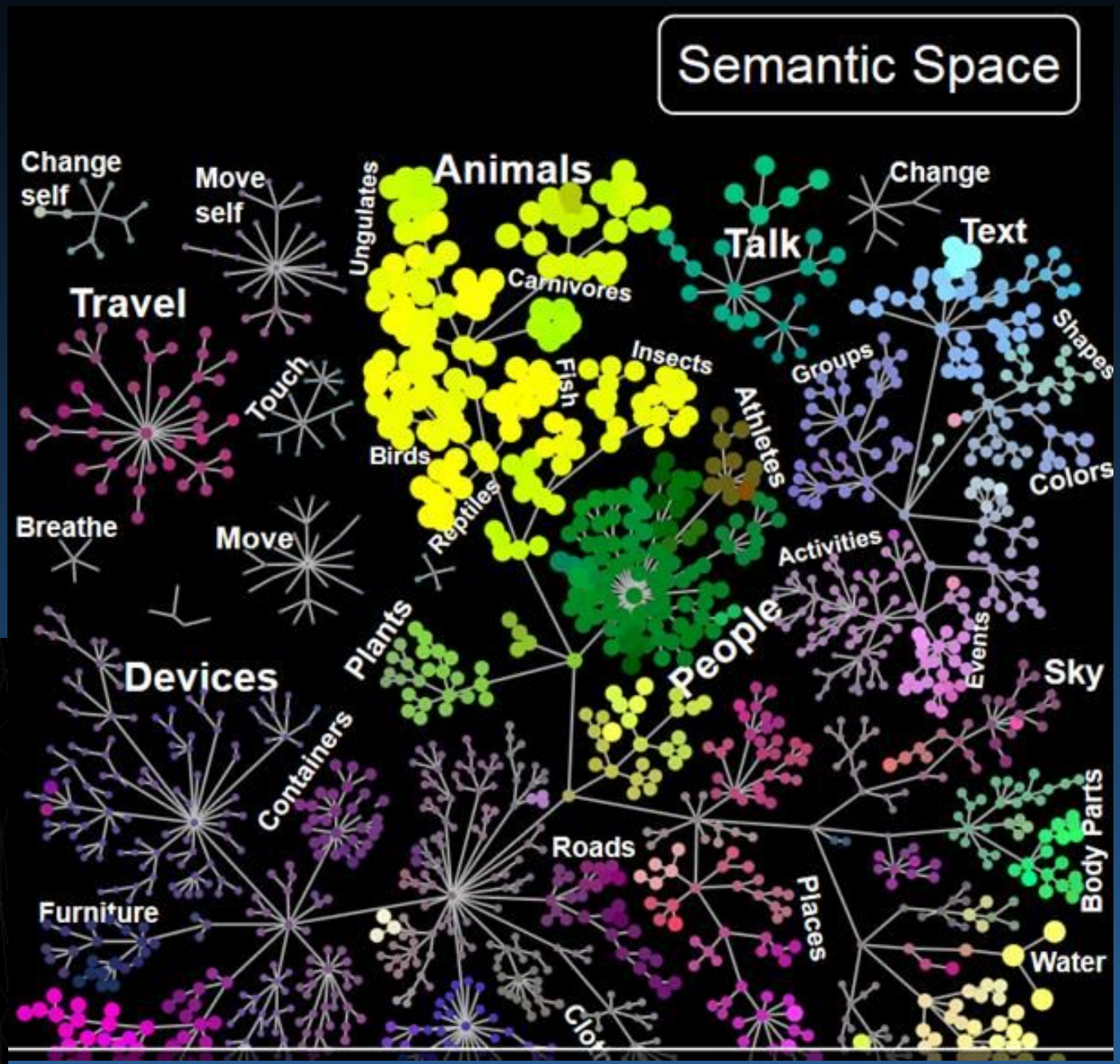
http://gallantlab.org/huth2016/ and short movie intro (A. Huth, Nature).

Can one do something like that with EEG or MEG?

Semantic neuronal space

1700 words in the semantic space are grouped by similarity. Words activate specific ROIs, similar words create similar maps of brain activity. Video or audio stimuli, fMRI 60.000 voxel). Gallantlab,Berkeley.





Nicole Speer et al.
Reading Stories Activates Neural Representations of Visual and Motor Experiences. *Psychological Science* 2009

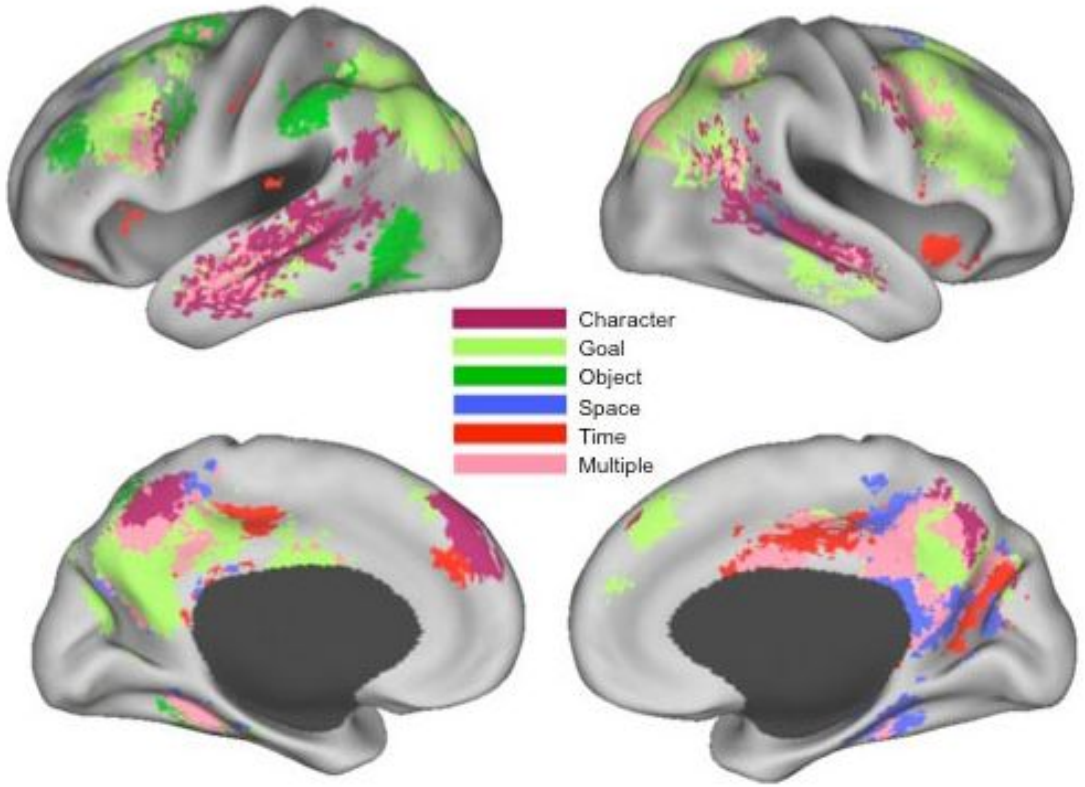
Automatic segmentation of experience is the basis of perception, facilitates planning, memory, association of information. Transitions between segments result from important observations in the current episode, entering new objects, places, goals, interactions, like in a movie.

Coherent narratives are recalled and coordinated by hippocampus (Cohn-Sheehy et al., Curr. Bio. 2021).

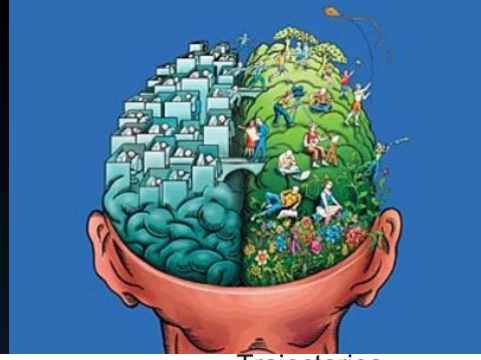
A

Clause	Cause	Character	Goal	Object	Space	Time
...[Mrs. Birch] went through the front door into the kitchen.	●				●	
Mr. Birch came in	●	●			●	
and, after a friendly greeting,	●					●
chatted with her for a minute or so.	●					●
Mrs. Birch needed to awaken Raymond.		●				
Mrs. Birch stepped into Raymond's bedroom,			●		●	
pulled a light cord hanging from the center of the room,				●		
and turned to the bed.						
Mrs. Birch said with pleasant casualness,						
"Raymond, wake up."						
With a little more urgency in her voice she spoke again:						
Son, are you going to school today?						
Raymond didn't respond immediately.		●				●
He screwed up his face			●			
And whimpered a little.						

B



Brains and memes



Memes are “units of cultural information” (Dawkins, 1976).

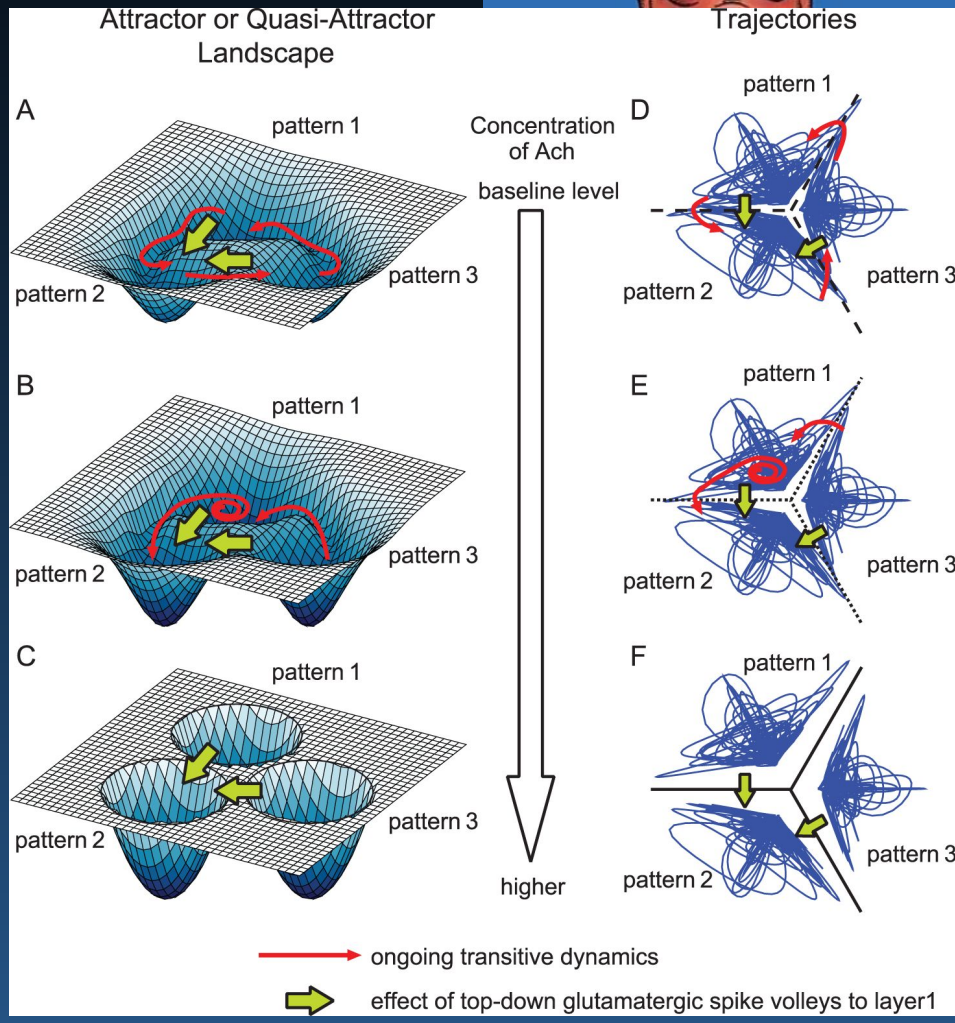
But … what is the physical carrier of memes?

Neural foundations of memetics have not been developed.

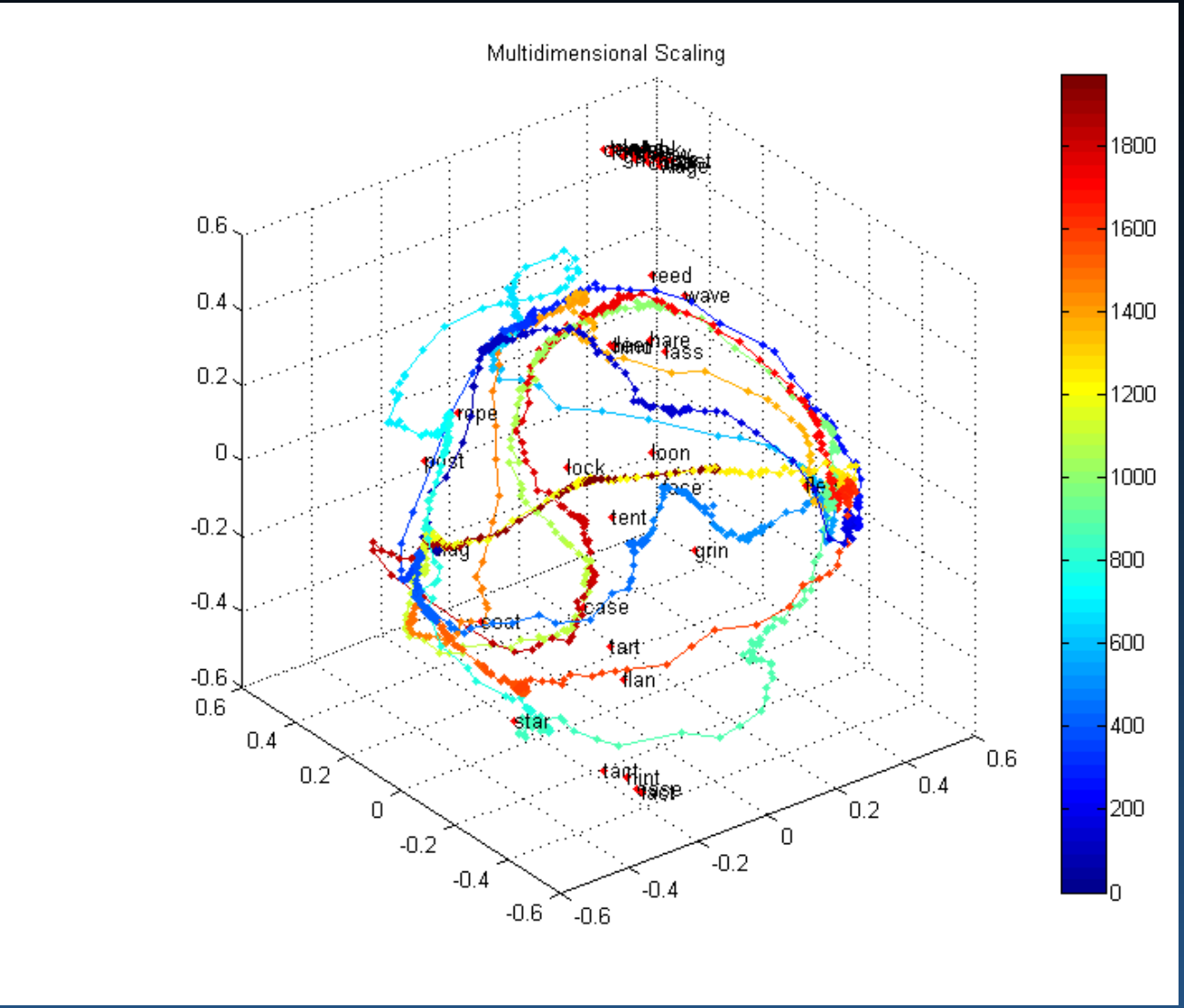
Memes are memory patterns much less stable then genes. Brain states are represented in the best way as dynamical system!

Memes are attractors of neurodynamics. Quasi-stable activations of the brain.

Amit, D. J. (1992). Modeling Brain Function: The World of Attractor Neural Networks. CUP.

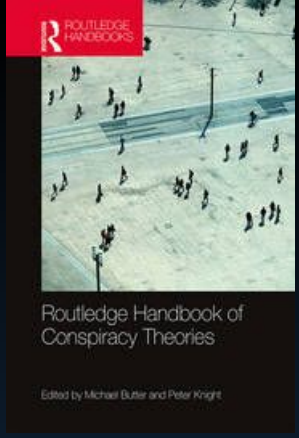


MDS: long trajectories



MDS visualization in 40-words microdomain, starting with the word “flag”. Several patterns close to the initial pattern, showing strong priming effects.

Conspiracy theories



EU COST network on “Comparative Analysis of Conspiracy Theories” (COMPACT) gathered researchers in history, sociology, psychology and political sciences to “generate the thorough comprehension of the history, politics, sociology, rhetoric and psychology of conspiracy theories needed to counter their often harmful effects on democratic values”.

Results: Routledge Handbook of Conspiracy Theories (2020), 800 pages, book series on conspiracy theories - all completely ignoring neurobiological mechanisms, Infographics.

Artificial neural networks: focused on the best learning methods, not memory errors.

I like what I know and I know what I like …
Consolidation of new memory states in the neocortex may occur quite quickly if they form strong connections to other memory states – our conceptual networks.
Tse et al. (2007) Schemas and Memory Consolidation. Science, 316

Neural models of schemas and sequences of associations may be based on attractor states in neural networks. Each episodic or semantic memory state is based on activations of synchronized, distributed network of brain regions.

Simple explanations are rewarding, save energy needed for thinking, create false impression of reducing uncertainty. Any reference to the false information encodes it in a stronger way in the memeplex.

Conspiracies in our brains

Why people start to believe in conspiracies?

The soul selects its own society, then shuts the door (Emily Dickinson, 1890).

Slow and rapid scenarios are possible, here only rapid presented:

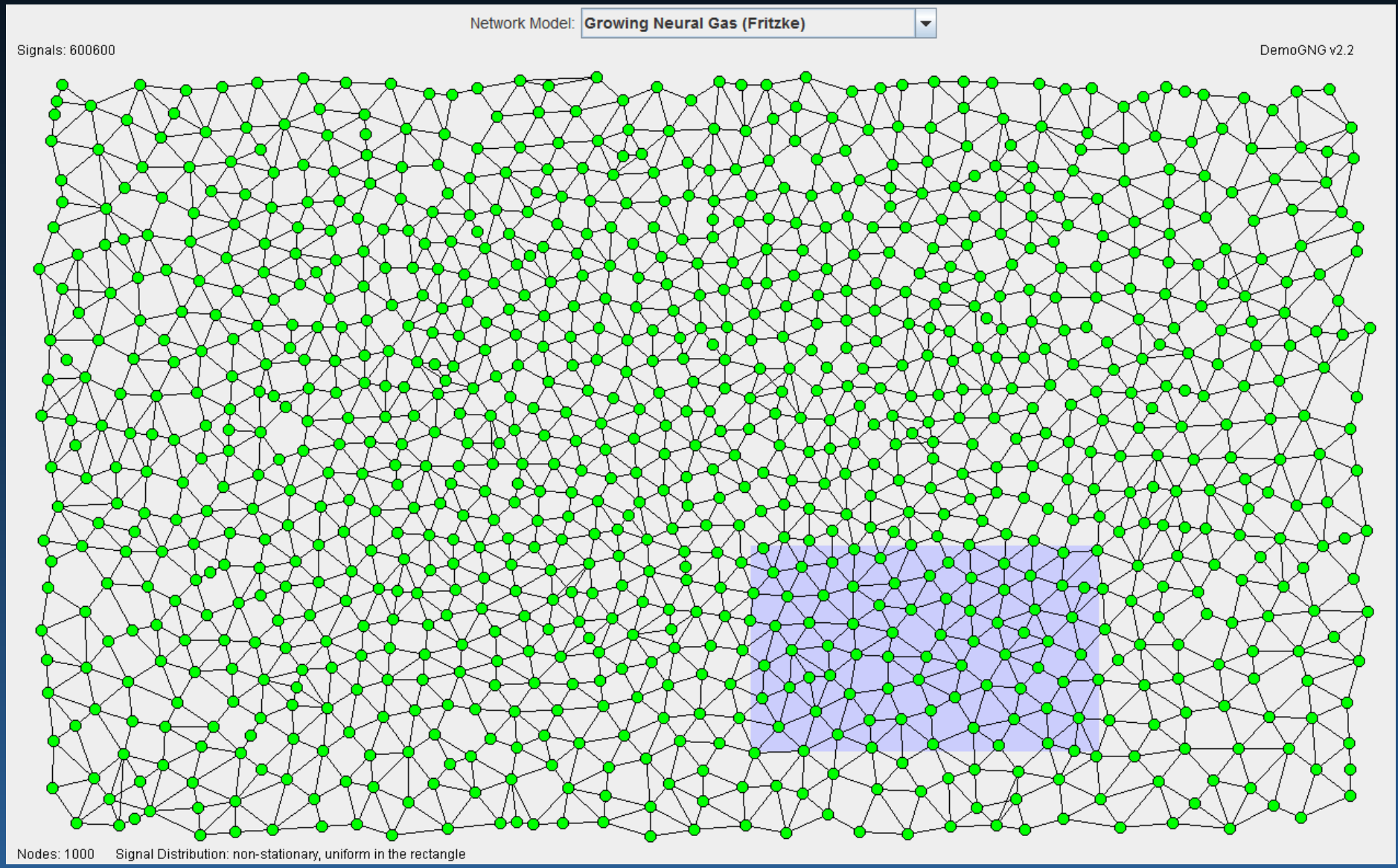
- Emotional situations => neurotransmitters => neuroplasticity => fast learning, must be important.
- Fast learning => high probability of wrong interpretation.
- Traumatic experiences, hopelessness, decrease brain plasticity and leave only strongest association – strongly connected pathways.
- Conspiracy theories form around such associations, "frozen" pathways lead to brain activations forming strong attractors, distorting rational thinking.

- Such strong associations save brain energy and cannot be changed by rational arguments, that influence weaker associations only.
- This explanation becomes so obviously obvious …

Model: concept vectors derived from a corpus + MDS or Growing Neural Gas visualization (Martinetz & Schulten, 1991).

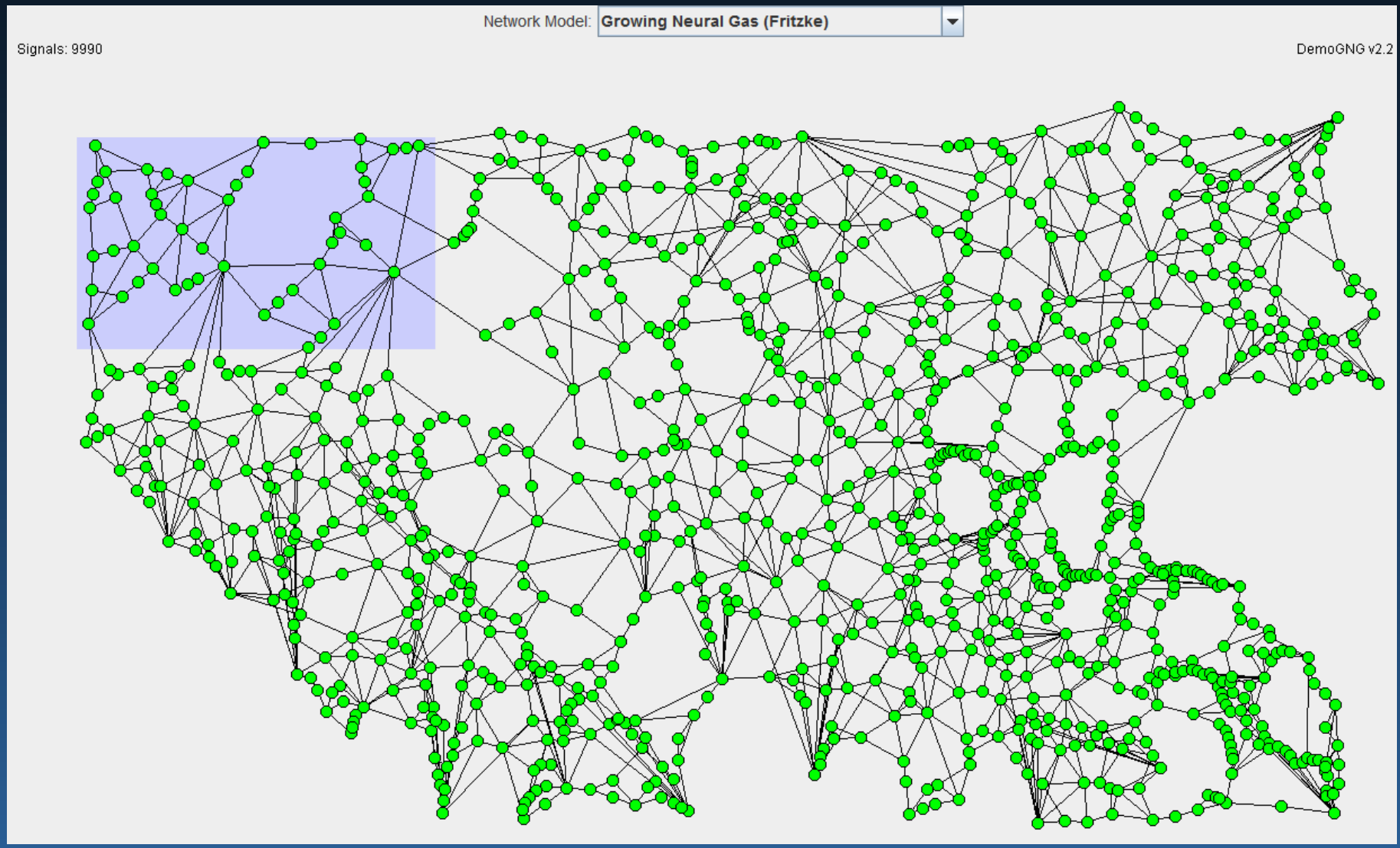
Internalization of environment

Episodes are remembered and serve as reference points, if observations are unbiased they reflect reality, creating correct associations and realistic evaluation.



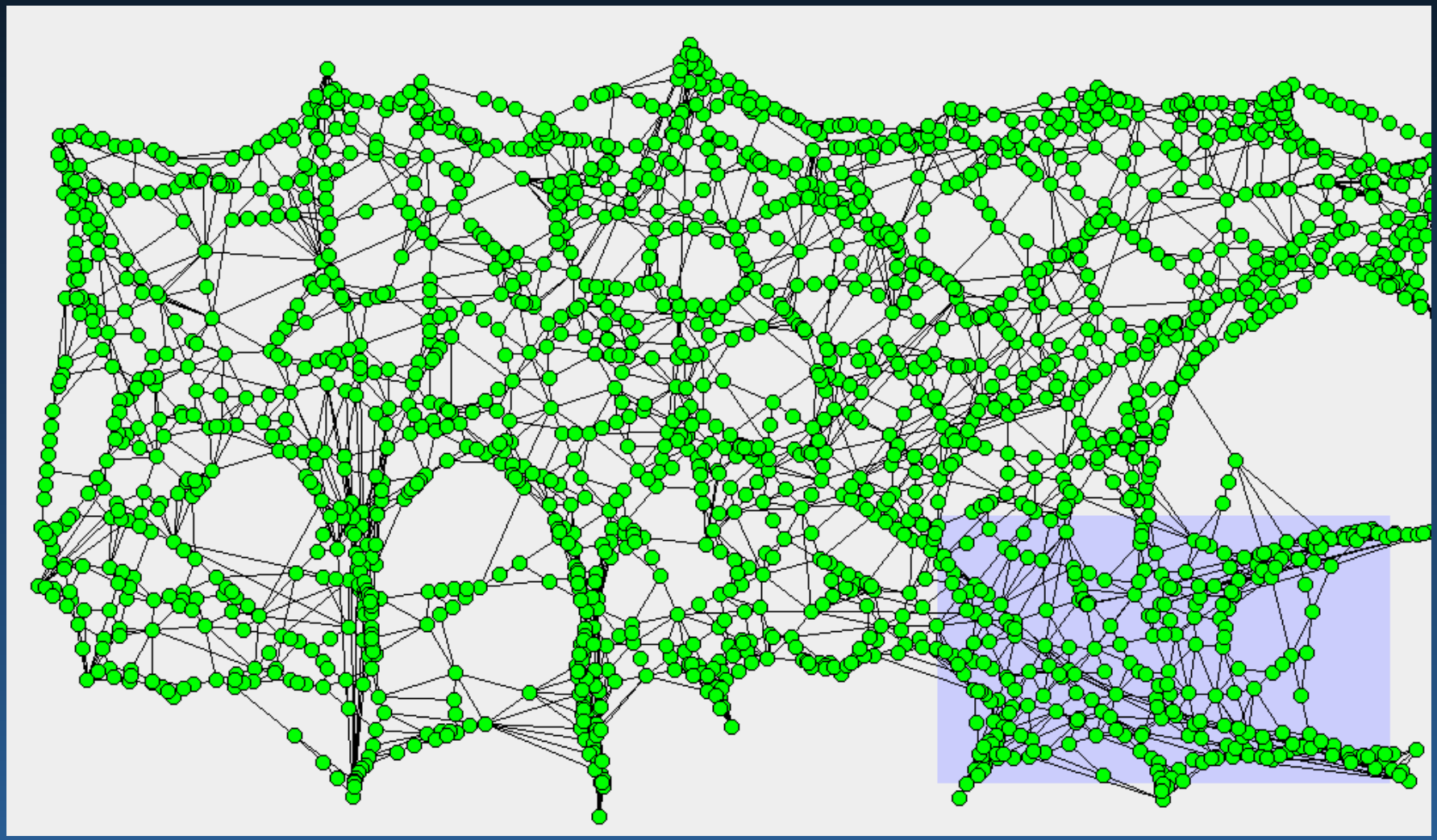
Extreme plasticity

Brain plasticity (learning) is increased if strong emotions are involved.
Rapid learning is not accurate, and if it is followed by depressive mood it leads to severe distortions, false associations, simplistic understanding.



Conspiracy views

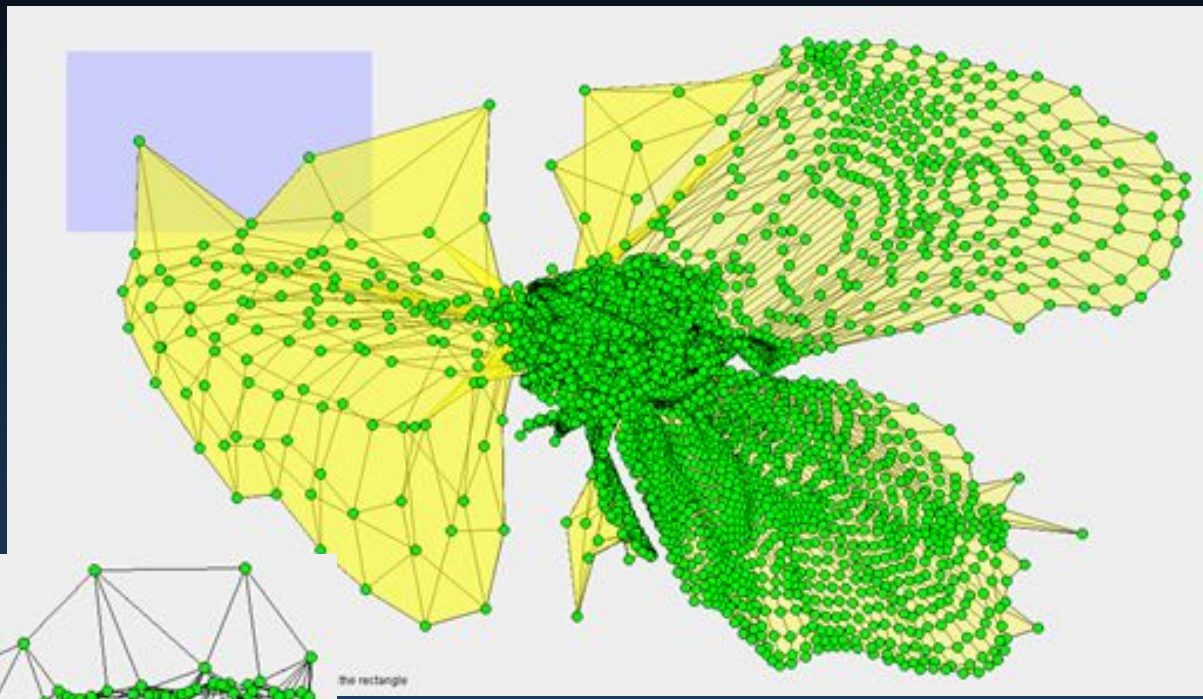
Illuminati, masons, Jews, UFOs, or twisted view of the world leaves big holes and admits simple explanations that save mental energy, creating „sinks” that attract many unrelated episodes.

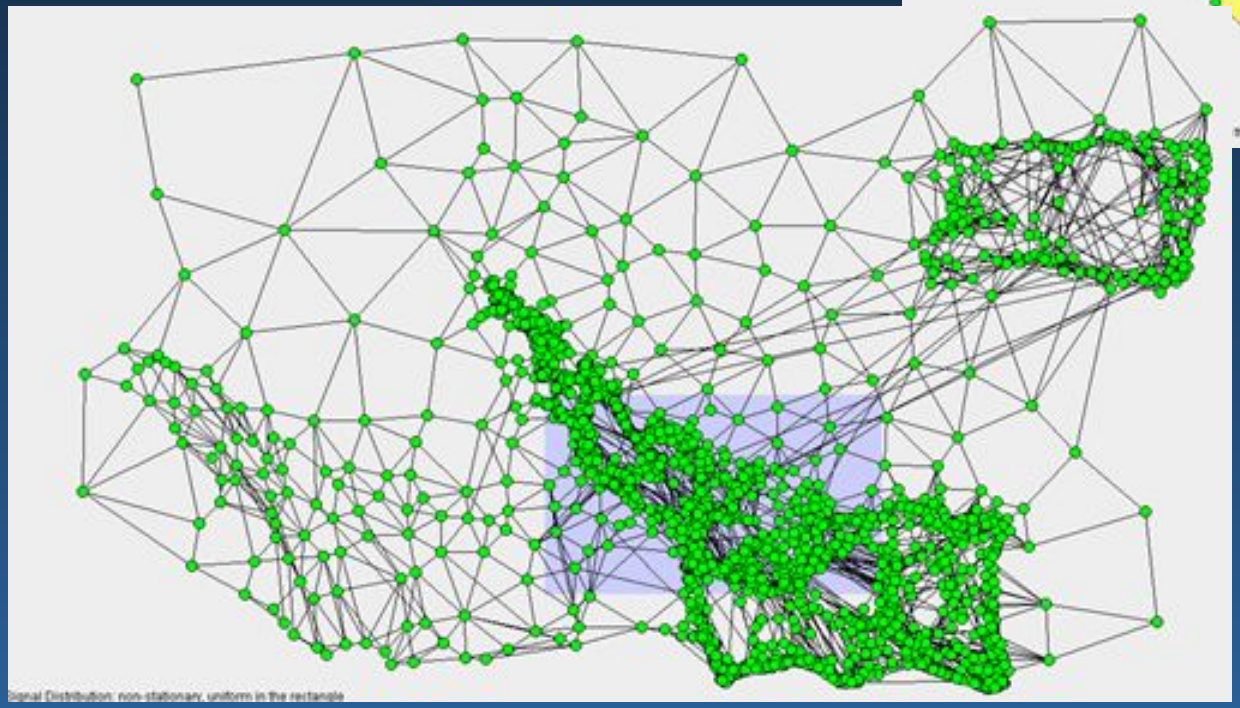


Memoids …

Totally distorted world view, mental processes are reduced to a memplex …

Ready to sacrifice oneself for a great idea.



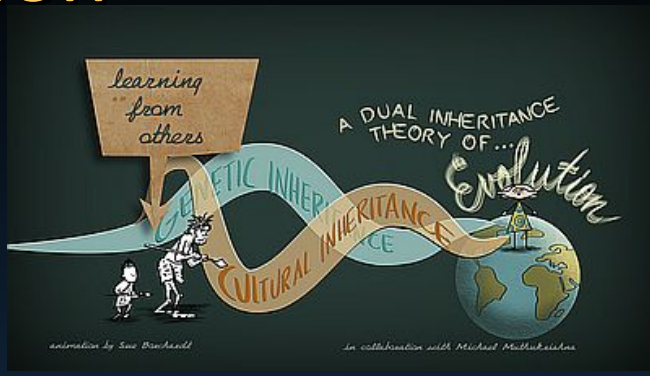


Neuroplasticity is
a curse, and a blessing …

I know what I like and
I like what I know.

Wonders of equilibria

Gene–culture coevolution



Dual Inheritance Theory (DIT), developed since 1960.

Culture = socially learned behavior, can profoundly influence gene frequencies in a population.

Human behavior ⇐ genetic evolution + cultural evolution.

Cultural traits alter the social and physical environments.
Agriculture caused genetic selection for to digest starch and lactose; domestication of animals => genotype for adult lactose absorption, 7,500 years ago.
Genetic selection => refinement of the cognitive architecture that stores and transmits cultural information (like reading) influencing culture.

- Demographic changes, the fall of birth rates in industrialized societies, are result of cultural changes.
- Genes affect cultural evolution via psychological predispositions on cultural learning. Genes encode much of the information needed to form the human brain.
- Cultural practice of raising cattle first for meat and later for milk led to selection for genetic traits for lactose digestion.
- Analysis of natural selection on the human genome suggests that civilization has accelerated genetic change in humans over the past 10,000 years.

Genes and taboo

Interaction between genes, environment and human culture may sometimes explain where taboos come from.

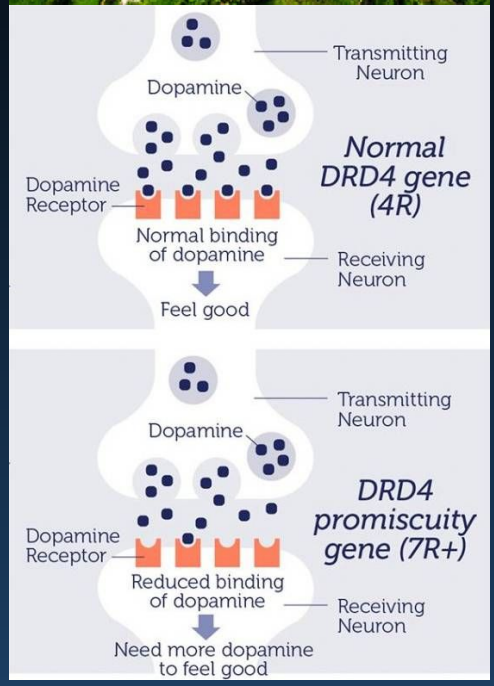
Why eating yam during the rainy season in West Africa is a religious taboo?

- In these areas malaria kills about 1.2 million people every year, spread by mosquitoes during the rainy season affecting ≈ 10% of the population.
- Sickle cell anemia is the most prevalent genetic disease in the world. It is a genetic disease of red blood cells (malaria-infected cells bend into a sickle shape).
- Genes encoding hemoglobin have several alleles (variants), creating hemoglobin types A, M, F, S and other variants. Hemoglobin S increases resistance to malaria.
- Mutation of the HBB gene leads to S-type hemoglobin. Occurring in a single chromosome gives mild symptoms of anemia, in both chromosomes leads to death.
- The yam is harvested at the beginning of the rainy season and eaten after the end. It contains a substance that blocks sickle cell anemia development.
- **Conclusion 1**: some taboos may be rational, increasing the chance of survival.
- **Conclusion 2**: information about genes and biology alone explains little, it is a question of balance, explanation is possible only in specific cultural context.
- In Southeast Asia and New Guinea different genes are involved; the distribution of mutation frequency is related to the chance of contracting malaria.

Genes and behavior

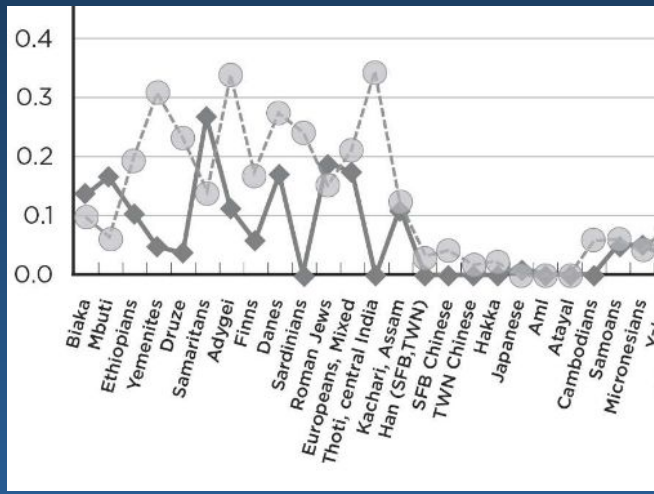
Study of links between ecology, food production, and culture show collectivist/individualist divisions in China, Bali, Turkey.

- Ecology ↔ living style ↔ food production ↔ culture ↔ genes.
- Rice was domesticated ≈ 10 000 years ago, requires massive communal work: transform the ecosystem: terraces, irrigation, harvesting, dividing up water fairly. In Bali it is regulated by priests in water temples. Irrigation system in Dujiuangyan (Western China) build 2000 years ago has > 5 000 km^2.
- In some parts of China farming is individual, people grow wheat. In standard tests those people are like Westerners. They also show high inventiveness—patent filings and higher rates of divorce.
- Dopamine D4 receptor is coded by extremely variable DRD4 gene. 25 human variants, controlling brain's reward system.



Most common: 4R variant, ½ of East Asians and Europeans. 7R variant, producing a receptor less responsive to dopamine in the cortex, associated with novelty seeking, extroversion, and impulsivity. It became much more common 10-20 000 years ago.

7R variant occurs in 20-30% of Europeans, and European Americans, but only in 1% of East Asians.



Discoveries and Traditions

More examples: Robert Sapolsky: Behave (Penguin Press, 2017, 800 pp.)

Example 2: in the 16th century Aztecs killed and ate about 300 people/year in religious ceremonies. Wars were the main means of obtaining victims.

It was a sophisticated culture, but undernourished, as animals could not be domesticated in the area (Diamond 2000).

Example 3: ancient discovery of El Niño. Farmers in the Andes determine the time of potato plantation during the ceremonial observation of the brightness of the stars in the Pleiades during June 15-25, when it is the winter solstice.
Weather predictions comes true more than 2/3 of the time.

The brightness of the stars depends on the presence at night at high altitude of cirrus, clouds that form more often when the warm El Niño current is stronger, causing drought a few months later, so you need to speed up planting!

Jane Goodall (1974) observed wars between herds of chimpanzees.
Perhaps poor diet (lack of phosphorus) is also the root cause here?

Not every taboo is rational. Cats may have infected many humans with toxoplasmosis, but superstitions about black cats are unlikely to have biological justification.

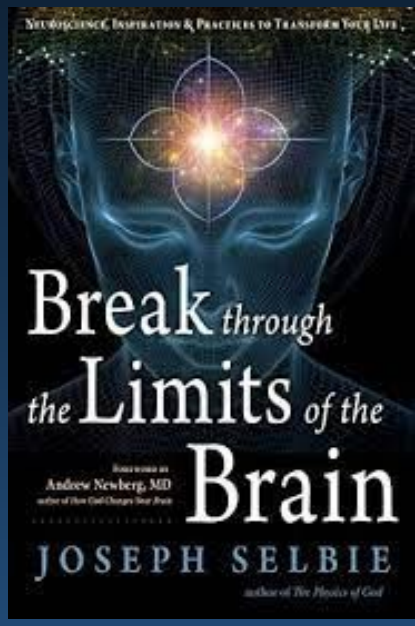
Koyaanisqatsi – Life out of balance. No time for rational taboos anymore.

Time for enhancement

Humans have limitations

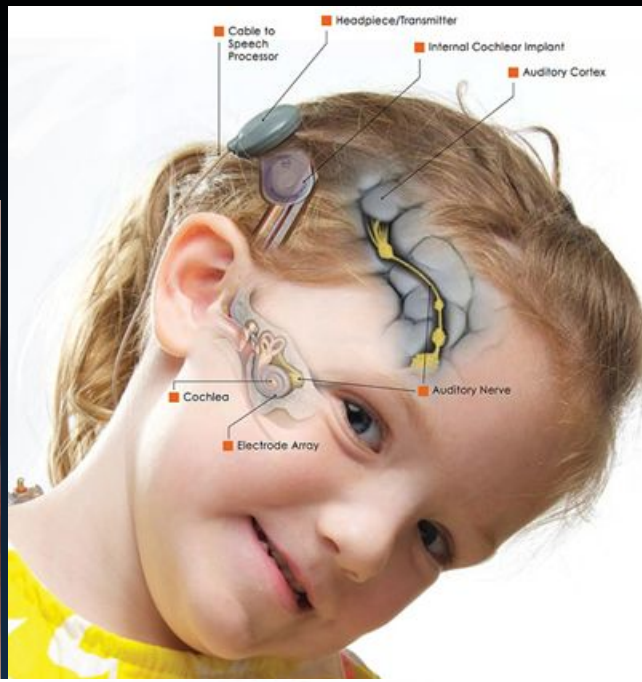
Humans have problems with emotional and cognitive functions:

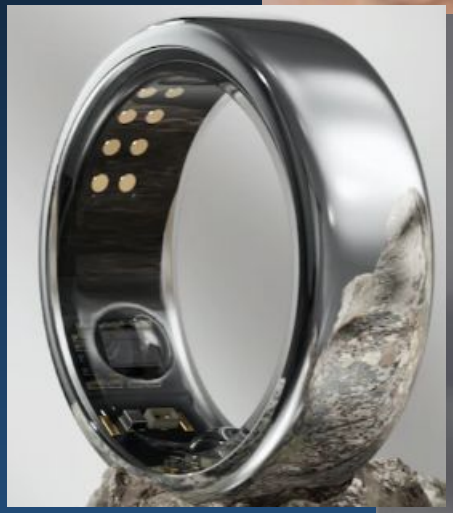
- Understanding their real needs, leading to happiness in a longer time.
- Separating emotional responses from rational conclusions.
- Wrong assumptions about the thoughts or intentions of others.
- Resisting addictions, immediate rewards.
- Forgetting and other memory problems.
- Handling complex problems/situations.
- Limitation of our senses.
- Making decisions based on limited available data.
- Holding multiple perspectives simultaneously.
- Use of educated guessing and verification to find new answers.
- Limited ability to predict future and construct what-if scenarios.

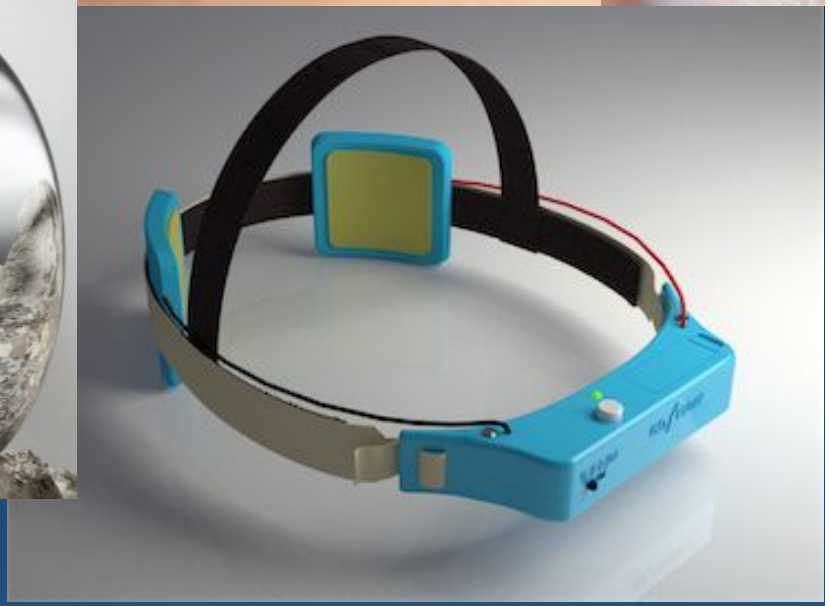


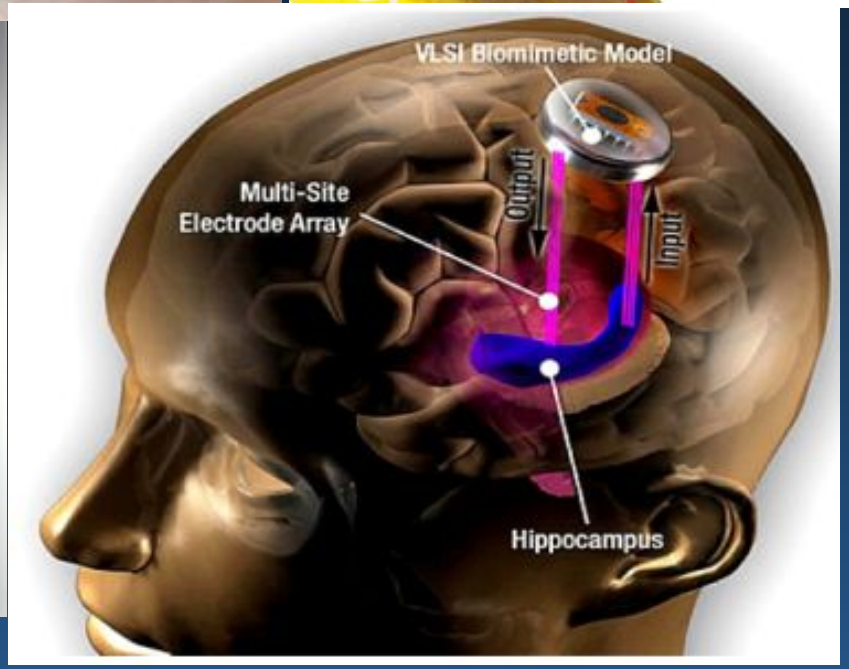
The good Lord has already done what He could, now its time to call experts.
We need to shape our minds/brains, empowering them to be more successful.

Augmentation









Improving our senses: sight, hearing, touch, memory, attention ...
Sens substitution and adding new senses (Eagleman, Livewired 2020).

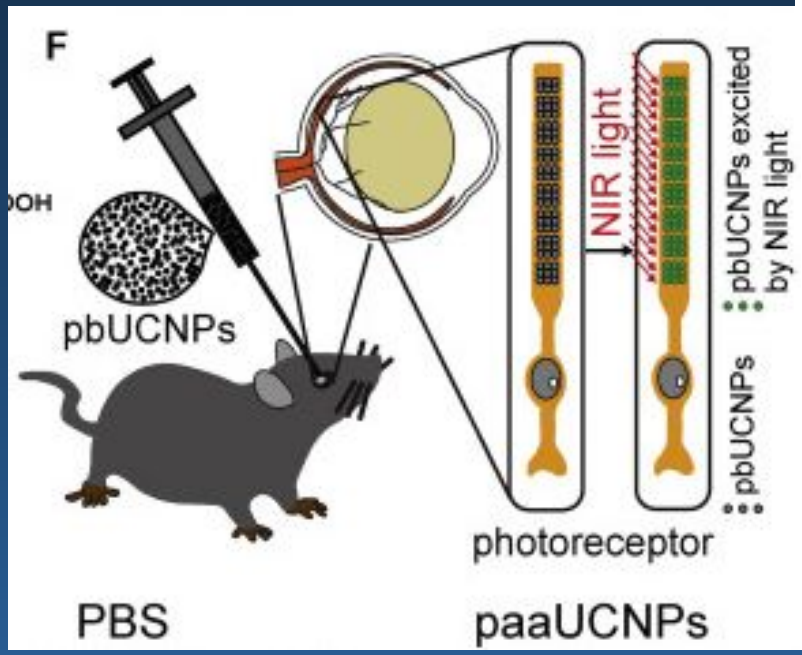
Cyborgs are coming …

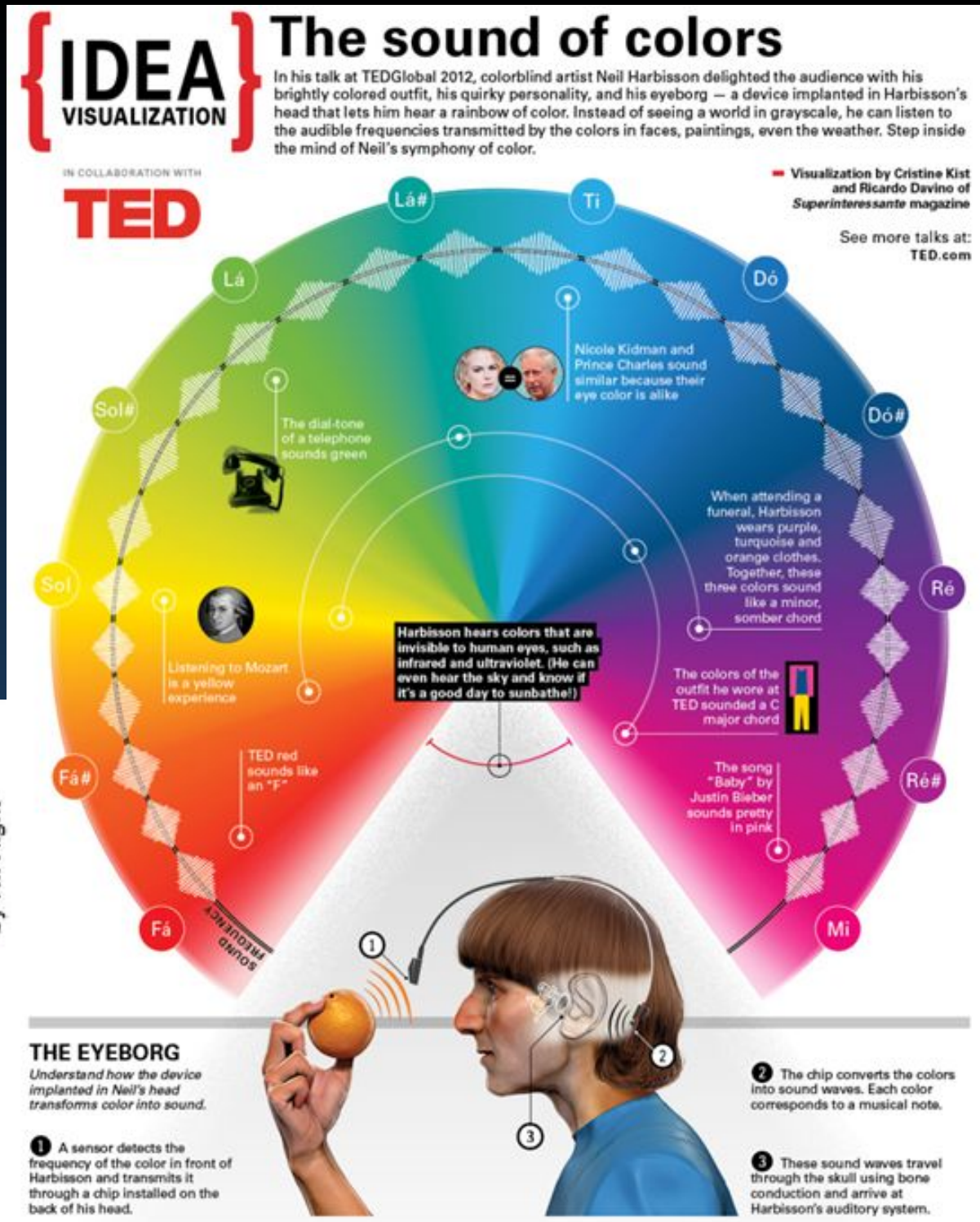
Jesse Sullivan, one of the first people with bionic prostheses.
Connected to nerves and controlled directly by motor cortex in the brain.

What more can we see?
Infrared and ultraviolet.
But not x-ray or gamma.

http://cyborgproject.com
https://www.cyborgarts.com

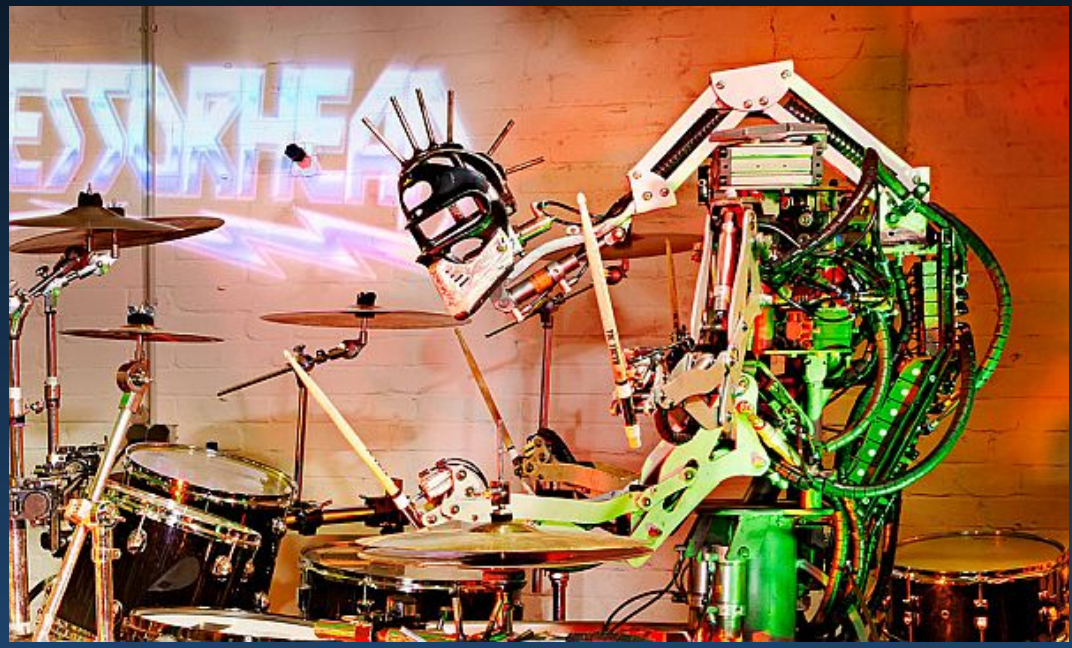
Nanoparticles in the eye will let you see in infrared! But retinal implants will do much more.





Can I learn to control more hands?

8 hands like octopus = perfect drum player?



Robots with 4 hands play around the world with the Compressorhead group .

Bdyhax

Bodyhacking, or modification of human bodies.

Cyborgization: prostheses, implanted biochips, cognitive enhancers, biometric tracers.

By 2025 this marked should be worth over 2.3 B$ per year

VR + EEG

VR

InteraXon

Looxid Labs

Neurable

VR + EEG, many possibilities to develop virtual subcultures.

Superhuman perception

Automatic analysis of facial features determines: gender, age, race, diseases, BMI.

Surprise! Also, **emotions, character traits, criminal tendencies, religious, political, and sexual preferences** can be read from faces with much greater accuracy than people are able to recognize.

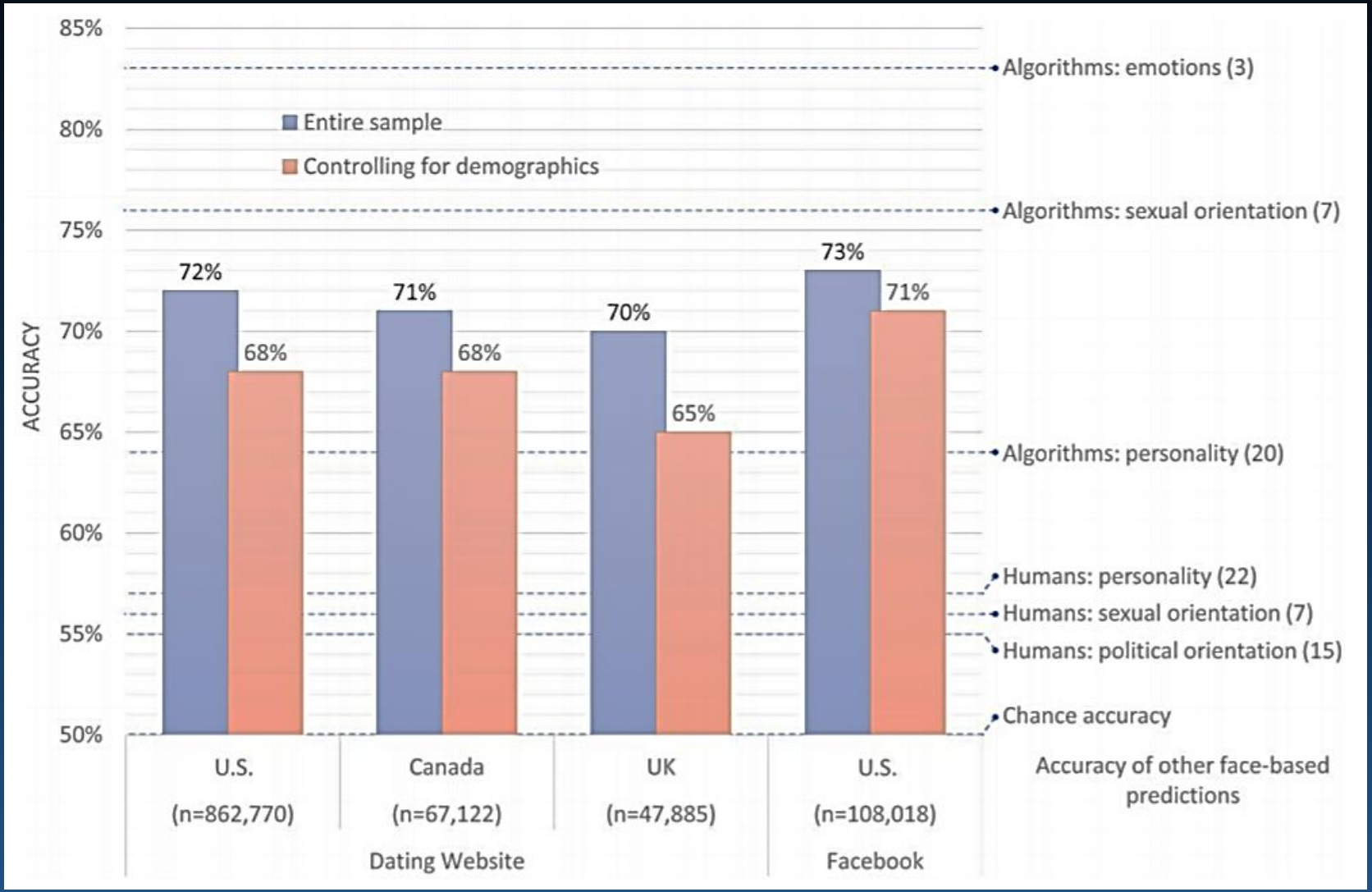
Sex: using 5 photos/person:
homo or hetero men 91% accuracy, women 83%. Humans: 35 people got only 61% and 54% correct.

(a) Three samples in criminal ID photo set S_c.

(b) Three samples in non-criminal ID photo set S_n

Analysis of over million photos allows to determine **liberal vs conservative** political preferences in 72% of cases. People - 55% correct (M. Kosiński, Sci. Rep. 2021).
Criminal tendencies: for 5,000 prisoners and the same number of control photos, CNN gave 97% accuracy (this work was withdrawn by ethics committee).

Preferences can be read from the face



How such real-time abilities will influence culture?

Control your dog ...

No More Woof (NMF) aims to be the first device to translate animal thoughts into English.

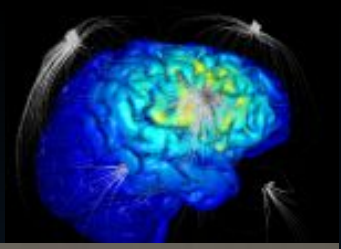
Restructure your brain!

Brain stimulation: DCS/TMS

Focus requires constant concentration. It is easier to achieve it by stimulating the brain with alternating current (tDCS), pulses of magnetic field (rTMS), or via Transcranial Electromagnetic Treatment (TEMT) using microwaves.

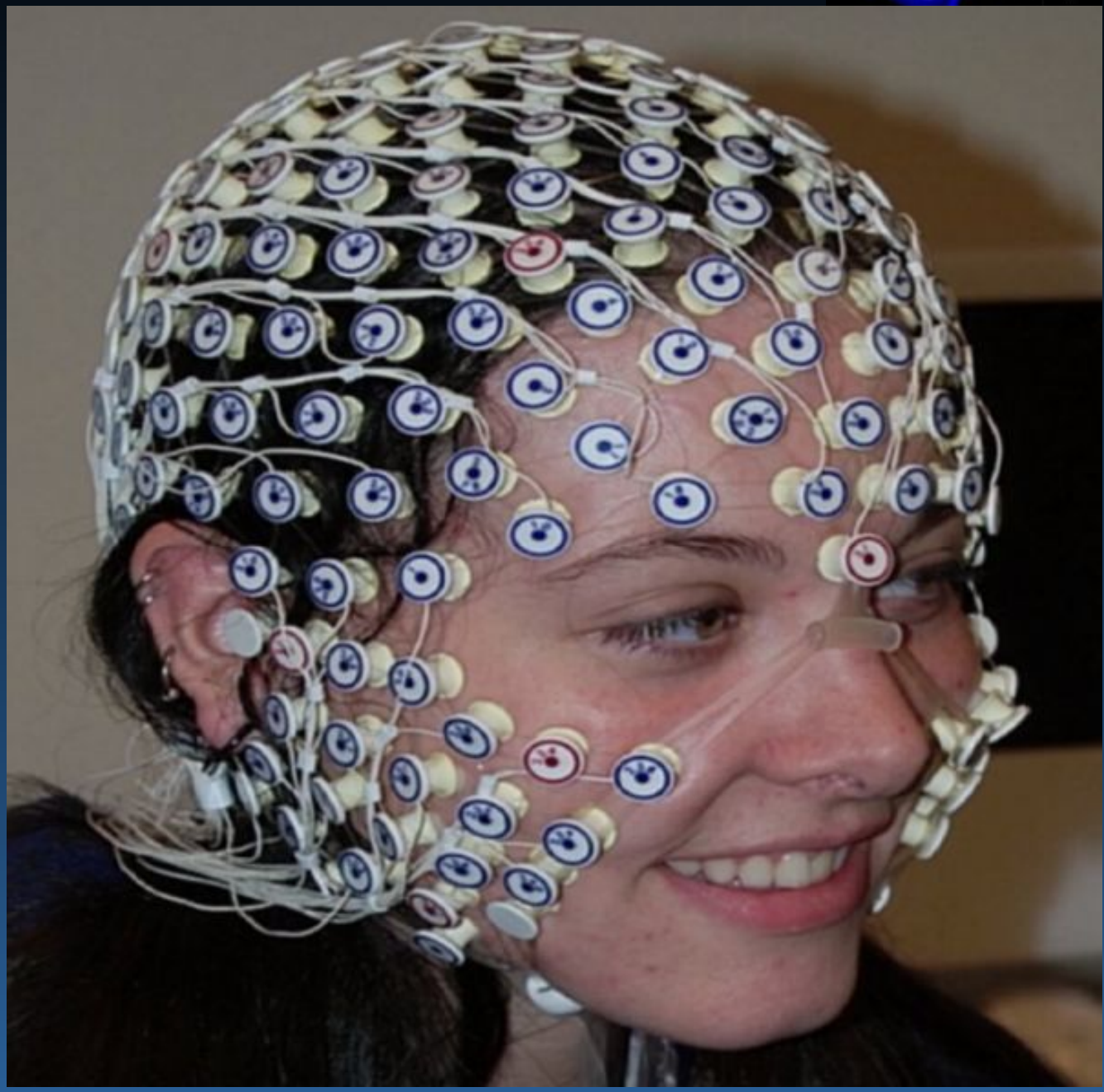
Used by arcade game geeks, pilots, as well as soldiers during marksmanship training. Thync energizes in the morning or before training and calms in the evening before bed: control your brain with your smartphone!

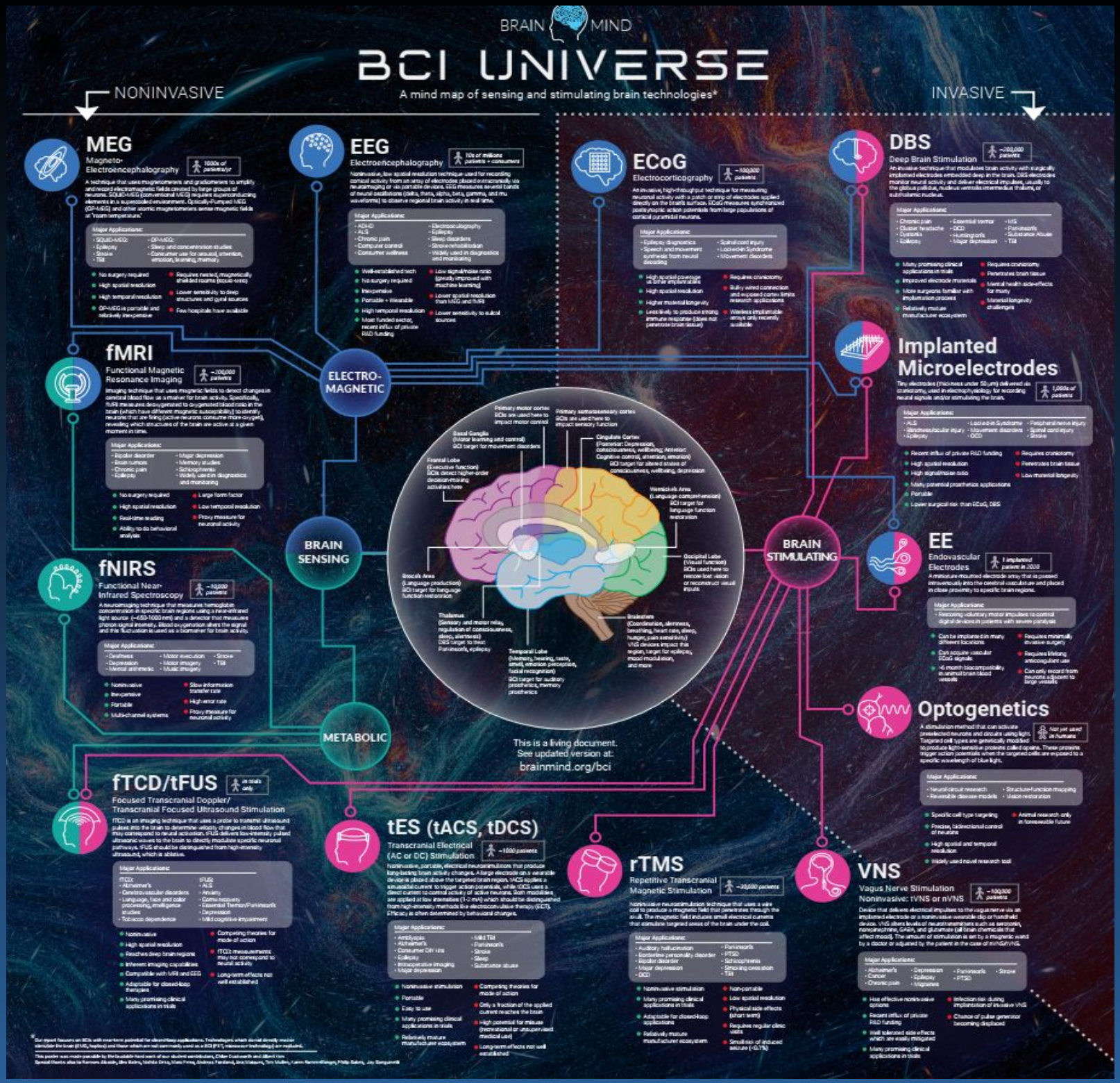
Resonance through HD DCS?



Reading brain states => transforming to common space => duplicating in other brains … Depression, neuro-plasticity, teaching!

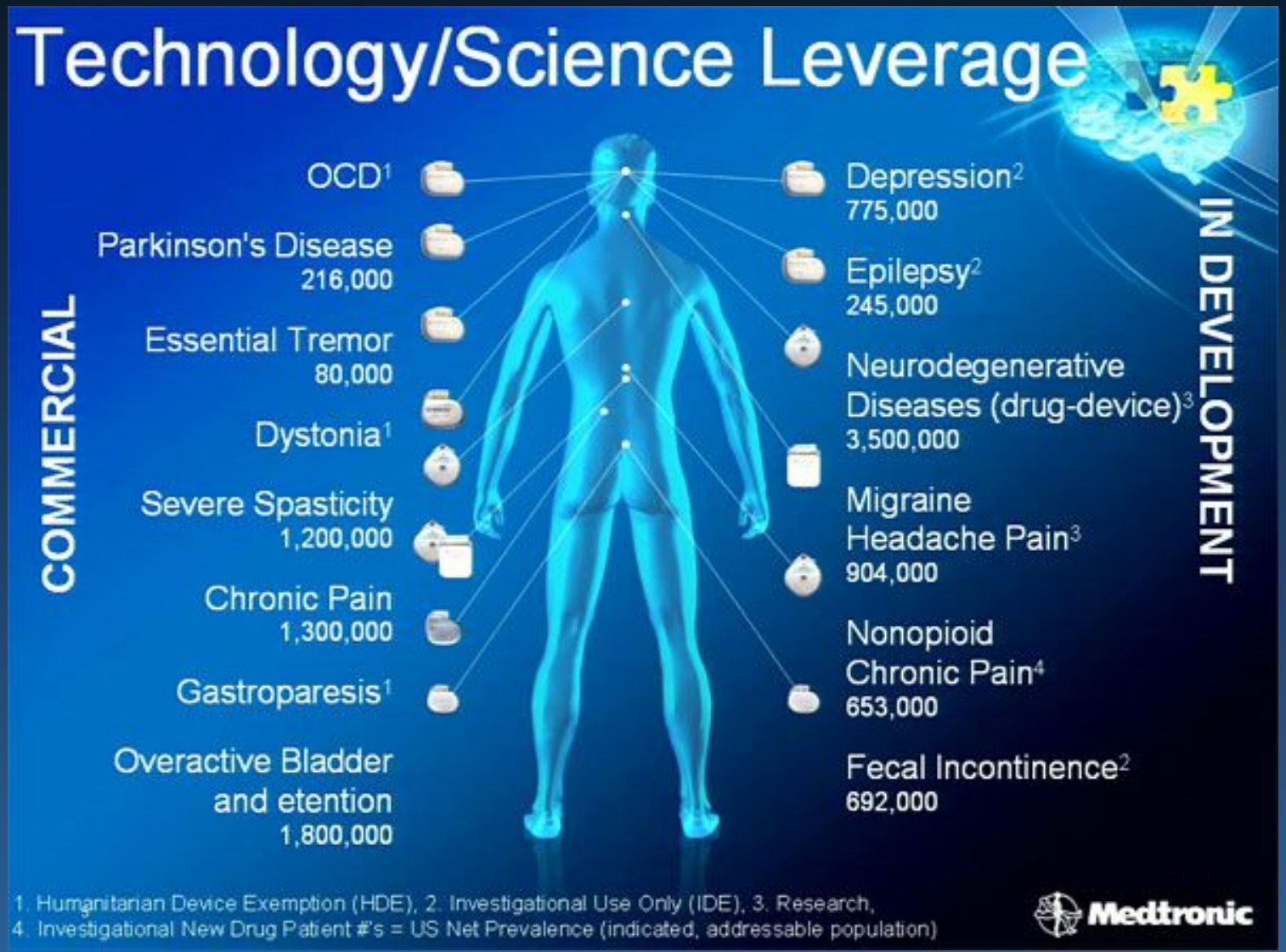
Multielectrode DCS stimulation with 256 electrodes induces changes in the brain increasing neuroplasticity.




BRAIN MIND
BCI UNIVERSE
A mind map of sensing and stimulating brain technologies*
NONINVASIVE
INVASIVE
MEG
Magneto-Electroencephalography
~1000s of patients/yr
Major Applications:
• SQUID-MEG: • Epilepsy • Stroke • TBI
• OP-MEG: • Sleep and concentration studies • Consumer use for arousal, attention, emotional scanning, memory
• No surgery required
• High spatial resolution
• High temporal resolution
• OP-MEG is portable and relatively inexpensive
• Requires heated, magnetically shielded rooms (liquid-state)
• Lower sensitivity to deep structures and gyral sources
• Few hospitals have available
EEG
Electroencephalography
10s of millions patients + consumers
Noninvasive, low spatial resolution technique used for recording cortical activity from an array of electrodes placed noninvasively via neuroimaging cap or via portable devices. EEG measures several bands of neural oscillations (delta, theta, alpha, beta, gamma, and mu waveforms) to observe regional brain activity in real time.
Major Applications:
• ADHD • ALS • Chronic pain • Computer control • Consumer wellness
• Electroencephalography • Epilepsy • Sleep disorders • Stroke rehabilitation • Widely used in diagnostics and monitoring
• Well-established tech
• No surgery required
• Inexpensive
• Portable + Wearable
• High temporal resolution
• Most funded sector, recent influx of private R&D funding
• Low signal/noise ratio (greatly improved with machine learning)
• Lower spatial resolution than MEG and fMRI
• Lower sensitivity to sulcal sources
ECoG
Electrocorticography
~100,000 patients
An invasive, high-throughput technique for measuring neuronal activity with a patch or strip of electrodes applied directly on the brain's surface. ECoG measures synchronized postsynaptic action potentials from large populations of cortical pyramidal neurons.
Major Applications:
• Epilepsy diagnostics • Speech and movement synthesis from neural decoding • Spinal cord injury • Locked-in Syndrome • Movement disorders
• High spatial coverage of brain implantable
• High spatial resolution
• Higher material longevity
• Less likely to produce strong immune response (does not penetrate brain tissue)
• Requires craniotomy
• Bulky wired connection and exposed cortex limits research applications
• Wireless implantable arrays only recently available
DBS
Deep Brain Stimulation
~200,000 patients
An invasive technique that modulates brain activity with surgically implanted electrodes embedded deep in the brain. DBS electrodes monitor neural activity and deliver electrical impulses, usually to the globus pallidus, nucleus ventralis intermedius thalami, or subthalamic nucleus.
Major Applications:
• Chronic pain • Cluster headache • Dystonia • Epilepsy • Essential tremor • OCD • Huntington's • Major depression • MS • Parkinson's • Substance Abuse • TBI
• Many promising clinical applications in trials
• Improved electrode materials
• More surgeons familiar with implantation process
• Relatively mature manufacturer ecosystem
• Requires craniotomy
• Penetrates brain tissue
• Mental health side-effects for many
• Material longevity challenges
fMRI
Functional Magnetic Resonance Imaging
~200,000 patients
Imaging technique that uses magnetic fields to detect changes in cerebral blood flow as a marker for brain activity. Specifically, fMRI measures deoxygenated to oxygenated blood ratio in the brain (which have different magnetic susceptibility) to identify neurons that are firing (active neurons consume more oxygen), revealing which structures of the brain are active at a given moment in time.
Major Applications:
• Bipolar disorder • Brain tumors • Chronic pain • Epilepsy • Major depression • Memory studies • Schizophrenia • Widely used in diagnostics and monitoring
• No surgery required
• High spatial resolution
• Real-time reading
• Ability to do behavioral analysis
• Large form factor
• Low temporal resolution
• Proxy measure for neuronal activity
ELECTRO-MAGNETIC
BRAIN SENSING
BRAIN STIMULATING
Implanted Microelectrodes
Tiny electrodes (thickness under 50 µm) delivered via craniotomy, used in electrophysiology for recording neural signals and/or stimulating the brain.
1,000s of patients
Major Applications:
• ALS • Blindness • Epilepsy • Locked-in Syndrome • Movement disorders • OCD • Peripheral nerve injury • Spinal cord injury • Stroke
• Recent influx of private R&D funding
• High spatial resolution
• High signal/noise ratio
• Many potential prosthetics applications
• Portable
• Lower surgical risk than ECoG, DBS
• Requires craniotomy
• Penetrates brain tissue
• Low material longevity
EE
Endovascular Electrodes
1 implanted patient in 2020
A miniature mounted electrode array that is passed intravenously into the cerebral vasculature and placed in close proximity to specific brain regions.
Major Applications:
• Restoring voluntary motor impulses to control digital devices in patients with severe paralysis
• Can be implanted in many different locations
• Can acquire vascular ECoG signals
• >6 month biocompatibility in animal brain blood vessels
• Requires minimally invasive surgery
• Requires lifelong anticoagulant use
• Can only record from neurons adjacent to large vessels
fNIRS
Functional Near-Infrared Spectroscopy
~10,000 patients
A neuroimaging technique that measures hemoglobin concentration at specific brain regions using a near-infrared light source (~650-1000 nm) and a detector that measures photon signal intensity. Blood oxygenation alters the signal, and this fluctuation is used as a biomarker for brain activity.
Major Applications:
• Deafness • Depression • Mental arithmetic • Motor execution • Motor imagery • Music imagery • Stroke • TBI
• Noninvasive
• Inexpensive
• Portable
• Multi-channel systems
• Slow information transfer rate
• High error rate
• Proxy measure for neuronal activity
METABOLIC
Optogenetics
A stimulation method that can activate preselected neurons and circuits using light. Targeted cell types are genetically modified to produce light-sensitive proteins called opsins. These proteins trigger action potentials when the targeted cells are exposed to a specific wavelength of blue light.
Not yet used in humans
Major Applications:
• Neurocircuit research • Reversible disease models • Structure-function mapping • Vision restoration
• Specific cell type targeting
• Precise, bidirectional control of neurons
• High spatial and temporal resolution
• Widely used novel research tool
• Animal research only in foreseeable future
fTCD/tFUS
Focused Transcranial Doppler/ Transcranial Focused Ultrasound Stimulation
In trials only
fTCD is an imaging technique that uses a probe to transmit ultrasound pulses into the brain to determine velocity changes in blood flow that may correspond to neural activation. tFUS delivers low-intensity pulsed ultrasonic waves to the brain to directly modulate specific neuronal pathways. tFUS should be distinguished from high-intensity ultrasound, which is ablative.
Major Applications:
fTCD: • Alzheimer's • Cerebrovascular disorders • Language, face and color processing, intelligence studies • Tobacco dependence
tFUS: • ALS • Anxiety • Coma recovery • Essential Tremor/Parkinson's • Depression • Mild cognitive impairment
• Noninvasive
• High spatial resolution
• Reaches deep brain regions
• Inherent imaging capabilities
• Compatible with fMRI and EEG
• Adaptable for closed-loop therapies
• Many promising clinical applications in trials
• Competing theories for mode of action
• fTCD: measurements may not correspond to neural activity
• Long-term effects not well established
tES (tACS, tDCS)
Transcranial Electrical (AC or DC) Stimulation
~1000 patients
Noninvasive, portable, electrical neurostimulators that produce long-lasting brain activity changes. A large electrode on a wearable device is placed above the targeted brain region. tACS applies a sinusoidal current to trigger action potentials, while tDCS uses a direct current to control activity of active neurons. Both modalities are applied at low intensities (1-2 mA) which should be distinguished from high-intensity methods like electroconvulsive therapy (ECT). Efficacy is often determined by behavioral changes.
Major Applications:
• Amblyopia • Alzheimer's • Consumer DIY kits • Epilepsy • Intraoperative imaging • Major depression • Mild TBI • Parkinson's • Stroke • Sleep • Substance abuse
• Noninvasive stimulation
• Portable
• Easy to use
• Many promising clinical applications in trials
• Relatively mature manufacturer ecosystem
• Competing theories for mode of action
• Only a fraction of the applied current reaches the brain
• High potential for misuse (recreational or unsupervised medical use)
• Long-term effects not well established
rTMS
Repetitive Transcranial Magnetic Stimulation
~30,000 patients
Noninvasive neurostimulation technique that uses a wire coil to produce a magnetic field that penetrates through the skull. The magnetic field induces small electrical currents that stimulate targeted areas of the brain under the coil.
Major Applications:
• Auditory hallucinations • Borderline personality disorder • Bipolar disorder • Major depression • OCD • Parkinson's • PTSD • Schizophrenia • Smoking cessation • TBI
• Noninvasive stimulation
• Many promising clinical applications in trials
• Adaptable for closed-loop applications
• Relatively mature manufacturer ecosystem
• Non-portable
• Low spatial resolution
• Physical side effects (short term)
• Requires regular clinic visits
• Small risk of induced seizure (~0.1%)
VNS
Vagus Nerve Stimulation
Noninvasive: tVNS or nVNS
~100,000 patients
Device that delivers electrical impulses to the vagus nerve via an implanted electrode or a noninvasive wearable clip or handheld device. VNS alters levels of neurotransmitters such as serotonin, norepinephrine, GABA, and glutamate (all brain chemicals that affect mood). The amount of stimulation is set by a magnetic wand by a doctor or adjusted by the patient in the case of nVNS/tVNS.
Major Applications:
• Alzheimer's • Cancer • Chronic pain • Depression • Epilepsy • Migraines • Parkinson's • PTSD • Stroke
• Has effective noninvasive options
• Recent influx of private R&D funding
• Well tolerated side effects which are easily mitigated
• Many promising clinical applications in trials
• Infection risk during implantation of invasive VNS
• Chance of pulse generator becoming displaced
Primary motor cortex: BCIs are used here to impact motor control
Primary somatosensory cortex: BCIs are used here to impact sensory function
Basal Ganglia (Motor learning and control): BCI target for movement disorders
Cingulate Cortex (Posterior: Depression, consciousness, wellbeing; Anterior: Cognitive control, attention, emotion): BCI target for altered states of consciousness, wellbeing, depression
Frontal Lobe (Executive function): BCIs detect higher-order decision-making activities here
Wernicke's Area (Language comprehension): BCI target for language function restoration
Occipital Lobe (Visual function): BCIs used here to restore lost vision or reconstruct visual inputs
Broca's Area (Language production): BCI target for language function restoration
Thalamus (Sensory and motor relay, regulation of consciousness, sleep, alertness): DBS target to treat Parkinson's, epilepsy
Brainstem (Coordination, alertness, breathing, heart rate, sleep, hunger, pain sensitivity): VNS devices impact this region, target for epilepsy, mood modulation, and more
Temporal Lobe (Memory, hearing, taste, smell, emotion perception, facial recognition): BCI target for auditory prosthetics, memory prosthetics
This is a living document. See updated version at: brainmind.org/bci

Neuromodulation

Cochlear implants are common, but deeper implants that stimulate or even replace some brain structures start to appear, not only for deficits at the level of perception, but to regulate cortical neural processes. Market 10B$ (2021), 25B$ in 2027.



Mobile deep brain recording and stimulation platform in 4-kg backpack.

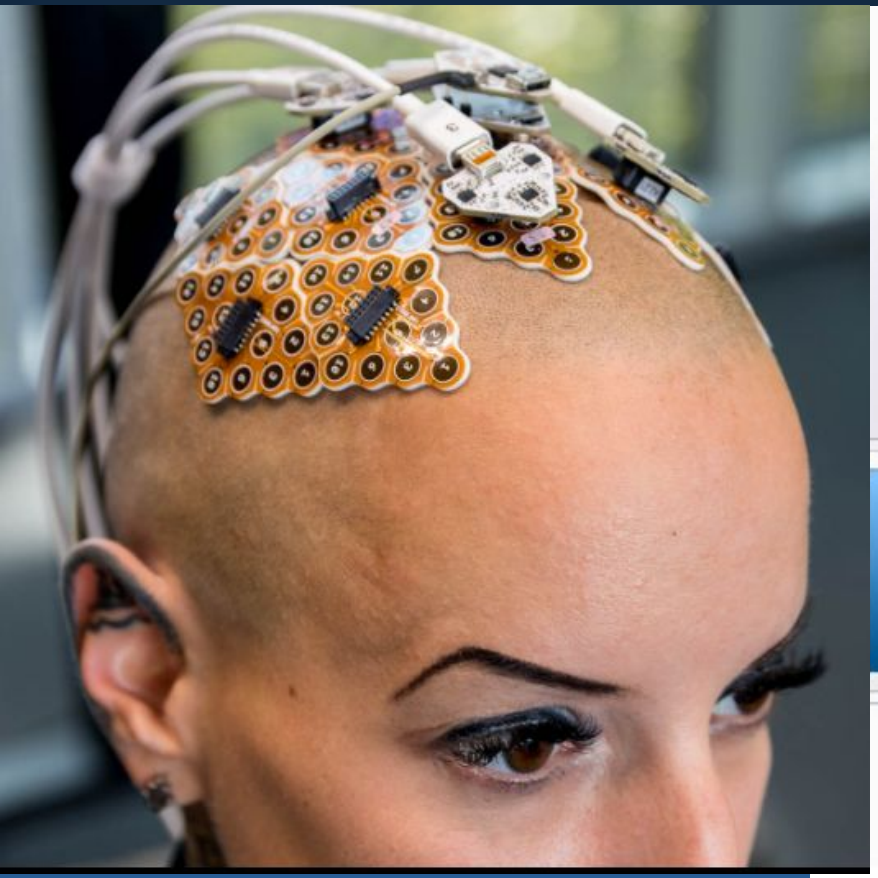
Real-time data collection from deep brain implant,
using EEG cap and various heart and breathing sensors plus intracranial EEG and direct cortex stimulation.

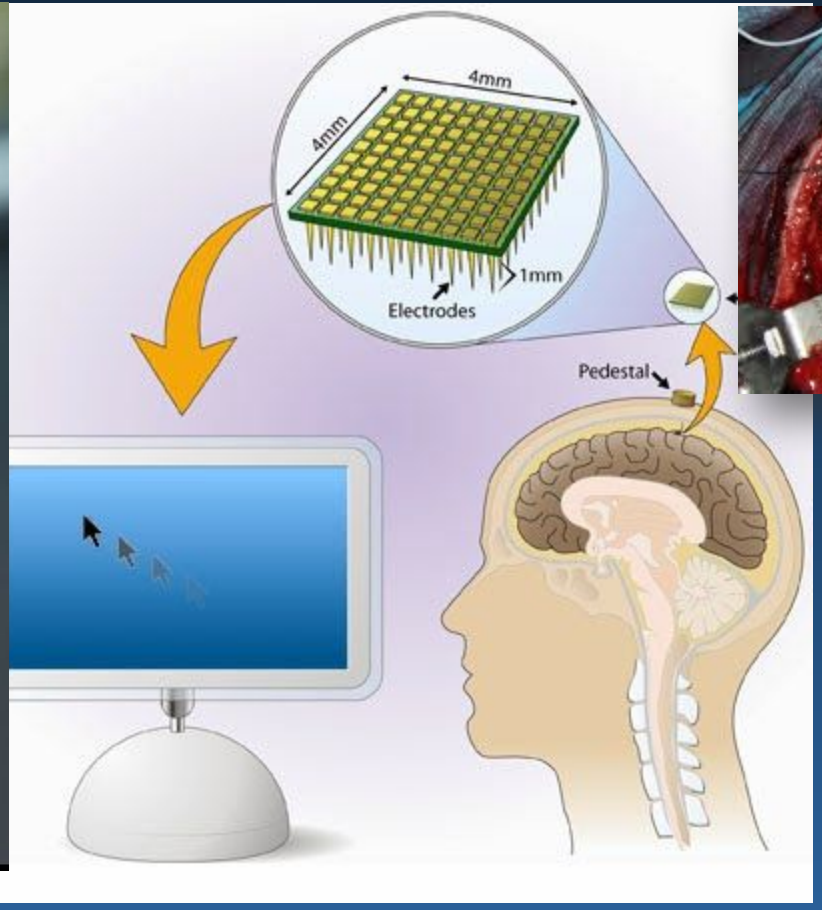
U. Topalovic, et al. 2020.
Wireless Programmable Recording and Stimulation of Deep Brain Activity in Freely Moving Humans.
Neuron 17/09/2020.

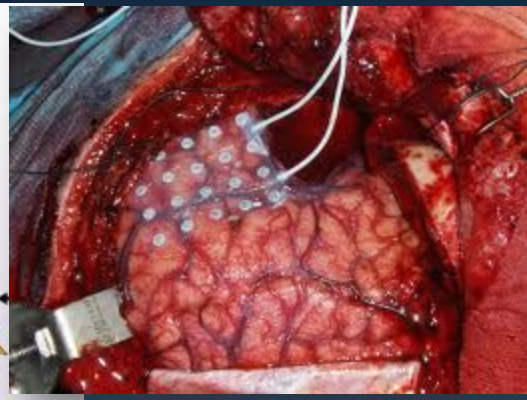
Brain access ...

Just give us access to your cortex, open your skulls, please.
BrainGate Turning Thought into Action chip will help (4x4 mm, 100 sensors).
G-Tec Pangolin up to 1024 channels!

Then you may learn what your brain has already discovered but it has not yet become conscious, and you may control your own behavior using remote pilot …



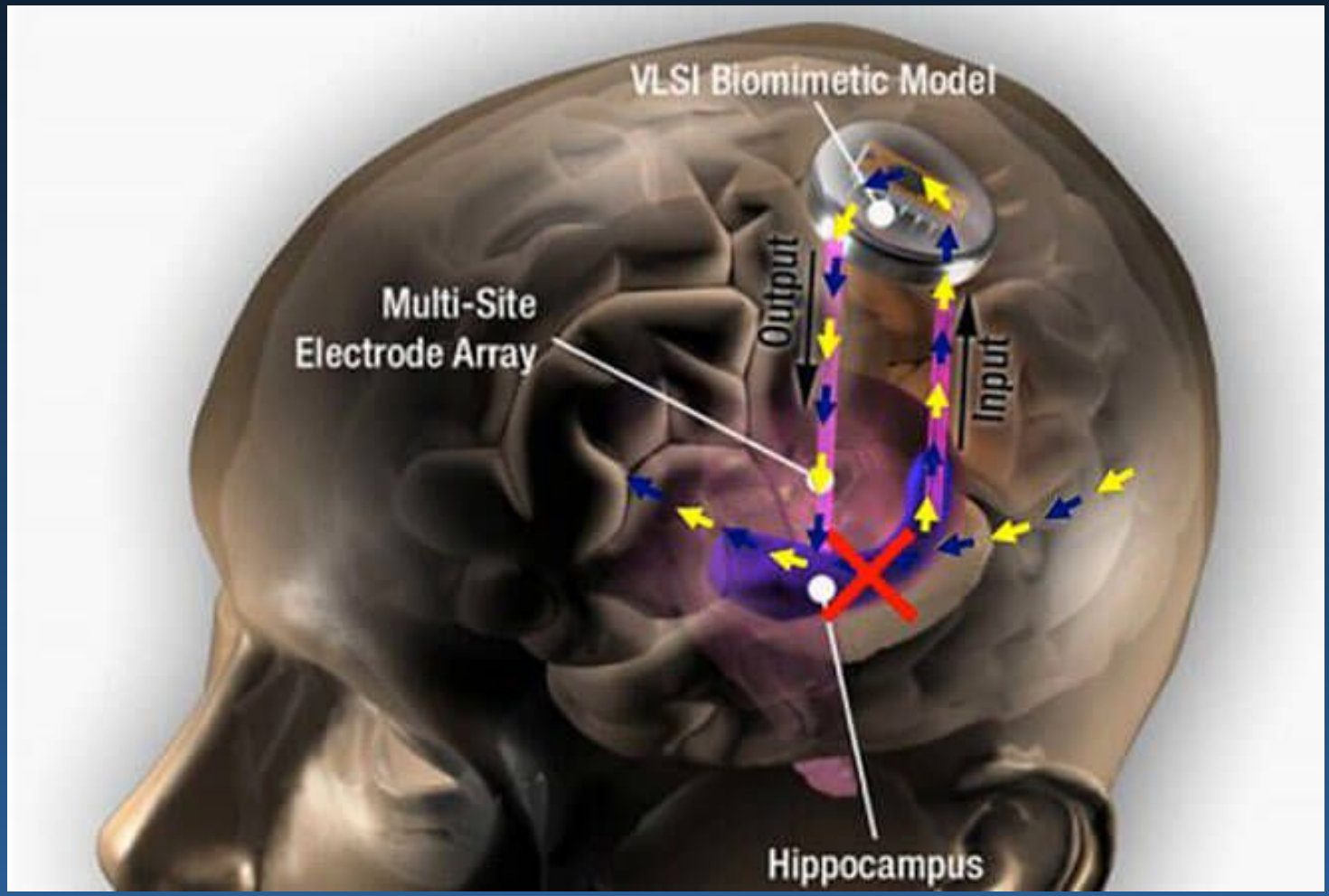




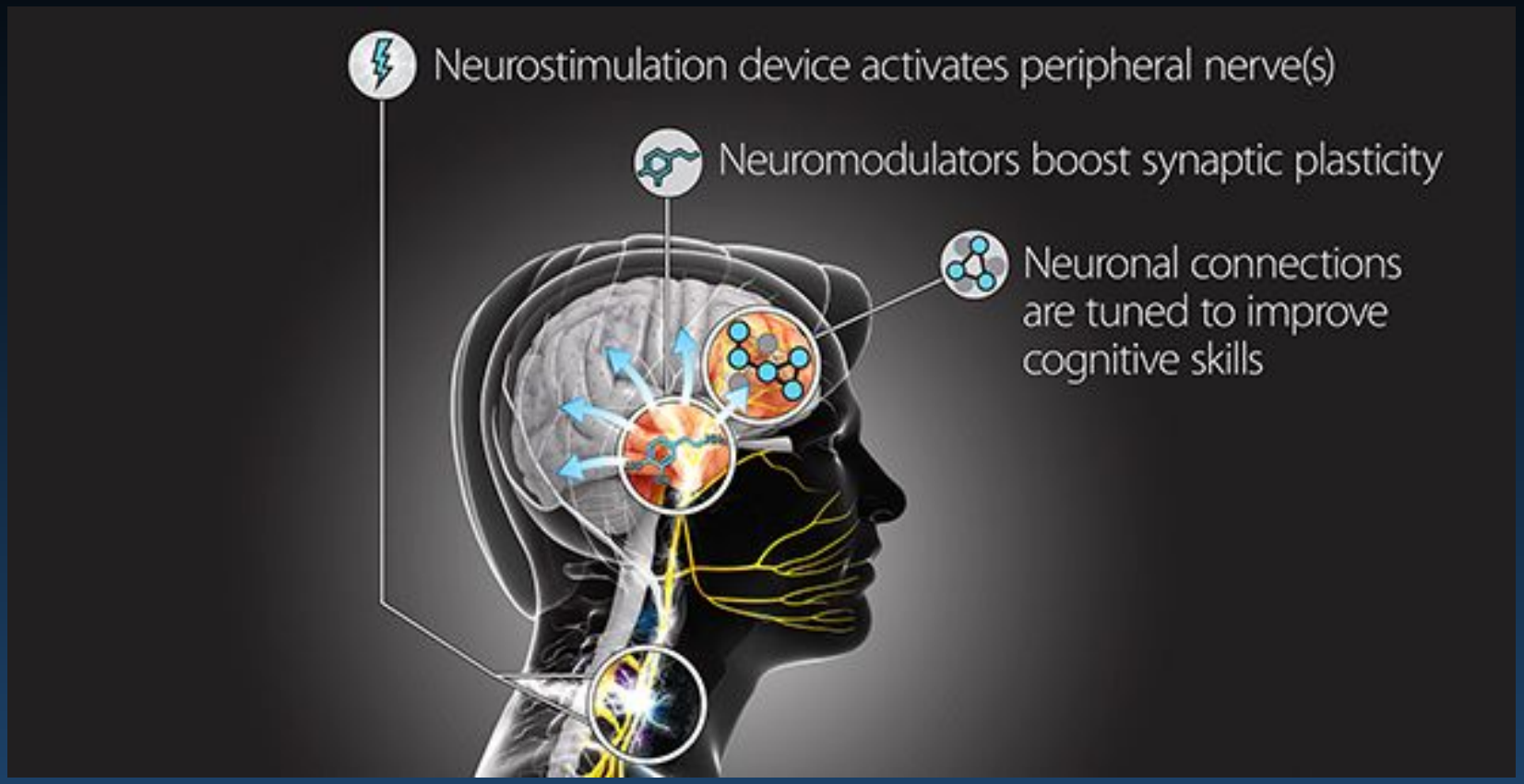
Memory implants

Ted Berger (USC, Kernel): hippocampal neural prosthetics facilitate human memory encoding and recall using the patient's own hippocampal spatiotemporal neural codes. Tests on rats, monkeys and on people gave memory improvements on about 35% (J. Neural Engineering 15, 2018).

DARPA: Restoring Active Memory (RAM), new closed-loop, non-invasive systems that leverage the role of neural “replay” in the formation and recall of memory to help individuals better remember specific episodic events and learned skills.



Targeted Neuroplasticity Training



DARPA (2017) Programs: **TNT to** enhance learning of cognitive skills, tuning neurons reduce cost and duration of the Defense Department's extensive training regimen, while improving outcomes, accelerate learning time needed to train foreign language specialists, intelligence analysts, cryptographers etc.

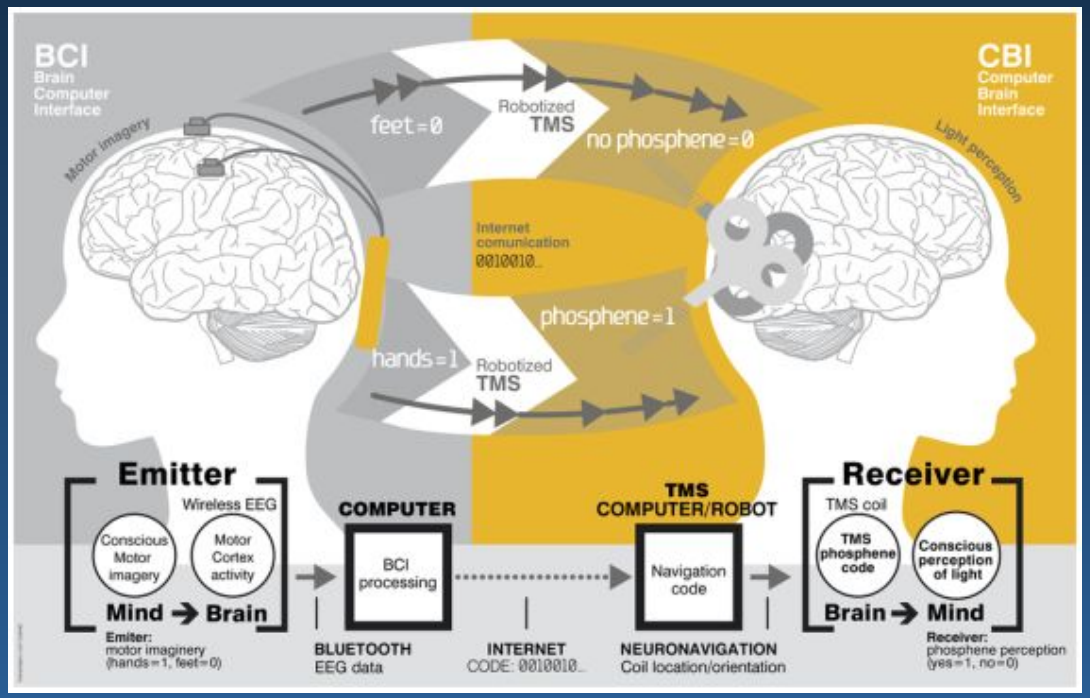
Restoring Active Memory (RAM) program is aimed at neurotechnologies to facilitate memory formation/recall in the injured brain.

Direct brain modulation

Sony has patent for direct streaming of multimedia to the brain.

Method and system for generating sensory data onto the human neural cortex. US Patent 6536440 B1

It should enable “sensory experiences” by firing “pulses of ultrasound at the head to modify firing patterns in targeted parts of the brain.”
This would allow the device to trigger various senses, including taste and sound, and even allow the deaf to hear again.
Will it facilitate Brain-to-Brain Communication?

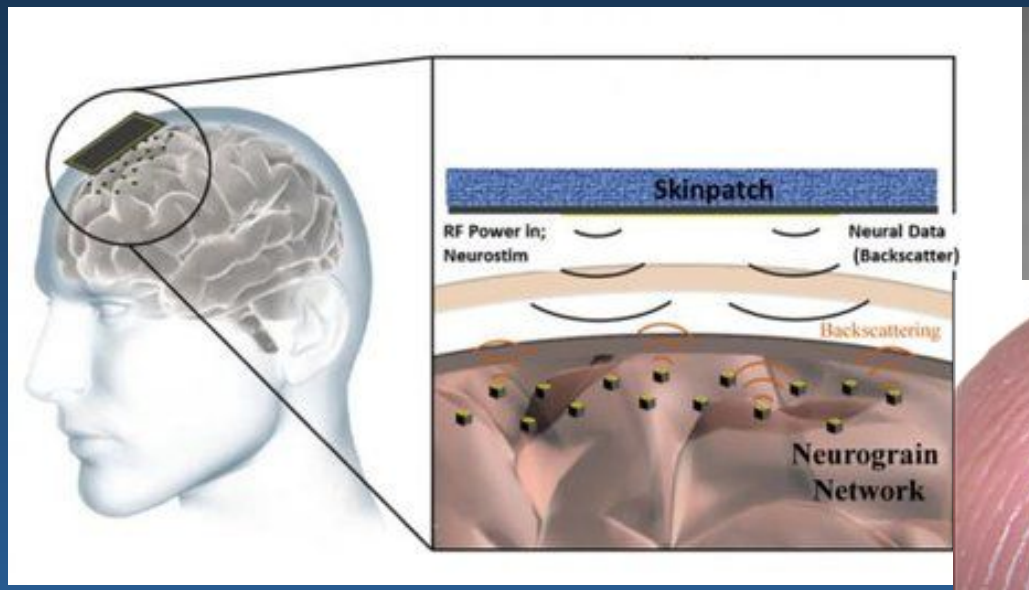


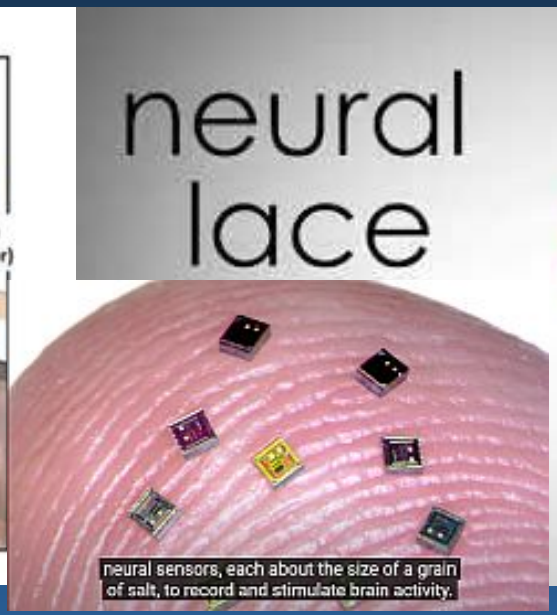
Million nanowires in your brain?

DARPA (2016): **Neural Engineering System Design (NESD)**
Interface that reads impulses of 10^6 neurons, injecting currents to 10^5 neurons, and reading/activating 10^3 neurons.

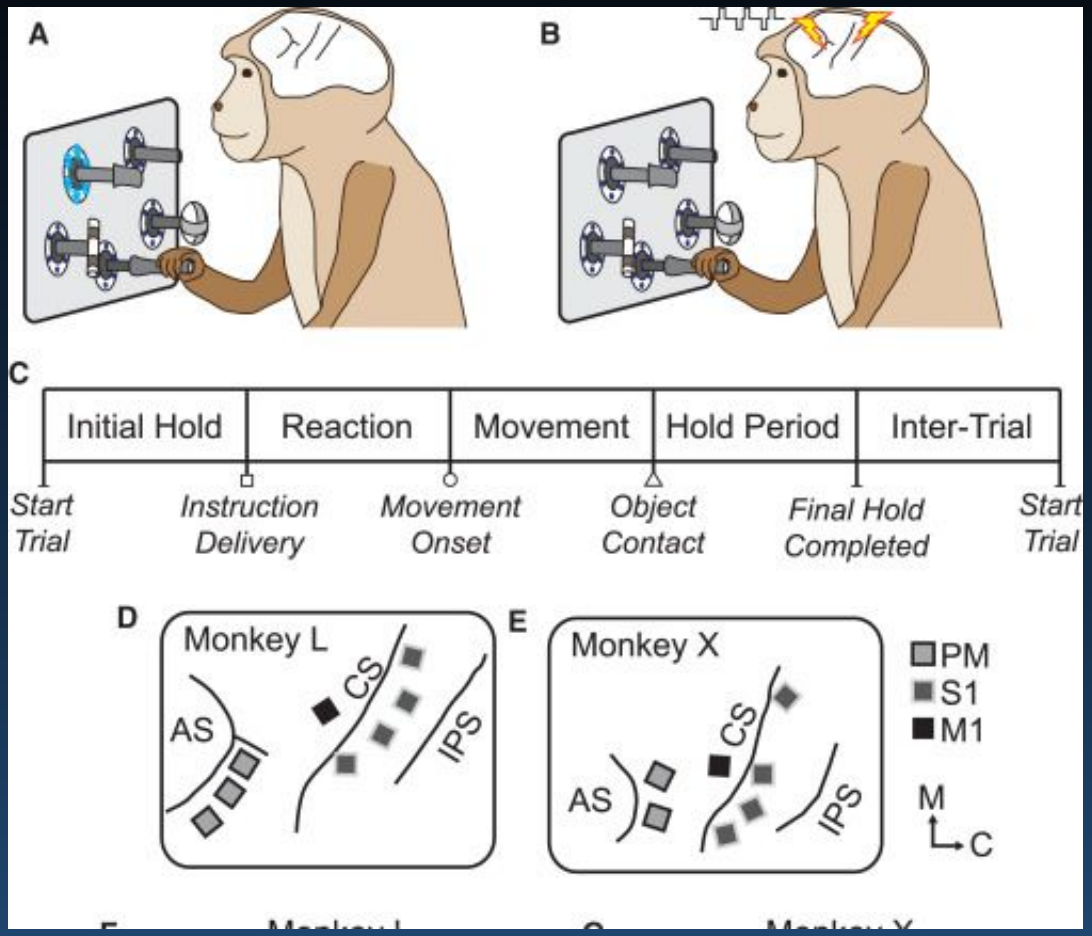
DARPA Electrical Prescriptions (ElectRx) project enables "artificial modulation of peripheral nerves to restore healthy patterns of signaling in these neural circuits. ElectRx devices and therapeutic systems under development are entering into clinical studies."

Elon Musk Neuralink project for cortex stimulation – control your brain!
Neural dust, neurograins – microscopic wireless sensors implanted in the brain.





Microstimulations

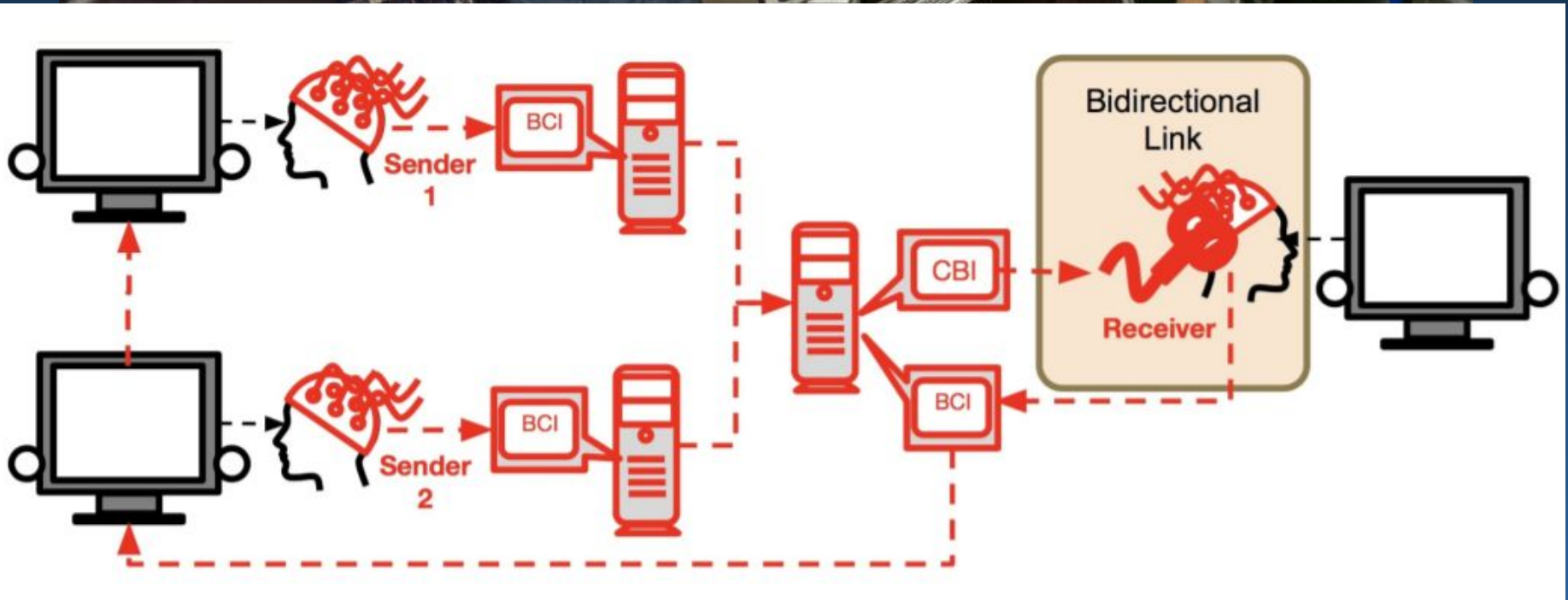


The association of different movements and the location of stimulation in the PM cortex can be learned. Action instructions can also be "injected" directly into the premotor cortex with electrical impulses so weak that they are not felt.

New skills can be learned without any training!

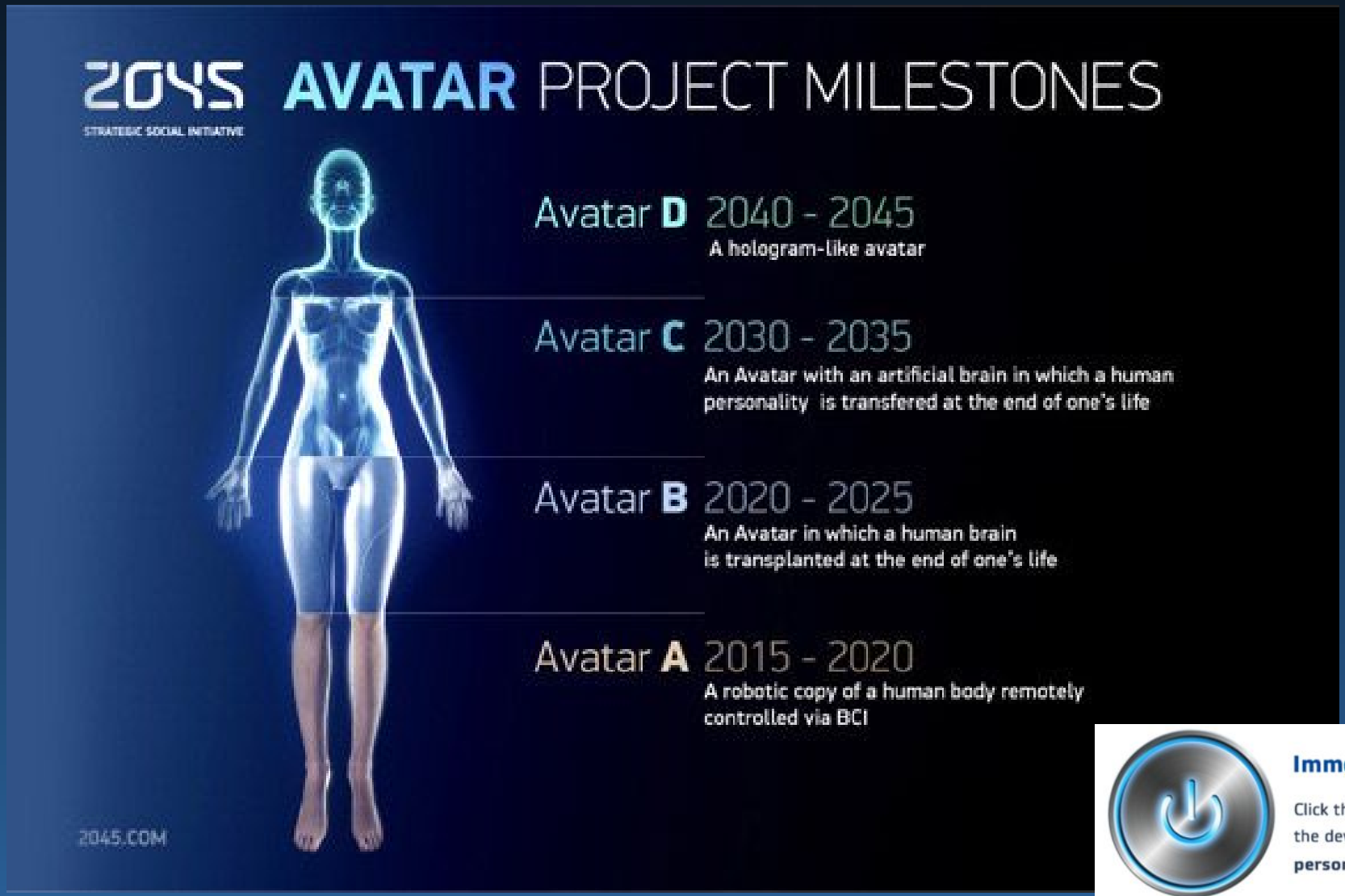
Thought transfer?

Reading brain states => transforming => recreating in another brain.

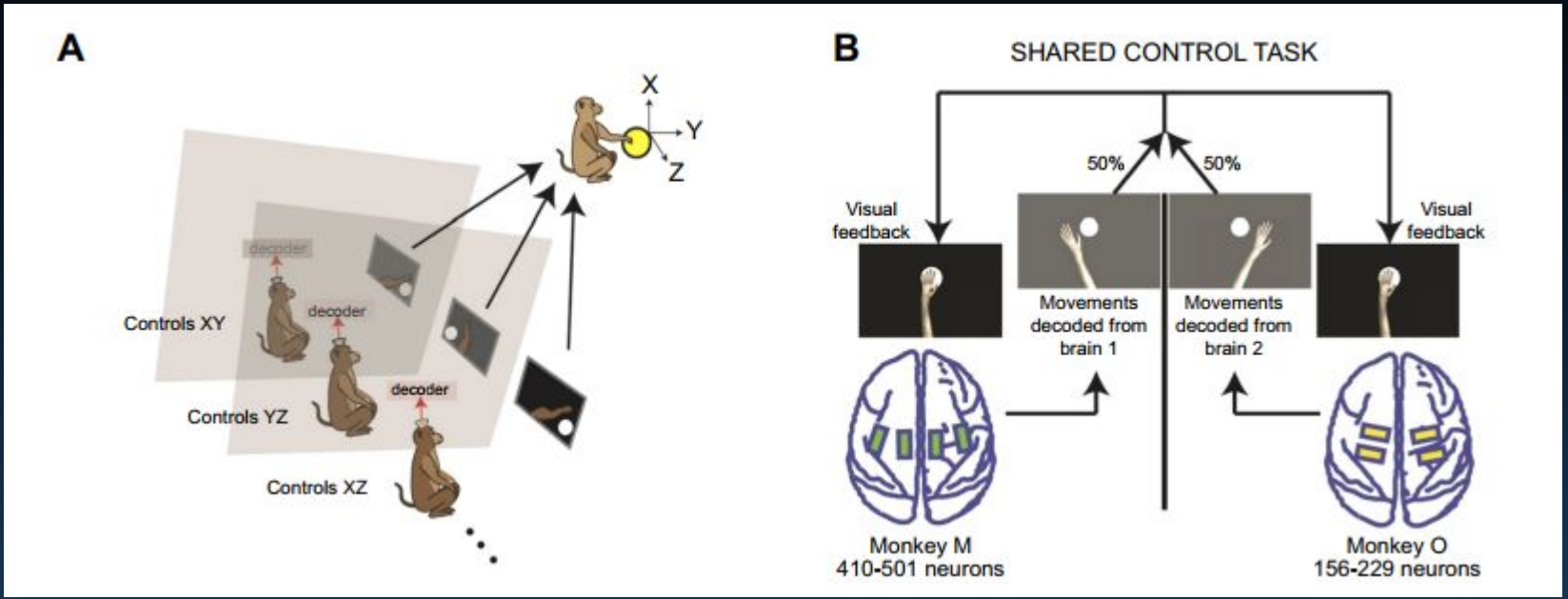


Transfer your mind to avatar

Projekt 2045 D. Itskov (Russian billionaire). He believes that by 2045 minds can be transferred from brains to neurocomputers and some people will become immortal. *The Electronic Immortality Corporation* is a kind of social network.



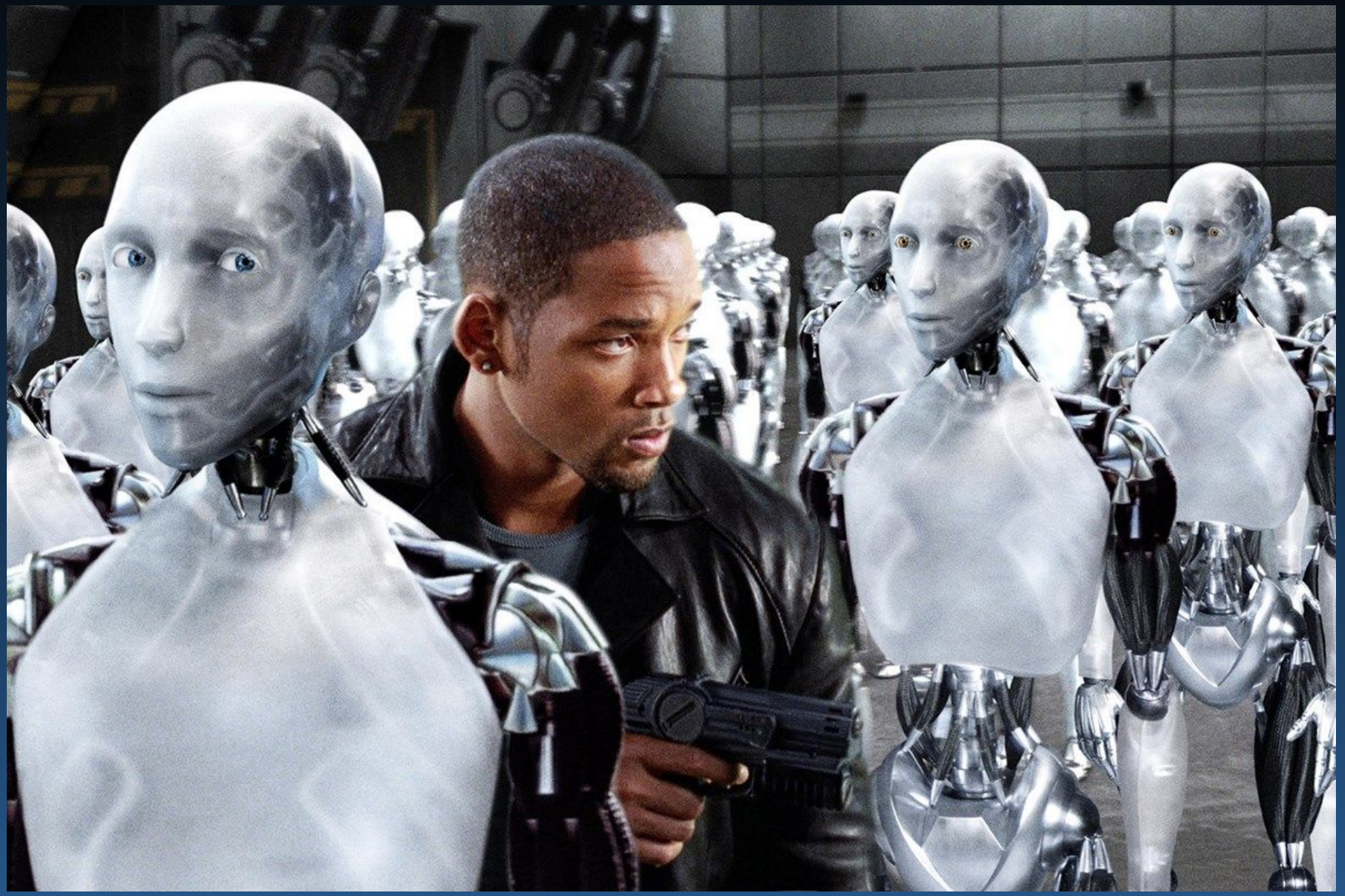
Brainnets and cBCI



3 monkeys in virtual reality synchronize their brain activity!
Lebedev, M. A., & Nicolelis, M.A.L. (2017). Brain-Machine Interfaces: From Basic Science to Neuroprostheses and Neurorehabilitation. *Physiological Reviews*, *97*(2), 767–837

Bhattacharyya, S., Valeriani, D., Cinel, C., Citi, L., & Poli, R. (2021). Anytime collaborative brain–computer interfaces for enhancing perceptual group decision-making. *Scientific Reports*, *11*(1), Article 1.

Neuromorfic robots

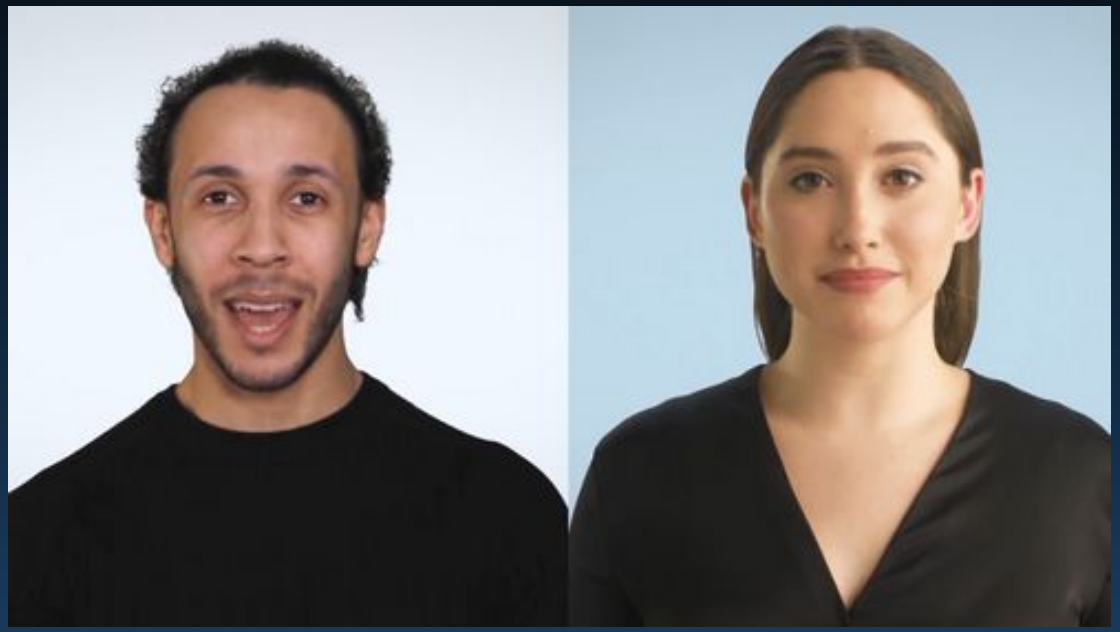


Bina48 and the LifeNaut project

Reconstructing the mind from information in mindfiles, creating mindclones: our alter-ego will be a self-aware digital being, with our memories and personality.

Conscious avatars?

Hal talks to Sophia about consciousness, using GPT-3 system.



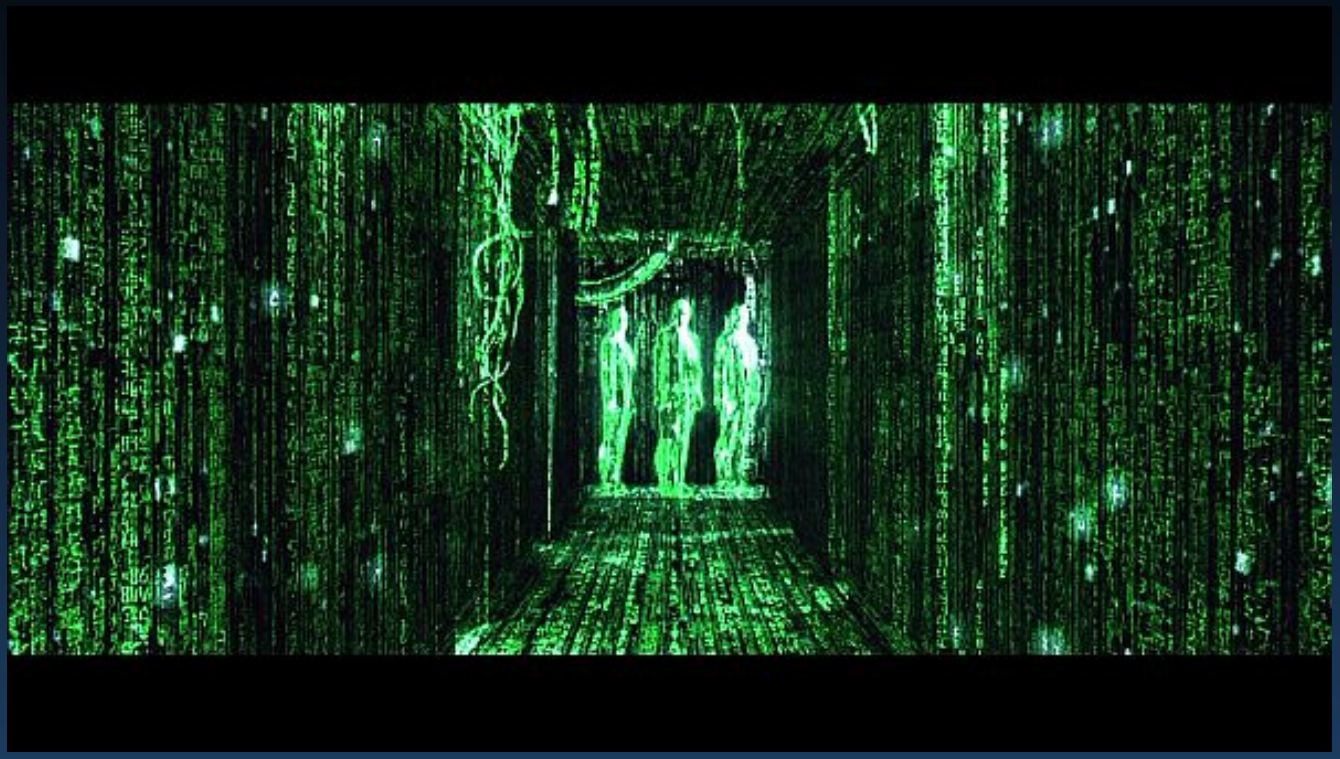
Avatars understand to some extent the meaning of questions – such language models allow for answering questions better than most humans.

Mental images are recalled in neural networks, providing a model of the world and imagery, so such system generate narrative description of "a perception of what appears in its mind" (J. Locke definition of consciousness, 330 years ago).

Essentially this is the processes of generating consciousness in our brains.

Świat bytów wirtualnych – my lectures on avatars (in Polish), 2005.

Matrix

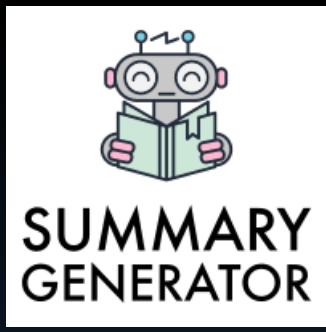


Are we going in the direction of a Metaverse that will change into Matrix?

From technical point of view it may be possible in not too distant future.

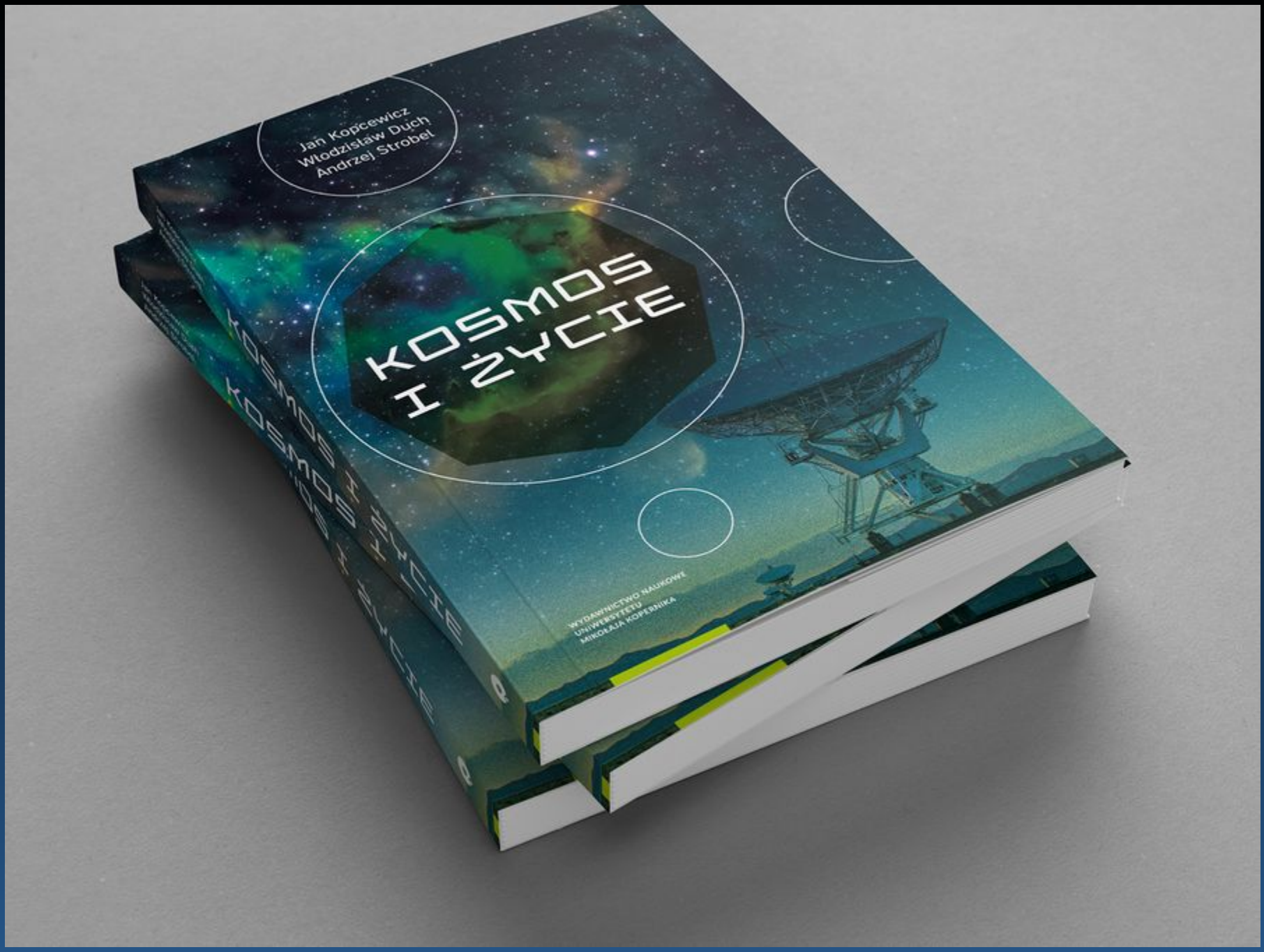
Robots won't become humans, but
what significant work will remain for humans to do?

Summary



- Culture is formed thanks to the neuroplasticity of our brains.
- Connectomes, unique brain connections, form as a result of experience.
- Education plays the key role in creating structure of our conceptual space.
- Neuroplasticity is a curse (conspiracy theories) and a blessing (learning/creativity).
- BMI has now hundreds of applications, from medical to entertainment.
- After a long time interaction of genes and environment leads may re-shape culture.
- Virtual reality + monitoring of brain activity will lead to superhuman perception.
- Cyborgization will augment human cognition, senses and the whole body.
- Neurocognitive technologies will profoundly change our selves.
  The integration of brains with AI becomes feasible.
- Synchronization of brains? Metaverse? Still primitive, but …

  What seems impossible today tomorrow will be common.
  The singularity may come faster than we think!



https://wydawnictwo.umk.pl/pl/products/5652/kosmos-i-zycie

In search of the sources of brain's cognitive activity

Project „Symfonia 4”, 2016-22

FACULTY OF PHYSICS, ASTRONOMY AND INFORMATICS

CENTRE FOR MODERN INTERDISCIPLINARY TECHNOLOGIES

INSTITUTE OF PHYSIOLOGY AND PATHOLOGY OF HEARING

nencki institute of experimental biology

1. PLACE WINNER

"NeuroBeat"

BCI application

Team members: Alicja Wicher, Joanna Maria Zalewska, Weronika Sójka, Ivo John Krystian Derezinski, Krzystof Tołpa, Lukasz Furman, Slawomir Duda

IMPROVING HUMAN DAILY LIFE FUNCTIONING

NEUROHACKATOR 2021

21. - 23. MAY 2021 // ONLINE

FRIDAY
Organisers presentation

workshops with Judges

SATURDAY
Project development in groups

STARTS 10 a.m.

SUNDAY
Evaluation

ENDS 10 a.m.

working 24h

REQUIREMENTS:

1. Create a team consisting of **3-5 people**.
2. Fill in the Registration Form (available on Facebook event).

DO YOU HAVE ANY QUESTIONS?

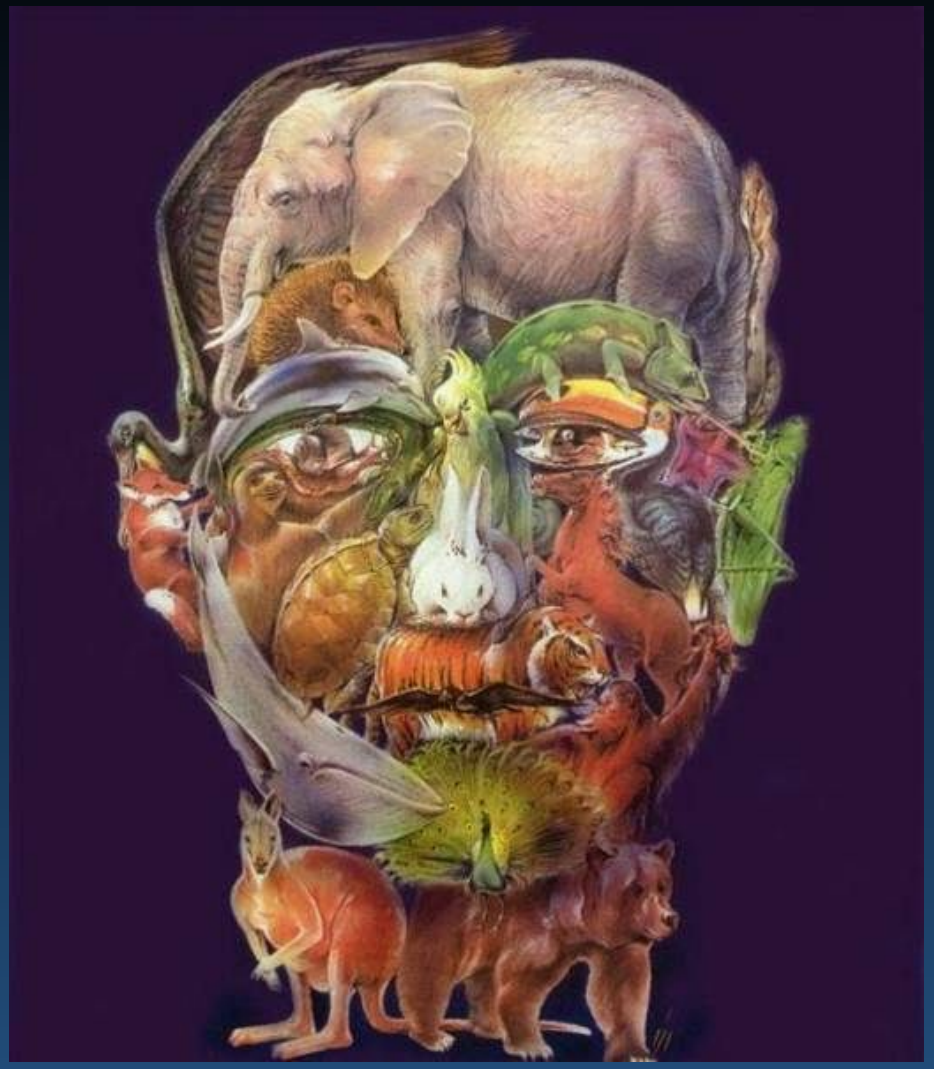
Write an e-mail:
NEUROTECHTOR@GMAIL.COM

Neurotechnology Scientific Club
Center for Modern Interdisciplinary Technologies
at Nicolaus Copernicus University in Toruń
Wileńska 4 Street

Thank you for synchronizing your neurons!

Our Neuroinformatics and Artificial Intelligence group, a part of the Dynamics, Mathematical Analysis and Artificial Intelligence Center, has new positions for PhD students, postdocs and visiting profs from abroad!
Please join our efforts!

Info is on our DAMSI webpage



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