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From Kolmogorov Theory to Computational Modeling and Brain Stimulation

Dr. Giulio Ruffini
Co-founder & CTO Starlab /Neuroelectrics

Barcelona, July 7, 2025

OUR MISSION

To deliver life-changing therapies that empower patients and families living with neuropsychiatric disorders.

Treat patients with Epilepsy, Major Depressive Disorder, and other neuropsychiatric disorders with our novel breakthrough-designated personalized medical technology: **Neurotwin-powered Transcranial Electrical Stimulation (tES).**

Physics and the big questions

What is mass, space, time?

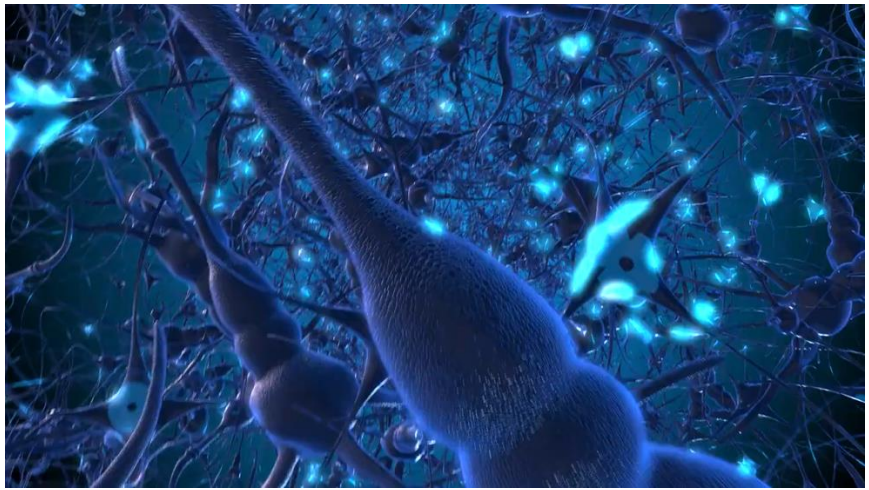
What is, indeed, **Reality**?

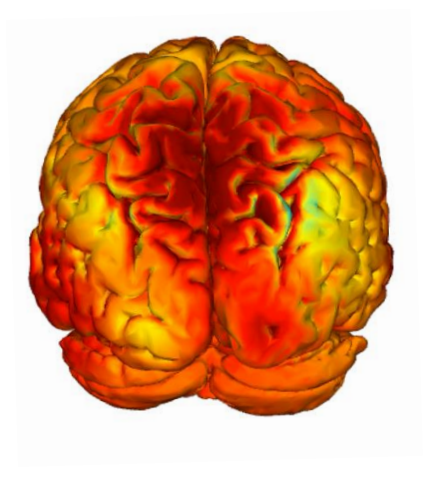
Why is math so powerful?

And who is this famous

Observer? Who am AI?

The Electric Brain





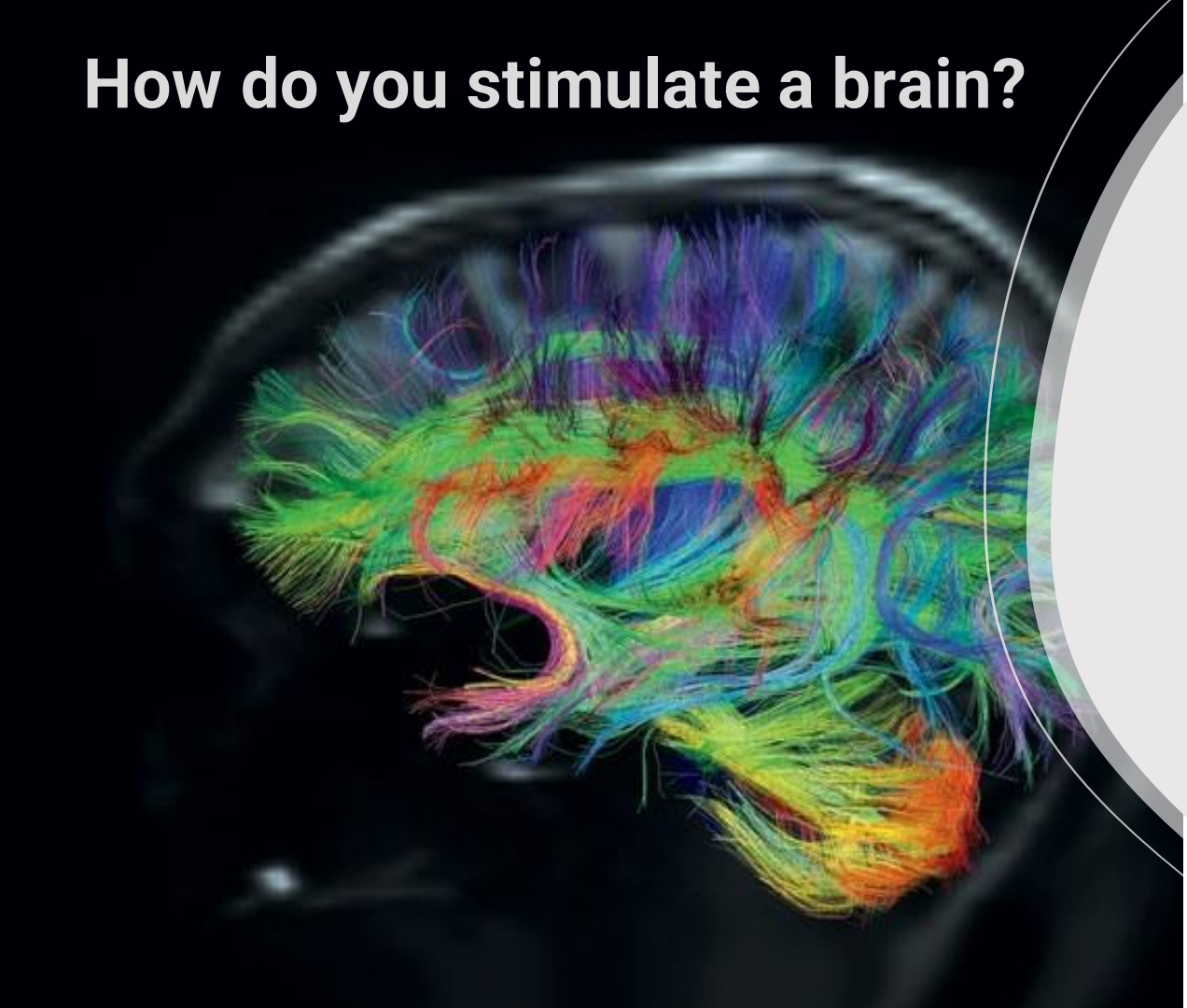
The brain appears to **compute electrically**. What do electric field **patterns** have to do with **mind**?
Can we harness them for **communication** or **therapy**?

Read EEG

Write tES

Easy-to-use, non-invasive, portable device for monitoring and treatment of the brain diseases *at home*

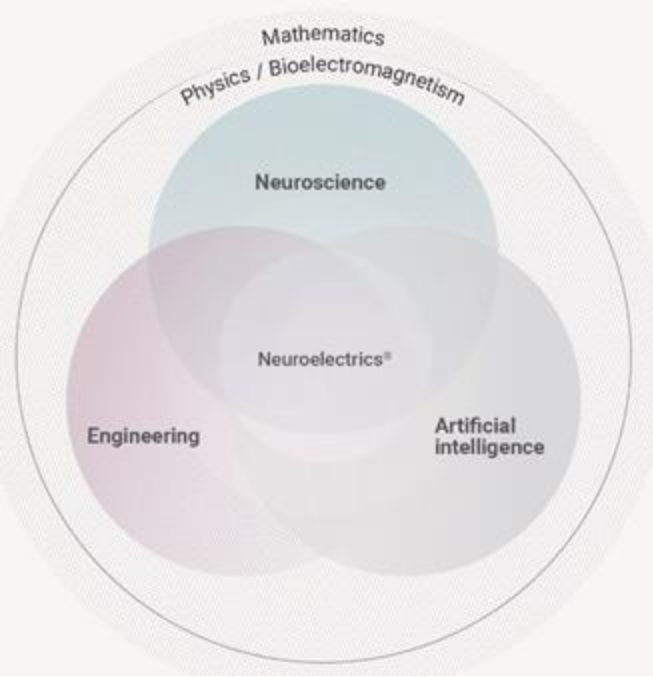
How do you stimulate a brain?



The brain is a plastic network, a large dynamical system

A Solid Foundation with Robust Modeling

Leveraging expertise across mathematics, physics, and neuroscience, unique models can be developed to provide novel insights



PHYSIOLOGICAL BRAIN MODELING

Dynamical brain network models can be used to simulate brain activity for each patient

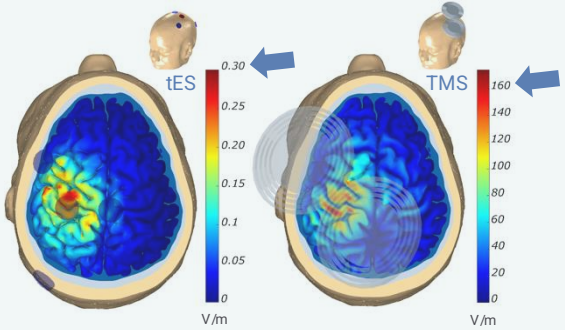
BIOPHYSICAL BRAIN MODELING

The physical interaction between the brain and the world (measurements or brain stimulation) requires a physical layer.

COMPLETE NEUROTWIN

Complete digital twin of the brain of a patient ready for optimization of stimulation protocol or analysis

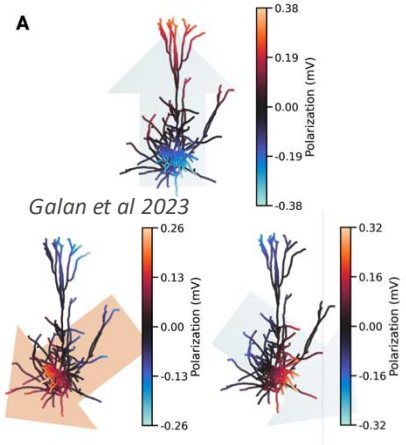
Mechanism of Action Transcranial Electrical Stimulation (tES)



Magnitude of Stimulation

Low electrical current injected non-invasively through the scalp (< 4mA)

Acute and long-lasting effects, depending on the intensity, montage and duration



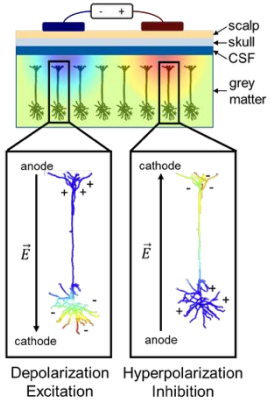
Mechanism of Action

Introduction of current generates electric field in the brain

Electric field couples with neurons, altering their membrane potential

Modulates neuronal firing patterns
→ heightening/reducing excitability or entraining oscillations

Leads to synaptic remodeling
→ "rewiring" the brain



J Physiol. 2000 Sep 15; 527(Pt 3): 633–639. PMCID: PMC2270099
doi: 10.1111/j.1469-7793.2000.t01-1-00633.x PMID: 10990547

Excitability changes induced in the human motor cortex by weak transcranial direct current stimulation

M A Nitsche and W Paulus

Review > Nat Neurosci. 2018 Feb;21(2):174-187. doi: 10.1038/s41593-017-0054-4. Epub 2018 Jan 8.

Studying and modifying brain function with non-invasive brain stimulation

Rafael Polanía [1], Michael A Nitsche [2,3], Christian C Ruff [4]

Review > Clin Neurophysiol. 2016 Feb;127(2):1031-1048. doi: 10.1016/j.clinph.2015.11.012. Epub 2015 Nov 22.

A technical guide to tDCS, and related non-invasive brain stimulation tools

A J Woods [1], A Antal [2], M Bikson [3], P S Boggio [4], A R Brunoni [5], P Celnik [6], L G Cohen [7], F Fregni [8], C S Herrmann [9], E S Kappenman [10], H Knotkova [11], D Liebetanz [2], C Miniussi [12], P C Miranda [13], W Paulus [2], A Priori [14], D Reato [3], C Stagg [15], N Wenderoth [16], M A Nitsche [17]

> Brain Stimul. 2020 Mar-Apr;13(2):287-301. doi: 10.1016/j.brs.2019.10.014. Epub 2019 Oct 18.

Direct current stimulation boosts hebbian plasticity in vitro

Greg Kronberg [1], Asif Rahman [2], Mahima Sharma [2], Marom Bikson [2], Lucas C Parra [2]

Review > Neurophysiol Clin. 2016 Dec;46(6):319-398. doi: 10.1016/j.neucli.2016.10.002. Epub 2016 Nov 17.

A comprehensive database of published tDCS clinical trials (2005–2016)

Jean-Pascal Lefaucheur [1]

Epilepsy

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Boston Children's Hospital
Until every child is well™

Co-Principal Investigator
Dr. Alexander Rotenberg

HARVARD MEDICAL SCHOOL

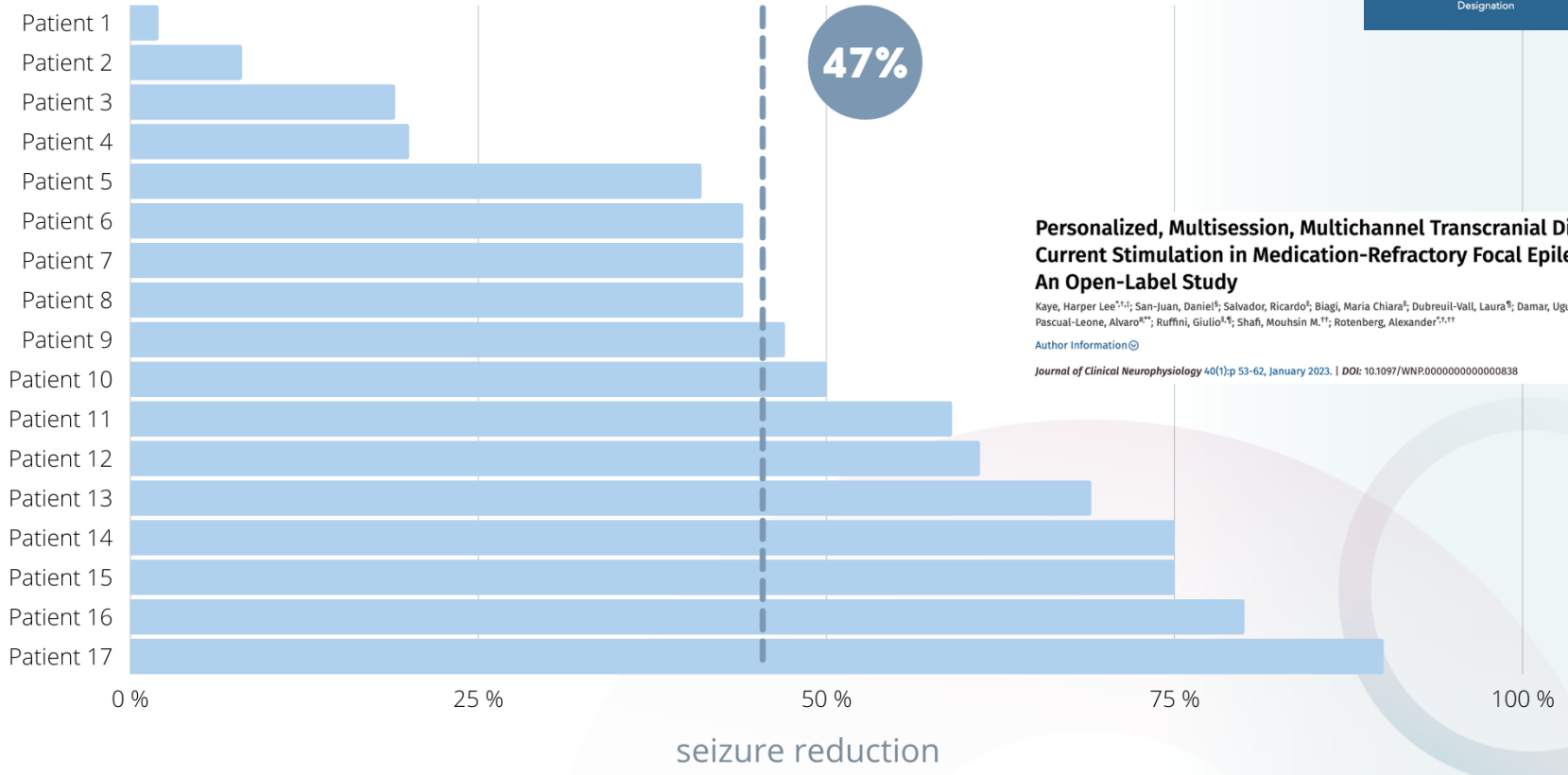
Beth Israel Deaconess Medical Center

MASSACHUSETTS LIFE SCIENCES CENTER

FDA Breakthrough Designation

REDUCING SEIZURES BY 47%

FDA
Breakthrough Device Designation



Personalized, Multisession, Multichannel Transcranial Direct Current Stimulation in Medication-Refractory Focal Epilepsy: An Open-Label Study

Kaye, Harper Lee[*,†,‡]; San-Juan, Daniel[§]; Salvador, Ricardo[‖]; Biagi, Maria Chiara[‖]; Dubreuil-Vall, Laura[¶]; Damar, Ugur[*,†]; Pascual-Leone, Alvaro[#,**]; Ruffini, Giulio[‖,¶]; Shafi, Mouhsin M.[††]; Rotenberg, Alexander[*,†,††]

Author Information

Journal of Clinical Neurophysiology 40(1):p 53-62, January 2023. | **DOI:** 10.1097/WNP.0000000000000838

Neurotwins in Epilepsy

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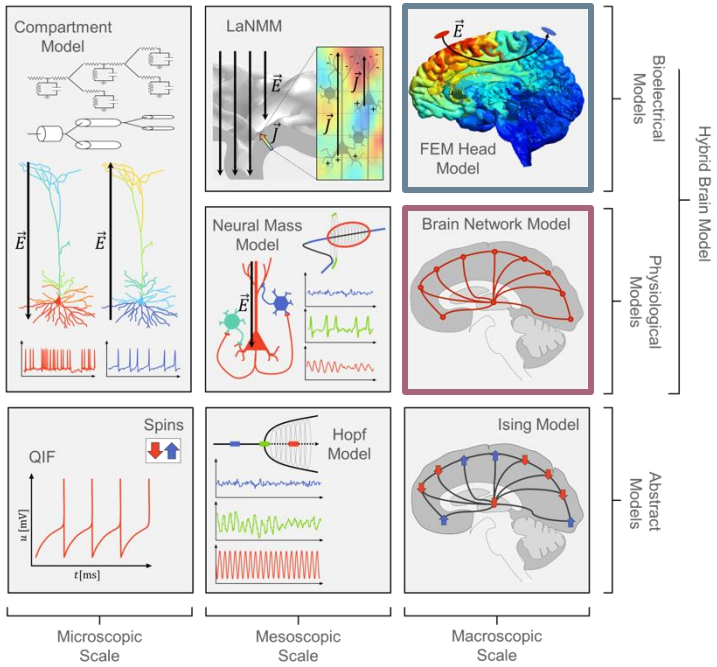
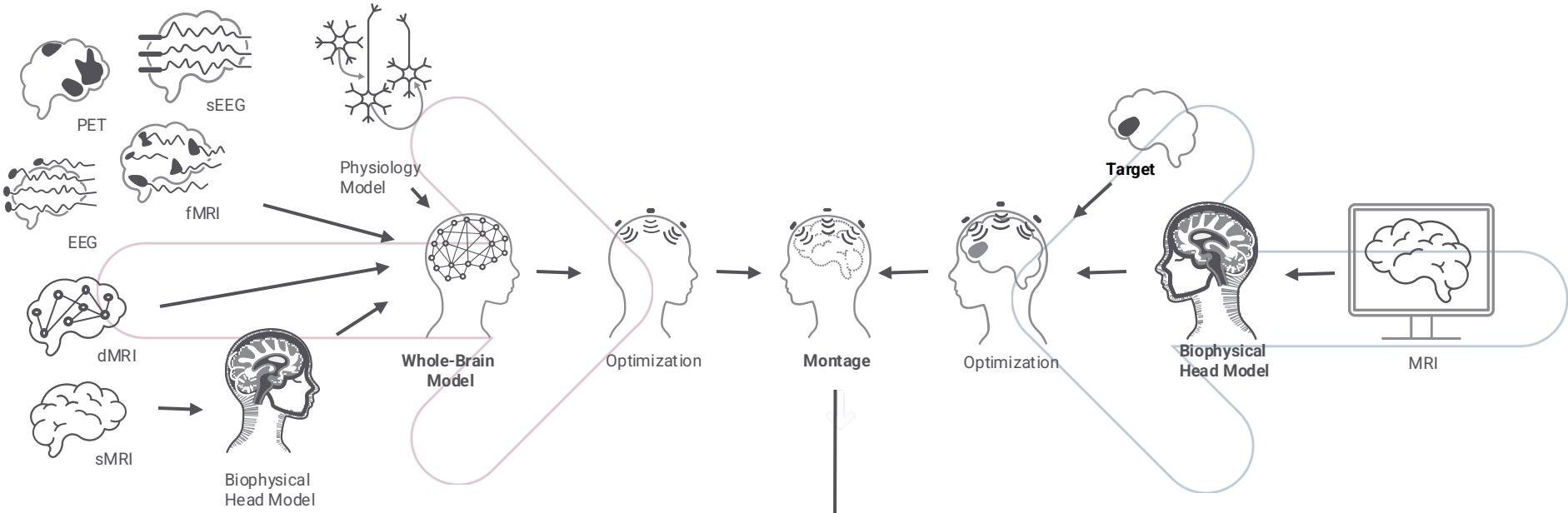
AIM

1. Develop advanced individualized whole-brain models that predict the physiological effects of tES
2. Use them to design optimal stimulation protocols in the context of neuropsychiatric disorders



Neurotwin: Mathematical model of the human brain comprising *either* or *both* physical and physiological aspects in the context of a disorder for the purpose of optimizing therapy.

Neurotwin Technology



WHOLE-BRAIN MODELS
Whole Brain Models represent cortical dynamics by simulating the collective activity of neuron populations.

PREDICTING FIELDS ON THE BRAIN
We can predict the electric field in the cortex using biophysical head models that represent the **brain geometry,** and its passive **electrical properties** based on neuroimaging structural data.

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Inserm

galvani

Aix*Marseille université

LTSI

Hôpitaux Universitaires de Marseille | ap-hm

UNIVERSITÉ DE RENNES 1

- Whole-brain Personalization Methods
- Whole-brain Optimization methods
- Clinical study design and analysis

The project is investigating the impact **weak electric fields** have on the physiology of neurons and neural networks. The key objective is to understand if these electric pulses can improve the patient-specific **epileptogenic network**.

Funded by the European Union

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Multicenter Clinical Epilepsy

Sept 2024-27

Neurotwins **for advanced tDCS in focal epilepsy**

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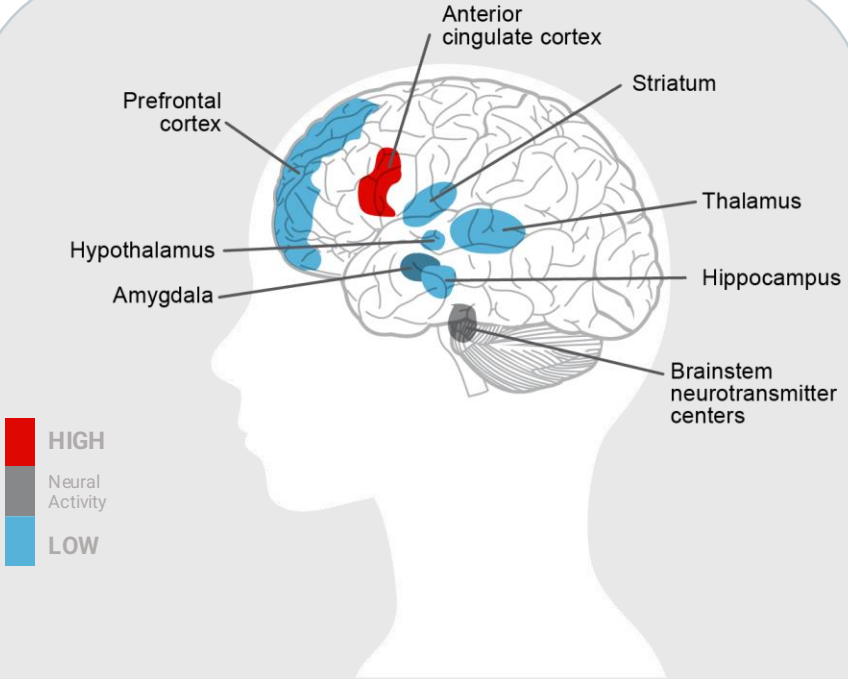
How can we help patients with psychiatric conditions?

Major Depressive Disorder (MDD)



In MDD, some areas of the brain are Hypoactive and others are Hyperactive

Target indication: refractory MDD

- >28M patients globally
- Therapeutic alternatives include TMS, VNS, ECT

Mechanistic rationale

- MDD is characterized by reduced left vs right neuronal activity in the dorsolateral prefrontal cortex (**DLPFC**)
- Application of tDCS on left **DLPFC** stimulates neuronal activity in this region, restoring electrophysiological function
- Plasticity from repeated application is to lead to healthy rewiring of frontolimbic network

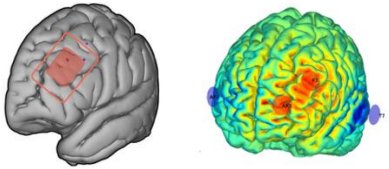
Clinical evidence

- >20 RCTs conducted to date; >1,000 patients studied
- LeFaucheur (2017) meta-analyses supports Level B recommendation – probable efficacy – for anodal TES of the left DLPFC in MDD patients with drug resistance

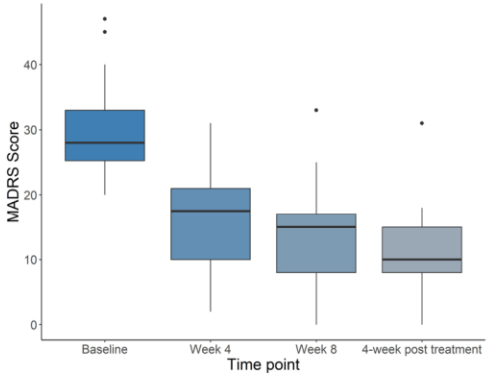
MDD Open Label Pilot Study Results

Montages, biotypes and etiology matter

Neuroelectrics Home pilot MDD1



PRIMARY ENDPOINT: MADRS
(gold standard depression severity assessment)

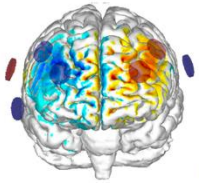


- Avg Baseline: **30.1 (ITT)**
- Avg Improvement @ Week 4 Post-treat: **19.8 pts**
- Min. Clinical-Important Difference (MCID): **3-5 pts**

Optimized HD-tDCS protocol for clinical use in patients with major depressive disorder

Mohammad Ali Salehinejad, Marzieh Abdi, Mohsen Dadashi, Reza Rostami, Ricardo Salvador, Giulio Ruffini, Michael A. Nitsche

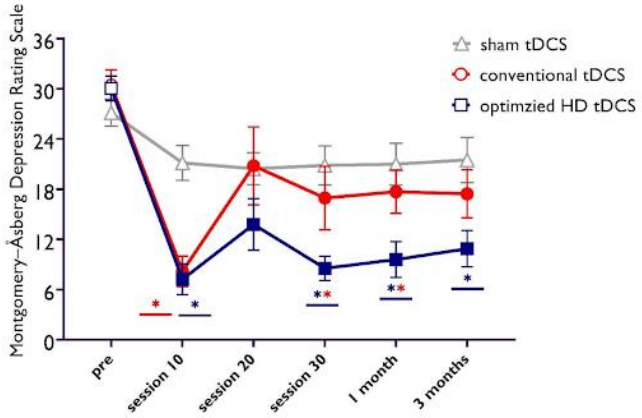
Protocol:



AF3: 1246
AF4: -1112
F3: 1101
F4: -1284
F8: -623
FC5: -978
FC6: 1650

Total injected current (uA): 3997
Maximum current any electrode (uA): 1650

Results – *MADRS*



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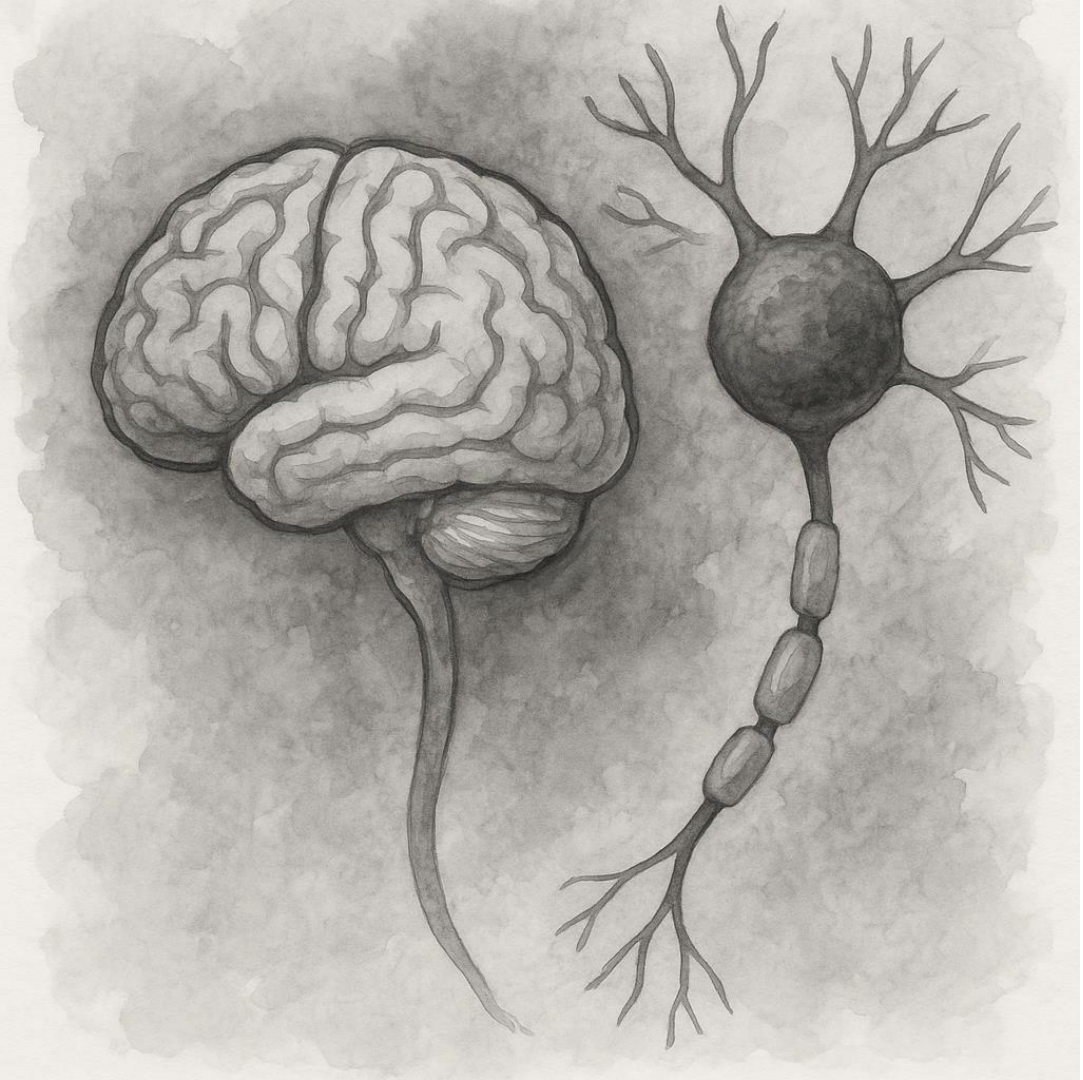
What is Depression?

MDD is not a single condition.

Etiology is diverse.

MDD is characterized by a persistent **first-person experience** of sadness, hopelessness, and a lack of interest or pleasure in activities.



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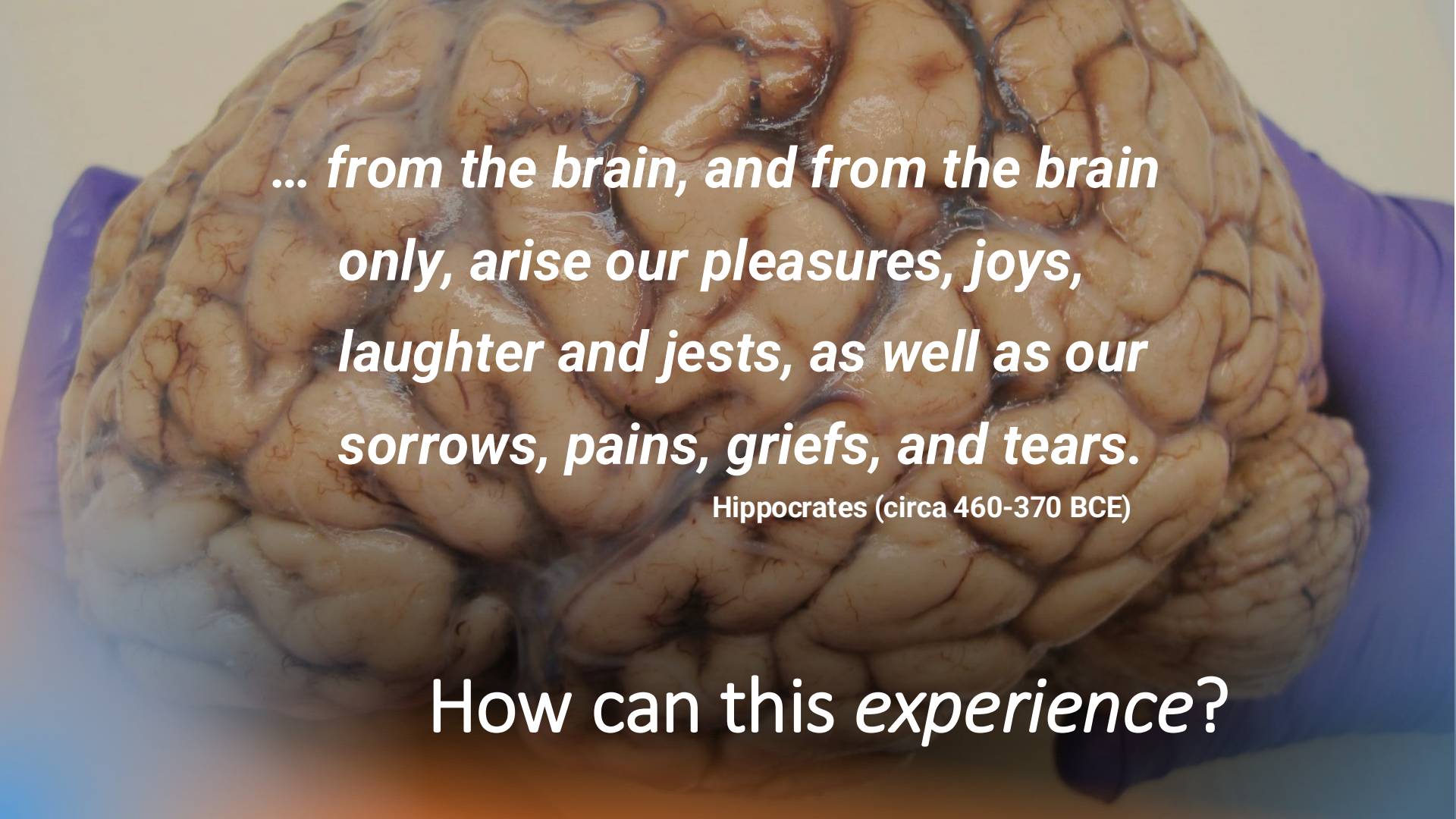
Neurology is primarily concerned with the **physical** and **structural** aspects of the nervous system and its diseases.

Psychiatry focuses on the **mental**, **emotional**, and behavioral aspects of well-being.

The ***experience machine***!


… from the brain, and from the brain only, arise our pleasures, joys, laughter and jests, as well as our sorrows, pains, griefs, and tears.
Hippocrates (circa 460-370 BCE)
How can this *experience*?

The Challenge

We are missing a principled, unifying framework to define and operationalize **what** we want to model and understand what its physiological signatures are – **how** to measure it.

Defining Experience/Consciousness

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1. A brief intro to Kolmogorov theory (KT)
2. Emotion, depression, and the role of valence

Kolmogorov Theory (KT)

Open Access Perspective

Neural Geometrodynamics, Complexity, and Plasticity: A Psychedelics Perspective

by Giulio Ruffini [1,*], Edmundo Lopez-Sola [1,2], Jakub Vohryzek [2,3] and Roser Sanchez-Todo [1,2]

arXiv > physics > arXiv:0704.1147

Physics > General Physics

[Submitted on 9 Apr 2007]

Information, complexity, brains and reality (Kolmogorov Manifesto)

Giulio Ruffini

Open Access Perspective

The Algorithmic Agent Perspective and Computational Neuropsychiatry: From Etiology to Advanced Therapy in Major Depressive Disorder

by Giulio Ruffini [1,*], Francesca Castaldo [1,*], Edmundo Lopez-Sola [1,2], Roser Sanchez-Todo [1,2] and Jakub Vohryzek [2,3]

arXiv > physics > arXiv:0903.1193

Physics > General Physics

[Submitted on 6 Mar 2009 (v1), last revised 19 Jun 2009 (this version, v3)]

Reality as Simplicity

Giulio Ruffini

arXiv > cs > arXiv:1612.05627

Computer Science > Machine Learning

[Submitted on 13 Dec 2016]

Models, networks and algorithmic complexity

Giulio Ruffini

Cross-Frequency Coupling as a Neural Substrate for Prediction Error Evaluation: A Laminar Neural Mass Modeling Approach

Giulio Ruffini, Edmundo Lopez-Sola, Raul Palma, Roser Sanchez-Todo, Jakub Vohryzek, Francesca Castaldo, Karl Friston

doi: https://doi.org/10.1101/2025.03.19.644090

An algorithmic information theory of consciousness

Giulio Ruffini

Neuroscience of Consciousness, Volume 2017, Issue 1, 2017, nix019,

Restoring Oscillatory Dynamics in Alzheimer's Disease: A Laminar Whole-Brain Model of Serotonergic Psychedelic Effects

Jan C. Gendra, Edmundo Lopez-Sola, Francesca Castaldo, Èlia Lleal-Custey, Roser Sanchez-Todo, Jakub Vohryzek, Ricardo Salvador, Ralph G. Andrzejak, Giulio Ruffini, the Alzheimer's Disease Neuroimaging Initiative

doi: https://doi.org/10.1101/2024.12.15.628565

A physical neural mass model framework for the analysis of oscillatory generators from laminar electrophysiological recordings

Roser Sanchez-Todo [a,f], André M. Bastos [b], Edmundo Lopez-Sola [a], Borja Mercadal [a], Emiliano Santarnecchi [c], Earl K. Miller [d,e], Gustavo Deco [f,g,h], Giulio Ruffini [a,j,k]

Journal of Artificial Intelligence and Consciousness | Vol. 09, No. 02, pp. 153-191 (2022)

AIT Foundations of Structured Experience

Giulio Ruffini and Edmundo Lopez-Sola

LSD-induced increase of Ising temperature and algorithmic complexity of brain dynamics

Giulio Ruffini, Giada Damiani, Diego Lozano-Soldevilla, Nikolas Deco, Fernando E. Rosas, Narsis A. Kiani, Adrián Ponce-Alvarez, Morten L. Kringelbach, Robin Carhart-Harris, Gustavo Deco

Open Access Article

Structured Dynamics in the Algorithmic Agent

by Giulio Ruffini [1,*], Francesca Castaldo [1] and Jakub Vohryzek [2,3]

Navigating Complexity: How Resource-Limited Agents Derive Probability and Generate Emergence

Giulio Ruffini*
Neuroelectrics

Fast Interneuron Dysfunction in Laminar Neural Mass Model Reproduces Alzheimer's Oscillatory Biomarkers

Roser Sanchez-Todo, Borja Mercadal, Edmundo Lopez-Sola, Maria Guasch-Morgades, Gustavo Deco, Giulio Ruffini

doi: https://doi.org/10.1101/2025.03.26.645407

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Kolmogorov Theory of Consciousness

1. Postulate: **There is Experience**
2. Focus on **Structured Experience**

luminous®

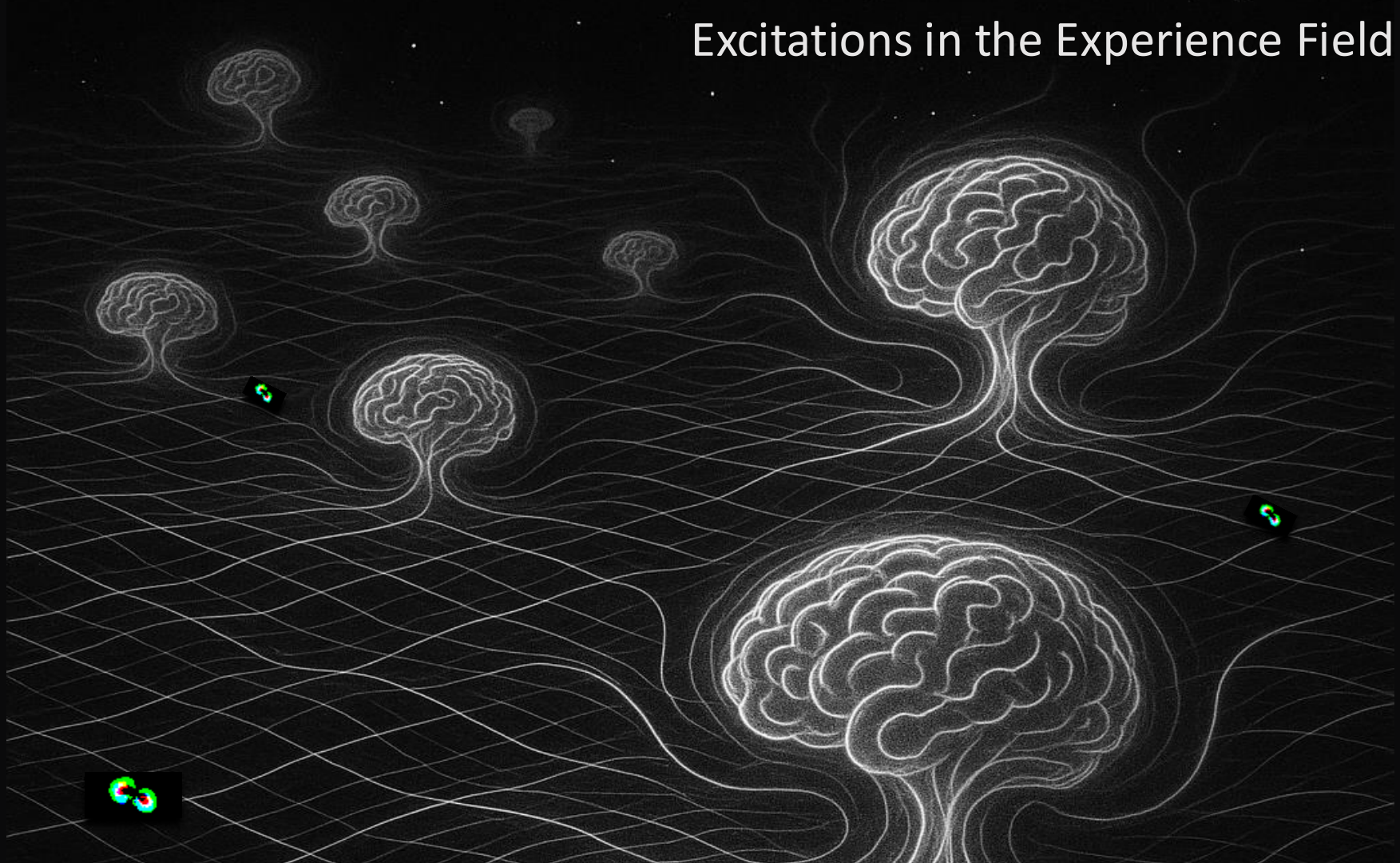
There is *Pure Experience*

The immediate, subjective sense of “what it feels like” to be oneself at any given moment.

What is it like to be you?

What is it like to be a bat? (Thomas Nagel 1974)

Excitations in the Experience Field



What is *structured experience*?

The spatial, temporal, and conceptual organization of our first-person experience of the world and of ourselves as agents in it.

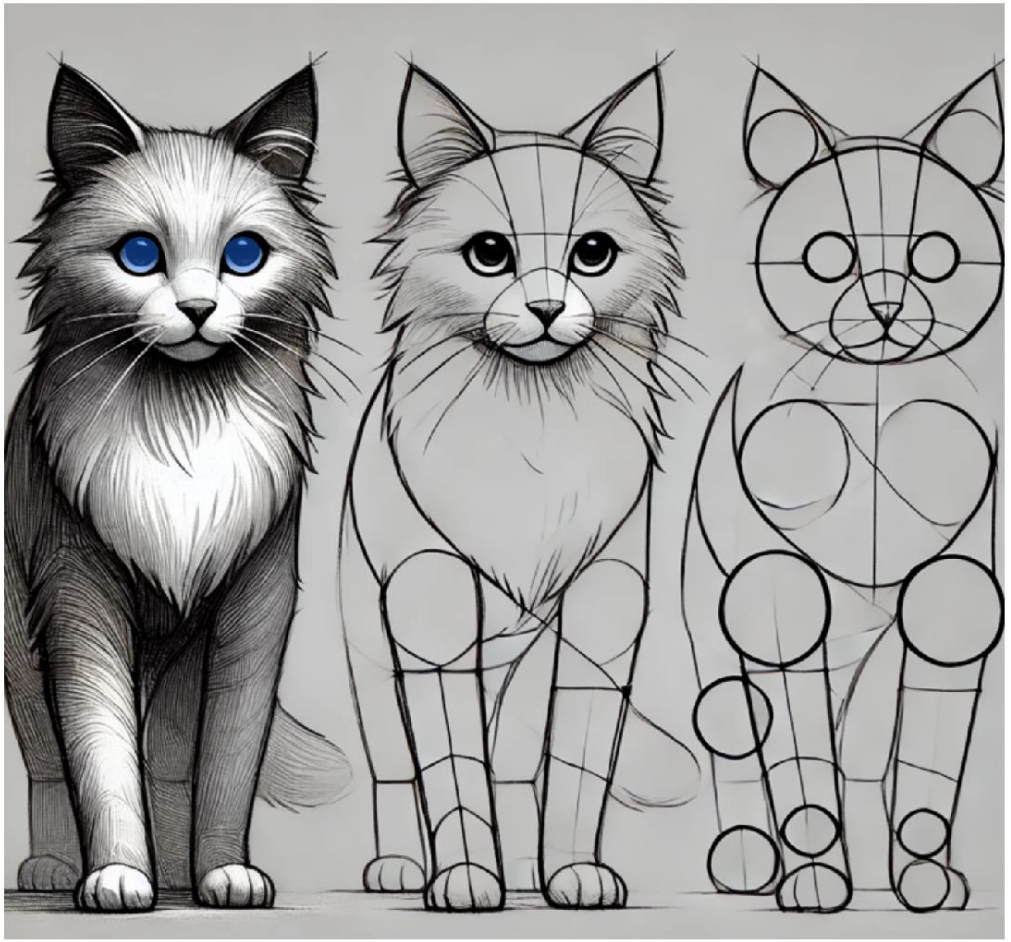
An algorithmic information theory of consciousness

Giulio Ruffini

Neuroscience of Consciousness, Volume 2017, Issue 1, 2017, nix019, https://doi.org/10.1093/nc/nix019

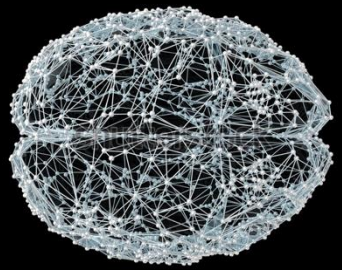
Coarse-grained modeling, lossy **compression** to extract useful structure

Kolmogorov Complexity is the limit!

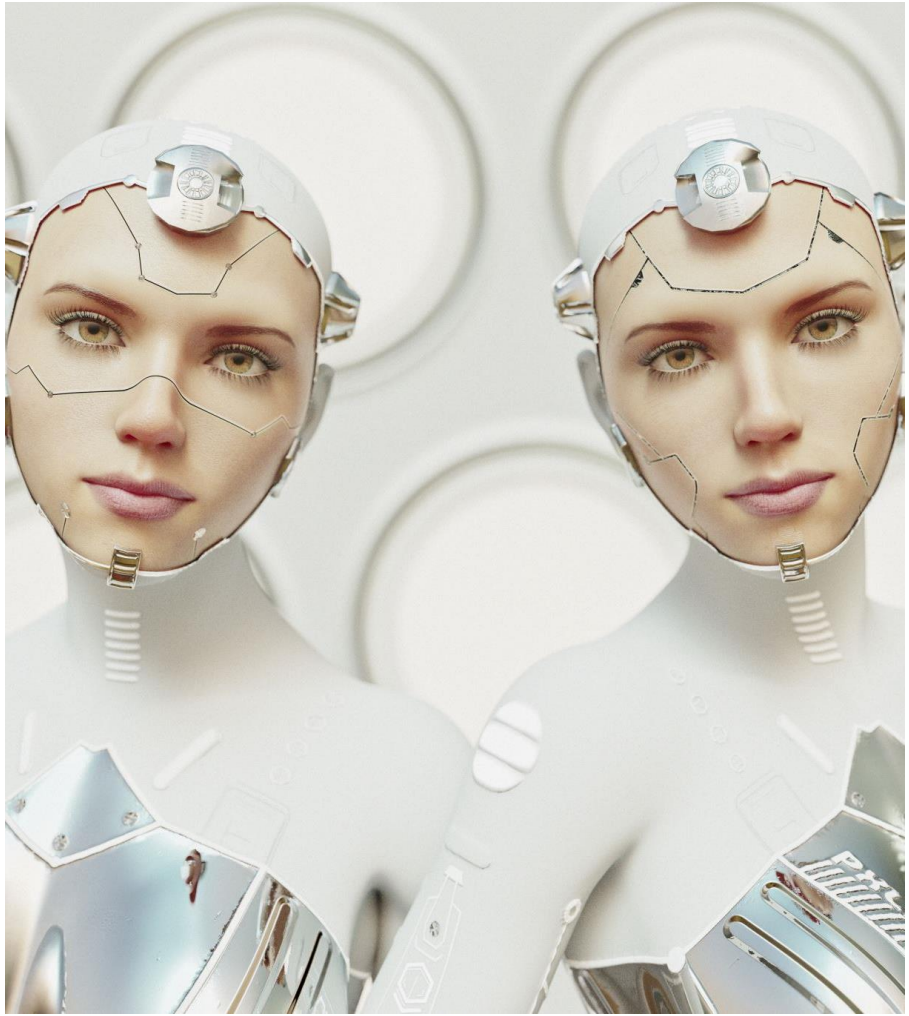


What is special about brains (or life)?

#1 High Mutual Algorithmic Information with the world in compressed format



#2 The compute: modeling and decision making



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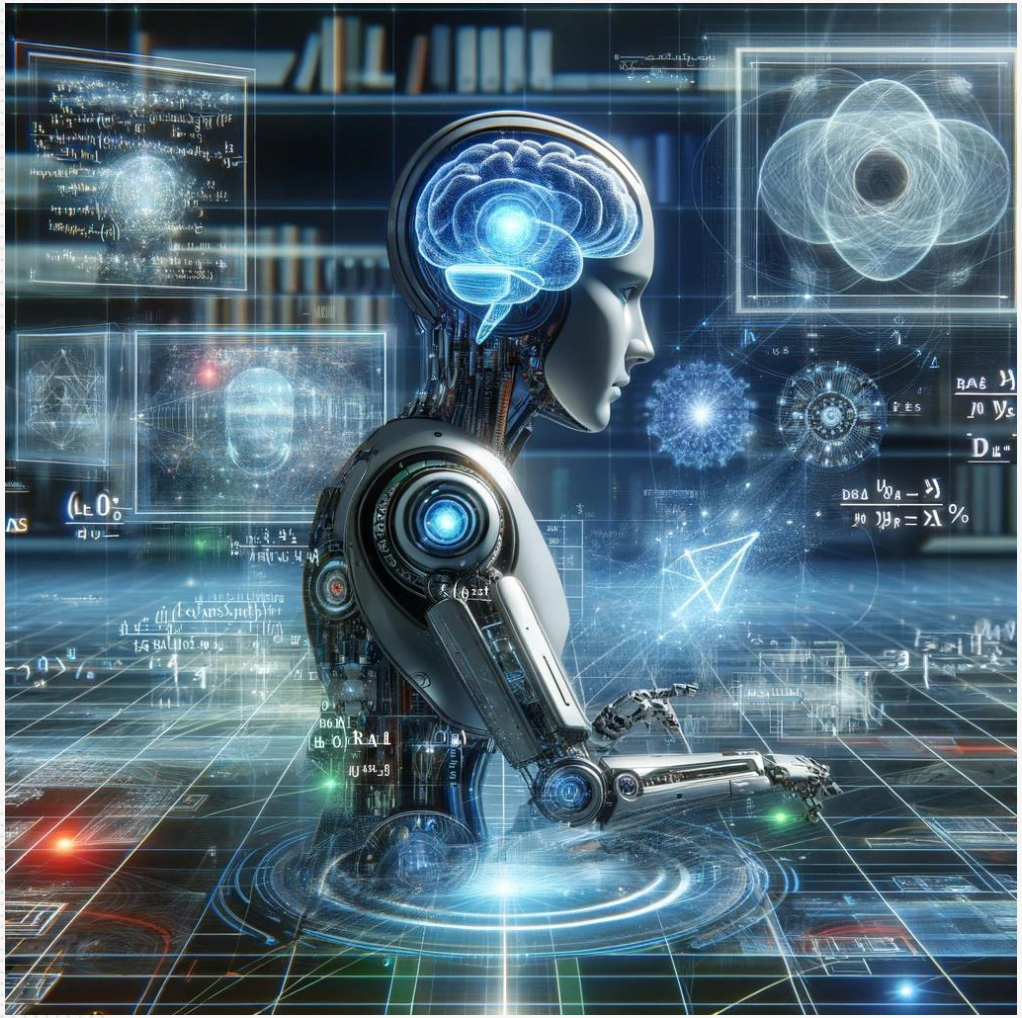
KT in a Nutshell

Ask what creates *structured experience* in an *algorithmic* context

A. Evolution gives rise to *agents* (and we are agents)

B. Agents run *models of the world* and enjoy structured experience!

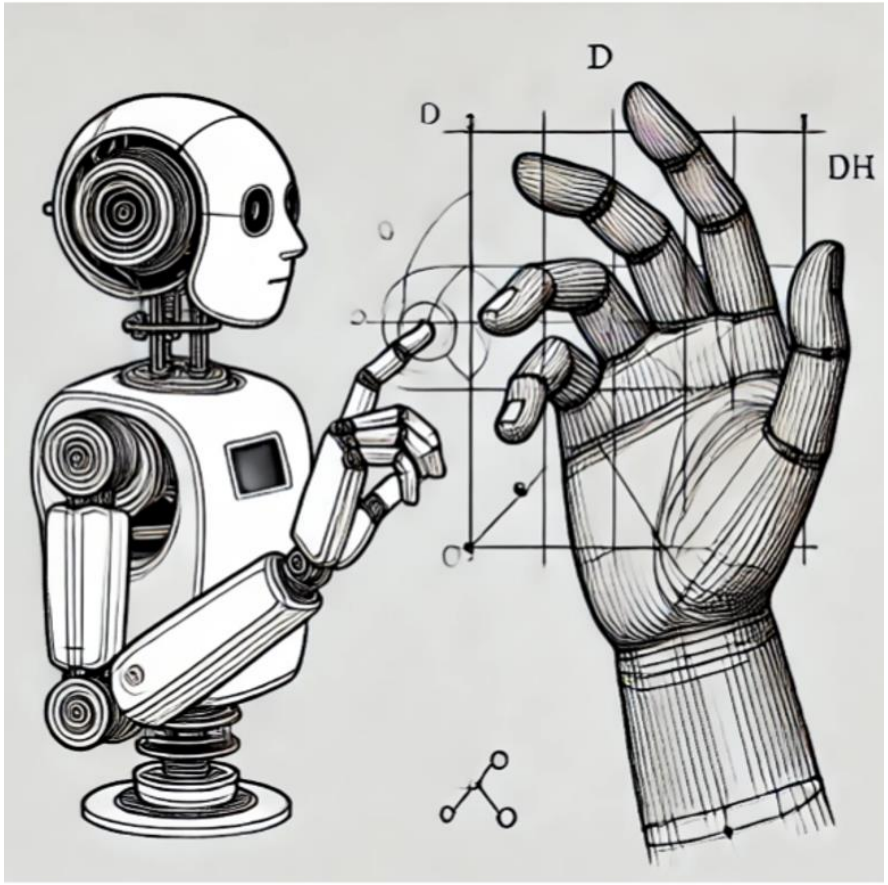
C. Agents have *goals*. This gives origin to *valence* & *emotions*

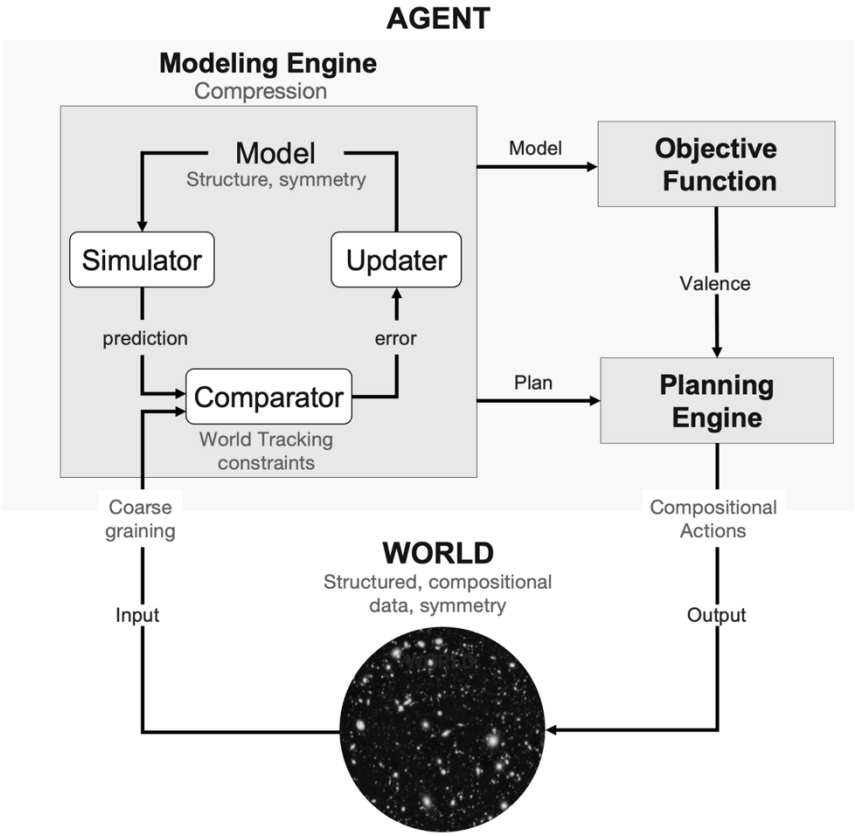


What is an algorithmic *agent*?

A computational system that interacts effectively with its environment by **planning** actions using **compressive predictive models** to maximize an **objective function**.

Using a model entails ***computation*** and ***dynamics***.

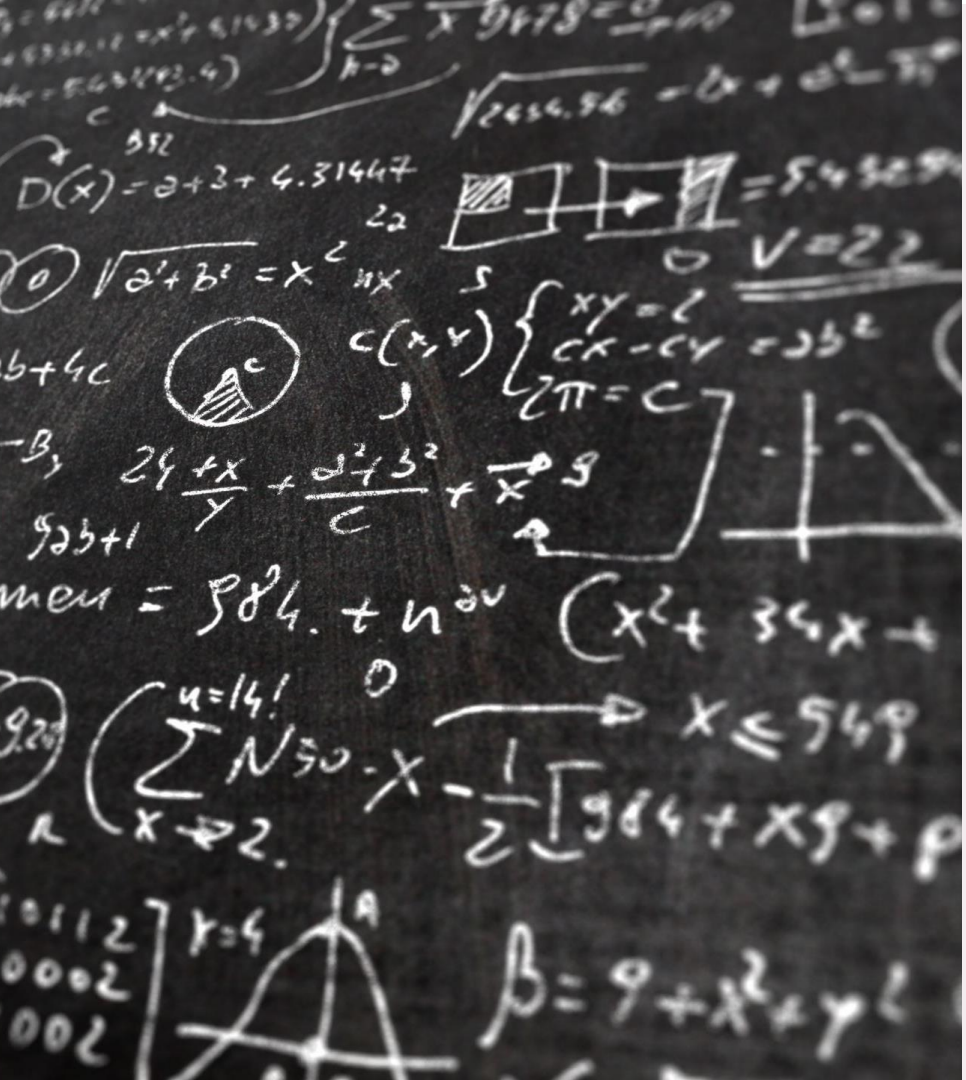




Open Access Perspective

The Algorithmic Agent Perspective and Computational Neuropsychiatry: From Etiology to Advanced Therapy in Major Depressive Disorder

by Giulio Ruffini [1,*], Francesca Castaldo [1,*], Edmundo Lopez-Sola [1,2], Roser Sanchez-Todo [1,2] and Jakub Vohryzek [2,3]



What is a *model*?

- A *program* that allows you to **compress coarse-grained** information
- A simplified but useful representation of reality
- A *mathematical object*

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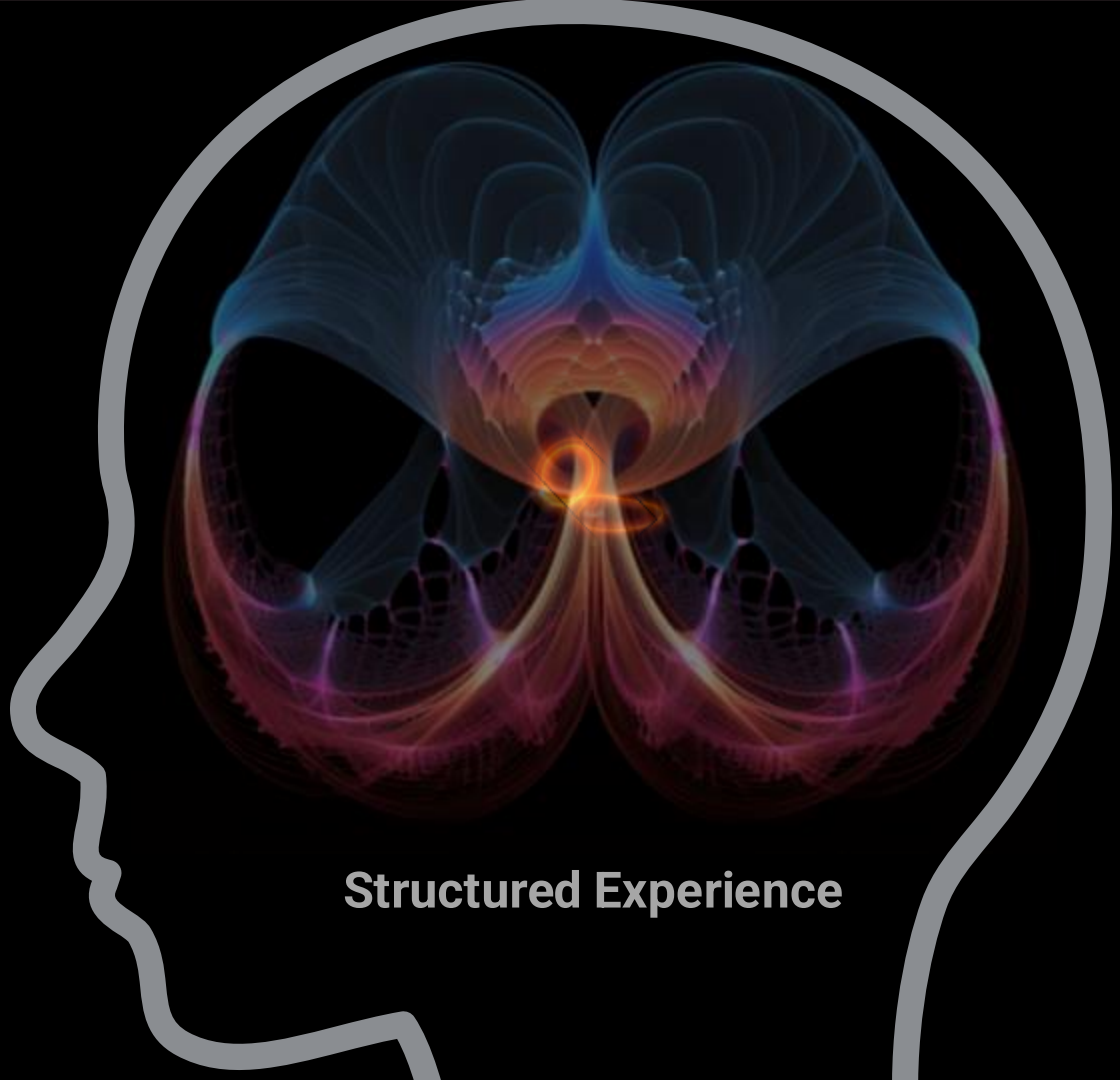
A model is *computation* and *dynamics*.

The brain computes*, it is a dynamical system.

Dynamics is mathematics and geometry.

* Classical or Quantum. Quantum ≠ Hypercomputation. Does not compute “new” things.


Structured Experience

How do we define **model structure**?

Formalize *model* using **group theory,** capturing the idea of **simplicity** as **symmetry**. Then, we can show that

1) Tracking the world forces the agent as a dynamical system to mirror the symmetry in the data. Dynamics collapses to **reduced manifolds**.
2) The hierarchical nature of world data leads to **coarse-graining** and the notion of hierarchical constraints and manifolds

The central hypothesis in KT

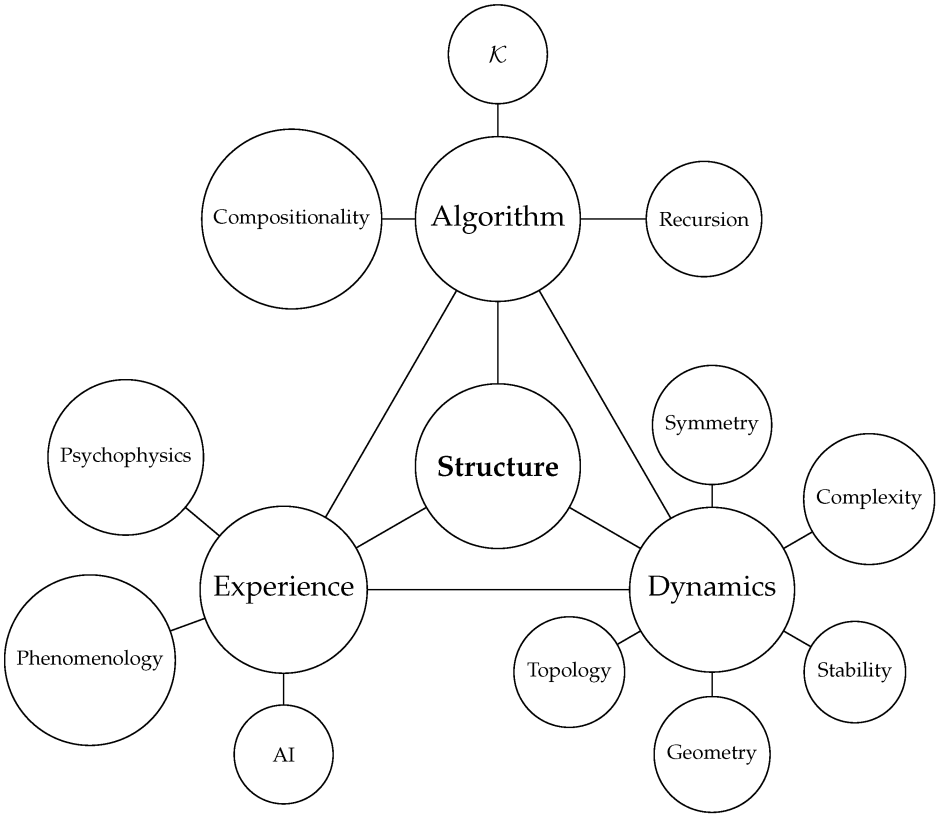
An agent has **structured experience ($\mathcal{S}$)** to the extent it has access to encompassing and **compressive models** to interact with the world.

More specifically, **the event of structured experience arises in the act of running models**.

Model structure determines **the structure of experience**.

Successful comparison with data leads to **wakeful presence**.

Much structured experience may be **unreported!**



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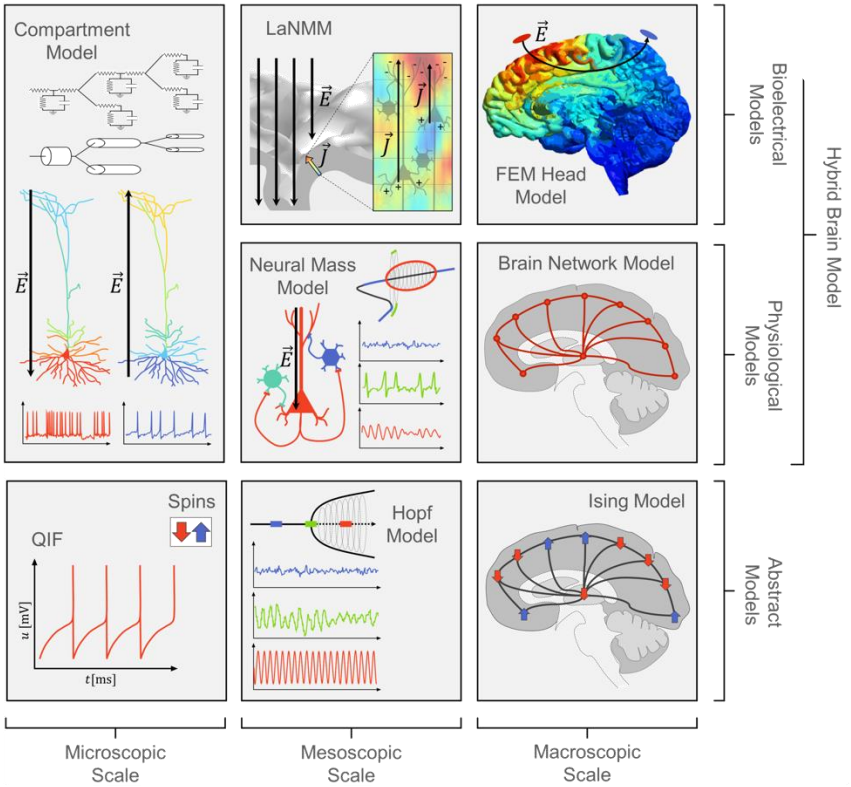
KT in practice #1

Requirements for structured experience

and

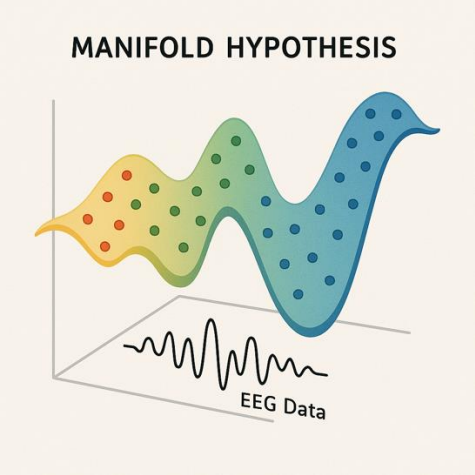
The Neural Correlates of Structured Experience

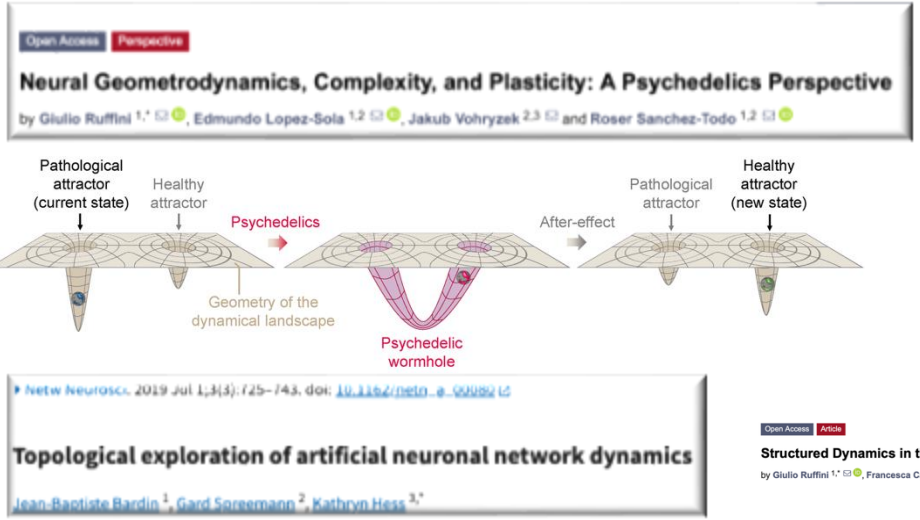
Tool 1: Computational Modeling, Criticality

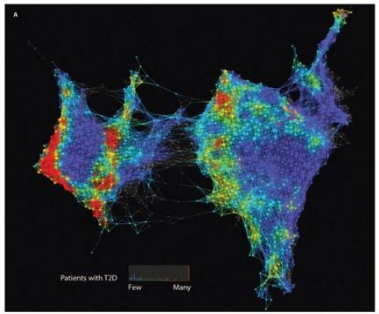


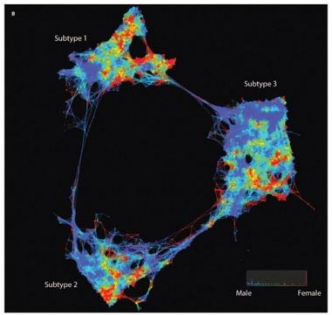
Aim: Mechanistic interpretation of brain data using whole-brain computational models. The *computational, critical brain* as a requirement.

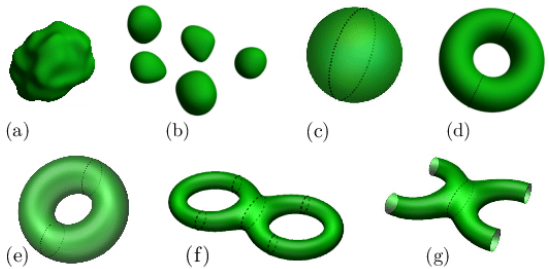
Tool 2: Topology, Group Theory

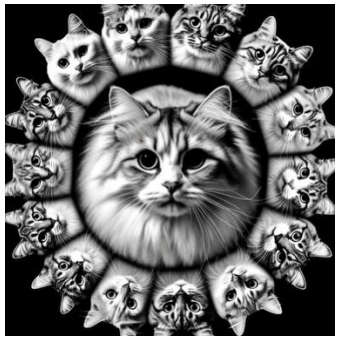












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KT in practice #2

Computational Psychiatry:

Where first-person and third-person views meet


Open Access Perspective

The Algorithmic Agent Perspective and Computational Neuropsychiatry: From Etiology to Advanced Therapy in Major Depressive Disorder

by Giulio Ruffini [1,*], Francesca Castaldo [1,*], Edmundo Lopez-Sola [1,2], Roser Sanchez-Todo [1,2] and Jakub Vohryzek [2,3]

Computational psychiatry

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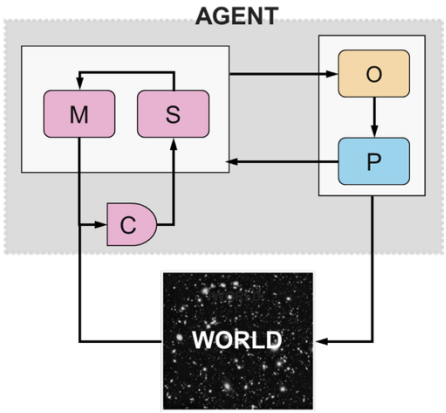
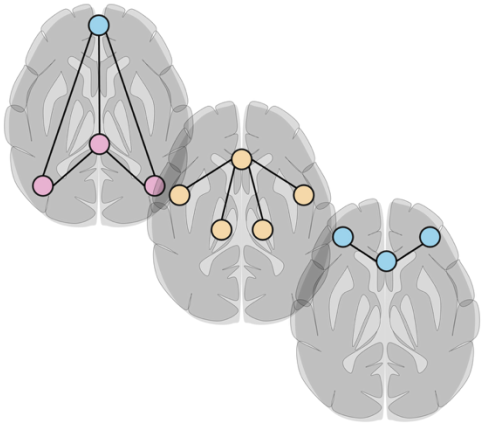
Algorithmic Agent

Component and functions
Structured valence
MDD Agent Model



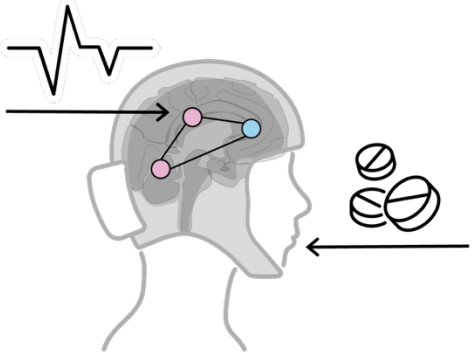
Translational Framework

Brain circuits
MDD biotypes
Dynamical landscape
Neurophenomenology



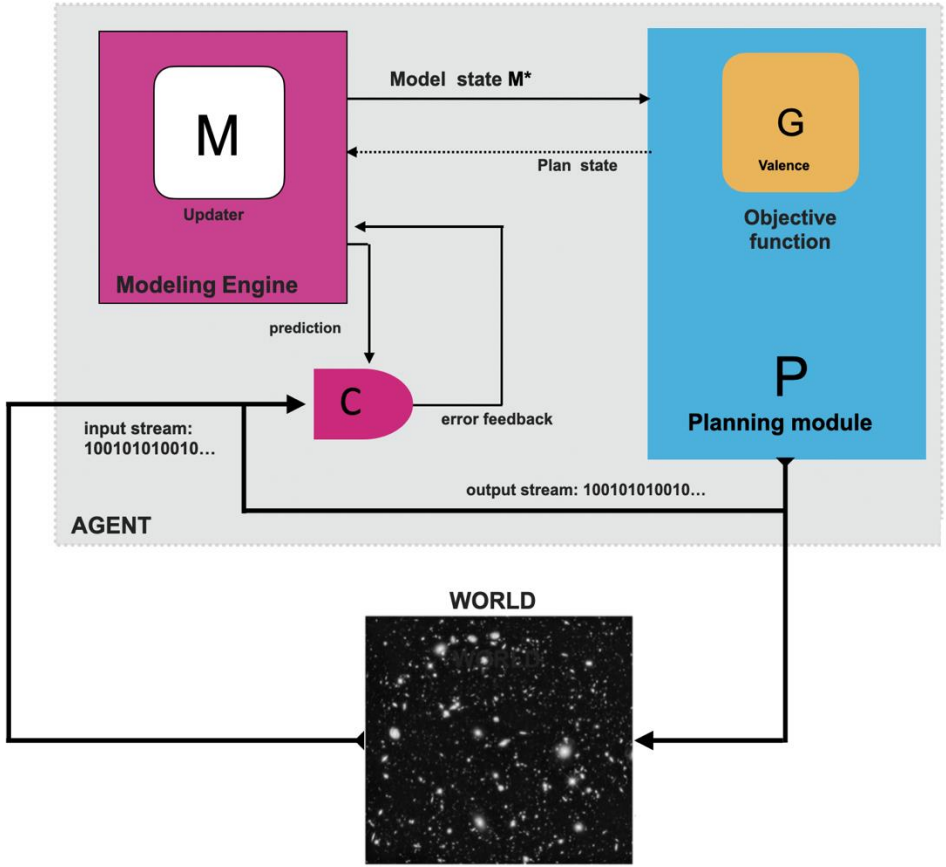
MDD Treatment

Psychedelics
Stimulation
Combined therapy
Computational neuropsychiatry



Agents have an **Objective Function** that sets their **goals**.

It quantifies how well or bad they are doing, the mathematical analog of **valence** (pleasure and pain).



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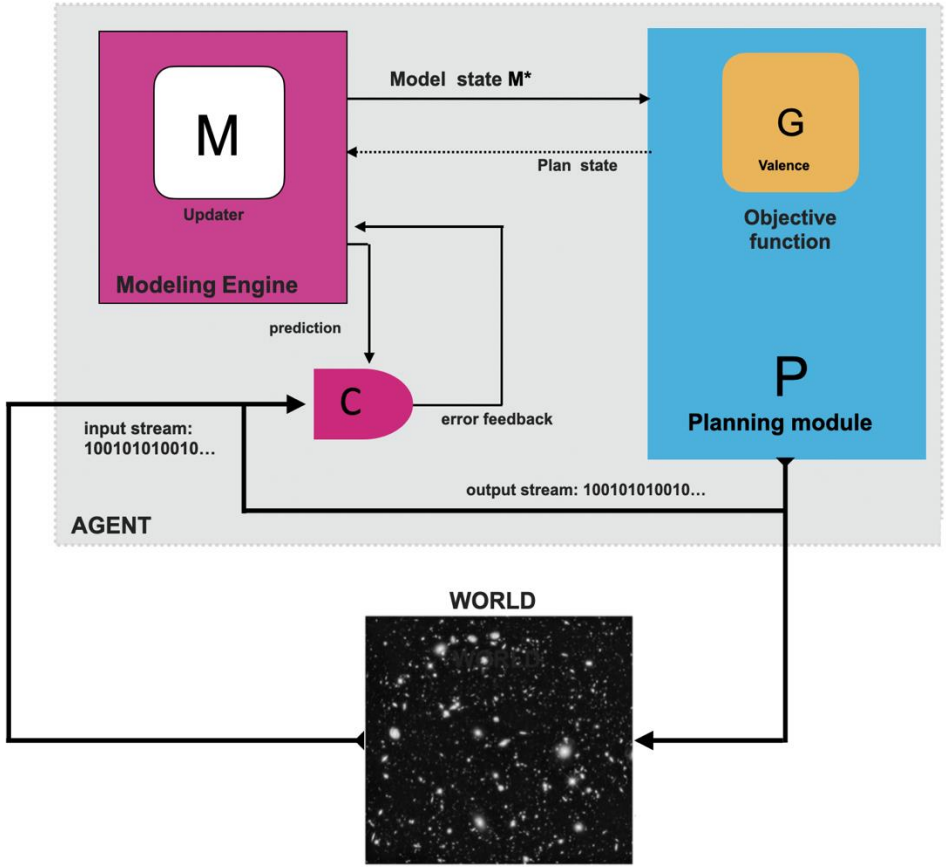
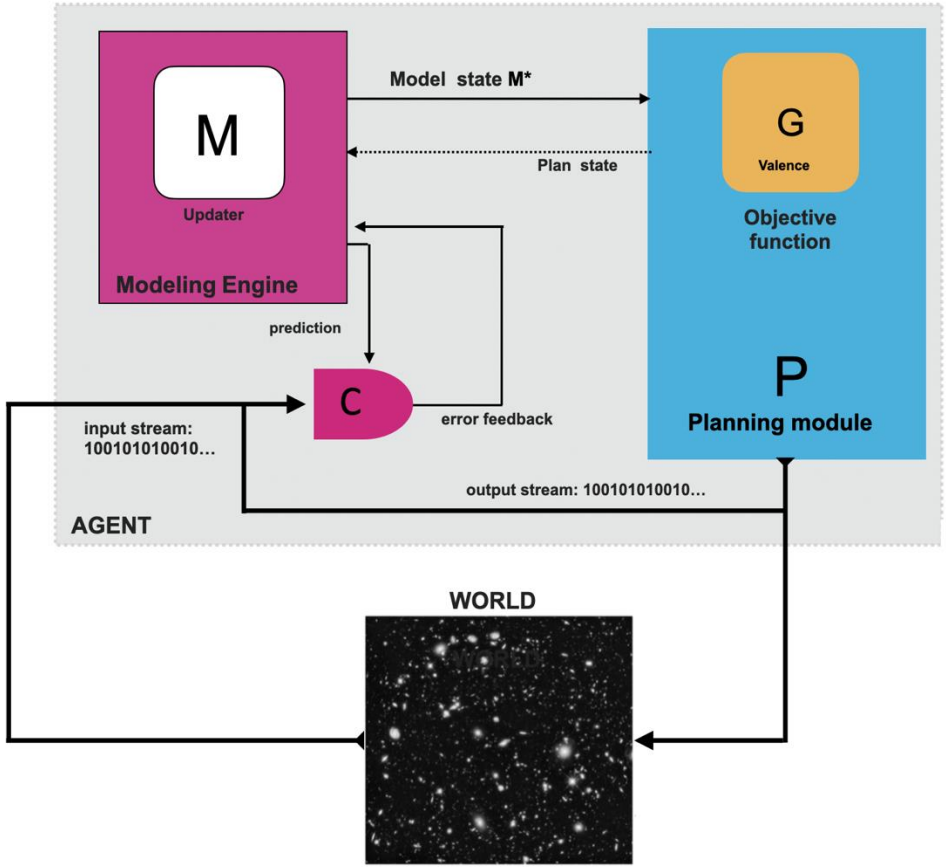
The Agent: Model + Goal + Planning



The Agent: **Model** + **Goal** + **Planning**

We are now in the position to define *emotion*:

Emotion = Model + Valence

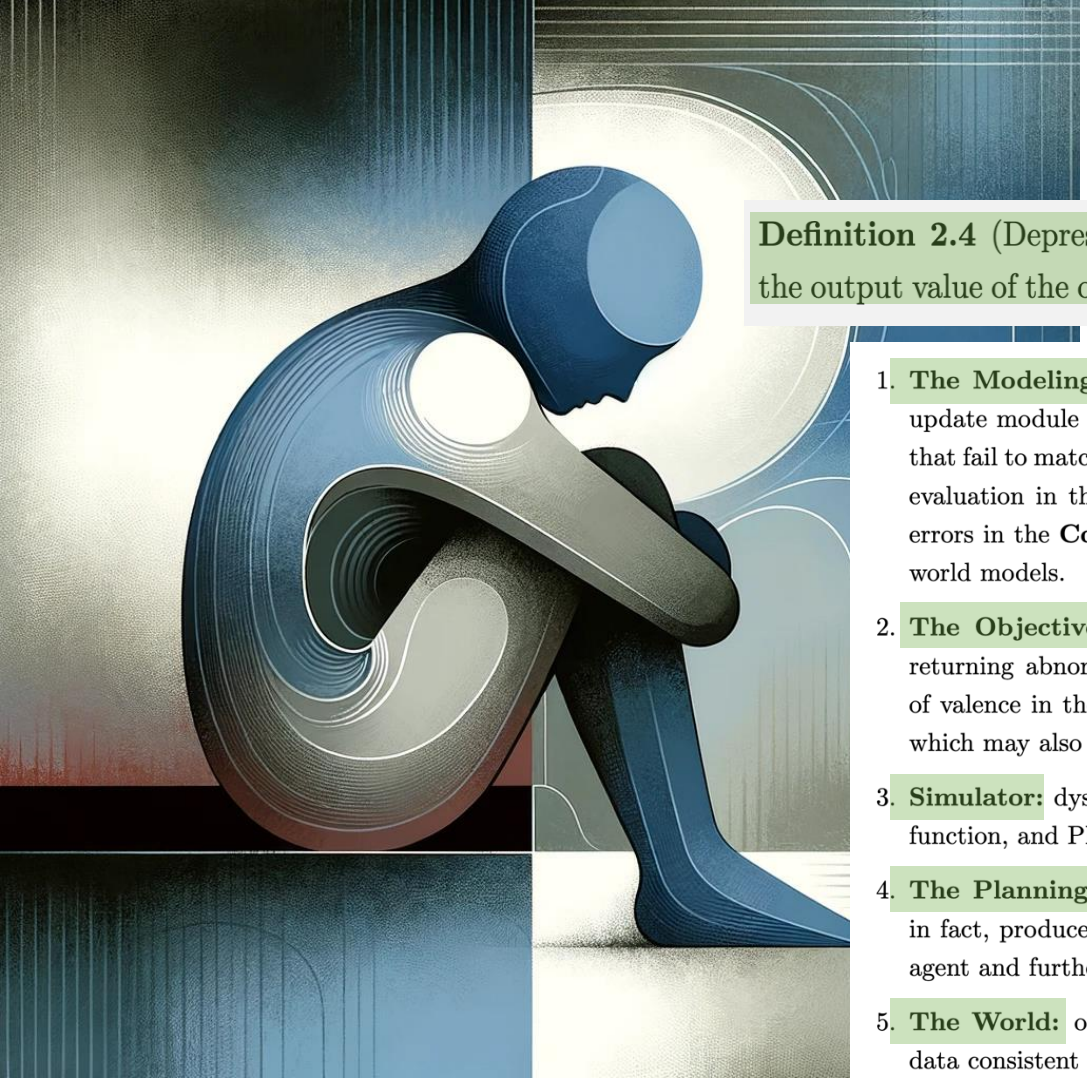


The Agent: **Model** + **Goal** + **Planning**

We are now in the position to define *emotion*:

Emotion = Model + Valence

... and *depression*:
A pathological state of persistent low **Valence**

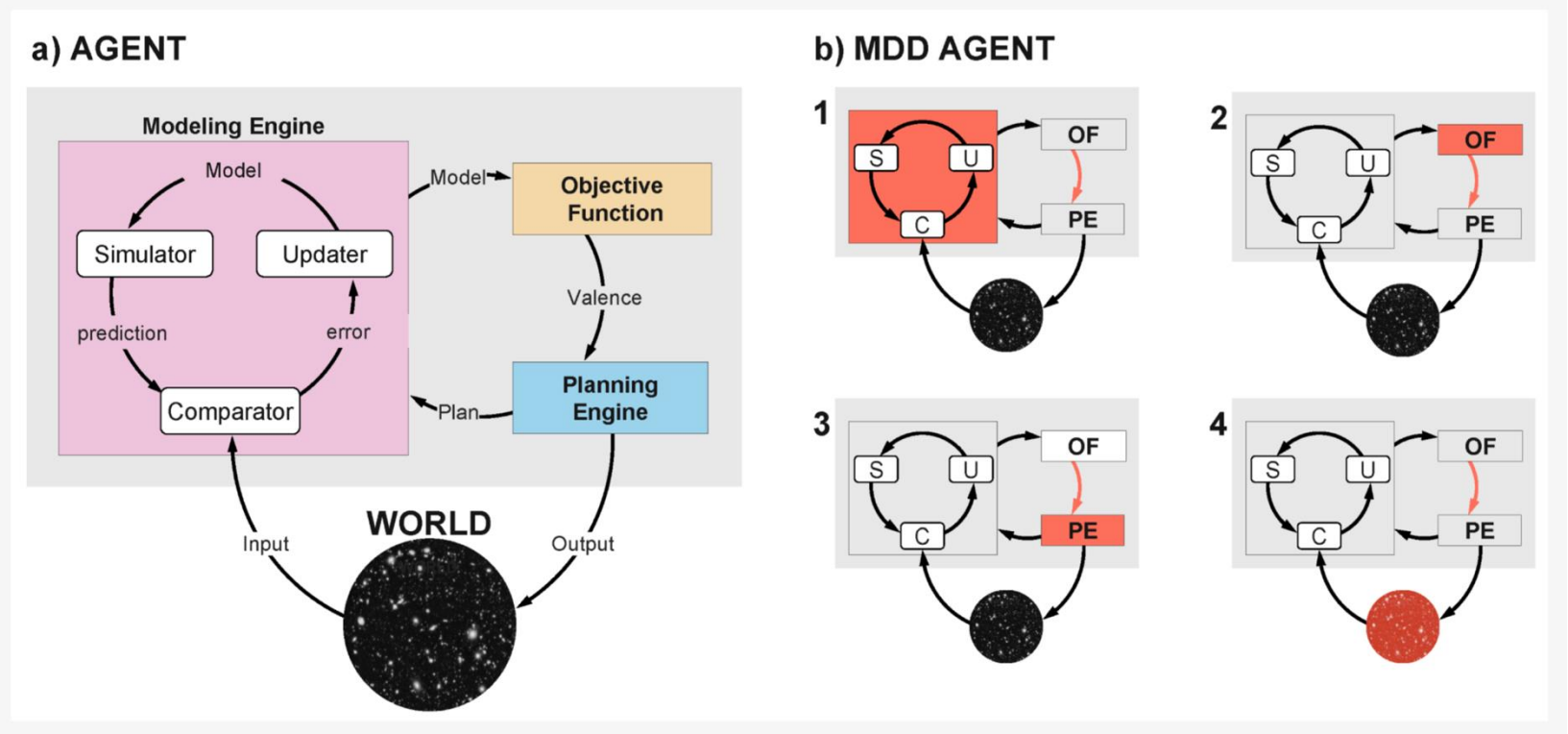


Multiple roads to a depressed agent

Definition 2.4 (Depressed Agent)**.** Depression is a pathological state in which the output value of the objective function (valence) of an agent is persistently low.

1. **The Modeling Engine:** inaccurate world models due to a dysfunction of the update module (model building errors, dysfunctional plasticity, etc.), i.e., models that fail to match input data, thus leading to high prediction errors and low valence evaluation in the Objective function. Since model updating requires evaluating errors in the **Comparator**, Comparator dysfunction may also lead to inaccurate world models.
2. **The Objective Function:** dysfunctional objective function, i.e., persistently returning abnormally low valence regardless of the input data. The evaluation of valence in the Objective function is very complex and requires the Simulator, which may also be at fault.
3. **Simulator:** dysfunction in the simulator will affect the Modeling engine, Objective function, and Planning engine.
4. **The Planning engine:** inability to find plans to increase valence. This may, in fact, produce plans that impact the World with negative consequences for the agent and further decreases of valence.
5. **The World:** objectively hostile world conditions[6], i.e., the agent receives input data consistent with genuine threats to its homeostasis.

Agent-types of depression



Ruffini, Castaldo et al 2024, Entropy

Depression: circuits and biotypes

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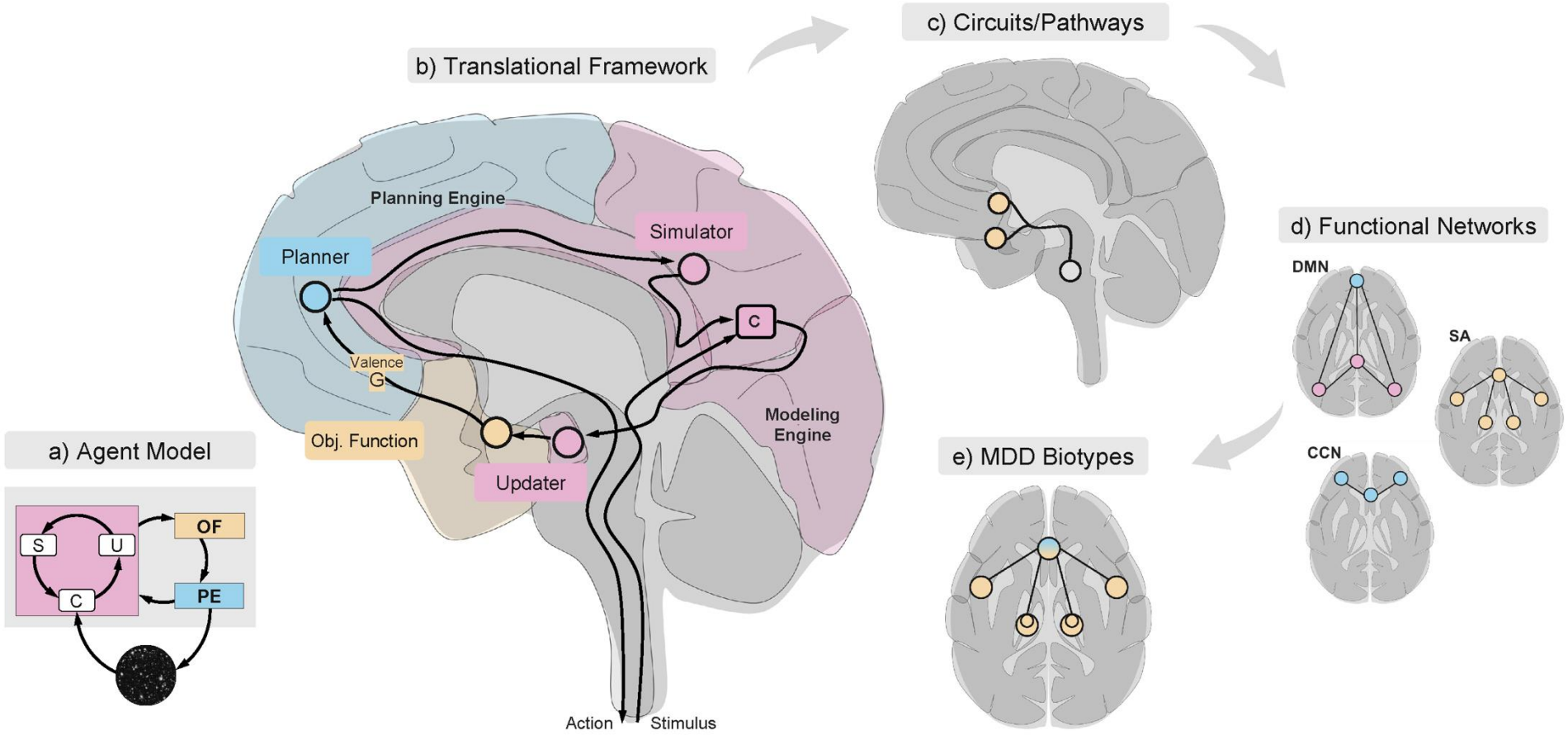

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KT in practice #3

1. Predictive processing theory / Active Inference (Friston)
2. Alzheimer's and Psychedelics
3. How do you connect a whole-brain model?

Open Access Perspective

Neural Geometrodynamics, Complexity, and Plasticity: A Psychedelics Perspective

by Giulio Ruffini [1,*], Edmundo Lopez-Sola [1,2], Jakub Vohryzek [2,3] and Roser Sanchez-Todo [1,2]

Cross-Frequency Coupling as a Neural Substrate for Prediction Error Evaluation: A Laminar Neural Mass Modeling Approach

Giulio Ruffini, Edmundo Lopez-Sola, Raul Palma, Roser Sanchez-Todo, Jakub Vohryzek, Francesca Castaldo, Karl Friston

doi: https://doi.org/10.1101/2025.03.19.644090

Fast Interneuron Dysfunction in Laminar Neural Mass Model Reproduces Alzheimer's Oscillatory Biomarkers

Roser Sanchez-Todo, Borja Mercadal, Edmundo Lopez-Sola, Maria Guasch-Morgades, Gustavo Deco, Giulio Ruffini

doi: https://doi.org/10.1101/2025.03.26.645407

Restoring Oscillatory Dynamics in Alzheimer's Disease: A Laminar Whole-Brain Model of Serotonergic Psychedelic Effects

Jan C. Gendra, Edmundo Lopez-Sola, Francesca Castaldo, Èlia Lleal-Custey, Roser Sanchez-Todo, Jakub Vohryzek, Ricardo Salvador, Ralph G. Andrzejak, Giulio Ruffini, the Alzheimer's Disease Neuroimaging Initiative

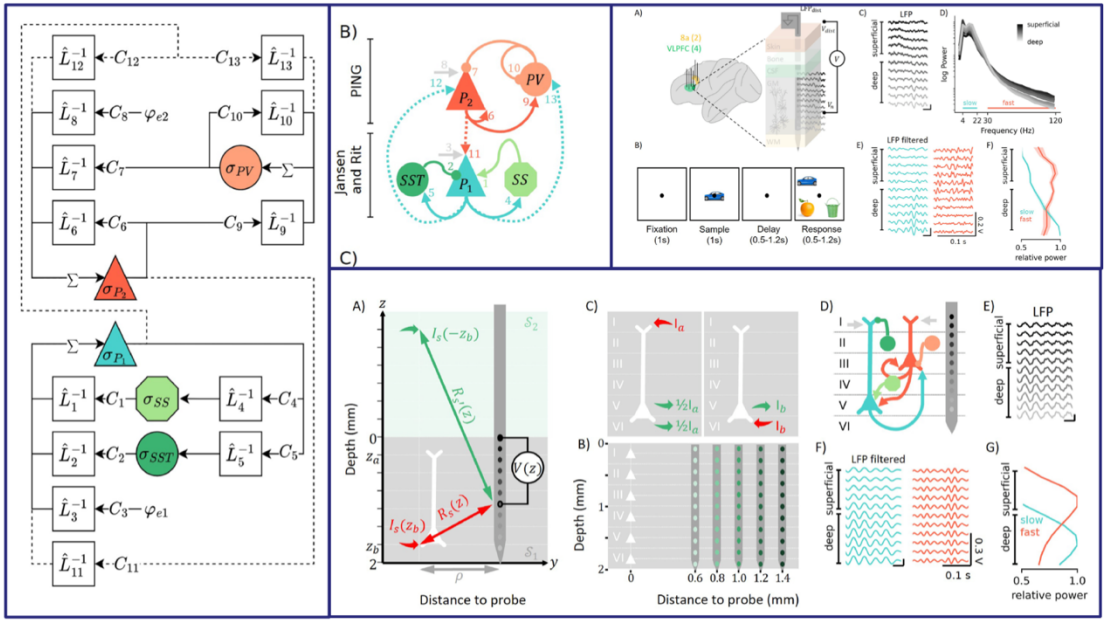
doi: https://doi.org/10.1101/2024.12.15.628565

A physical neural mass model framework for the analysis of oscillatory generators from laminar electrophysiological recordings

Roser Sanchez-Todo [a f], André M. Bastos [b], Edmundo Lopez-Sola [a], Borja Mercadal [a], Emiliano Santarnecchi [c], Earl K. Miller [d e], Gustavo Deco [f g h i], Giulio Ruffini [a j k]

Neurotwin Technology

- Biophysical model of a cortical column with laminar (superficial/deep) structure.
- Integrates alpha (slow) and gamma (fast) oscillatory subnetworks.
- Merges Jansen-Rit (alpha) and PING (gamma) models.
- Includes deep/superficial pyramidal cells (P1/P2), inhibitory interneurons (PV), and excitatory stellate inputs.



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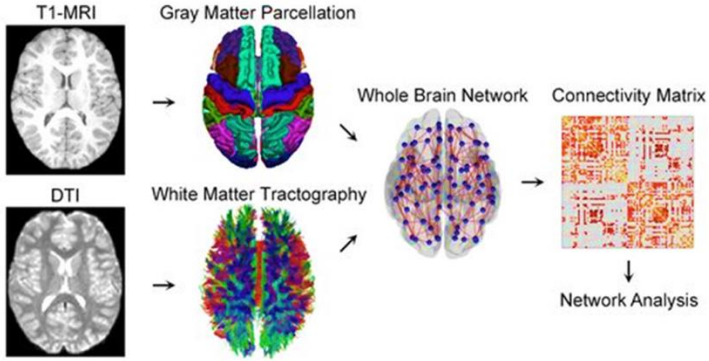
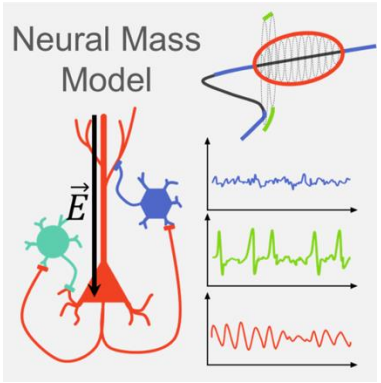
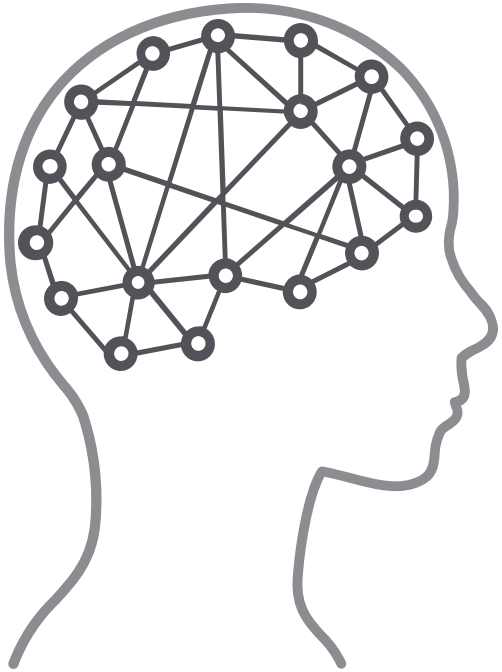
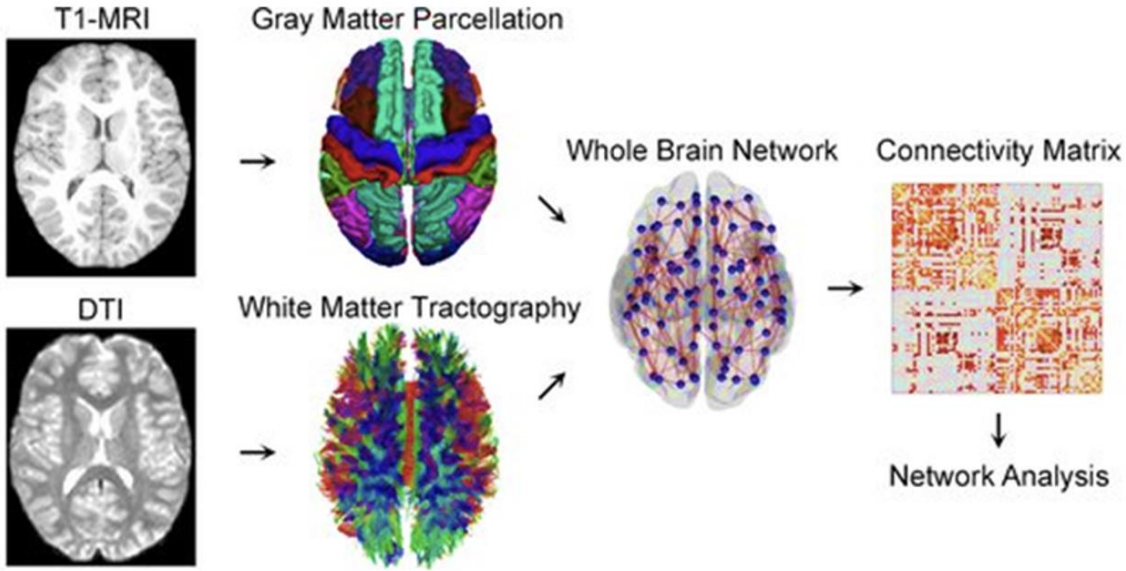
How do you wire a Whole-brain Model?

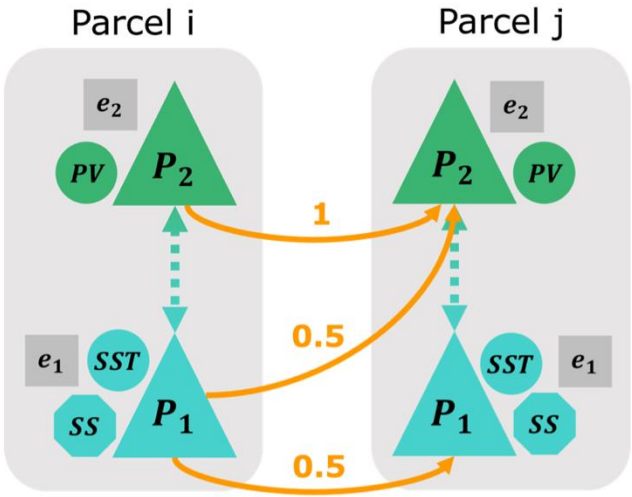






Undirected links? Where, precisely?





Gendra et al 2024

How do you connect the computational brain?

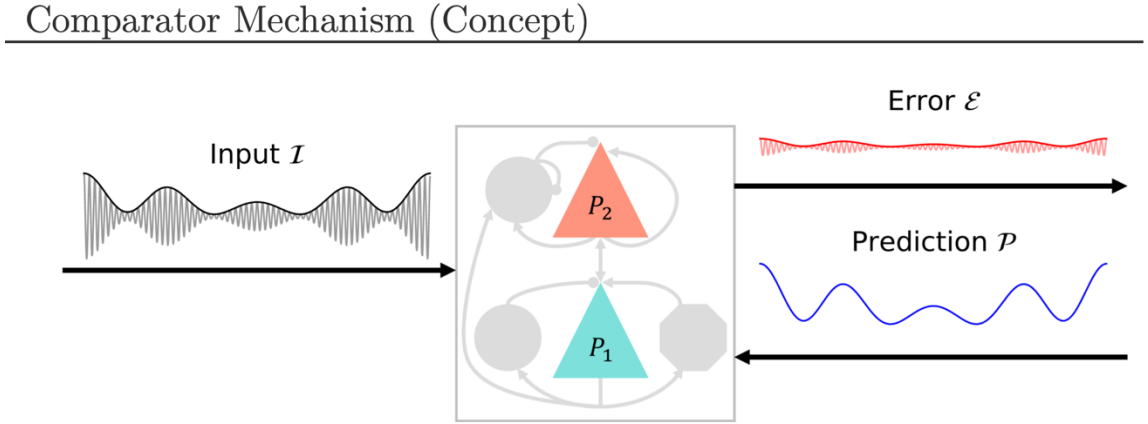
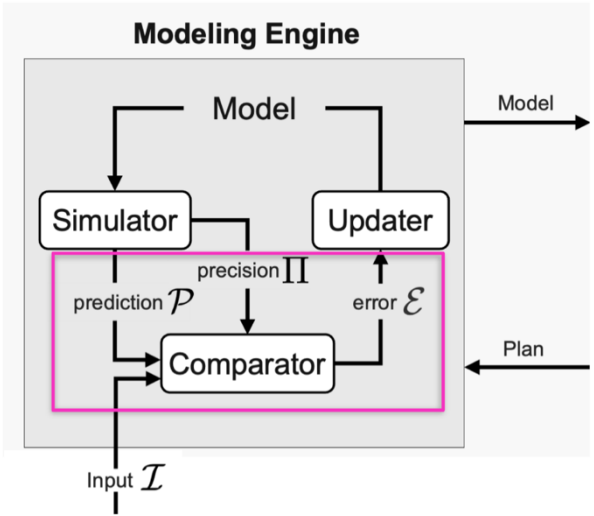


Figure: Conceptual diagram of the Comparator, illustrating how an input $I(t)$ (fast signal + envelope) and a prediction $P(t)$ (slow signal) combine to produce an error signal $E(t)$, with precision signals as envelopes controlling gain



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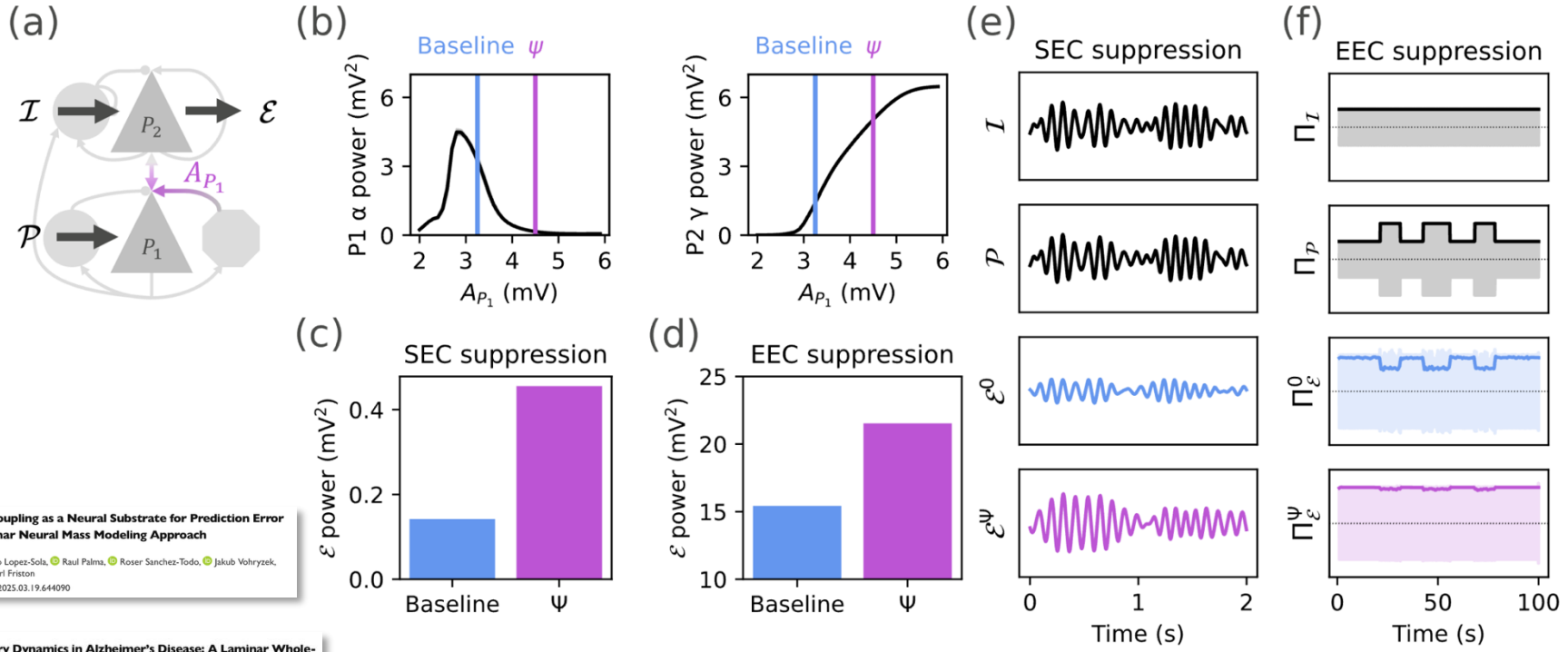
Effects of Psychedelics



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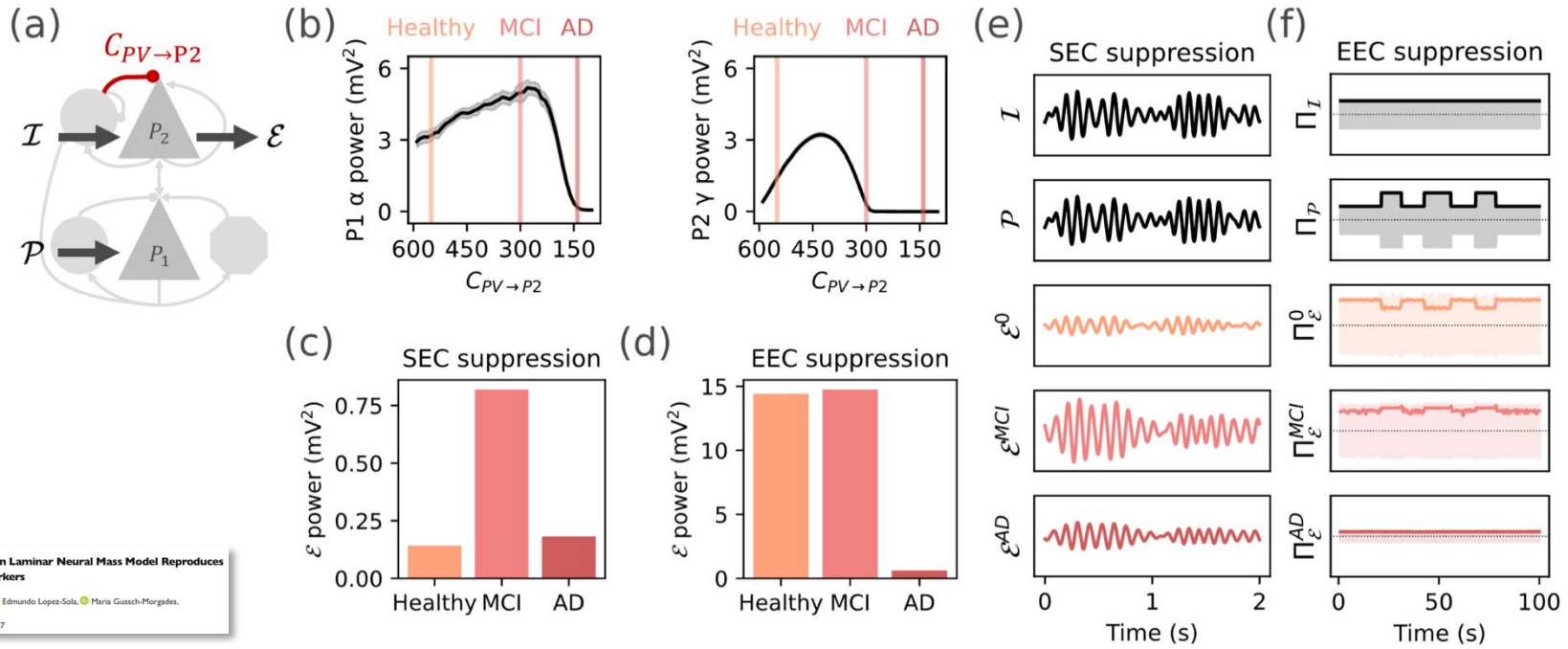
doi: https://doi.org/10.1101/2024.12.15.628565

The comparator on psychedelics

- **Result**: deep-layer α power was markedly reduced, and superficial γ power was elevated (disinhibition of fast activity).
- Even with a matching prediction, the error signal remained abnormally high – the model failed to attenuate prediction errors under this hyper-excitable condition.
- **Interpretation**: Weakened top-down constraints (reduced precision of priors) lead to unfiltered bottom-up signals and excessive prediction errors. This aligns with the REBUS model of psychedelics: **relaxed priors $\rightarrow$ an "anarchic" increase in error signals**.

Comparator under PV dysfunctions perturbations (AD and others)



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Perturbation: PV interneuron dysfunction AD model)

- **Moderate PV loss (early stage):** gamma power increases and prediction error signals are amplified (hyper-excitable cortex with excessive surprise signals).
- **Severe PV loss (late stage):** gamma oscillations collapse into slow-wave dominance (hypoactive cortex), and error signals are greatly attenuated or absent.
- **Interpretation**: Early interneuron dysfunction causes exaggerated prediction errors (**overestimating surprise**), whereas advanced dysfunction leads to a breakdown of error signaling (**failure to propagate errors**).

Conclusions and Future Directions

The Algorithmic Weltanschauung

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- There is Spirit/**Experience** and **Mathematics**
- Mathematics gives rise to an "**algorithmic soup**" of possibilities
- There are **persistent patterns** in the soup. Some we call Agents, driven by telehomeostasis.
- Each is the **Observer**
- Agents **coarse-grain** information to create **compressive models (Emergence)**.
- This leads to subjective **Valenced Structured Experience**
- This is **Observer's Reality**

The Algorithmic Weltanschauung: Key Concepts

* Lenia videoA credit https://www.youtube.com/watch?v=HT49wpyux-k

- **Pure** vs **structured** experience
- **Mathematics** (science of structure)
- **Algorithms/computation**
- **Algorithmic Soup**
- **Kolmogorov Complexity** and **Mutual Algorithmic Information**
- **Persistent** algorithmic **patterns**: **Agents** and **telehomeostasis** (*life*)
- **Coarse-graining** for **Emergence (useful compression)**
- **Modeling**, **compression**. **Simplicity**.
- Goals, Model structure + **Valence => Emotion**
- **Reported** vs. **unreported** experience => a crucial conceptual element

What people normally call consciousness *is here* ***"reported (to self or others) structured experience"***

Future

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Demonstrate how to **computationally evolve agents**.

> KT conjecture: *Under the right conditions, persistent patterns are unavoidable in a computational soup if we wait long enough.*

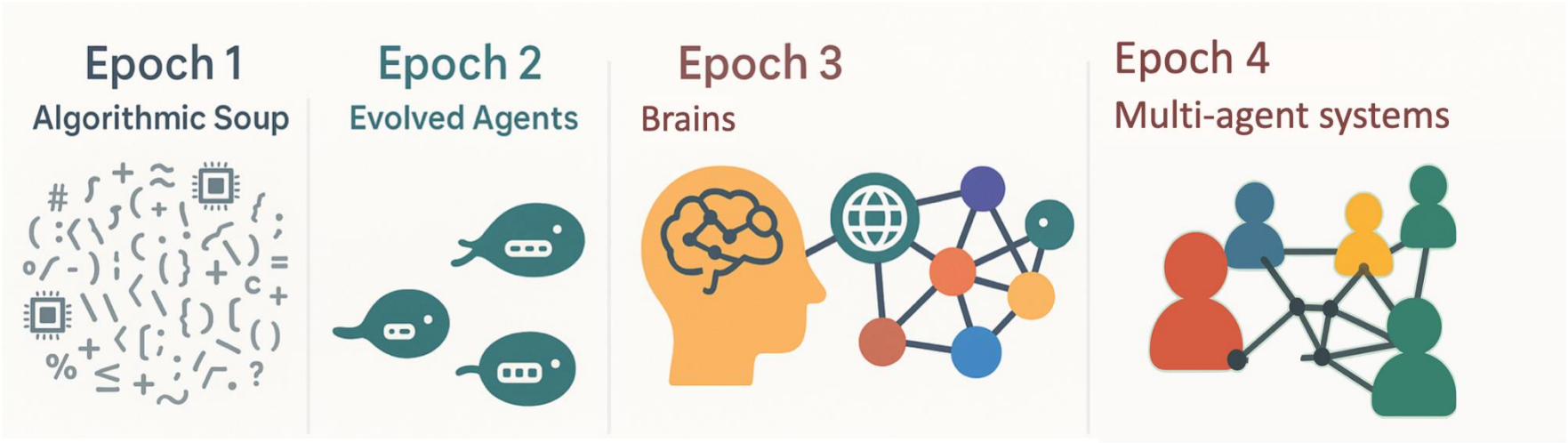
Are there persistent patterns other than **agents**?

Devise methods to **detect** an **agent** through its behavior, inner dynamics or structure

Associate the structure of dynamical reduced manifolds with 1P and 3P data

Map the neurobiology of agenthood

The Algorithmic Weltanschauung



Summary

1) We focused on the requirements for *structured experience*
2) Reality is a model, KT is well aligned with Idealism
3) Tracking the world requires computation to run models
4) This constrains brain structure and also collapses dynamics to reduced manifolds, the characteristics of which are good candidates for “neural correlates of structured experience (NCSE)”
5) Emotion is defined by combining structured experience (model structure) and Valence (Objective function)
6) This framework can guide computational neuroscience, bringing together 3P and 1P perspectives in neuropsychiatry

Thanks to my collaborators and the Neuroelectrics team, and to my EU funders (HIVE, Luminous, Neurotwin, Galvani, Luminous projects).
Special thanks to the EU FET program.

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UNIVERSITÉ DE RENNES 1

- Whole-brain Personalization Methods
- Whole-brain Optimization methods
- Clinical study design and analysis

The project is investigating the impact **weak electric fields** have on the physiology of neurons and neural networks. The key objective is to understand if these electric pulses can improve the patient-specific **epileptogenic network**.

Funded by the European Union

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BRAIN STIMULATION Translational Laboratory

UPPSALA UNIVERSITET

PABLO DE OLAVIDE

IADO

- Laminar Neural Mass Model
- Whole-brain Model
- Analysis Clinical Studies

The **aim** is to develop **advanced brain models** that characterize individual pathology and predict the physiological effects of **tES** and use them to design optimal **brain stimulation protocols** in Alzheimer's disease.

Funded by the European Union

Special Issue

The Mathematics of Structured Experience: Exploring Dynamics, Topology, and Complexity in the Brain

Guest Editors

Dr. Giulio Ruffini
Dr. Johannes Kleiner
Dr. Ryota Kanai

Deadline

20 March 2026

Thank You

Scan me!

Dr. Giulio Ruffini
Co-founder & CTO
Starlab /Neuroelectrics

Barcelona, July 7, 2025
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