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Electromagnetic field theories of consciousness and
neurophenomenology of N,N-Dimethyltryptamine (DMT):
How can they inform each other?

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Abstract

This thesis examines the intersection of electromagnetic field (EMF) theories of consciousness and the neurophenomenology of N,N-Dimethyltryptamine (DMT), exploring their potential to inform each other. EMF theories propose that consciousness arises from the dynamics of electromagnetic fields in the brain, offering natural insights into the binding problem and the boundaries of conscious experience. Most theories suggest that existing models of consciousness may not be incompatible with EMF-based approaches but instead represent subsets of a broader electromagnetic framework.

Psychedelic experiences - particularly those induced by DMT - challenge traditional neuroscientific models of consciousness. The neurophenomenology of DMT, especially regarding boundary problems of consciousness, may be better explained by EMF theories than by traditional neural spike code approaches. Notably, the topological solution to the boundary problem proposed by Gómez-Emilsson & Percy (2023) offers a promising avenue for empirical validation using techniques such as transcranial magnetic stimulation (TMS) and other EMF-based methods. Additionally, integrating connectome harmonic decomposition by Selen Atasoy et al. (2016) with EMF measurements could provide further insights into the harmonic organisation of brain states and its implications for consciousness. Furthermore, neurophenomenological research on non-ordinary states of consciousness, particularly those induced by DMT, can provide valuable insights for EMF theories. Given that DMT induces profound alterations in brain signalling, perception, and qualia, studying its effects may help elucidate the mechanisms underlying the construction and deconstruction of our reality.

This thesis concludes that a field-based ontology of consciousness presents a promising direction for future research. Employing neurophenomenological methods and harmonic decomposition techniques in the study of non-ordinary states of consciousness, combined with an openness from academia to re-evaluating or challenging established models and conventional theories, may contribute to closing the explanatory gap in consciousness research further.

Zusammenfassung

Diese Masterarbeit untersucht die Schnittstelle zwischen Theorien des elektromagnetischen Feldes (EMF) des Bewusstseins und der Neurophänomenologie von N,N-Dimethyltryptamin (DMT) und erforscht ihr Potenzial, sich gegenseitig zu informieren. EMF-Theorien postulieren, dass Bewusstsein aus den dynamischen Wechselwirkungen elektromagnetischer Felder im Gehirn entsteht und bieten eine natürliche Erklärung für das Bindungsproblem sowie für das Grenzproblem des Bewusstseins ('boundary problem'). Die meisten bestehenden Bewusstseinstheorien stehen möglicherweise nicht im Widerspruch zu EMF-basierten Ansätzen, sondern stellen vielmehr Teilaspekte eines umfassenderen elektromagnetischen Modells dar.

Psychedelische Erfahrungen - insbesondere solche, die durch DMT induziert werden - stellen traditionelle neurowissenschaftliche Modelle des Bewusstseins infrage. Die Neurophänomenologie von DMT, insbesondere im Hinblick auf verschiedene Grenzprobleme des Bewusstseins, könnte durch EMF-Theorien besser erklärt werden als durch klassische neuronale Spike-Code-Ansätze. Insbesondere die von Gómez-Emilsson & Percy (2023) vorgeschlagene topologische Lösung des Grenzproblems bietet erstmals einen theoretischen Ansatz und vielversprechende Möglichkeiten für eine empirische Überprüfung mittels transkranieller Magnetstimulation (TMS) und anderer EMF-basierter Methoden. Darüber hinaus könnte die Integration der Connectome Harmonic Decomposition von Selen Atasoy et al. (2016) mit EMF-Messungen tiefere Einblicke in die harmonische Organisation von Gehirnzuständen und deren Implikationen für das Bewusstsein liefern. Zudem kann die neurophänomenologische Erforschung nicht-ordinärer Bewusstseinszustände - insbesondere solcher, die durch DMT induziert werden - wertvolle Erkenntnisse für EMF-Theorien liefern. Da DMT tiefgreifende Veränderungen in der Gehirnsignalverarbeitung, der Wahrnehmung und der Qualia hervorruft, könnte die Untersuchung dieser Effekte dazu beitragen, die Mechanismen der Konstruktion und Dekonstruktion von Realität besser zu verstehen.

Diese Arbeit kommt zu dem Schluss, dass eine feldbasierte Ontologie des Bewusstseins eine vielversprechende Richtung für zukünftige Forschungen darstellt. Der Einsatz neurophänomenologischer Methoden und Connectome Harmonics zur Untersuchung nicht-ordinärer Bewusstseinszustände, kombiniert mit einer Offenheit der Wissenschaft gegenüber der Neubewertung oder Infragestellung etablierter Modelle und konventioneller Theorien, könnte dazu beitragen, die Bewusstseinsforschung voranzubringen.

Abbreviations

abbreviations of EMF theories are not listed here

ANS: Autonomic nervous system

BCI: Brain-computer interface

C: Consciousness (this is only used as an abbreviation in tables and figures)

CHD: Connectome Harmonic Decomposition

CFC: Cross-frequency coupling

CSF: Cerebral spinal fluid

DMT: N,N-Dimethyltryptamine

EEG: Electroencephalogram

EM: Electromagnetic / electromagnetism

EMCC: Electromagnetic correlates of consciousness

EMF: Electromagnetic field

DIED: Drug-induced ego-dissolution

fMRI: Functional magnetic resonance imaging

HRE: Heart rate entropy

LSD: Lysergic Acid Diethylamide

MEG: Magnetoencephalography

MCC: Measurable correlates of consciousness

NDE: Near-death experiences

IIT: Integrated Information Theory

IV: Intravenous

PAC: Phase-Amplitude Coupling

PEC: Phase to Envelope Coupling

PNS: Parasympathetic nervous system

SNS: Sympathetic nervous system

TIC: Temporally Integrated Causality

TMS: Transcranial magnetic stimulation

QRI: Qualia Research Institute

1PP: First person perspective

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1. Introduction

Explaining consciousness has been one of the biggest mysteries of human existence. In over 3,000 years of documented thinking, not much progress has been made in finding a satisfying definition. The ever-advancing increase in scientific disciplines has not made it easier, as each field has come up with its own definitions. This is especially relevant in the field of cognitive science. This thesis is approaching the topic of consciousness from a neuroscientific, philosophic, physical, psychological and phenomenal side.

Traditional neuronal spike code theories of consciousness argue that consciousness emerges from the firing rates and network connections of these neuronal spikes (what is called 'Emergentism'). In contrast, electromagnetic field (EMF) theories propose that consciousness is not just a byproduct of neuronal activity but is actively shaped by the brain's electromagnetic (EM) field. While the spike code approach focuses on discrete, localised signals, EM field theories focus on a field-based ontology of consciousness. While critics argue that electromagnetic theories lack empirical support compared to well-studied spike-based mechanisms, proponents suggest that they may be better suitable to explain the binding and/or boundary problems of consciousness.

„Psychedelics are for the mind/psychiatry what the telescope is for astronomy or the microscope is for biology “ (Grof, 2008)

Psychedelic research, ever since legislation loosened up in the late 2000s, is experiencing a comeback after 40 years of prohibition. In the last 15 years, institutions like Johns Hopkins University in the United States, Imperial College London, and MAPS (Multidisciplinary Association for Psychedelic Studies) have reignited interest, with studies showing psilocybin's potential for treating depression and MDMA's effectiveness for PTSD. Today, psychedelics are not only being reconsidered for medical use, but they are also being explored as tools to expand human consciousness and understand the nature of the mind in research settings. DMT (N,N-Dimethyltryptamine) has been traditionally used in ayahuasca, a psychoactive brew prepared by indigenous Amazonian cultures for spiritual and healing ceremonies for hundreds of years or even longer. The brew combines DMT-containing plants with MAO inhibitors, allowing for an extended psychedelic experience, often described as deeply introspective and transformative. In recent years, scientific research on DMT has gained momentum, with studies exploring its potential for treating depression as well as its role in understanding consciousness and near-death experiences (e.g.: Timmermann et al., 2018; Timmermann et al., 2024).

The aim of the thesis is to address EMF theories of consciousness and neurophenomenology of N,N-Dimethyltryptamine (DMT) and scrutinise both in light of each other. It opens with a short discussion of the terminology of 'consciousness', focusing on the boundary problem of consciousness, which pertains to the difficulty of determining where consciousness begins and ends on an intra- and interindividual level. Afterwards, a systematic review of electromagnetic

field and resonance theories of consciousness highlights the growing importance of implementing physical concepts in this field of research and how selected key concepts can potentially contribute to the so-called boundary problem of consciousness. The next section summarises the neurophenomenology of N,N-Dimethyltryptamine (DMT) experiences. In the last part, the findings of the two systematic reviews are synthesised and contrasted, providing a possible empirical framework of testing the proposed EMF theories with psychedelic research methodologies and addressing if the neurophenomenological findings can potentially be explained by EMF theories. To conclude, this thesis addresses if DMT research can benefit from EMF theories and vice versa, if EM field theories can benefit from conducting research with DMT.

1.1. Terminology

In order to write a thesis about consciousness, it is mandatory to first define what is meant with the term 'consciousness' and how it is distinct from other definitions. Too often is the term consciousness being misused in scientific papers or in public discussions, people disagreeing with each other not noticing that they are in fact, not using the same definition for the word. The most common misconception one encounters in the literature is equating the term consciousness with self-awareness (Seth, 2021). Arguments and explanations of 'anaesthetics leading to a loss of consciousness' (Alkire et al., 2009) or 'of losing consciousness while sleeping' (Tononi et al., 2024) are widely accepted and used even by leading experts in these fields. While there is truth in these statements in the sense that the qualia of experience differs in these states compared to being awake, even though brain wave activity during dreaming is remarkably consistent to that of being awake (Nir & Tononi, 2011), to call it 'non-conscious' or 'loss of consciousness' can be misleading for developing a theory of consciousness. If we defined these states as '(self)-awareness' or as 'loss of (self)-awareness', many discussions among scientists would be deemed redundant. In the 20th Century, the term *unconscious* was used by doctors and psychiatrist like Sigmund Freud or Carl Jung, emphasising that there is a distinction between consciousness and unconsciousness. The *unconscious*, in their sense has some kind of agency over one's beliefs or even behaviour - it is not equated with non-consciousness. Since this can lead to confusion, I will therefore use the term 'subconscious' if I refer to processes under the threshold of awareness. Two other distinctions are worth mentioning here, the distinction between 'access & phenomenal consciousness' as well as the distinction between 'primary & secondary consciousness'. The first distinction goes back to Block (2005), *phenomenal consciousness content* is what differs between an experience of e.g. seeing red vs. green whereas *access conscious content* is about the availability of information for cognitive functions such as reasoning, decision-making, and guiding actions. This type is essentially about being aware of information and having access to it. The second distinction has similarities to the previous distinction. *Primary consciousness* being the basic level of awareness that allows organisms to experience sensory information on a moment to moment basis. It involves immediate, non-reflective experience but does not include self-awareness or complex thoughts about other than the present. *Higher-order or secondary consciousness* involves a higher level of cognitive processing, including the ability to reflect on one's own thoughts and an

expansion of the time horizon by including distant past and future (see 'cognitive lightcone' by Levin, 2019). It is associated with self-awareness and more complex forms of mental representation, such as understanding one's role in social contexts or contemplating abstract concepts. Primary consciousness is still also always present when secondary consciousness is active (Edelmann, 2003).

Therefore, it is crucial to always dissect and differentiate between different definitions when addressing consciousness:

(Self-)awareness, agency, subconscious, non-conscious and ultimately, phenomenal experience.

I want to briefly mention the idea of defining consciousness in terms of information processing as it has gained significant attention with the development of *Integrated Information Theory* (IIT) (Tononi, 2012). While this definition holds merit, it raises a philosophical issue: a computer is capable of processing vast amounts of information, even more efficiently than a human brain, yet most people still do not consider computers to be conscious in the way humans are. This discrepancy highlights the challenge of equating consciousness solely with information processing, as it involves additional dimensions. As stated, the science of consciousness is hard to grasp, due to many different definitions of the word itself. In this thesis, the word *consciousness* is thus being used in the sense of a subjective experience, it is equated with qualia, a first person perspective (1PP), or what Nagel likes to call: "*What it is like to be x (a bat)*" (Nagel, 1974). Whenever the word consciousness is thus used in this thesis, it refers to this 1PP account of phenomenal experience, all the while remaining open to the possibility that there might be a spectrum of consciousness, with differences in degree.

1.2. Different Problems of Consciousness Theories

1.2.1. The hard & soft problem of consciousness

Philosophy of mind is deeply concerned with two central challenges introduced by David Chalmers (1995): the so-called *soft (or easy) problem* and the *hard problem of consciousness*, which reframe the classical mind/body problem. The soft problem focuses on understanding how specific processes influence behaviour and which processes give rise to particular functions, such as our attention: how neural processes enable us to focus on specific stimuli, filter out irrelevant information, and allocate cognitive resources. In contrast, the hard problem of consciousness examines how subjective experience arises from physical matter, posing the profound question of why certain configurations of matter result in awareness. From an evolutionary perspective, this issue becomes especially intriguing: why and when did self-awareness emerge as a necessary feature for natural selection? Alternatively, could this simply be a byproduct of certain physical structures being organised in specific ways?

1.2.2. The binding problem / combination problem

These problems address the difficulties that disciplines encounter when it comes to explaining how a unified perception or in the latter case, how a unified experience of qualia emerges out of different sensorial inputs. The binding problem can be categorised into three subcategories:

- Feature / intra-modal binding: How are different sensory features of an object combined into one coherent perception? The brain receives information about shape, texture and colour of an object and integrates this information into an unified category.
- Cross-modal binding: addresses how input from different sensory modalities (such as f.e vision and sound) binds into one perceptual event.
- Object binding: How does the brain differentiate between different objects in its perceptual field? How are the necessary boundaries between objects drawn?
- Phenomenal binding: addresses how all different phenomenal states in a moment can be experienced as one single experience (also called 'combination problem').

Gestalt (German word for shape, figure or pattern) psychologists were the first ones to address the now called binding problem. They introduced the idea that objects are perceived holistically rather than by individual properties with examples like musical notes only getting their value by perception of a melody or words being perceived in their entirety rather than as a collection of letters (McFadden, 2021). These lines of reasoning laid the groundwork for conceptualising phenomenal experiences as functions of a field, leading to the development of the first field theories. This approach was pioneered by Wolfgang Köhler, one of the founders of Gestalt psychology, and later expanded upon by philosopher Karl Popper and neuroscientist Benjamin Libet. I will explore these contributions further in section 2.2.2.

The combination problem addresses the broader issue of how a unified experience arises from disparate sensory modalities - for example, the combined qualia of seeing a red apple. It is particularly significant for panpsychist positions and is conceptually related to the binding problem but shifts the focus away from the mechanisms underlying individual perception (Chalmers, 2017). Instead, it. While various theories tackle the feature binding problem by explaining how the brain integrates sensory features, they often fall short of explaining the overall unity of the accompanying phenomenal experience. Panpsychists further complicate this issue by positing that everything, down to molecules and even atoms, possesses a first-person perspective (1PP). The challenge then becomes explaining how the aggregation of countless individual 1PPs combines to form a unified, human 1PP. Computational theories like Integrated Information Theory (IIT) suggest that the brain predicts objects using learned patterns and established priors, thereby addressing feature binding, but they fail to account for the mechanisms that produce the overall unity of a 1PP. Hunt and Schooler (2019) refer to the combination problem as 'the easy part of the hard problem' and propose a potential solution through their 'General Resonance Theory' (see section 2.2.5.). The boundary problem on the other hand, discusses how our

experience appears to have clear subjective limits, raising the question of why consciousness seems to be confined to a particular individual or point of view.

1.3. The boundary problem(s)

In this thesis I want to focus especially on the boundary problem of consciousness and how electromagnetic field theories or psychedelic research findings are addressing this problem. Most scientists focus on the combination/binding problem, all the while forgetting that once this is solved, the boundaries of these combination(s) are still to be defined. Solving the combination problem is not enough if we cannot establish clear boundaries between certain 1PPs. How hard this boundary really is remains questionable, as insights into phenomenal experiences such as group experiences (Young et al., 2022) or psychedelic states (see section 3.5.) indicates possibilities that these boundaries are able to be fuzzier than mainstream research is currently considering. Gomez-Emilsson & Percy (2023), emphasise the importance of addressing the boundary problem and define five subproblems of the boundary problem:

- *The hard boundary problem*: discusses the boundary between a 1PP and the outside, material world. Our phenomenal field appears to be enclosed by an absolute boundary. This does not deny different levels of self-awareness, just as during non-aware experiences like dreamless sleep or anaesthesia, the boundary still exists and it is rather the content within that boundary that dissipates. Panpsychism argues that consciousness is to be found in all material things. If this holds true, how does our individual 1PP come about then? Even if the hard boundary is to be claimed an illusion, the question of the underlying mechanisms of these illusory boundaries as well as the evolutionary reason for such an illusion remains nevertheless.
- *The lower-levels boundary problem*: What creates the boundary between our perceived 1PP experience and lower levels of our organism? If our 1PP arises out of a conjunction of a multi-part mechanism, how are the boundaries developed at this meso-level of experience. How come we don't experience a 1PP of our immune system operating within our bodies? What is the mechanism that pushes the 1PP out of the molecular or subatomic level up to the human level but not further. Research conducted by molecular biologist Michael Levin shows that bioelectrical signals play a crucial role in shaping the organisation and function of biological systems. He further argues that bioelectrical field processes contribute to the collective intelligence of cellular networks and thus offers a potential mechanism - like bioelectrical fields - or how higher-order processes like cognition and possibly consciousness might emerge and remain bounded at the meso-level of experience (Levin, 2019). Michael Levin's research will be discussed in more detail in the following sections.
- *The higher-levels boundary problem*: Similar to the lower-levels problem, this problem addresses why the 1PP is precisely at the meso-level of experience and not part of one bigger 1PP. As many different 1PPs come together during soccer games or singing choirs, the resulting

1PPs do act in causal synchrony (Young et al., 2022). While there is research addressing the so called macro-consciousness or group phenomena, the different single 1PP's appear to still exist. Are there phenomenal experiences existing at higher levels as well? How are the meso-level boundaries of experience then established?

- *The private boundary problem*: Our 1PP is separate from the outside world and also from other people's 1PP. What mechanism makes this boundary? How come our experience is not merging with other people's experience when being sufficiently in sync or resonance with them? With Elon Musk's company Neuralink succeeding to implant the first brain computer interface (BCI) chip into a human brain in early 2024, the topic of merging with other's experience is slowly shifting from science-fiction towards getting actual scientific meaning, emphasising that the private boundary problem could only be a technical barrier yet to overcome rather than an absolute biological one. Other phenomenal experiences, such as romantic couple brain synchronisation while sleeping, also point to this boundary being rather fuzzy than absolute (Shao et al., 2023).
- *The temporal boundary problem*: How does our 1PP persist over a certain amount of time? Our normal experience is typically of a single bounded entity persisting over time. How are moments of experience put together to form a continuous experience over time? This becomes especially relevant considering the perceived disruptions in temporal congruency of self during sleeping, moments of unawareness or mind wandering. The temporal boundary problem could also be described as a form of binding problem in 4D spacetime, where the brain integrates and synchronises information over time in 4D spacetime to create a unified perception of reality.

Whether hard or fuzzy, boundaries to our experience do exist with *phenomenal certainty*, which does not mean that they could not be phenomenally interrupted. Especially when it comes to reports of non-ordinary states of consciousness, particularly those of psychedelic experiences, many of these boundaries are said to feel like being dissolved, being accompanied by a feeling of oneness and dissolution of self (Milliere, 2017; Lawrence et al., 2022).

1.4. Common approaches to consciousness

While neurobiological theories of consciousness focus on neuronal brain activity as the foundation for conscious experience, computational theories like *Integrated Information Theory* (IIT), one of the most recent theory of consciousness (which is simultaneously also a fundamental theory of consciousness) developed by Tononi (2004, 2012), suggests that consciousness arises from the integration of information within a system. Details about a categorisation of the most common approaches can be found in the table 1 below. While most focus in research is put on neurobiological and computational theories, this thesis will focus on electromagnetic field theories.

Table 1: Categorisation of different approaches to consciousness (self-made)

Theories / Disciplines	Philosophical Standpoint	Methodology	Kind of 'consciousness' being addressed	What problem of consciousness is being addressed?
Neurobiological theories	Materialism Reductionism	The spike code approach	Self-awareness. Perception	Binding problem
Computational theories	Functionalism	Algorithmic models, predictive coding	Mostly agency - IIT also touches upon 1PP	The explanatory gap (i.e. hard problem)
Higher-order theories of consciousness	Representationalism	Functional & cognitive neuroscience	Self-awareness Metacognition	Higher-order problem: how is self-awareness reached?
Fundamental theories of consciousness: IIT	Panpsychism	Philosophically, IIT & EMF theories	1PP	Inverting the hard Problem
Quantum-mechanical theories of consciousness	Physicalism, Idealism, Dual-aspect monism: both mental and physical aspects emerging from a single fundamental substrate.	Quantum coherence, entanglement	1PP, Agency	Measurement problem, Combination problem
Electromagnetic field theories of consciousness	Physicalist Field Theories	Theoretically & EM field measurements: TMS, MEG, EEG, fMRI	1PP, Self-awareness	Binding problem Boundary problem

2. Systematic Review of EM-field theories

As we go deeper into the topic of EM-field theories, let's first briefly explain two physical concepts that many of these theories are basing their arguments on: electromagnetism and resonance.

2.1. Electromagnetism

After Newton and Einstein, Maxwell is said to be the most influential physicists of our time. In 1865, he formulated four equations ('four Maxwell equations'), explaining the interdependency of electromagnetism and electricity and unifying them into one *electromagnetic field*. These equations are part of the four fundamental forces of the standard model of particle physics: weak and strong force, gravity and electromagnetism (Hales & Ericsson, 2022). Put in simple terms, Maxwell's equations describe how electric charges produce magnetic fields (equation I) and that magnetic field lines are closed loops and there is always both a north as well as a south pole (Gauss' law - equation II). Furthermore, Faradays law (equation III) describes how changing magnetic fields can produce electrical fields. Faraday had already established a relationship of these two principles, but he was missing the mathematical equations to put the relationship into numerical terms. The last equation (equation IV) - the Ampere-Maxwell law - shows that changing electrical fields produce magnetic fields. Together, the last two equations describe the

interrelationship of electrical and magnetic fields and a circularity. Through these equations, Maxwell introduced the idea of fields as a primary concept, shifting physics from a purely material-based view to involving field-based interactions, based on mathematical equations. It required a major shift in perspective for physicists of the late nineteenth century to adapt to this ontology. As Dyson noted in 1870 (Longair, 2015, p. 18):

"Maxwell replaced the Newtonian universe of tangible objects interacting with one another at a distance by a universe of fields extending through space and only interacting locally with tangible objects. The notion of a field was hard to grasp because fields are intangible."

The interactions of these principles were long considered to be supernatural forces, until they were finally put into scientific context in the 19th century, paving the pathway to a vast array of new physical concepts as well as modern applications. Electromagnetism, as it turns out, is fundamental to physics, chemistry and biology, as the interaction of electrons and nuclei depend on electromagnetic forces - which means that the formation of chemical elements and in turn also of molecules is dependent on these forces. Molecular biologist Micheal Levin emphasises the importance of including electromagnetism into the science of biological cells, as it seems to be crucial for the interaction of cells and as various applications of medical advancements can be accomplished through using electromagnetic field alterations (Levin, 2014).

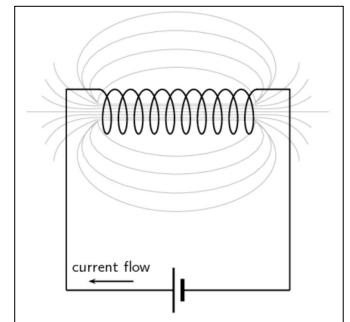


Figure 1: The magnetic field around a solenoid (siyavula.com.).

The circular alternation between electric and magnetic fields leads to electromagnetic energy propagating in forms of waves travelling at the speed of light, unifying the fields of electrics, magnetism and optics. These waves are now known as being on a spectrum ranging from radio waves, microwaves, infrared, visible light, ultraviolet, x-rays up to gamma rays (see figure 1.1.). The discovery of electromagnetic waves is fundamental to many everyday technologies. Different wavelengths have unique properties that enable a wide range of applications, such as electricity generation through transformers and generators, induction cooktops, microwaves, and medical devices like X-ray machines and fMRIs. Most notably, electromagnetic waves are essential for telecommunication, facilitating wireless data transmission through radio signals, cellular networks, Wi-Fi, and Bluetooth. Living on Earth means being constantly surrounded by electromagnetic waves and fields, from the sunlight we experience to the signals used by our phones. Ultimately, everything can be considered an EM field (Hales & Ericsson, 2022). A visible demonstration of an electromagnetic field acting in motion are auroras, mostly seen in the northern or southern part of the world, as a magnetic field is the strongest at the poles. Through solar wind particles interacting with the earth's magnetic field they make this field visible to the human eye in a dynamic and colourful way. Auroras themselves are not electromagnetic fields, but they are the closest visible phenomenon of EM field interactions. Electromagnetism in neuroscience will be

discussed in the following sections. I want to briefly mention the 'Lorenz force': it is the force experienced by a charged particle when it moves through an electromagnetic field. The electric field pushes the charge in a straight line, while the magnetic field deflects it in its loop, depending on the particle's velocity and the direction of the magnetic field. It causes charged particles to spiral in magnetic fields and is the principle behind technologies like electric motors. The strength and direction of the force depend on the charge, the speed of the particle, and the orientation of the fields.

The distinction between materialism and physicalism is important, as the two are often conflated. Fields are physical even though they are not necessarily material. Immaterial fields, such as electromagnetic or gravitational fields, are fundamental to physics and should not be confused with metaphysical beliefs. While all material substances are physical, not everything physical is necessarily material.

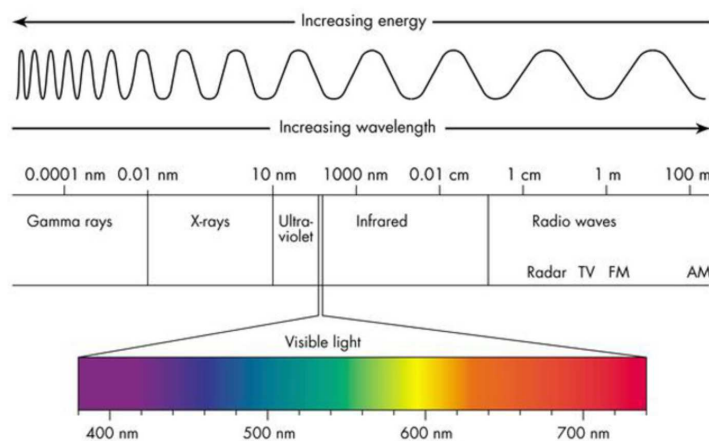


Figure 1.1.: The electromagnetic spectrum. Visible light only accounts for a fraction of the spectrum (Online Learning College, 2022).

Electromagnetic Radiation

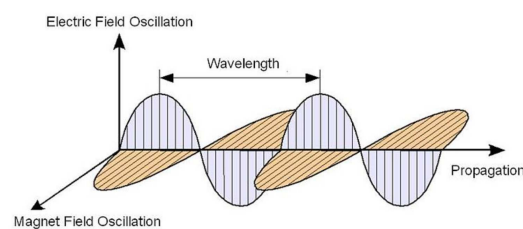


Figure 1.2.: Electromagnetic radiation visualised (Wikipedia).

2.1.1. The concept of resonance

Every object has a natural frequency - its 'Eigenfrequency'. Resonance occurs when an external frequency aligns with the natural frequency of a system. This causes the system to oscillate with a bigger amplitude, amplifying the original natural frequency. The concept of resonance was already important before electromagnetism was discovered, as it affects everything around us, touching upon any form of waves, be it sound, electromagnetic, mechanical, water, seismic or even matter waves, the latter describing quantum mechanical properties of particles. The term comes from the Latin word '*resonare*', which was used particularly in the field of acoustics. It originally described the phenomenon where musical instruments began to vibrate on their own when exposed to certain tones. Galileo described the mechanism of swinging pendulums in the 17th century. In the 19th century, the mathematical description of resonators and phase transitions was developed by Thomas Young. After the empirical discovery of EM waves by physicist Heinrich Hertz, the unit of frequency (one cycle per second) of these waves was named after him (Hertz: Hz). The spectrum ranges from three up to 30 Exahertz (Mulligan, 1989). Resonance is a principle we encounter in everyday life. For example, when a glass shatters due to an opera singer's voice, it happens because the singer's voice matches the glass's Eigenfrequency. This causes the glass to vibrate intensely and ultimately break. Engineers of bridges need to take into account the concept of resonance as well, as bridges collapse if they start resonating with their Eigenfrequency due to wind-induced resonance. Resonance and electromagnetism are intrinsically connected in many modern technologies and also everyday applications. Through the principle of resonance, electromagnetic fields can be selectively controlled or enhanced by changing specific frequencies. In 1891, Nikola Tesla invented the Tesla coil, a resonant transformer circuit of high-frequency and high-voltage electromagnetic waves, paving the way for wireless transmission of information through radio waves. Resonance is used to tune into the desired frequency and isolate it from other frequencies. In medical engineering, resonance and EM fields are critical for technologies like fMRI. Resonance can be considered a specific type of motion, characterised by a synchronised oscillation between two states. When two different processes come into proximity, they will often synchronise to the same frequency, allowing for faster energy flows. Synchronisation can be found in all areas of life, ranging from fireflies synchronising their flashing lights in large gatherings up to neural synchrony being associated with conscious processes. The question of how two independent systems communicate with each other and how they achieve synchronisation is sometimes called 'complex network theory' or 'harmonic oscillator theory' (Hunt & Schooler, 2019). Resonance in the realm of neuroscience will become important when discussing the *General Resonance Theory* (section 2.2.5.). The term is so deeply embedded in our culture that 'being resonant with something or someone' signifies being in harmony or alignment, fostering stronger and more harmonious human interactions. Hartmut Rosa has developed a comprehensive theory of resonance in 2016, extending the physical concept to macroscopic phenomena, including inter-relational forms at the interpersonal and societal levels (Rosa, 2016). The next chapters will be a systematic scoping review of EMF theories of consciousness.

2.2. Systematic Scoping Review according to PRISMA-ScR method

Keywords used for 'topic': electromagnetic field theory AND consciousness

Date of retrieval: July 25th, 2024

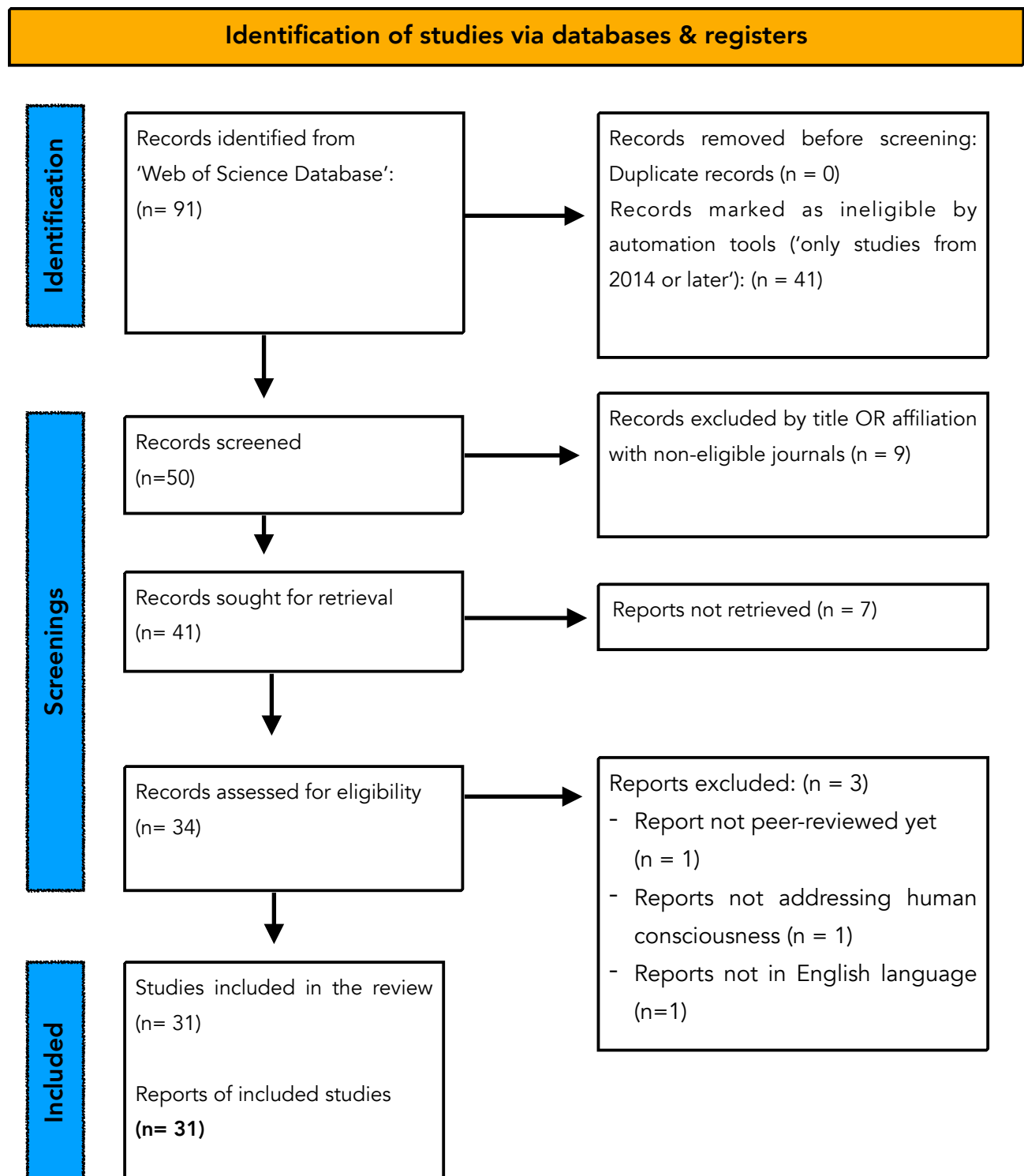


Figure 2: Overview of the systematic review (self-made).

2.2.1. Screening Process of the systematic review

The systematic scoping review has been sorted by the PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-Analyses for scoping reviews) method. 'Web of Science' (WOS) database was used, accessed through credentials of the University of Vienna. After the initial search with the keywords used for ,topic': electromagnetic field theory AND consciousness (yielding 91 results), the selection process was limited to the last ten years (only including studies from the latest of 2014), thereby excluding 41 studies by atomisation tools of the WOS database. Furthermore, eight studies from non-eligible journals or titles were excluded as they exceeded the scope of this Master's thesis. To polish the remaining studies, each study was hand selected for this systematic review. Seven of which could not be accessed as a student. One study was excluded due to not being peer-reviewed yet. Another study did not address human consciousness and another one was not in English language. The data from this review was thus collected from 31 studies (listed in [section 6.1.](#)) published by 13 different journals. As seen in table 2, most of the studies are from the journal 'Frontiers in Human Neuroscience' (35.5%), followed by 'Frontiers in Psychology', indicating that this review will focus mostly on empirical neuroscientific and psychological discussions combined with physical and bioelectrical topics, and less with philosophical or historical implications of EMF theories on consciousness. Notably, 22.6% of included studies have been published in the last four years (2021 or later), indicating a growing trend and increasing importance of EMF theories in the field of consciousness science.

Table 2 - Overview of included Journals in the systematic review

Journal Names (n = 13)	Number of Studies (n= 31)	Percentage
Frontiers in Human Neuroscience	11	35.5
Frontiers in Psychology	5	16.1
Elsevier	2	6.5
MDPI: Entropy	2	6.5
MDPI: Neuroscience	2	6.5
Journal of Consciousness Studies	2	6.5
Other: Applied Sciences, Bioelectricity, Biosystems, Brain Science, Frontiers in Physics, Journal of Physics, Perspectives on Psychological Science	7	22.6

2.2.2. Introduction of EMF theories

As mentioned in section 1.2.2., the first time the topic of mental states being associated with a field goes back to the early 20th century, when Gestalt psychologists were addressing the topic of

the binding problem of perception. Wolfgang Köhler proposed that the mechanism of object perception is based on electrochemical brain fields that are isomorphic with the field of a percept: the 'phenomenal field' and the 'transphenomenal field', the brain. He was an epistemological dualist, asserting that our perception of the physical world is fundamentally constructed through phenomenal experiences (Lindahl & Århem, 2016, p. 232). This perspective aligns closely with the philosophical framework of 'idealism' today (Kuhn, 2024, p. 121). When the basis of neuronal functioning was discovered, the concept of a field gradually receded from scientific focus, as it became challenging to empirically measure the existence of such a field. However, the idea of the binding problem continued to persist within scientific discussions. The philosopher Karl Popper also proposed the importance of a 'mental force field' in the brain that could integrate information on a subconscious level. With his 'mental force field hypothesis' he suggested that there were three worlds - which are distinct from each other: the physical, the mental and qualia. For him, EM fields represent the subconscious mind, which we can interact with through the proper use of attentional processes, which in turn he did not attribute to any physical field (Lindahl & Århem, 2016, p. 239). This was later on extended by neurophysiological approaches of Benjamin Libet along with Lindahl & Århem in the 90s. Libet proposed a bidirectional influence of the brain and the 'conscious mental field' (CMF), emphasising that the CMF remains phenomenologically independent and cannot be fully explained by any known physical fields (Hales & Ericson, 2022, p. 11). These theories can be categorised as 'dualist field theories', and since they are not addressing how different qualia arise, they will not be discussed further. In 1994, Lindahl and Århem showed that endogenous EM fields might not be strong enough to lead to the excitation of neuronal activity, but that a neuron with ongoing activity can be affected by the generated inward EM field - therefore challenging the general arguments of endogenous EM fields not being strong enough to have any causal effect.

According to fundamental physics, all atoms have an electric charge and magnetic spin, meaning that electromagnetic fields play a crucial role in the structure and interactions of all matter, including that of the human body. Taking the ontology of fields into account is therefore crucial for a better understanding of consciousness, no matter what degree or form of consciousness one is studying, be it 1PP, awareness, the subconscious or the state of being unconscious (Hales & Ericson, 2022, p. 7).

2.2.3. Classical Electromagnetic field theories

Susan Pockett's theory (2000 & 2002), one of the earliest published electromagnetic field (EMF) theories of consciousness - alongside McFadden's theory (2002) - represents a pioneering contribution to this field of research. However, since her work did not surface in my WOS search and numerous more detailed theories have emerged in recent years, her foundational ideas will only be briefly acknowledged here. In Pockett's theory, consciousness is an epiphenomenon associated with spatial patterns in EM fields, defined as a structure or object instead of a process.

Under her view, EM fields do not have casual influence, which differs from most other EMF theories. (Pockett, 2017).

2.2.4. Conscious Electromagnetic Information (CEMI) field theory (McFadden, 2020)

McFadden's theory, originally published in 2002, leans on the fact that information is physical, and must thus also be physically integrated. The theory proposes a scientific dualism rooted in a differentiation between matter and energy. His main argument emphasises that in neural networks, information is encoded temporally whereas in an EM field, information is encoded physically/spatially. Consciousness must thus be physically integrated as causally active information encoded in the brain's global EM field, more similar to quantum computing than classical Turing machines (McFadden, 2020, p. 1). Information in his theory refers to 'Shannon information', which quantifies the relationship between the degrees of freedom in a sender's message and the receiver's capacity to interpret it. It is measured in bits, where a bit represents the basic unit of information used to resolve uncertainty about a message. Just like a magnet 'computes' its field instantly, it represents an algorithm in space rather than in time. McFadden postulates that our thoughts are field-implemented algorithms and awareness emerges out of synchronous firing neurons - emphasising that the synchrony of firing rates is more predictive of consciousness than the firing rates per se. This theory is the first EMF theory that stresses the importance of synchronisation of EM fields. The strength of the CEMI field theory lies in having a measurable physical parameter to differentiate between subconscious and conscious brain information: the magnitude of EM field perturbations that are capable of influencing neural firing.

When it comes to identifying correlations between EM fields and neuronal activity, neuroscience is encountered with an *inverse problem* of EM field measurements: There are potential infinite combination of electrical sources to create a specific EM field. We are thus still unable to predict the pattern of neuronal firing responsible for generating a specific EEG/MEG signal (McFadden, 2023, p. 4).

McFadden distinguishes between subconscious and conscious (i.e. aware) mental processes, highlighting the evolutionary development of this separation. He proposes that the brain has evolved both EM field-sensitive streams, associated with synchronous neuronal firing, and EM field-insensitive streams, linked to asynchronous firing. Central to his theory is the idea of a unified conscious EM field as mechanism of attentional processes, functioning as a serial processor capable of focusing on one task at a time - in contrast to subconscious parallel processing. So according to CEMI field theory, subconscious processes are predominantly mediated by synaptic spikes - local electrochemical interactions between neurons - while conscious awareness results from the interaction of the brain's global EM field with neurons (see figure 2.1. below.)

Regarding information integration, IIT seems to fail to address that information integration alone cannot account for awareness or conscious experience. Our immune system for example,

integrates a vast amount of information and does so without conscious awareness. Information in IIT is integrated causally in time rather physically in space. The unique prediction of CEMI is that causally integrated information cannot be (self-)aware, only physically integrated information can be.

In his paper of 2021, McFadden addressed the concept of free will: McFadden uses the term consciousness to refer to conscious awareness (vs. subconscious processes), postulating that awareness arises out of a feedback loop of EM fields and neuronal firings (see figure 2.1. & 2.2.). Under this approach, what is called free will, is the influence of the brain's EM field on neural firings. While subconscious firings also emit EM field radiation, they are too weak to enter a feedback loop. Conscious awareness is thus defined as the way electromagnetic field inputs are experienced within neural processing (McFadden, 2021, p. 294). This resembles the analogy of Douglas Hofstadter (Hofstadter, 2007), about consciousness being a strange loop, indicating that consciousness is not merely a spectator but an active participant, causally influencing neuronal activation and thus thoughts and behaviour in a never-ending loop. Neurons are both generators and receivers of EM field based content. This could be visualised by the concept of a 'Kleinbottle' (see figure 2.2.). Even though the field's causal agency seems to be deterministic, what feels like free will is our experience of being in control of our voluntary actions, even though it might not be fully a-causal from neuronal firings (Detmar, 2022).

To summarise, consciousness is what physically integrated information (algorithms in space) in an EM field *feels* like, from the frame of the photons encoding that information (McFadden, 2020, p. 10). According to CEMI, neural activity that is localised (such as action potentials or synaptic spikes) does not significantly affect the brain's global EM field. These processes remain subconscious because their EM fields are too weak or unsynchronised to contribute to the overall brain-wide field. Empirically, McFadden predicts that agents that disrupt the interaction between the brain's EM field and neurons will induce unconsciousness (i.e. unawareness). He also proposes that the cerebral spinal fluid could be acting as a potential faraday cage, therefore briefly addressing the boundary problem. Boundaries seem to be rather hard than fuzzy according to McFaddens theory.

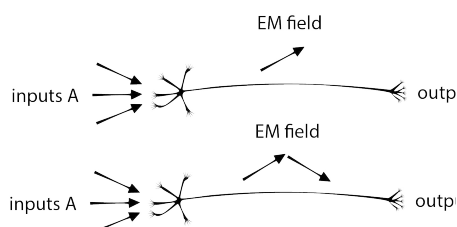


Figure 2.1.: Difference between subconscious & willed (aware) actions. Awareness emerges through the feedback loop of EMFs. The EM-field carries information from various inputs (not only input A) and feeds them back (self-made remake of original figure - McFadden, 2021)

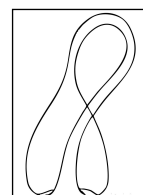


Figure 2.2.: Kleinbottle topology as an example of a possible EM field loop: i.e. the neuronal mechanisms that lead to the formation of the field which in turn influences neuronal mechanisms. (Self-made)

2.2.5. General Resonance Theory (Hunt & Schooler, 2019)

Large-scale neuronal synchronisation has been attributed to mammalian consciousness throughout the last 30 years by Crick & Koch (Hunt & Schooler, 2019). Compared to neurochemical processes, neuronal synchronisation accomplishes much faster communication. Resonance and EM fields are related through their role in neural communication, particularly in the generation of Local Field Potentials (LFPs). LFPs are low-frequency electrical signals that reflect the collective activity of neurons in a localised area of the brain (more on this on p. 35 & 42). Resonance occurs when specific frequencies of neural oscillations align, amplifying EM field interactions and facilitating efficient information exchange.

Hunt & Schooler (2019) suggest to possibly solve the combination problem through the concept of resonance by postulating three axioms:

1. *Resonance axiom*: All physical entities resonate.
2. *Panpsychism axiom*: All physical entities have some form of 1PP on a spectrum from the most rudimentary form to more complex forms. The notion of panpsychism is shifting from a purely philosophical speculation to a possibly empirically testable theory as theories like IIT also posit themselves in the panpsychist field.
3. *Coupling axiom*: given some time, processes that resonate in proximity will sometimes resonate together.

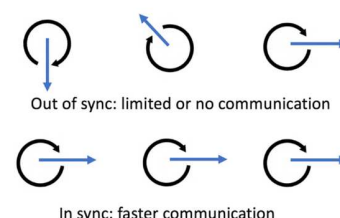


Figure 2.3.: Abstract representation of synchronisation of matter leading to faster communication (Hunt & Schooler, 2019).

When considering the first axiom of their theory, a quantum field theory perspective needs to be taken, where all matter is fundamentally a more wave-like concentration of energy than a stationary concentration of energy, as Newtonian physics originally positioned. While the authors are not getting into specific quantum mechanical aspects, they do address the possibility of quantum phenomena playing a role apart of classic electromagnetism or possibly being 'two sides of the same coin' at an organic scale (Hunt & Schooler, p. 12). While the second axiom may appear speculative to some researchers, advocating for emergentism can be viewed as equally - if not more - speculative than considering 1PP as fundamental. Cognitive Scientist Donald Hoffmann underscores this point through his position of 'conscious realism', which identifies consciousness as fundamental aspect of reality (Kuhn, 2024, p. 126). This argument is especially relevant because the field of neuroscience has so far failed to even come closer to the hard problem of consciousness under the aspect of emergentism after more than three decades of research.

GRT proposes ways of empirically testing their theory through three defined conjectures:

1. *Shared-resonance conjecture*: shared resonance is what leads to the combination of micro-consciousness' to one macro-consciousness.
2. *Boundary-Conjecture*: the boundary of this macro-conscious entity depends on the velocity and frequency of the individual resonance chains.
3. *Nested-Consciousness-Conjecture*: A macro-conscious entity will entail various subsidiary, nested micro-conscious entities.

Hunt (2020) addresses the boundary problem in context of the GRT in terms of the 'slowest shared resonance' (SSR) principle, stating that the slowest common denominator frequency or resonance constitutes the boundary of any given macro-conscious entity. Slow frequencies traverse spatial distances at greater speeds. The paper of Young, Hunt et al. (2022), is one of the few that addresses resonance in different forms across the human body, encompassing an embodied perspective of consciousness. According to the SSR principle, it is predicted that a system's SSR decreases with distance between brain and resonating structures in the body. Cross-frequency coupling (CFC) is a fundamental mechanism in neural communication, enabling different brain regions to coordinate their activities across various frequency bands to support complex cognitive functions like attention and memory. A prevalent form of CFC involves the modulation of the amplitude of higher-frequency neural activity by the phase of lower-frequency oscillations. In this process, the phase of slow oscillations, such as theta or delta waves, influences the strength (amplitude) of faster oscillations, like gamma waves. This modulation allows small populations of neurons, which generate high-frequency activity, to be influenced by the broader, low-frequency oscillations occurring over larger neuronal populations. Young, Hunt et al. (2022) examined the resonance relationships across the body (retinal-brain, olfactory-brain, cardiac-brain and gastric-brain) and proposed that resonance frequency decreases with greater spatial distance between the brain and the resonating structures, supporting the SSR principle. They propose that phase-amplitude coupling (PAC), a specific form of CFC, plays a key role in these interactions. The paper discusses how slow peripheral rhythms (e.g. from the stomach or heart) modulate the amplitude of faster brain oscillations, emphasising the role of taking into account body rhythms' influence on brain activity and possibly - consciousness. The notion of the SSR does address the boundary problem but it does not solve it. Instead, it functions as a gradient, depicting a gradual decrease in shared resonance as the distance between interacting systems increases, without defining explicit or fixed boundaries.

The concept of shared resonance, encompassing brain wave, neuronal and certain bodily synchronisations, plays a significant role in various EMF theories of consciousness. GRT - therefore - stands out not merely as another EMF theory but as a framework that highlights a potentially pivotal aspect of a broader transition toward field-based theories of consciousness (this is discussed further in section 2.4.).

2.2.6. Coherence Field Theory - CFT (Bond, 2023)

This theory can be seen as an extension to the GRT account of consciousness to lower quantum levels. While this theory also focuses on various EM field synchronisations, Bond introduces a shift in emphasis from the coherence of electromagnetic particles to the broader coherence of EM radiation. This radiation, emitted by active neurons in the form of photons, is proposed by Bond to have fewer mass-related constraints than electrons or atoms. He further hypothesises a potential role for infrared radiation in facilitating EM field coherence throughout the brain. In this framework, electromagnetic radiation and molecular arrays oscillate together within a 'coherence field', measurable through variations in temperature. Evidence for this is mentioned as anaesthesia has been shown to lower brain temperature, which could hint at a possible role of temperature (and thus EM radiation of infrared waves) in consciousness instead of temperature being merely a waste byproduct. Indications seem to exist that neurons may be tailored to sustain the brain's infrared spectrum at robust levels. Activation of neural tissue seems to be closely linked to temperature variation. He furthermore explores how vibrations in nanoscale atomic structures and photonic waves may contribute to consciousness. CFT uniquely focuses on light interactions with biological systems and internal brain EM fields contributing to consciousness. Furthermore, Bond suggests that the coherence field concept may eventually be able to explain phenomenological reports of perceiving the field of awareness outside of our bodies and brains (Bond, 2023, p. 11).

Bond backs up his hypothesis by going into molecular neuroscience and physics, exploring the concept of local field potentials (LFPs) through the movement of ions. These LFPs represent oscillatory neuronal activity and are thus key to the generation of EM fields. CFT provides a biological basis for how localised synaptic activity can lead to a broad, supervenient coherent EM field. Within this physicalist framework, the EM field is the binding agent for perception and 1PP in general. According to Bond, consciousness arises from the interaction and synchronisation of various EM fields, with one supervening on the other smaller ones, causally influencing the behaviour of biochemical pathways in the brain (Bond, 2023, p. 10) and producing a unified electromagnetic structure that could potentially explain awareness as well as 1PP.

2.2.7. The Adaptational Theory of Consciousness - 'ATC' (Detmar, 2022)

This theory is one of the few theories that emphasises the importance of integrating an evolutionary perspective and exploring the reasons for a 1PP to evolve in nature into the science of consciousness. It is also unique as it provides a framework that unifies neuroscience and physics by highlighting the importance of the 1PP feeling of pleasure by presenting a range of arguments.

One of the most important arguments is what Detmar calls the 'topographic argument' according to which natural selection arranged neurons in a way that increase the ability of the endogenous EM fields to causally influence the neurons and thus itself in a feedback loop (can be illustrated just like the Kleinbottle in figure 2.2.). This arrangement lead to improved information processing

and organisation of the endogenous EM field. Eventually, through error correction processes, the topographic alignment mutated in just the precise way to allow for (self)-awareness to emerge (Detmar, 2022, p. 41).

In Detmars theory, resonance “refers only to the hypothetical coordination between EM field rhythms and molecular vibrations of sodium channels.” (Detmar, 2022, p. 42). Detmar also formulates the ‘q-problem’, which states that neurons can only transmit the quantitative data of a stimulus through frequency encoding and cannot generate the qualitative aspect of these sensations, which must therefore arise from internal sources. He distinguishes between frequency and place encoding, indicating that the initial place a signal is sent from is controlled by the topographic arrangement and determines the generation of patterns of the EM field. Each pattern of EM field has its own phenomenality. The role of *meaning* is crucial in his theory and he tries to explain meaning under an evolutionary perspective of rhythmic vs. arrhythmic EM field patterns. Accordingly, meaning or pleasure arose as motivational factors of movement towards nourishing vs. moving away from dangerous stimuli.

“I propose that rhythmic patterns of the EM field, particularly ones that are able to resonate with voltage gates, tend to have a pleasant feeling, while arrhythmic patterns (which are ineffective at opening gates) tend to feel unpleasant.” (Detmar, 2022, p. 46)

Under the ATC, pleasant patterns in the brain contain significant free energy, characterised by low entropy and efficient organisation. In contrast, unpleasant patterns are marked by reduced free energy and higher entropy. Detmar extends the free energy definition originally formulated by Friston in his *Free Energy Principle* (Friston, 2010), to explain how pleasure and other emotional experiences arise from the brain minimising free energy through harmonic EM patterns. He suggests that pleasant patterns increase fitness by facilitating more efficient communication between neurons, making the phenomenology of pleasure evolutionarily advantageous for living systems. Detmar also distinguishes between unconscious processes (consisting of purely material interactions) and conscious processes (manifesting as a physical field). He theoretically postulates that when an unconscious thought generates an arrhythmic pattern in the global EM field, it is experienced as a feeling of unpleasantness. This concept mirrors the already on p. 15 mentioned approach of Michael Levin to cellular behaviour, which posits that cellular dysfunction (such as the phenomenon of cancer) arises from disruptions or dissonance in the bioelectric field. According to Levin, the cell’s behaviour is guided through the bioelectric field modulating top-down processes that direct how cells should operate (Levin, 2014). Just as Detmar associates pleasure with harmonic, efficient patterns in the brain, Levin suggests that rhythmic and coherent bioelectric patterns reduce cellular stress and maintain their healthy function. Both theories emphasise the importance of rhythmic, harmonic fields in reducing stress and promoting stability. For Detmar, these patterns govern conscious experiences, while Levin is focused on cellular health. Disruptions thus, whether in the form of arrhythmic brain activity or dissonant bioelectric fields lead to negative experiences like unpleasantness or in Levins case, to cellular stress.

Detmar's theory is furthermore applicable to all animals or even to all beings that are capable of experiencing pleasure, each having evolved their own suitable 'meaning' or resonating EM field patterns suitable for their environment. His argument from natural selection is that consciousness evolved incrementally from ephaptic coupling of neurons where organised couplings were favourable. As in McFaddens theory, the ontological gap between mind and matter is physical, not metaphysical and is supposedly closed through the EM field feedback loops to influence neuronal states.

The *Qualia Research Institute* (QRI)¹ explores how specific neural and EM patterns correlate with subjective experiences, similar to Detmar's approach. QRI's '*Symmetry Theory of Valence*' (Gomez-Emillson, 2017) links symmetry in neural activity to feelings of pleasure, echoing Detmar's claim that harmonic EM patterns underlie pleasurable qualia. Both approaches focus on neural harmonics and resonance as the basis for specific qualia experiences and both aim to unify 1PP with measurable physical or mathematical processes. QRI's work complements Detmar by formalising how brain dynamics create qualia, emphasising the role of harmony and symmetry particularly in shaping aesthetic experiences or experiences of valence.

Another revolutionary framework consistent with the ATC, is the connectome harmonic decomposition (CHD) (Atasoy, 2017) which provides a framework for understanding how the brain's activity is organised into harmonic patterns that reflect its intrinsic functional architecture. Detmar's theory connects this to the nature of subjective experience, proposing that the pleasing quality of harmonic sounds arises because they resonate with these neural harmonics. CHD will be scrutinised further in section 4.9.

2.2.8. Abstract Realism (Sanfey, 2023)

Abstract Realism (AR) is not an electromagnetic field theory of consciousness but rather a proposed metaphysical principle that seeks to connect physical reality with phenomenal experience through causally interacting electromagnetic fields. It does so without invoking panpsychism or introducing any yet-to-be-discovered laws of physics. While AR shares similarities with concepts in quantum field theories, which will be briefly mentioned in the following sections, it posits that physical reality and first-person perspective experiences are co-occurring phenomena that mutually influence each other ('bridging principle'). Building on the idea that neither physical reality nor 1PP is reducible to the other, consciousness in Abstract Realism (AR) is not merely emergent or secondary to physical processes but is posited to exert a causal influence on physical reality. In this sense, it serves as a first principle for understanding the relationship between the material and the phenomenal. By arguing that consciousness is unobservable, its relationship to physics can only be found by argument.

¹ <https://qri.org/>

Abstract Realism emphasises *simultaneity*, suggesting that physical and phenomenal realities occur together in a way that lacks a clear physical explanation. Traditional notions of causation in physics are inherently tied to time, linking past to present or present to future. In contrast, AR challenges this framework by proposing a metaphysical foundation for understanding causal emergence in neuroscience, where physical and conscious processes dynamically co-influence one another. It basically challenges the notion of time altogether, as time only 'emerges' through the mind of an observer. AR posits that matter is dynamic, with its perception linking the past and future through an observer's mind.

The AR framework proposes a solution to the combination problem by emphasising the metaphysical fundamentality of the observer-observed duality. While AR proposes a metaphysical foundation for the interaction between consciousness and the physical world, it uses EM fields as a concrete analogy or explanatory model for how that interaction might manifest. It is predicted that awareness arises when two EM fields interact causally with the substrate generating the other. This is achieved when one EM field resonates with another EM field generated in microtubules, - which are tubular structures that exist in cells and are important for cell division, construction as well as plasticity of dendritic connections (Sanfey, 2023). Microtubules are highly sensitive to general anaesthetics, which is generally seen as the off-switch of awareness. AR predicts that the dual-field interaction between synchronous neuronal and microtubular EM fields are critical for awareness. The postulate is that information in the EM fields tries to mirror itself in system memory, achieved through resonating with other EM fields created by microtubules. This is similar to the Orchestrated-Objective Reduction (Orch-OR) theory (Hammeroff & Penrose, 2014), which suggests that consciousness arises from quantum processes in the brain's microtubules. The theory proposes that quantum superpositions in microtubules collapse through a process called 'objective reduction', which is influenced by gravity - making it the only theory of consciousness incorporating gravity in the collapse of wave functions. These quantum collapses are orchestrated by biological processes, leading to discrete moments of conscious experience. Orch-OR posits that this quantum activity within microtubules is crucial for conscious awareness, which is distinct from classical brain activity. While controversial and debated within the scientific community, the theory continues to attract attention and ongoing exploration in the field of consciousness research.

Since the development of quantum field theory in the 1920s, a wave- & field-based ontology has emerged as an essential part of modern physics, contrasting classical physics. Because quantum mechanics is complex and often counterintuitive, this alternative ontology has not yet been fully integrated into mainstream physics or fields like consciousness studies, where the potential connection between quantum phenomena and biological systems is still being debated. The initial argument against quantum phenomena playing a role in consciousness was that such effects could not occur in warm, wet environments - like those found in biological systems. However, growing evidence now suggests that quantum phenomena can indeed manifest within biological

systems, giving rise to the emerging field of 'quantum biology' (Lambert et al., 2013). Exploring quantum mechanics in detail is beyond the scope of this thesis, even though it will be mentioned again in section 2.2.10.

2.2.9. The Neuroelectrical, pure panpsychist theory (NP) (Jones 2017, 2019)

Although this theory was not retrieved through the WOS database search, it being mentioned in several other papers highlights its possible significance, as it offers a distinct perspective compared to other theories discussed. According to Jones' framework, the neuroelectrical aspect ties consciousness to strong, continuous neuroelectrical EM fields produced by ion currents along neural circuits, enabling integration into unified experiences. Qualia are not merely properties of but are considered neuroelectrical EM substances themselves. In this view, everything, beyond just EM fields, is composed of qualia. This idea aligns conceptually with theories like 'conscious realism' (Kuhn, 2024, p. 126) or idealism, where the true ontological nature of reality is inaccessible to direct observation and remains hidden from us. What sets this theory apart is its claim that qualia can still be measured within molecular proteins. For instance, specific qualia are attributed to proteins such as the 5-HT_{2A} receptor, which has been extensively studied for its role in psychedelic experiences. This receptor is particularly notable for its correlation with states associated with 'pride-wellbeing'. The theory thus tries to offer a measurable link between molecular biology and subjective experience while still adopting a panpsychist view (Jones & Hunt, 2023).

2.2.10. TRAZE theory: zero-point field & consciousness (Keppler, 2024)

This theory is arguably the most controversial one discussed in this review, positioning itself as a fundamental, macroscopic quantum theory. Keppler bases his model on the quantum electrodynamical (QED) framework of the vacuum state, termed the zero-point field (ZPF) - a dynamic ocean of energy. According to quantum mechanics, the ZPF is the fundamental substrate mediating all electromagnetic forces, making it the ultimate basis of all EM phenomena. Keppler emphasises the need to move beyond incomplete classical electromagnetism toward a quantum theory incorporating the ZPF. Although the ZPF has been referenced by many in spiritual contexts to explain certain phenomena, it remains a topic of debate in physics and requires careful scientific investigation. Given that this theory and frameworks appeared frequently in my WOS database search, published by scientific, peer reviewed journals, I believe it warrants discussion alongside other theories, despite its controversial nature. In 2020, Keppler & Shani postulated that the ZPF is inherently sentient (i.e. it entails a first-person perspective (1PP)), proposing that the brain functions as a resonant oscillator coupling to specific ZPF modes. Through these interactions, modulated by neurotransmitters, a stable attractor forms, leading to a partially ordered state of ZPF modes. Keppler criticises classical EM field theories for their *demarcation problem*: the challenge of distinguishing non-conscious EM field patterns from those associated with 1PP. He argues that instead of imposing arbitrary thresholds, consciousness should be understood as an intrinsic property of the ZPF, manifesting in a dual-aspect structure: physical

oscillations as an extrinsic manifestation and phenomenological awareness as its intrinsic counterpart. The theory postulates that through resonant coupling with the ZPF, a system falls into an attractor state (e.g., coherent gamma band activity in the cortex), leading to the formation of highly correlated field modes. The capacity to modulate these field interactions distinguishes conscious from non-conscious systems (Keppler & Shani, 2020).

A key component of this modulation is neurotransmitter activity - particularly that of glutamate - the brain's most abundant excitatory neurotransmitter. Keppler suggests that a neurotransmitter-receptor profile determines the selection of ZPF modes, shaping the possible phenomenal qualia states. Recent research supports glutamate's role in conscious experiences, with studies linking it to psychedelic-induced altered states (Mason et al., 2020). Empirically, this could be tested by modulating neurotransmitters and observing changes in coherent activity patterns. In his 2023 paper, Keppler mathematically tested the theory, calculating the necessary critical coupling strengths and neurotransmitter concentrations in cortical microcolumns required for potential resonant coupling to the ZPF.

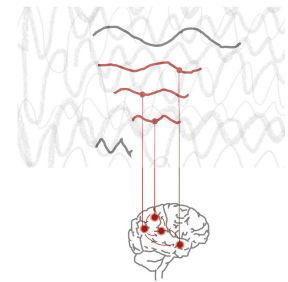


Figure 2.4.: TRAZE principle illustrated: a brain coupling to the zero-point field. (diwiss.de - 2025).

Under this theory, microcolumns act as a bridge between molecular-level interactions and large-scale neural synchronisation. His calculations suggest that macroscopic quantum phenomena in cortical microcolumns are feasible, indicating that the brain is structured to resonate with the ZPF. The underlying self-organised criticality of cortical dynamics supports this resonance mechanism. Neuronal avalanches, following power-law distributions, emerge through the collective organisation of spatiotemporal activity. Keppler argues that this dynamic balance, regulated largely by glutamate, allows the brain to remain at a critical point, facilitating phase transitions necessary for consciousness. Individual neurons may resonate with different ZPF modes, but global coherence ensures these resonances integrate into a unified conscious experience. This coherence provides a possible solution to the combination problem, suggesting that consciousness emerges from the brain's ability to bind neural activities across space and time via the ZPF. Selection of ZPF modes is driven by resonance, triggering an ignition stage where dominant EMF modes (i.e., brain wave patterns) are locally amplified, potentially leading to heightened regional brain activity.

In his 2023 paper, Keppler mathematically demonstrated that strong coupling of glutamate molecules to ZPF modes drives microcolumns toward a stationary coherent state. He calls for further scrutiny of ion channel modulation via intracolumnar microwave radiation in future research. His calculations confirm that glutamate concentrations in synaptic vesicles are sufficient to induce phase transitions, supporting the feasibility of quantum phenomena occurring under the brain's warm and wet conditions. Furthermore, he establishes a correlation between intracolumnar

microwave radiation fields and the modulation of voltage-gated ion channels. In 2024, these insights were consolidated into a formal theory of consciousness, termed *TRAZE* (*The Resonant Amplification of Zero-Point Modes*). TRAZE posits that 1PP arises through the resonant amplification of ZPF modes, with the spectrum of phenomenal qualities being represented by specific ZPF oscillations. The modulation of glutamate plays a crucial role in controlling this resonance. The theory is empirically testable by inhibiting glutamate-ZPF coupling in cortical microcolumns and assessing the resulting phenomenological experiences, calling for neurophenomenological research methods (more on this in section 3.3.). Nevertheless, despite being published in peer reviewed eligible journals, TRAZE and the existence of a ZPF itself, are still highly controversial topics in scientific fields and remain very speculative.

2.2.11. Operational Architectonics (OA) approach (Fingelkurts et al., 2019)

The Operational Architectonics (OA) approach is a theoretical framework that unifies brain and mind functioning through nested, dynamic, and hierarchical EM brain fields. First introduced in 2009 (Fingelkurts et al., 2009), it has since been enriched by concepts from physics, including EM fields (Fingelkurts et al., 2013), self-organised criticality, and even spacetime itself (Fingelkurts et al., 2019). The OA framework describes how the mind's phenomenological nested architecture corresponds to the brain's operational nested architecture (the physical processes of the brain mirror the nested organisation of conscious experience) - framing them as aspects of the same continuum, a perspective the authors call *emergent monism*. These architectures operate within a dynamic, spatiotemporal continuum, where different levels of brain activity (from local neural interactions to large-scale brain networks) interact in a highly coordinated way to generate consciousness. Within this model, EM brain fields are highly structured and nested - eventually leading to a unified conscious experience. The OA framework also allows for EM fields to emerge within other fields, where multiple processes occur simultaneously across different timescales, resulting in spatially distributed yet temporally integrated EM activity. What sets this theory apart is that similarly to the concept of Abstract Realism it is one of the very few to incorporate concepts of spacetime and phenomenological time into the understanding of consciousness. The OA framework distinguishes between internal physical space-time (IPST), phenomenal space-time (PST) and operational space-time (OST). At the IPST level, information from the outside world gets ordered and combined by the brain. OST is composed of spatial-temporal patterns of the brains electromagnetic fields, the brains physical activity is transformed into subjective experience. According to the framework, OST represents the constitutive mechanism of phenomenal consciousness, linking phenomenology with neurophysiology. These EM fields are called *operational modules* and they have intrinsic phenomenal character.

In summary, the OA framework emphasises that rapid transitional periods represent brief, dynamic shifts within the brain's operational architecture, facilitating fluid transitions between different conscious states or cognitive tasks. A key argument of OA is that every part of the brain is deeply interconnected with its surrounding context, and it is through these *relationships* that meaning

and value emerge. This interdependence forms the foundation for understanding both brain and mind processes and to the formation of qualia. The mind's phenomenal nested architecture consists of interrelated contents. This is also important in the next section.

2.2.12. Temporally Integrated Causality Landscape approach (TICL) (Winters, 2021)

As last theory I will address the TICL model by Winters (2021). In accordance with OA, both propose that consciousness arises from a dynamic, nested hierarchy of electromagnetic fields in the brain (temporal and spatial nesting). While both OA and TICL posit a nested, hierarchical structure for consciousness, OA focuses on the levels through which subjective experience arises in relation to brain activity and electromagnetic fields, whereas TICL focuses on the causal interactions of different Subsystems in the brain and how that structure gives rise to the conscious state and its contents.

Winters frames the neural correlates of consciousness in terms of temporally-integrated causality landscapes containing nested Subsystems (content-specific neural correlates of consciousness). He uses the label of 'landscape of causality' to describe the complex web of causal interactions that are processed by the brain. This landscape isn't static but constantly evolving as new information is integrated into our understanding. Consciousness is thus inherently defined as a dynamic process, emerging when our brain processes and integrates events across time, emphasising the importance of cause-and-effect relationships for our understanding of experience. The landscape (the System defined as 'A' in the figure below and described as an integrated structure within the thalamocortical brain) provides the context for the content of the Subsystems. The nested arrangement is hierarchical, with the System being the wider, overarching structure and the Subsystems being the smaller, differentiated structures contained within it. The Subsystems are nested within the System both spatially and temporally and provide the contents of consciousness, which are experienced in *relation* to the System as a whole.

TICL proposes that the NCC is a structure of temporally-integrated causality occurring over a large portion of the thalamocortical system. The structure composes of different Subsystems, which have a higher level of temporally-integrated causality ('TIC') than the System as a whole.

Winters (2021, p. 4) identifies five factors of human phenomenology. In terms of the TICL framework, their contents:

1. are unified and compositional: Subsystems occur within the physically integrated system.
2. are specific & meaningful: the Subsystems are composed of specific neuronal elements and are experienced in meaningful ways from the perspective of the System.
3. exist from a subjective point of view (POV) (private boundary problem): contents of the Subsystem are experienced from the POV of the System. POV should not be equated with the concept of Self, as content can also be present with absence of Self (or 'ego-dissolution'), as is the case with experiences under high-dosage psychedelics (Milliere,

2017; Lawrence et al., 2022). The System as a whole is aware of the existence of Subsystems, which are considered to be intrinsic to it.

4. are temporally continuous (*temporal boundary problem*): Subsystems change and disappear, but the System as a whole persists in time.
5. are limited and coherent: as Subsystems have a higher information content than the System as a whole, they are distinguishable and meaningful to the System. Subsystems can only exhibit one form at the same time.

The primary distinction of TICL to other theories lies in its feature of spatial and temporal nesting. The System as a whole must be distinguished from its Subsystems, which are necessary to exist for conscious content. "*The content which is produced by a Subsystem is nested within the phenomenal time and space produced across the System*" (Winters, 2021, p. 44). The framework predicts that the Subsystems activity is experienced as geometrical spacetime relationship to the System as a whole. Just like in the OA framework, *meaning* arises through the nature of *relation*. Once an activity sufficiently contributes to a Subsystem, it can be considered as aware to the System. In comparison - under IIT - only maximally integrated information is considered conscious, as defined by its 'exclusion principle'. The TICL considers Subsystems with a higher level of temporally integrated causality ('TIC') analogous to operational modules in the OA framework, defined as the basic unit of brain activity with phenomenal character.

Ions, biomolecules and everything composed of atoms directly exhibit causality upon one another by EM forces ('Lorentz force'). While neuronal function is often described in terms of ion movement across cell membranes, TICL suggests that it is the EM force that is the fundamental force through which these ions exert causal influence on one another. Empirical verification of TIC can thus be achieved by measuring EM field properties at a spatial and temporal resolution appropriate to the System and its Subsystems. The theory emphasises that the complex arrangements of these EM interactions - resulting in temporally-integrated causality - seem to be the source of experience. The nested structure of these EM fields gives rise to both the unity of consciousness (binding problem) and the differentiated content of the conscious experience. Although TICL suggests that a complex arrangement of EM fields leads to the temporally-integrated causality of the System and its Subsystems, the theory does not limit itself to EM forces alone. In principle, any structure of causality that exhibits both a System and Subsystems could be considered conscious.

In his own podcast '*The Hard Problem by Jesse Winters - Episode: Existence and Relationship*'², Winters - who developed the TICL model - draws an analogy to parallelism in order to explain the importance of relationship when it comes to explaining consciousness. Parallelism for example,

² Jesse Winters Podcast on Spotify - <https://open.spotify.com/episode/0YQKi8irb2ZTJlhPpL8hkl?si=0bc0620af4994177>

does not exist by itself, as one line by itself cannot be parallel, it only emerges out of the relationship to another line. He argues thus, that consciousness is not a thing but a process, only to be recognised by relational meaning.

To conclude, TICL proposes a System (the full neural correlate of consciousness) containing nested Subsystems (content-specific neural correlates of consciousness) and suggests that the temporally integrated causality of the System and its Subsystems is a result of complex EM field arrangements. A recent paper (Jacobs et al., 2025) suggests that traveling waves in artificial neural networks integrate spatial information through time, which aligns with the TICL's concept of temporally integrated causality underlying consciousness. The success of these waves in processing global information suggests a potential mechanism for the TICL's unified 'System' to integrate information across space. The demonstrated effectiveness of traveling waves offers computational plausibility for the dynamic mechanisms that could support the temporally integrated causality proposed by the TICL in the biological brain.

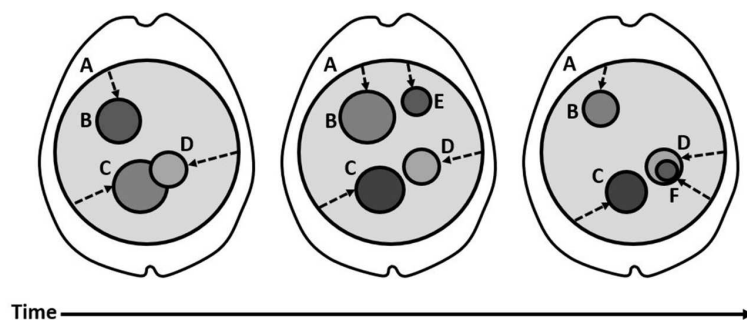


FIGURE 1 | The Structure of the Temporally-Integrated Causality Landscape. (A) The large, light gray circle corresponds to the System, which has a non-zero level of TIC and covers a substantial area of the thalamus and cortex. Over time, the System persists with little overall change. The dotted arrows are meant to show that the System is the point of view upon the nested Subsystems. (B–F) The smaller, darker gray circles correspond to Subsystems within the System. (B) This Subsystem shows a change in size and TIC (darkness of color) over time, with less TIC and spatial extent in the third panel relative to the first. (C) This Subsystem shows a change in size and TIC over time, with higher TIC but smaller spatial extent in the third panel than in the first. (D) This Subsystem shows some drift in position relative to Subsystem (C), over the three panels. In the third panel, it comes to contain a smaller Subsystem (F), which has even higher TIC (darker gray). (E) This Subsystem appears briefly in the second panel, then disappears again. F, This small Subsystem appears within the spatial domain of Subsystem D. It has a higher level of TIC (darker gray).

Figure 2.5.: Structure of the TICL. 'A' is defined as the System, while the other letters are nested Subsystems (Winters, 2021).

2.3. Results

For a broad and detailed overview according to 12 categories of the ten presented EMF theories see Supplementary material in the Appendix (tables 7.1. - 7.3.). The categories used are: their philosophical standpoint, their core idea, the function & causality of EM fields, the distinction between the subconscious and awareness, empirical testing possibilities, their relation to other theories, their limitations and if the theory is limited to biological systems. Most of the papers were published in the last three to four years, suggesting a possible paradigm shift from spike code oriented approaches to (EM-) field approaches to consciousness. In essence, according to the majority of the discussed studies, 1PP seems to be dependent on a particular aspect of the brains local EM structure and interaction with either other fields or with itself.

The philosophical perspectives of these theories span a broad spectrum, from classical panpsychism, exemplified by the GRT postulates, to physicalist - not to be conflated with materialism - approaches like Detmar's Adaptational Theory (2023) and the TICL framework. Between these extremes lie various intermediate positions, such as *dual-aspect monism* (seen in CEMI theory, TRAZE and ATC), *emergent monism*, which views the mental and physical as hierarchically structured and metastable (OA framework), and *field realism*, a panpsychist interpretation within the NP approach. Abstract Realism, a distinct form of dualism, finds some alignment with the Orch-OR framework. The key distinction between these theories lies in whether EM fields, or consciousness itself, are considered fundamental aspects of the universe. What unites them, however, is the recognition that a field-based approach to consciousness appears more suitable for addressing certain challenges, with the EM field appearing as the most likely candidate for addressing these.

Common denominator of all discussed theories and approaches is the concept of synchronisation through resonance or coherence. Degrees of consciousness (e.g. non-conscious vs subconscious vs awareness) seem to be caused by different degrees of resonance between neurons or their respective EM fields. In the TRAZE approach, resonance is what leads to neuronal coupling to the ZPF, in AR, TICL or OA the resonance of different EM fields interacting with each other is what leads to phenomenal experiences. The GRT is the first theory solely based on the principle of resonance between neuronal firing leading to awareness.

Except in Orch-OR and Pockett's EM field theory, EM fields are considered to be causally active in one way or another, especially for processes of awareness. CEMI takes a strong stance by asserting that consciousness is the EM field itself, whereas the OA approach treats the structured interaction between EM fields as primary to experience.

Most of the theories presented either do not discuss the possibility of conscious AI or argue that it is either fundamentally impossible or not yet achievable, depending on their underlying philosophical perspective. If quantum computers are developed and allow for EM field loops, awareness could theoretically be present according to CEMI, Orch-OR, NP, AR, TICL and GRT. This would only happen once computers have switched from bottom-up to causally acting top-down approaches.

Not many theories of consciousness do discuss the notion of time, as time - just like consciousness - is a difficult concept to grasp. This is what makes AR, TICL or OA different to other theories, as they emphasise the importance of integrating the phenomenology of time to address consciousness properly.

Only two papers discuss the importance of scrutinising consciousness through an evolutionary perspective: Detmar's Adaptational Theory of Consciousness is the only theory that explicitly

discusses consciousness as an evolutionary adaptation to respond to the environment. The distinction between awareness and subconscious processes is also explained in evolutionary terms in McFaddens CEMI theory (distinguished as serial vs. parallel processing) though. Most approaches share the stance that awareness arises through EM field interactions. CEMI field theory explains this through the level of resonance (similar to GRT): subconscious processes are defined here as fields that are active but not resonating in a way that leads to full awareness.

The OA framework distinguishes between nested EM field interactions, where subconscious processes exhibit lower levels of integration and remain more fragmented while the global EM field is associated with awareness. This concept aligns with the TICL approach, which posits that activities failing to achieve sufficient causal-temporal integration are not meaningfully contributing to a Subsystem and therefore remain subconscious. Both the OA framework and the TICL share the notion of relation as important factor. Consciousness is seen as emerging from a complex, nested structure in the brain. The key difference between the two frameworks is that TICL frames the neural correlates of consciousness in terms of temporally-integrated causality, while OA focuses on nested electromagnetic fields. Under TICL, subconscious processes are considered background activity that doesn't reach the TIC threshold to be part of the content of conscious experience. As encountered often, the boundaries of subconscious processes vs. awareness are not clearly defined in neither of these theories. The only principle that tries to do address this kind of boundary is the *Slowest Shared Resonance principle* (Young, Hunt et al., 2022), but it is described as a gradient rather than a strict cutoff. The notion of a soft boundary instead of a hard one does make sense from a psychologists or psychoanalysts point of view, as the subconscious does stand in direct relationship to conscious awareness and contents can spill over from the subconscious to conscious awareness (Freud, 1915).

Noticeably, very few approaches actually address qualia. While some, like the NP, AR or TRAZE simply postulate that qualia is within the EM fields themselves, most fail to account for the emergence or presence of qualia. The adaptational theory of consciousness by Detmar is the only one which accounts for an evolutionary arising of qualia, postulating *meaning* as the core driver of 1PP. McFadden does address this topic too, by reformulating Nagel's quote about "what it feels like to be a bat" to: *what it feels like to be an EM field*.

2.4. Discussion

All the examined EM field theories acknowledge that most of the brain's information is transmitted through spike codes. However, when attempting to separate electromagnetic fields into their individual components, one faces a classic 'chicken or egg' dilemma: What comes first: the electricity from neuronal firing or the magnetic field generated by that firing? This, however, is the wrong question. Electromagnetism consists of two interdependent aspects: electricity and magnetism, which cannot be fully separated. This is why isolating magnetic fields in the brain for empirical testing proves challenging. Neuronal spikes, being more easily measurable, have

understandably become the focal point in neuroscience. Nevertheless, it seems as field theories are becoming more relevant, especially as other scientists, such as the molecular biologist, Michael Levin (2014) emphasise the importance of bioelectrical fields in cells for regulating cellular behaviour or as technological advancements such as Brain-Computer-Interfaces (BCIs) show that field recording are apparently working smoother than single cell recordings. McFadden (2021, p. 299) already points out that as BCIs get more advanced in the future, EM fields will also become more relevant for signal transmission as well as interpretation. BCIs use EEG signals as the interface, implementing the same informational loop from EM field encoded neuronal information to motor actions, just as proposed by the CEMI field theory. In an interview with podcast host Lex Fridman, brain interface software lead at Neuralink, Bliss Chapman said³:

"We are switching from individual spike detection to spike band power. We thus have less resolution about which individual neuron is doing what but a broader picture of what is going on near an electrode overall."

Noland Arbaugh is the first human to have a Neuralink device implanted in his brain and emphasised in the same interview how signal transmission and interpretation worked noticeably smoother after switching to spike band power. If spike band power offers a clearer and more effective signal for brain interfacing, both from a decoding and user perspective, it suggests that cognition, perception and consciousness in general might be better understood through collective neural field effects rather than isolated neuronal firings.

The main experimental method for confirming that electromagnetism plays a pivotal role in consciousness as discussed by Strupp (2024) is *electromagnetic shielding*, which involves inserting an electrically shielding membrane into the inter-hemispheric gap to interrupt or significantly impede the presumed long-distance electromagnetic effect between the two cerebral hemispheres. The core idea is that if spatial electromagnetic integration is a prerequisite for consciousness, then disrupting this field should cause alterations in experience and behaviour, potentially even a division of consciousness. Strupp (2024) notes that these kind of experiments could only be conducted for a short duration with an awake participant, ensuring no damage to brain tissue or severance of neuronal connections.

2.4.1. Do EMF theories yield more explanation than classical neurological models?

The classic neuronal doctrine posits that individual neurons are the fundamental functional units of the nervous system and consciousness, communicating through synaptic transmission. A key aspect of this process is the neuron's membrane potential, with the neuronal membrane being electrically polarised. Classic Neural Correlates of Consciousness (NCC) are identified by determining the activity in relevant brain regions, typically through the firing of action potentials. EEG recordings detect the summed activity of large populations of neurons, but not all neurons

³ Lex Fridman Interview: Neuralink: <https://www.youtube.com/watch?v=Kbk9BiPhm7o>. (timestamp: 08:04)

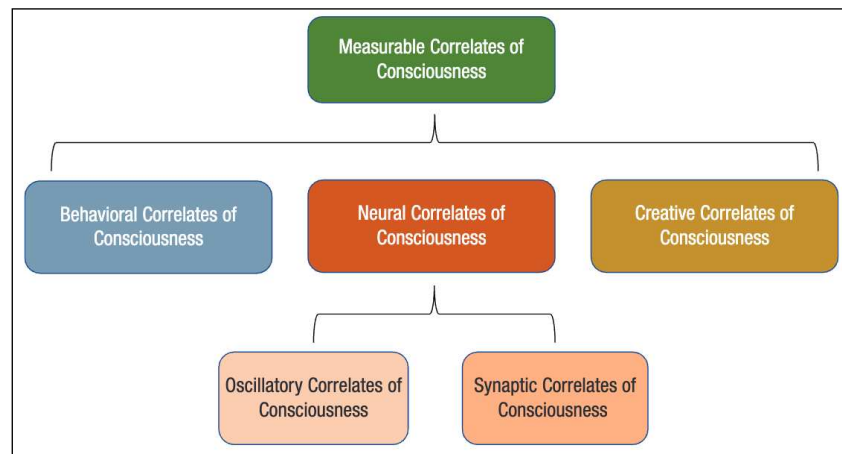


Figure 2.6.: Overview of measurable correlates of consciousness (MCC) (Hunt et al., 2022).

contribute equally to the signal, cortical neurons located near the electrode are the primary contributors. After being in the forefront of consciousness studies for the last 30 years, the classic spike code approach has failed to provide a sufficient explanation for the emerging of consciousness (Hunt et al., 2022). So far, NCC approaches focus on explaining functional integration (i.e. how different brain regions coordinate and communicate with each other) through recurrent or feedback loops of neural circuits and synaptic communication. Another possibility of integration is resonance-based integration through coherent oscillatory activity (shared EM frequencies), as proposed by GRT (Hunt & Schooler, 2019).

Consequently, all of the discussed theories emphasise that non-synaptic communication via electrical fields either through ephaptic coupling (short range) or entrainment (larger range) needs to be further scrutinised in the field of neuroscience. As Bond (2023) explains in his paper, ephaptic coupling was shown to be inhibited when an anti-electric field was used to block the coupling. Additional evidence (Bond, 2023, p.6) comes from studies that applied pharmacological blockers to neuronal tissue while stimulating the tissue with an electric field, resulting in ephaptic coupling despite the inhibition of neurotransmitter-based communication. In another study (Shivacharan et al., 2019), a voltage clamp was applied to a slice of neuronal tissue, leading to disrupted synchronisation and ephaptic coupling. Extracellular recordings can detect field potentials, which represent the synchronised activity of large groups of cells. The tools used to measure brain activity are primarily electromagnetic in nature, such as local field potentials, EEG, MEG, and ECG, which involve spatially averaged, time-sampled, and temporally averaged electromagnetic field properties. Imaging techniques like MRI and fMRI rely on electromagnetic interactions with the material being studied. These interactions are additionally not limited to the brain, as the paper of Young, Hunt et al. (2022) points out, different resonances appear to play a role across different parts of the body in general (e.g. gastric-brain, cardiac-brain or retinal-brain shared resonance axis). In their paper from 2022, Hales and Ericson argue that all correlates of any

neuroscientific theory is - in fact - measuring electromagnetic correlates of consciousness (EMCC's) with or without them explicitly mentioning this.

As seen in 2.6. below, Hunt et al. (2022), provide an overview of the measurable correlates of consciousness (MCC). Creative correlates of consciousness involve dynamic neural processes that link conscious awareness with the generation of novel ideas and flexible problem-solving. While NCC methodologies have primarily focused on synaptic correlates, oscillatory correlates of consciousness (OCC) may be more easily to measure with tools as EEG, MEG or TMS than with the classic spike code approach (Hunt et al., 2022). Both types of correlates are essential for understanding consciousness, and it is time for contemporary science to recognise the importance of oscillatory components.

To dive deeper into the differences between these approaches, the difference between a *transmissive* and a *productive* model of brain function should be addressed (Roleau, 2022). The productive model of brain function represents the classic neuronal doctrine - a bottom-up approach: all aspects of cognition and consciousness originate from the brain's neuronal activity. In the late 19th Century, William James proposed a transmissive model of brain function, drawing an analogy of the brain operating like a prism with light shining through it and breaking into different colours. The prism itself does not produce a spectrum of colour from white light, it passively filters the white light, splitting it into different waves of colour that exist independently from the prism. Under this perspective, the brain acts as a receiver or transducer of external EM fields, rather than a sole producer of cognition or consciousness. The brain can thus both emit and receive light and other electromagnetic signals and is considered to be an electromagnetic organ in of itself, producing and transducing EM signals at the same time (see Kleinbottle figure 2.2.). Damage to the brain would alter 1PP by misinterpreting an intact signal, rather than failing to generate accurate activity. Both approaches should be synthesised to make further scientific advancements (Roleau, 2022).

Furthermore, it is important to incorporate the principle of *non-locality* when it comes to studying consciousness. Non-locality in the realm of quantum physics describes how particles that are at a distance from each other appear to affect each other under certain conditions, seemingly without a material connection. In neuroscience thus, non-locality means that neurons can synchronise their operations without material connections despite being far away from each other (Fingelkurts et al., 2019, p. 127), like it is the case with ephaptic coupling: a non-synaptic connection where cells respond to EM fields of neighbouring cells, which further corroborates the notion of non-locality based consciousness.

While discussing his Adaptational Theory of Consciousness, Detmar (2022) makes an important observation about the ontological gap neuroscience seeks to bridge. He suggests that, while the ontological gap in materialist theories appears metaphysical, in electromagnetic field theories, it is a physical difference, a mere distinction between material-based and field-based interactions.



Figure 2.7.: Two approaches and their ontological gaps. Under a materialist perspective, qualia are mere epiphenomena. Detmar (2022, p. 32)

Material refers to substances such as neurons or cells, while physical encompasses everything that follows the laws of nature. While all material substances are physical, not everything physical is material, as briefly mentioned in section 2.1. when discussing the discovery of electromagnetism (Detmar, 2022, p. 35).

Under the neuronal doctrine, the mechanisms behind memory formation and retrieval remain insufficiently explained. A remarkable finding by Pinotsis and Miller (2022), shows that the neuronal ensembles activated during working memory tasks vary from trial to trial, a phenomenon called *representational drift*. However, EEG measurements revealed that the brain's electric field dynamics remained stable. This suggests that conscious memories are not encoded in specific neurons, as traditionally assumed, but rather in patterns of activation, reinforcing the idea that EMF-theories offer a more comprehensive explanation of memory processes (McFadden, 2022).

To briefly mention the problem that classic computational theories like IIT face, is the assumption that information transfer is equated with consciousness. These theories often rely on abstract models, which may overlook the subjective aspects of experience. Another problem IIT faces, is that complexity and awareness are not always directly linked, as simple stimuli like pain can dominate and override conscious awareness instantly. Under an EMF perspective, complexity itself does not automatically yield awareness, it is the activity of synchronously firing neurons which is transmitted into the brain's EM field and thus contributing to awareness.

Another argument supporting the significance of a field-based ontology comes from insights gained through studies using transcranial magnetic stimulation (TMS). TMS has been employed to treat a range of conditions, including the aftereffects of a stroke, epilepsy, pain, migraines, and even depression. By applying a targeted electromagnetic field to specific brain regions, TMS can induce changes not only in biological tissue but also in phenomenal experience (Chervyakov et al., 2014). This will be briefly mentioned again in section 4.3.

In his TAME ('Technological approach to mind everywhere') framework, Levin (2022) points out that EM fields, manifested through bioelectricity, are fundamental to the organisation and function of living organisms. They enable cellular communication, regulate morphogenesis and tumor suppression, shifting the focus towards a top-down approach on biology, similarly to what the ontological shift to field-based theories of consciousness emphasises. Furthermore, these bioelectrical mechanisms are essential for cognition at different levels, from single cells to multicellular systems, suggesting that intelligence is not exclusive to the brain but is also present throughout the body (Levin, 2022). Additionally, Fröhlich & McCormick (2010) reported evidence

for a feedback loop between neuronal activity and endogenous electrical fields, suggesting that endogenous electric fields could indeed guide neocortical network activity.

2.4.2. How is the boundary problem addressed in EMF theories?

The predictive processing approach (Friston, 2013) addresses the boundary problem briefly, by stating that the formal boundaries of a system are defined by their Markov blanket. What exactly constitutes a Markov blanket and how it is generated, remains open. Consciousness emerges when information is bound into a particular pattern through abstract informational binding. In IIT, boundaries are defined by the exclusion principle, by ensuring that only one maximally irreducible conscious system exists at any time. This means that a conscious experience is self-contained and nested conscious systems are excluded (in contrast to approaches like TICL or OA). The few EMF theories that mention the boundary problem differ in their definitions. While the boundary in GRT is limited through resonance or synchrony, OA proposes the threshold of the boundary to be determined by the strength of extracellular EM fields. Under TICL, limitation happens through Subsystems, they must have greater TIC than the System itself.

A solution to the boundary problem was proposed by Hunt (2020). As already mentioned on p. 24, the problem of SSR principle as a solution to the boundary problem lies in it being a gradient without defining explicit or fixed boundaries. Furthermore, McFadden mentions the possibility of the cerebral spinal fluid (CSF) functioning like a Faraday cage for the EM field, potentially postulating the boundary of the EM field to be contained within the CSF (McFadden, 2020).

When it comes to EMF theories, only one paper did specifically address the boundary problem and offered a theoretical and empirical solution to it (Gomez-Emilsson & Percy, 2023). As this paper points out, the boundary problem often seems to be forgotten in consciousness theories and is seldom investigated. The authors propose beginning with a unified ontology to address the classic binding problem, which is solved effortlessly under this ontology. Under this framework, everything is inherently bound, shifting the focus to the more critical task of defining boundaries. They argue that a proper theory of consciousness must fulfil these criteria:

- Frame invariance: the structure that is giving rise to the boundary shouldn't be frame specific, it should be an intrinsic objective property of the object, thus being observer independent. Connected to EM fields, this frame variance is also called 'Lorentz variance'.
- Non-Epiphenomenalism: The formation of boundaries and 1PP serves an evolutionary purpose and is not merely a byproduct of physical processes. Qualia should have causal interaction with the physical processes that generate it. It is essential to explain the causal interactions between local field potentials (LFPs) and neuronal activity. As previously mentioned, transcranial magnetic stimulation demonstrates a feedback loop between LFPs and synchronous neuronal activity. A key concept here is downward causation, where higher-level systems influence and regulate lower-level processes ('top-down approach'). In biology,

for instance, an organism regulates cellular behaviour, while in physics, electromagnetic fields can guide molecular or atomic interactions. Similarly, in the study of consciousness, system-wide phenomena may influence neuronal activity, which in turn causally affects local field potentials. This interplay suggests a continuous feedback loop in which higher-order cognitive or conscious processes modulate neural activity, which then reinforces or alters the emergent system-wide dynamics.

- **Weak emergence:** a structure causally influences the behaviour of its constituent parts. The authors suggest that different topologies of EM fields operate as a unified whole that has weakly emergent, downward causation on the types of activities that are possible within their given environment. In contrast to strong emergence, the inherent nature of a system can be predicted by the lower-level components alone. Traffic congestion is used as an example of weak emergence.

Alongside these criteria, Gomez-Emilsson & Percy (2023) propose a *topological approach to the boundary problem*, which involves segmenting EM fields topologically. This segmentation creates hard boundaries that enclose holistic, frame-invariant units capable of influencing downward causality. Importantly, this approach does not introduce new physical laws; instead, it relies on the intrinsic properties of EM fields, which naturally allow for nontrivial topological structures that can influence both information flow and boundary formation. Topology, in essence, remains unchanged under Lorentz transformations, making it frame-invariant. By understanding the geometric properties of EM fields that are preserved under these transformations, it becomes possible to define ontologically closed spaces in which information appears to be enclosed, with boundaries that maintain their integrity across reference frames.

Qualia is ontologically and axiomatically equated with EM fields shaped into bounded topological pockets. According to Gomez-Emilsson & Percy (2023), it does not necessarily have to be an EM field that is topologically enclosed, it just seems like the most probable field in our current understanding. The topological approach will also be discussed again in greater detail in section 4.2.

Their topological approach addresses the five boundaries problems (as discussed in section 1.3.) in the following way:

1. **Hard boundary:** like the binding problem, this is accomplished by the very physical nature of a topology of a field. They emphasise the need for a hard boundary rather than a fuzzy one. How boundary dissolution or weakening would manifest on a phenomenological level or under a topological perspective, will be discussed in sections 3.5. & 4.1.2.
2. **Lower & higher-level boundaries:** the authors propose that all topological pockets have their own 1PP, may it be rudimentary or short-lived. The inability to explain these is an empirical question of measuring field topology, not an epistemological boundary.

3. Temporal boundary: Time, which in physics is often termed as fourth dimension, does play a role in the topological approach, as the topology of EM fields is automatically defined by temporal aspects. The topological pocket integrates information from sequential instances in the recent and immediate past, specifically from what they call the brain's 'memory modules'. They argue that only one closed pocket can include immediate memory modules which in turn creates a temporal boundary. Conceptually, a repeated referencing of memory by different, consecutive bound 4D pockets of EM fields is what creates the sense of persistence, they do not specifically address which brain areas are involved in this defined 'memory modules'. This framework is consistent with the phenomenology of Self that can change over time or be disrupted through certain disorders or chemicals.
4. Private boundary: by each topological pocket being linked to our own memory modules, it makes sense that the pockets are private. Cases of shared awareness should be more meaningfully described as the emergence of a new 1PP rather than a merging. They argue that it seems more likely that these cases reflect information being shared between 1PPs by the same brain mechanisms.

Field theories appear to resolve the binding problem naturally - as fields are inherently interconnected through forces. A field-based approach to consciousness is also often aligned with panpsychism and offers a potential way to address the combination problem. Since fields are inherently continuous and interconnected, a global conscious field could - in principle - unify micro-conscious entities. However, it remains an open question whether this framework fully explains the emergence of a single, unified subject of experience. Additionally, the fundamental question of how qualia arise from these fields remains unanswered. Some theories challenge the framing of the hard problem of consciousness altogether by proposing that EM fields - or even the quantum zero-point field - are inherently sentient (e.g. Keppler, 2021). Rather than asking how mind emerges from matter, they suggest inverting the question to "how does matter emerge from mind?" (e.g. NP approach or TRAZE model - just like Don Hofmann's 'conscious realism'). Most of the discussed approaches simply do not address the issue of how 1PP is formed but mostly focus on the distinction between attentional processes of awareness vs. subconscious processes.

The main limitation of EMF theories lies in the difficulty of measuring the sole influence of magnetic fields, as it is not easy to turn only the magnetic field off or on (so called 'inverse problem') (Gross, 2019). Causality is thus hard to establish and empirical testing of the theories remains limited. Most theories are theoretical in nature, although some have offered possibilities to empirically test the hypotheses (e.g. GRT through SSR principle; mathematical calculations & experimental conditions with glutamate in the TRAZE model; for further information on this see Appendix 8 under 'empirical testing'). Especially fundamental EMF theories or approaches like the concept of *Abstract Realism* or *Neuroelectrical Panpsychism*, the *TRAZE model* - remain highly speculative, as the preassumption of EM fields to be inherently sentient will be very difficult to prove scientifically. Most of the discussed theories do not attempt to solve all problems of

consciousness anyways, and since the neuronal doctrine has not yielded sufficient explanatory power about the origin of 1PPs, it is reasonable to have open questions. It seems to be just the beginning of a possible paradigm shift, recognising the limitations of the theories is thus crucial. Even if some theories (like e.g. TRAZE) possibly take their speculations a bit too far, it is still worth exploring new avenues in this field. Furthermore, as already mentioned, most of these theories do solve the binding problem, but fail to account for the boundary problem of consciousness, emphasising the importance of scrutinising this topic further.

2.5. Conclusion

The most important take away from this review is accepting the importance of the interactions of these electrical and magnetic fields and taking the field effects rather than defining them as mere epiphenomena of neuroelectrical activity. Further testing through tools like EEG, MEG, fMRI and disciplines like phenomenology, physics, neuroscience, psychology, philosophy and evolutionary biology will eventually bring us closer to the mystery of consciousness. The problem of materialist theories lies in them precluding phenomenology a priori but then trying to explain phenomenal states in material ways. They seem to be in a loop that cannot be closed. This is where EMF theories could potentially help out.

It is essential to recognise that even if a paradigm shift toward a field-based ontology occurs and gains mainstream acceptance, this does not invalidate other neuronal theories like IIT or the paradigm of predictive processing. Essentially, most conventional theories of consciousness can coexist along an EMF framework (Hales & Ericson, 2022). A field-based perspective can coexist with spike code approaches rather than replacing them. Instead of discrediting either framework, science should focus on integrating both as complementary pieces of the puzzle and materialists, physicalists and even panpsychists should work together and be open to each others perspectives.

It would be surprising if electromagnetism played no role in consciousness given that it dominates our experience of physical reality (Hales & Ericson, 2022; Kitchener & Hales, 2022), but without a metaphysical governing principle, the conclusion that consciousness is instantiated by EM fields suffers from the same fatal flaw in terms of the hard problem as all other psycho-physical identities. Most non-fundamental EMF theories of consciousness - even if solving the binding problem and boundary problem correctly - still leave us with the explanatory gap of how it is possible that 1PP is present within / through these fields or the fields interactions. The simplest solution to this gap appears to be postulating a fundamental stance of qualia in the universe, as radical as it seems.

To summarise the section of EMF theories of consciousness, there are many different EMF theories of consciousness and there is no need to choose between the different theories yet, it seems more important to acknowledge the upcoming 'electromagnetic turn' (Hales & Ericsson,

2022, p. 14) - the apparent upcoming shift from classical spike code approaches or material approaches to physical field theories of consciousness. What other insights might appear from switching to a field based ontology? Can we get closer to neurophenomenology of non-ordinary states of consciousness considering field interactions instead of spikes? In the next chapter the neurophenomenology of N,N-Dimethyltryptamine (DMT) experiences will thus be discussed. After a general overview of the substance, its neural effects are summarised as well as somatic markers of the DMT experience. Afterwards, the phenomenal effects are discussed, calling for neurophenomenological research methodologies. At the end of the chapter, the connection between the DMT experience and the boundary problem of consciousness is being elaborated.

3. Neurophenomenology of N,N-Dimethyltryptamine (DMT)

3.1. About the substance

N, N-Dimethyltryptamine (DMT) is an endogenous, serotonergic (predominantly acting on 5-HT_{2A} and sigma-1 receptors) psychedelic compound which is capable of producing radical shifts in conscious experience (Szabo et al., 2016). Compared to other serotonergic psychedelic substances like psilocybin, mescaline or LSD, DMT experiences produce the most radical shifts in conscious experience, with subjects reporting a hyper-real, otherworldly, often ontologically challenging but potential transformative experience, including encounters with entities and experiencing visualisations of geometric fractals, shapes or patterns (see table 5 & 6). The rapid onset and short duration (the peak is reached after two to three minutes and effects last about ten minutes) of inhaled DMT experiences, the drastic change in phenomenological conscious experience it produces, as well as the fact that current research indicates the compound to be endogenous to mammals (Dean et al., 2019) and to a variety of plants, suggests the uniqueness of the compound and the importance of conducting more research around it.

DMT use has been part of several ancient Amazonian traditions as 'ayahuasca' for hundreds of years - orally consumed as liquid combined with other plant material which contain monoamide-oxidase (MAO) inhibitors. The psychedelic experience is prolonged drastically and can last up to ten hours. Trends in usage in the western world as well as clinical trials of administering DMT to patients with treatment resistant depression or anxiety and non-clinical research to explore non-ordinary states of consciousness have increased in the last ten years. Despite still being illegal in most countries, ayahuasca rituals are being offered all over the world and have been popping up more and more in the last decade. For this thesis, I will focus on inhaled or IV injected (these only in laboratory studies) DMT and not discuss orally consumed ayahuasca, as the setting of these experiences differs drastically to experimental settings and the co-founding effects of the co-use of other plant material limits generalisability of the effects of DMT.

According to a global drug survey of 2012 recreational DMT administration is overwhelmingly done through the mode of inhalation (92.2%). Data on prevalence of use is scarce, a study of 2018 found that use of DMT is generally increasing and prevalence was substantially higher among individuals who use other substances (Palamar & Austin, 2018; Lawrence, 2022). Latest research indicates similarities of these phenomenological experiences across subjects (Lawrence et al., 2022). It remains unclear how much of these similarities are due to cultural or individual priming and/or influencing, as stories about 'DMT entities' or the 'DMT parallel world' can be found all over the internet.

The pineal gland, a single gland at the centre of our brain, important for the biosynthesis of various enzymes like melatonin, was long believed to be the central hub of DMT production. But DMT has been found to be metabolised in other organs such as the gastrointestinal tract and the

lungs and may accumulate and potentially be stored in neuron vesicles (Chaves et al., 2024). DMT is also metabolised in the gut and in the liver, along with MAO enzymes. This immediate MAO activity (an example of a first-pass effect) is avoided when DMT is inhaled through the lungs, making it psychoactive (Neumann et al., 2024, p. 9). Administering DMT to mice with a 5-HT_{2A} knockout receptor leads to an abolished head twitch response, which is generally a response interpreted as experiencing a psychedelic effect in rodents (Glynos et al., 2024), indicating the importance of the 5-HT_{2A} receptor for the psychedelics experience. Neumann et al. (2024) also point out that DMT not only acts through 5-HT_{2A} receptors (the receptors that research predominantly has focused on so far) but many others, including 5-HT₄ receptors. Interestingly though, 5-HT_{2A} receptor activation promotes glutamate release indirectly by stimulating excitatory neurons and reducing inhibition, contributing to increased cortical excitation and sensory and cognitive effects. This could potentially align with the TRAZE approach to consciousness mentioned in section 2.2.10., where consciousness is mediated through the release of glutamate.

Common beliefs about DMT production are that it gets released closely before death and at birth, both claims have not scientifically been proven. In case of near-death experiences, there are phenomenological significant similarities (see p. 61) to the experience, neurological evidence is limited as during these experiences the brain releases all kinds of neurotransmitters in high quantities and data on humans are limited. Even though endogenous DMT production in humans has been proven - but as it is metabolised by MAO enzymes really fast many scientists concluded that it has no physiological role in ordinary states of consciousness. Further research about endogenous DMT production is needed. Stress has been associated with elevation of DMT levels in rodents (Grammenos et al., 2015) and Dean et al. (2019) also observed a sudden increase in DMT levels in rats during cardiac arrest. Therefore, the hypotheses that DMT is part of acute stress responses and part of near-death experiences does not seem too far fetched. According to the '*transmethylation hypothesis*', psychosis could result from a biochemical disruption in the stress mechanism by releasing DMT, which could account for some positive symptoms of psychosis as there is an established phenomenological overlap between the DMT experience and psychotic states (Grammenos et al., 2015).

Unlike other classical psychedelics, DMT's interaction with sigma-1 receptors may enhance neuroplasticity, neuroprotection (as it helps to protect the cells from hypoxia) and cognitive function (Chaves et al., 2024). This activation of sigma-1 receptors may thus also offer therapeutic benefits in neuropsychiatric disorders. It has also been suggested that DMT may be involved in diverse physiological functions like synaptic plasticity, neonatal brain development, normal sensory perception or modulation of brain mitochondrial function (Chaves et al., 2024), see figure below. Nevertheless, DMT's natural role remains elusive. While endogenous DMT is confirmed in the rat brain, its presence in the human brain and exact physiological roles need further exploration.

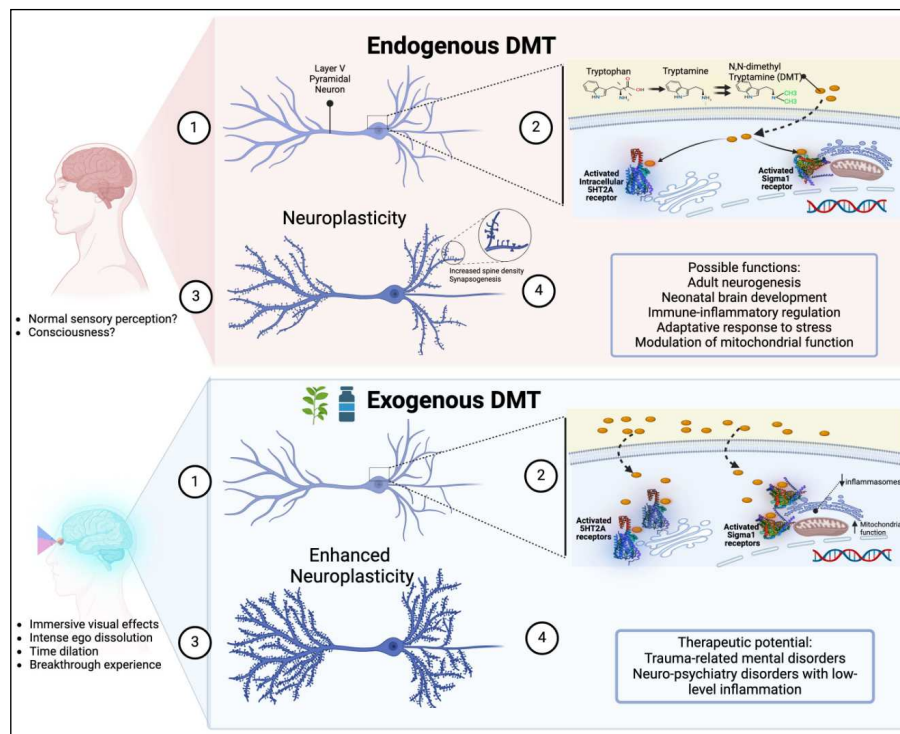


Figure 3: Postulated functions of endogenous and exogenous DMT in the human brain (Chaves et al., 2024)

3.2. Neurological effects of DMT

As Christopher Timmermann, head of the DMT Research Group at Imperial College London, points out in various presentations⁴, measurements have to be interpreted from two perspectives, especially when it comes to effects of a psychedelic experience:

1. The *static perspective* describes results as an average over the time course of the psychedelic experience.
2. The *dynamic perspective* takes into account the transitions that happen within the experience - includes a temporal perspective and the unfolding of the experience.

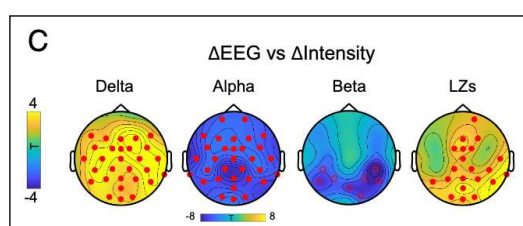


Figure 3.1.: A dynamic minute-by-minute intensity ratings correlate positively with increases in delta power and LZs and negatively with global alpha and posterior beta power changes (Timmermann et al., 2023)

Electroencephalogram ('EEG' - which is characterised by a good temporal resolution) spectral power analyses show that the DMT experience generally reduces oscillatory power in alpha and beta bands and increases spontaneous signal diversity. Higher concentrations of DMT were associated with greater reductions in alpha and beta power. Oscillatory activity within delta and theta frequency bands furthermore correlate with the peak of the experience. The increase of theta and delta oscillations together with the collapse of alpha and

⁴ Christopher Timmermann: The Neurophenomenology of the DMT State: https://www.youtube.com/watch?v=p66i9RFqgMw&list=PLxJ9F3zr14wgDkgCe_vee6hh6nL8q_Pqw&index=24; timestamp: 17:50

beta rhythms has been associated with REM sleep dreaming and other visionary states, when switching from exogenous information processing to endogenous information generation as well as processing. Suppression of alpha power as well as increased complexity or signal diversity (also referred to as brain entropy), often represented as Lempel-Ziv ('LZ') complexity signal - a compression algorithm which measures of the complexity or randomness of a signal recorded with EEG. It quantifies how frequently new patterns or sequences appear in the signal - seem to be the most robust functional brain effect of psychedelics in general (Timmermann et al., 2019). While Timmermann et al. (2019) did not find differences in the gamma band activation, Pallavicini et al. (2021) most salient result in their naturalistic study consisted of increased gamma power under DMT. They postulate that gamma hyper-synchrony can be a manifestation of increased information binding, underlying psychedelic-induced unitive experiences. They point out though, that the role of gamma activity remains unclear, as this activity can also result from muscle tension, jaw clenching or micro saccades. A detailed description of brain wave changes as well as changes in brain area activities and the respective phenomenological correlates can be found in table 3 below.

Figure 3.1. compares changes in EEG activity across different frequency bands and neural complexity (measured as LZs) to changes in intensity, referring to the subjective intensity of an experience. This indicates that more intense experiences are associated with greater increase in delta power and LZc as well as decreases in alpha and beta power. Figure 3.2. reflects a relationship between the complexity of brain dynamics (described by LZc - averaged across channels) a measure of neural signal complexity) and the subjective richness of conscious experience. It suggests that greater neural complexity is associated with richer subjective experiences. Both of these figures support the entropic brain hypothesis (Carhart-Harris, 2019). It has been shown that reductions in alpha power through administration of psychedelic substances seem to depend on the activation of 5-HT2A receptors. Furthermore, regions with densest expression of 5-HT2A receptors (e.g. the primary visual cortex) are most affected by DMT intake (Timmermann et al., 2023).

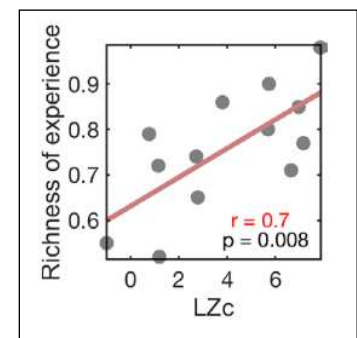


Figure 3.2.: Correlation between LZc and 'richness of the experience' (Timmermann et al., 2023)

To infer valid neurophenomenological correlates, fMRI measurements - characterised by good spatial resolution - should be included in addition to the spectral power analyses. According to these measurements, DMT intake leads to a dysregulation of high-level brain systems like the TOP ('transmodal association cortex pole'), which is involved in complex integration and abstraction of information as well as in the default mode network (DMN), most commonly attributed to the sense of self (Timmermann et al., 2023, p. 2).

Table 3: Correlations between brain wave and area changes assessed through EEG & fMRI measurements and phenomenological reports assessed through questionnaires or microphenomenological inspired interviews under the influence of DMT (self-made)

Brain waves & brain area changes	Phenomenological effects
Decrease of oscillatory alpha rhythm bands (8-13 Hz), particularly in sensory and perceptual areas like visual cortex.	State of increased attentiveness, sensory engagement, active interaction with external environment. Changes in emotional or metacognitive effects (Pallavicini et al., 2021; Bonelle et al., 2024). Top-down processing decreases.
Decrease of oscillatory beta rhythm band (13-30Hz)	Beta band is associated with bodily perceptions such as motor perceptions, actions & observations, which are decreased (Timmermann et al., 2019)
Increase in theta band (4-8Hz), replacement of alpha rhythms	Dream-like states. Power of theta oscillations was inversely correlated with feelings of unity and transcendence (part of mystical-type experiences). There seems to be a link between anxious rumination and increased theta power. Theta band is linked to autobiographical memories, mental time travel etc. (Tagliazucchi et al., 2021).
Increase in delta band (1-4Hz)	<u>Seems to be a marker of conscious disconnection from reality</u> - not a marker for reduced awareness. This increase in delta waves may be a unique feature of DMT compared to other psychedelics, and therefore hints at the possible importance of delta waves for the construction of a sense of reality - as this construction is unique for DMT experiences (Timmermann et al., 2023).
Low-gamma activation (30-55Hz)	Remains unclear, could be due to movement artefacts or anxiety. Correlates with 'experience of unity', 'disembodiment', 'anxiety' (from 5D-ASC), 'mystical', 'awe' & 'transcendence of time' (from MEQ-30). Increased gamma activation in natural settings, just like in near-death experiences. Discrepancies hypothesised to be due to contextual factors (Pallavicini, 2021, p. 8 & 12 ff.).
Increase in Lempel-Ziv complexity	Richness of experience (Timmermann et al., 2023).
Deactivation of hippocampus & medial parietal cortex	Changes in time perception, spatial awareness & self-referential processing (Pasquini et al., 2024).
Activation in superior temporal lobe	Sensory hallucinations and entity experiences (Pasquini et al., 2024).
Hyperconnectivity in high-level networks & disconnected low-level sensory systems (Soares et al., 2024)	Increased abstract semantic processing & meaning making: novel concepts & attributing mind to others & decrease of felt embodied self.
Backward travelling waves decreased & forward travelling waves increased	Reality seems to be deconstructed and then reconstructed (Alamia et al., 2020).

The specific regions involved and their functional connections give rise to very different experiences. Global hyper-connectivity and reduced intra-network integrity was correlated with decreased alpha power and increased overall entropy. The authors also found similarities in their results on brain function - a dysregulation of activity in high-level cortex and a compression of the brains hierarchical organisation - to brain profiles of experienced meditators while meditating as well as in individuals with schizophrenia and infancy (Timmermann et al., 2023). More details on fMRI measurements of the DMT experience assessed through a relatively new method of dissecting fMRI data - a method called 'connectme-harmonic decomposition' - Atasoy et al. (2016) - and what insights this method can bring about measurements of non-ordinary states of consciousness are discussed in section 4.9.

Reality construction

Participants and users report of being immersed in another reality under the influence of DMT (more on this in the next section: *Phenomenological effects of DMT*). By looking at the brain correlates when such a reality is constructed, it might be possible to infer more about the brain mechanisms responsible for general reality construction - also under ordinary states of consciousness. Brain waves seem to be correlated with backward travelling brain waves when engaged in reality construction, while forward travelling waves are associated with integration of new information. DMT decreases backward travelling brain waves and increases forward travelling ones, which seems to indicate that 'normal' reality is deconstructed while simultaneously new information is being integrated (Alamia et al., 2020). These results support a recent model aligning the data with predictive processing accounts. The 'REBUS' ('relaxed beliefs under psychedelics') model proposes that psychedelics reduce the 'precision-weighting of priors', thus altering the balance of top-down versus bottom-up information processing (Carhart-Harris & Friston, 2019), albeit there are new approaches like the ALBUS ('altered beliefs under psychedelics') model which proposes a dose-dependent effect, where different levels of 5-HT_{2A} signalling lead to distinct alterations in perception and belief formation (Safron et al., 2025). Importantly, Timmermann (2023) points out is that an increase in delta waves seems to be a marker of conscious disconnection from reality, not a general marker for reduced awareness, as previously assumed. A hypothesis on the ontological feeling of reality is discussed on p. 62. Another study demonstrated that DMT modulates brain connectivity in socio-emotional and affective-value circuits by increasing functional connectivity in the posterior supramarginal gyrus and amygdala (Soares et al., 2024). They showed that DMT inhalation modulates functional connectivity between theory of mind, limbic and reward brain areas. To summarise, DMT seems to lead to a hyper-connectivity in high-level networks, while low-level sensory systems get disconnected (Soares et al., 2024). This hyper-connectivity in high-level networks is generally associated with abstract semantic processing, meaning making and mentalisation and correlated with psychiatric disorders like schizophrenia or depression, where hyper-connectivity leads to overactive meaning making by exaggerated self-relevance (Whitfield-Gabrieli & Ford, 2012).

3.2.1. Somatic Markers

Bodily effects of the DMT experience include a sense of rush, vibration, warmth, distorted bodily perception and perceived boundary dissolution. Interoception is generally reduced during the DMT experience after the initial onset which is characterised by an elevated heart rate during the first minute of the experience, as seen in the figure below (Timmermann et al., 2019). The overall sense of self, along with the distinctions between narrative vs. bodily vs. phenomenal sense of self will be discussed further in section 4.1.1.

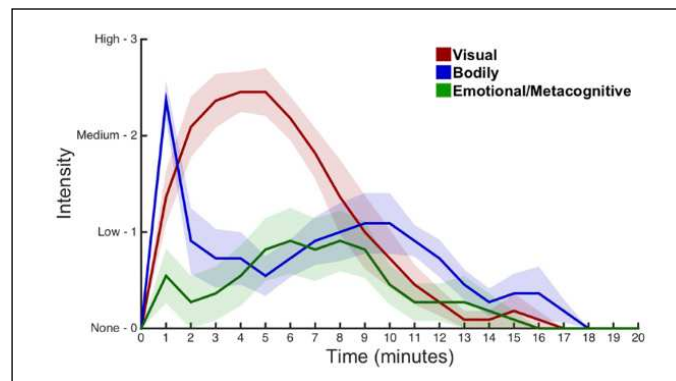


Figure 3.3.: One of the first scientific visual representations of the effects of the DMT experience over time clustered into visual, bodily & emotional/metacognitive effects (Timmermann et al., 2019). The blue line indicates how after the initial quick onset of the experience, bodily intensity ratings drop sharply leading to an overall decreased bodily awareness.

Heart Rate Variability (HRV) & the autonomic nervous system (ANS)

HRV is a marker of cardiac ANS regulation. It is a measure of the variability in the time interval between heart beats. Reductions in HRV have been correlated with negative health outcomes: mortality, cardiovascular disease, indicating to be markers of stress, poor sleep quality, psychiatric

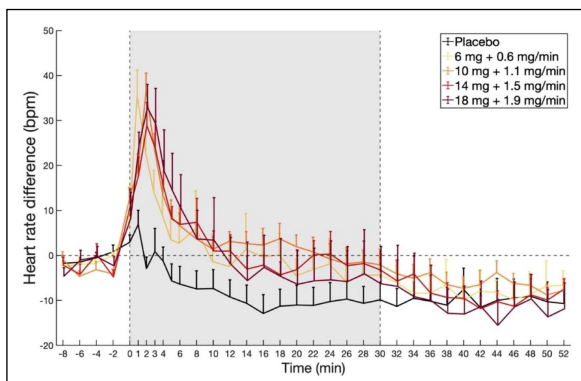


Figure 3.4.: Acute changes in HR following continuous infusions of placebo and different doses of DMT (minutes 0-30) (Luan et al., 2024).

conditions and depressive symptoms (Lawrence, 2022). A low HRV marker has been associated with reduced ANS flexibility, increased sympathetic activity and reduced parasympathetic activity. A case study (Lawrence, 2022) reported acute elevations in heart rate after administration of DMT for approx. three to four minutes after DMT inhalation. A persistent elevation in HRV one day after DMT intake was also reported. This raises the question if an elevated HRV following DMT ingestion can have some positive therapeutic effects.

The ANS plays an important role in mediating emotional experiences, its involvement in psychedelic experiences has not been completely understood yet. The ANS is composed of the sympathetic (SNS) and parasympathetic nervous system (PNS). While most of the research done on DMT or psychedelics in general has been done on the neurological effects on the human brain, the effects on the human nervous systems remain under-researched even though brain and body are intrinsically linked - as every Cognitive Scientist or somatic therapist knows - also emphasised by the *embodied approach* to Cognitive Science (Varela et al., 2017). The importance of the ANS activation at the cardiac level is becoming more recognised. Classic psychedelics generally activate the SNS, whereas the PNS is subsequently activated as a homeostatic response to the initial stress response, leading to a contemplative quality of the experience. This unusual coactivation between SNS and PNS has been termed '*sympathovagal coactivation*' (Bonelle et al., 2024).

The paper (Bonelle et al., 2024) states that this sympathovagal coactivation over cardiac activity was positively related to participant's subjective reports of spiritual experience and insightfulness during the DMT experience - which in turn have been associated with positive changes in behaviour and thought patterns. The paper points out that this coactivation can be seen as a cardiovascular recovery from initial physiological stress, a process called '*vagal rebound*', which has also been associated with oxytocin and cortisol level reduction after being exposed to a stressor. This vagal rebound could explain the phenomenological effect of the '*after-glow*' phase, in which individuals report a state of peaceful arousal shortly after DMT intake. Additionally, the sympathovagal coactivation has been correlated as a marker for improved well-being for up to two weeks after the session. What is more, is that the baseline balance between these two branches was more predictive about well-being scores during the DMT experience than subjective reports (Bonelle et al., 2024), making it a possible marker of '*readiness*' for the experience.

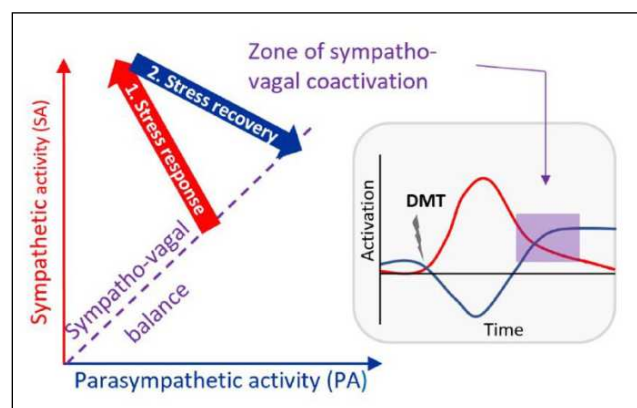


Figure 3.5.: Proposed model for the ANS involvement during the DMT experience: sympathovagal coactivation of SA and PA lead to an initial stress response which is afterwards modulated. Peak experiences as well as 'after glow' seem to be related to this dual influence as well as to starting the experience from a balance of this two branches (Bonelle et al., 2024).

Unlike HRV - which primarily focuses on the intervals of variability within specific frequency bands - heart rate entropy (HRE) captures the degree of randomness or disorder in heart rate dynamics. According to Bonelle et al. (2024) DMT intake also consistently increases heart rate entropy. Changes in heart rate entropy during the experience were also found to correlate with brain

entropy in various areas, particularly during intense periods of the psychedelic state. Increased brain entropy - associated with an expansion of the repertoire of active brain states (Atasoy, 2017) - has been associated to psychological flexibility by possibly relaxing prior beliefs - 'REBUS model' (Carhart-Harris & Friston, 2019). Bonelle et al. (2024) propose that a coactivation of SNS and PNS could therefore not only lead to a higher heart rate entropy but also to a higher brain entropy. Also, HRE served as a predictor for certain aspects of the psychedelic experience - such as the intensity and complexity of the experience - indicating that heart rate dynamics could serve as a non-invasive way to track the effects of psychedelics on non-ordinary states of consciousness in general. They point out though, that only the coactivation with the branch of the PNS related to rest and safety - compared to the second branch associated with immobilisation - promotes peak experiences. Surprisingly, lower sympathetic activity - typically associated with reduced stress responses - does not automatically result in a more pleasant experience. The key emphasis and strongest predictor lies on maintaining a balanced ANS before entering such an experience. A study done in Switzerland regarding the effects of psychedelic assistant therapy (PAT) found that apart from so called 'peak experiences' - defined by Maslow in 1970 as a sense of awe, wellbeing or transcendence (Cummins & Lyke, 2013) - the greatest predictor of antidepressant outcome was relaxation during the PAT session, which again hints at the importance of parasympathetic activation during the psychedelic experience (Calder et al., 2024) and shifts the focus of the importance of mystical-type peak experiences towards also considering the somatic effects of the experience.

Gut-Brain Axis & psychedelics (DMT)

Even though the topic about the gut-brain axis' mechanisms of psychedelics is very limited, I want to mention the importance of investigating the bidirectional relationship between psychedelics and the gut microbes further. Caspani et al. (2024) call for more thorough research on this topic as it is possible to target tryptophan availability for serotonin synthesis by the individual participants - which can potentially be beneficial for maximising psychedelic effects. They postulate that the gut microbiota is an indirect modulator of the effects of psychedelics on psychological outcomes and that furthermore, psychological improvements affect gut microbial composition. DMT is metabolised by monoamine oxidases (MAO) which are present throughout the blood vessels in the body but especially abundantly present in the gastrointestinal tract (Manzoor & Coda, 2020). This is a factor to consider when examining effects of endogenous as well as exogenously administrated DMT.

Other somatic markers worth mentioning

This short subsection mentions various somatic markers that have been identified in the literature but lack sufficient research depth to warrant individual sections. Table 3 below summarises potential correlations between all discussed somatic markers and neurophenomenological findings. Reports of perceiving an auditory ringing sound, feeling like bursting through a membrane during the 'breakthrough experience' are not uncommon (in Lawrence et al., 2022:

15.4%, n=3778). It is described as a 'buzzing, vibrating, humming or electric popping, a high pitched tone or as an auditory carrier wave' (Lawrence et al., 2022). How this can be explained neurologically is still unclear, but since tinnitus can be considered to be a partly psychosomatic condition and auditory hallucinations are also the main form of hallucination in patients with schizophrenia, it does not surprise that perceiving auditory sounds can occur in absence of any corresponding external sound source (Gasparre et al, 2023; Hugdahl et al., 2008). Possibly the biggest study (regarding number of included reports) on the phenomenology of DMT done as a qualitative analysis of a *Reddit* community over a ten year period from 2009 to 2018, also found somaesthesias - body vibrations or tingling sensations and outer-body experiences (dissociation or body dissolving) - to be very common during DMT intake. The feeling of falling or moving at a high velocity was found in 8.8% of reports. Furthermore, amnesic events, forgetting at least part of the experience was prevalent in 15.4% (Lawrence et al., 2022 - n=3,778).

Table 4 - Correlations between somatic markers & neurophenomenology

Somatic 3rd person markers	Neurological and/or phenomenological correlates
Heart Rate increase	Hippocampus deactivation & experience of entities (Pasquini et al., 2024). Reduction in self-referential processing (Pasquini et al., 2024).
Increased Heart Rate Variability (HRV) (Lawrence, 2022)	Increased ANS variability, potential increase in well-being.
Increased Heart rate entropy (HRE) (Bonelle et al., 2024)	Increased brain entropy (Atasoy, 2017).
Increased cortisol levels (Neumann et al., 2024, p. 10)	Fear response at the onset of the experience.
Increased prolactin & adrenocorticotrophic hormone (Neumann et al., 2024)	No direct report: Generally, together, increased prolactin and ACTH could create a mixed subjective experience of feeling emotionally receptive but on edge or more alert, experiencing an intensified awareness of emotional or bodily states.
Pupillary dilatation	SNS activation: alertness
SNS activation (Bonelle et al., 2024, p. 6)	Increase in bottom-up processing & reduction in power of alpha brainwaves.
PNS activation (Bonelle et al., 2024)	Recovery phase: increase in alpha power & decrease in bottom-up processing.
Sympathovagal coactivation / balance (Bonelle et al., 2024)	• Peak experiences • Afterglow • Readiness for experience • Increase in well-being after two weeks
Activated hypothalamic-pituitary-adrenal axis (HPA) axis	Increased ACTH and cortisol (Caspani et al., 2024).

Somatic 3rd person markers	Neurological and/or phenomenological correlates
Gut microme: tryptophan synthesis & MAO composition	Increased or decreased psychological effects (Caspani et al., 2024).

3.3. The neurophenomenological approach to non-ordinary states of consciousness

Studying the relationship between phenomenal and neurobiological phenomena remains one of the biggest challenges in the study of consciousness. Poor reliability of first-person reports, the inability of categorical questionnaires to capture the full breadth and nuances of the experience as well as the dynamic nature of experience or the contextual factors leading to it are still to overcome (Timmermann et al., 2023). Quantitative, laboratory studies of DMT use are limited by their clinical setting (not taking into account the importance of set & setting of psychedelic experiences - more on this on p. 63) and most are lacking a qualitative analysis of the phenomenological content. This indicates the growing importance of a thorough investigation of the phenomenological aspects of the intake of this substance. Furthermore, what most of the traditional methodologies lack - apart from an in-depth and individual nuanced view of the experience - is a longitudinal approach. So far, there is neither a questionnaire targeted at long-term effects of psychedelic use nor are there many studies addressing long-term effects of psychedelic use in general. The neurophenomenological (NP) approach can bridge between subjective experience (first person approach) and neurobiological activity (third person approach) and can help explain intra- and inter-subject data that traditionally would be considered as 'data noise' by making this relationship more accessible, falsifiable and perhaps reproducible (Timmermann et al., 2023). It characterises the interplay between experience, brain, body and environment at multiple spatial and temporal scales (Timmermann et al., 2023, p. 150). This is consistent with the perturbational approach to consciousness, which focuses on the biological organism and its physical environment but also takes into account its experience and the intersubjective content the body is embedded in. The most cost and time efficient way to deploy neurophenomenological approaches are the use of self-answered questionnaires after an experience, even though these methodologies are limited by not capturing the full spectrum of the experience ('thin phenomenology') (Berkovich-Ohana, 2020).

Here a list of used questionnaires to assess phenomenological states in psychedelic research (Yaden & Griffiths, 2024) - sorted alphabetically - the most encountered ones in *italic*:

- Awe questionnaire: connectedness, self-loss, time alteration etc.
- Ego Dissolution Inventory (EDI)
- Emotional Breakthrough Inventory (EBI)
- *Challenging Experience Questionnaire (CEQ)*: grief, fear, isolation, paranoia
- Hallucinogen Rating Scale (HRS)
- *Mystical Experience Questionnaire (MEQ-30)*
- Psychological Insight Questionnaire (PIQ)

- Psychotomimetic States Inventory (PSI): negative effects like delusory thinking, perceptual distortions or paranoia
- Watts connectedness scale (WCS): to self, to others, to the world
- 5 Dimension Altered States of Consciousness (5D-ASC)
- 11-D ASC: unity, blissful, insightfulness, disembodiment, anxiety

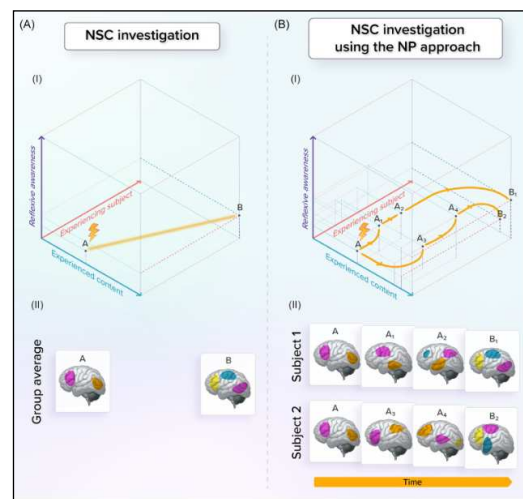


Figure 3.6. - the NP approach for NSC visualised. First person data leads to a greater explanatory power of what under traditional methodologies is considered inter- and intra subjective noise. (Timmermann et al., 2023)

Petitmengin (2006) introduced the micro phenomenological interview (MPI) method to assess phenomenological states in a as pre-reflective and thorough manner as possible ('thick phenomenology'), capturing more details than the use of questionnaires. The MPI method is used to help get closer to the actual essence of the experience. Many experiences are ineffable, meaning they cannot be described, particularly not in words. Petitmengin distinguishes between verbal, non-verbal and para-verbal indicators. Other experiences are below the threshold of awareness, subliminal or subconscious, making them inaccessible to direct introspection while others are pre-reflective. The latter ones are in conscious awareness but not explicitly noticed or analysed, as is often the case with our interoception. Only by actively paying attention to our bodies or our breathing, we become aware of the sensations associated with it. Through the use of MPI, focus can shift to how a particular experience unfolds, rather than on the mere content. Participants are encouraged to focus on micro-temporal aspects - the precise sequence and structure of their experience. Through the use of sensory and spatio-temporal cues, the interviewer helps participants to recall experiences with greater detail (Petitmengin, 2006).

According to Francisco Varela, the core working hypothesis of neurophenomenology is the reciprocal circulation between external analysis and first-person phenomenological reports. He emphasises that true insight comes not from examining the content of an experience but from analysing its structure - the underlying patterns and organisation of experience. Varela also adapted the concept of 'epoché' - a term originally from phenomenology - which involves bracketing assumptions to study the invariants of experience directly and free from preconceived biases (Varela, 1996). Applied to neurophenomenology of psychedelics, instead of explaining the effects in terms of brain chemicals and a feeling of otherness, the structure of the experiences - i.e. the intensity; the changes over time; how attention, emotion or physical sensations are affected etc. - is being studied. In neurophenomenology, *structural invariance* refers to stable patterns or relationships (so-called 'invariant structures'). Structural invariance aims to provide a coherent framework for identifying stable patterns that remain consistent both within individuals

(intra-level) and across different individuals or contexts (inter-level). By uncovering these invariances, the approach forms the foundation for scientifically understanding non-ordinary states of consciousness and psychedelic experiences.

3.4. Phenomenological effects of the DMT experience

Rick Strassman is an American psychiatrist and researcher known for his groundbreaking studies on DMT in the early 1990s. His research was among the first federally approved human trials on psychedelics after decades of prohibition. Strassman administered DMT to volunteers in a controlled clinical setting, documenting their profound experiences - including reports of encounters with 'otherworldly' entities. He developed the Hallucinogen Rating Scale (HRS) as part of his research to systematically measure the subjective effects of DMT and other psychedelic substances. The HRS is a structured questionnaire designed to assess various aspects of the psychedelic experience, including visual, emotional, cognitive, and bodily effects. It provided a first standardised framework for analysing the experiences of participants (Berger, 2016, p. 162ff.) Berger (2016) further cites the work of Peter Meyer of 2015, where Meyer identified five levels of the DMT experience, depending on dosage (Berger, 2016, p. 232):

1. *Threshold Experience*: inner experience of the flow of energy.
2. *Visual distortions*: geometric patterns moving around.
Transition Phase: bursting through a tunnel. Entering a new dimensional world.
3. *Higher dimensional space*: possible contact with some sort of intelligent and independent entities.
4. *White light*: mostly accompanied by amnesia of the experience.

A newer, but similar approach to defining these different levels has been taken by Andres Gomez -Emilsson in 2019⁵: dose ranges from inhaled 1-4mg up to a breakthrough apparently reached at about 25mg. As seen in the figure 3.7., Gomez-Emilsson's approach distinguishes between energy and information when it comes to the visual effects of the experience. In the last ten years many more studies about the phenomenology of DMT have been published. Christopher Timmermann described the DMT experience in a presentation⁶ as *content-full*, compared to 5-MEO-DMT, an even more powerful naturally occurring psychedelic found in certain plant species and the venom of the *Bufo alvarius* toad, which can be described as *content-less*, as it seems to be a good candidate to measure minimal phenomenal experiences (MPE)⁷ (more on p. 66). This distinction could be relevant for future studies about different states of conscious experiences.

⁵ Andres Gomez, Presentation at Harvard Science of Psychedelics Club - *Qualia Research Institute*, 2019 - <https://www.youtube.com/watch?v=loCBvaj4eSg>

⁶ Chris Timmermann - The Neuroscience of DMT: Past, Present, and Beyond
https://www.youtube.com/watch?v=dd7dcmbGJcQ&list=PLxJ9F3zr14wgDkgCe_vee6hh6nL8q_Pqw&index=25

⁷ Christopher Timmermann - Preliminary findings of the utility of employing 5-MeO-DMT to study MPEs
<https://www.youtube.com/watch?v=iY7hXwr8UyU>

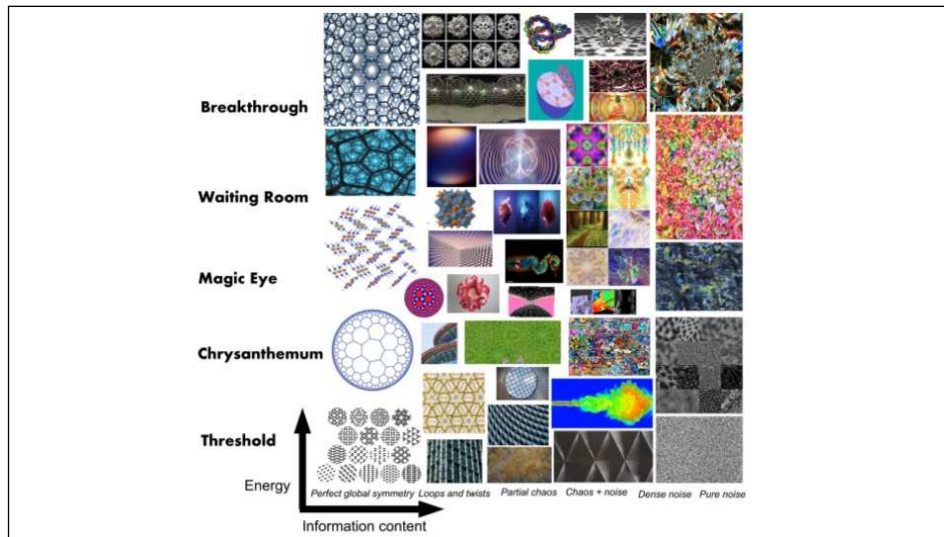


Figure 3.7.: A non-peer reviewed representation of the different 'levels' of the visual effects under DMT, depending on dose differentiated into informational complexity and energy levels. The chart highlights how increasing energy and information content correspond to richer, more immersive experiences and how the different levels of experience could be termed (footnote 5 at p. 57).

Phenomenological reports can be summarised into these main points, more details can be found in the tables below (Lawrence et al., 2022; Millièrè, 2017; Pallavicini et al., 2021; Davis et al., 2020; Michael et al., 2021):

- Perceived Geometry / Hyperbolic geometry / symmetrical visuals
- Ego-Dissolution / Losing one sense of self
- Sense of being transported and immersed into another dimension
- Sense of other presence: entity encounters
- Sense of perceiving information - a noetic quality to the experience (i.e. 'a strong sense of gaining genuine and immediate insight or encountering ultimate reality - being more real than real' (Letheby, 2025)):
 - "I understood time"
 - "I felt the interconnectedness of nature"
 - "Everything that one can ever possibly see is right in front of you"

What remains unclear, is why entity encounters happen mostly with DMT and are quite infrequent with other psychoactive compounds such as LSD or psilocybin (Griffiths et al., 2019). Even though there is a similarity in phenomenological experience with non-drug God-encounter experiences, the perceived entities on DMT differ from encounters with non-drug elicited entities by being generally more benevolent (Griffiths et al., 2019). Under the lease of enactivism and predictive processing, it seems more plausible that the perceived encounters with entities are constructed by the brain to make sense of the experience, rather than these entities being ontologically real. While these encounters are an important phenomenological effect to acknowledge, one should not accept these accounts at face value. Instead, the question should be raised as to how these conclusions are reached after the experience and what implications these conclusions have.

Table 5: Phenomenological effects of the experience clustered in three categories. Somatic sensations excluded (Lawrence et al., 2022; Millière, 2017; Pallavicini et al., 2021; Davis et al., 2020; Michael et al., 2021).

PERCEPTIONAL CHANGES	EMOTIONAL REACTIONS	SENSE OF OTHERNESS
Distorted sense of time // Complete loss of sense of time	Spiritual & Mystical Experiences: • Feelings of Unity • Sense of Transcendence	Veridicality of experience: Noetic aspect: It feels more real than real
Visual & auditory hallucinations: most similar to a dream-like state.	Love; Euphoria; Rewarding / Positive High intensity & valence	Experience is outside of normal human experience; outside of classical three dimensional realm
Geometrical patterns: Fractals, very fast moving shapes	Profundity; one of most meaningful life experiences with lasting effects on life-satisfaction	Still: sense of familiarity, of having been there before
Imploding of the perceptive visual field; distortion of objects	Challenging emotions / Fear	Experiencing otherworldly, sentient beings; communicating with these beings

Table 6: Content of DMT experiences clustered into the two broadest categories identified - some overlap with the previous table 5

DMT WORLD: The changes in perception appear to be really dose - dependent!	ENTITY ENCOUNTERS (Griffiths et al., 2019; Lawrence et al., 2022)
Perceiving: Geometrical Patterns; Shapes; Colours; Mandalas	Seemingly autonomous; conscious; intelligent; benevolent entities
Collapse of Euclidian geometry: Entry into 'Hyperspace' - hyperbolic geometry	Predominantly feminine archetype
Ineffability of the experience	Predominantly positive encounters
Altered dimension: being immersed in more than three dimensions	Descriptors: Being; Spirit; Guide; Alien; Helper
Bursting through a membrane; sometimes perceived through a ringing tone (15.4% of n=3778)	Feeling of omnipresence of these entities
Sense of Familiarity: 'of having been there before'	Feeling that entities continue to exist after experience
Veridicality of DMT space: feels as or even more real than real	Entity encounter is considered to be among the most emotional meaningful life events
Gnostic characteristic: Arriving at awareness of the intrinsic nature of reality - called: 'Ultimate Reality' Salvational Knowledge of the true nature of oneself and the universe.	COMMUNICATION WITH ENTITIES Mode of Communication: Mostly visual; telepathic; gestures & dance Some people receive a message: mostly positive/ reassuring

The pervasive themes reported during DMT experiences may very much reflect cultural priming. Another theory that could explain these themes is that the DMT-state taps into the '*collective unconscious*' - a term coined by Swiss psychiatrist Carl Jung in the 20th Century (Lawrence et al., 2022). This resembles the TRAZE model as discussed in section 2.2.10. (Kepler, 2021), of our brain's tapping into the ZPF and modulating different qualia states. This unconscious repository of shared archetypes, symbols, and instincts is postulated to influence all human individual unconsciousness and behaviours but lacks a clear ontological account. Theoretical approaches like 'biogenic structuralism' attempt to ground Jung's archetypes within a neurobiological and quantum framework, suggesting that archetypes and 'neurognosis' (i.e. how the brain develops knowledge) relate to brain organisation during development and quantum neural network activity (Laughlin, 2010). Future studies should explore these themes' origins through a neurophysiological lens by making sure that cultural or other forms of priming do not influence the reported experiences (Lawrence et al., 2022, p. 18). Also Stanislav Grof, psychiatrist and pioneering researcher of non-ordinary states of consciousness, saw Jung's Archetypes as personified, universal central principles that can potentially yield more insights into our understanding of the world (Berger, 2016, p. 226).

Comparing the DMT experience to other experiences

A high overlap between near-death experiences (NDEs) and ego-dissolution induced by DMT intake could be established. While the experience of unity might be the core component binding both phenomena, the factors 'transcendence of time & space' of the MEQ were more typical for DMT-induced experiences compared to NDEs (Timmermann et al., 2018). A significant correlation could also be found to *Spontaneous Spiritual Awakenings* (SSA), while DMT experiences were found to be slightly more visual and disembodied (Corneille & Luke, 2021). Non-DMT entities that have been encountered in NDEs are rather described as '*humanoid beings having large bald heads and having rather negative objectives*' compared to DMT induced entity encounters (Davis, Clifton et al., 2020). Moreover, individuals having a NDE were more likely to call the experience an encounter with 'God' compared to DMT-induced experiences, which were rather called '*Ultimate Reality*' (Griffiths et al., 2019). Compared to other psychoactive substances, DMT has been shown to be the highest in terms of ineffability, transcendence of time & space and had the highest rate of endorsing positive features and consequences of the experience (Griffiths et al., 2019).

Risks of the DMT experience

Apart from high blood pressure, increased pulse, dizziness, vomiting or in the very worst case serotonin syndrome, there are certain psychological risks to take into account, especially concerning the distortion in sense of reality:

- Ontological shock: experiencing something that challenges the fundamental understanding of reality.
- Troubling revelations which are hard to verify: with no proper integration a sense of loneliness can be experienced afterwards.

- '*Spiritual bypassing*': escapism from reality, giving the illusion of growth without integrating the new insights into every day life.
- Change of metaphysical beliefs and losing sense of reality.

When it comes to the veridicality of the DMT space, the experiencing of this world as 'being more real than real' does of course not verify its reality. Neither should it be simply dismissed as a hallucination. Considering that psychotic people are under the impression that what they are perceiving is real even though their perception of the world does not match up inter-subjectively, the feeling of it being real does not verify its reality. The experience of 'feeling real' should therefore be scrutinised further in a neurophenomenological way. What is more, is that receiving a message about the future or reach the conclusion that every-day reality might just be a simulation, can lead to individuals engage in self-destructive behaviour or can lead to the onset of a psychiatric illness.

A possible explanation for the experience of 'realness' could be the ontological shock that people are experiencing. Through the lens of predictive processing, one hypothesis could be that the ontological shock stems from the brain's inability to match sensory input to its existing models. The high amount of endogenous (bottom-up) prediction error signals that the brain receives during the experience (Schartner & Timmermann, 2020) lead to top-down prior updating to construct a new, coherent world-model which can phenomenologically feel like reality shaping. In predictive processing, action and perception are inseparable from each other. The concept of *active inference* describes the process of minimising prediction errors through action (Seth, 2021, p. 112). Under the influence of DMT, the fast changing, altered perception and disorganised sensory input can make it more difficult for the brain to integrate prediction errors and adjust its actions in a typical, coherent way. Therefore, the brain might experience difficulty in aligning action with predictions during the experience. Framed simply, the brain generates a new model based on altered sensory input but struggles to act on it, leading to a distortion of the active inference feedback loop. This disruption might result in the brain assuming the new model is correct or 'real,' causing it to become a-criterial - no longer subject to the usual standards for assessing reality.

Furthermore, valence and intensity are emotional consequences of prediction errors. The greater the prediction error, the greater the uncertainty and the more intense the emotional experience is going to feel. DMT experiences are usually associated with highly intense states - either frightening or blissful - thus with a high degree of valence and novelty - or uncertainty - which additionally aligns with the hypothesis that prediction errors and active inference could help explaining the experienced ontological shock. Future research could scrutinise this further.

Therapeutic effects of DMT

Changes in depression and trait anxiety correlated with peak experiences (assessed through 5D-ASC with the item of *Oceanic Boundlessness*). The study by Timmermann et al. (2024) concluded that DMT may reduce depressive symptomatology by inducing peak experiences. The study used four different dosages (which obviously limits generalisability) but the authors were still able to conclude that the key variable for a correlation with psychological benefits was the occurrence of peak experiences rather than the dose itself. In depressed individuals, alpha power seems to be increased and delta power decreased which hints at a therapeutic potential of DMT use from a neurological perspective. Setting is important to take into account in neuroimaging environments, which have generally been associated with less therapeutic benefits (Borkel et al., 2024). Therapeutic intent and context increases relevant mental health outcomes - the precise therapeutic effects of DMT thus are still to be assessed. The short duration of the effect was traditionally seen as not beneficial, as the therapists cannot work with the patients within this short time frame and due to people generally feeling fully immersed in the other world, not being able to go through memories or reliving experiences as is the case with MDMA therapy (MAPS, 2015, pp. 31). Furthermore, some experiences are associated with such an ontological shock that integration of them can be very hard. Ayahuasca thus, could potentially be more beneficial for therapeutic outcomes, as it is usually also always embedded in a therapeutic context - or at least in a ritualistic setting. Extended DMT infusion may also address these limitations by offering more controlled, sustained effects (Luan et al., 2024). DMT could offer a cost-effective psychiatric treatment option but more studies are needed to address the efficacy of DMT for therapeutic applications.

Limitations of the neurophenomenological studies

The neurophenomenological studies that have been scrutinised had similar challenges and thus also similar limitations. The most prevalent limitation is the non-uniformity between the dosages, not only across studies but also intra-studies. Some studies concluded that trying out different dosages could have benefits (such as finding differences between dosages). This necessarily leads to different phenomenological experiences though (Timmermann et al., 2019).

Most naturalistic studies that have assessed the phenomenology of DMT, did not take into account dosage or purity of the substance which also limits generalisability (sometimes the use of 'Changa' (Pallavicini et al., 2021) is reported - which is DMT freebase and Beta-Carbolanin put on additional plant material (Berger, 2016, p. 303)). Through the inhalation of this plant material other psychoactive effects could occur, limiting the validity of the presented results. Same goes for the use of ayahuasca, which also includes other plant material and a totally different setting. What is more, is that when it comes to online surveys or meta-analysis of online forums like Reddit or 'Erowid'⁸ (Lawrence et al., 2022), demographic data or pre-existing psychological conditions

⁸ <https://www.erowid.org/>

cannot be assessed. Furthermore, the retrospective aspect of most studies could alter the results, since some of the examined experiences were already years ago (Griffiths et al., 2019). Also, social desirability biases should be taken into account. Through the use of these methods, the sample also represents a self-selected population, which could already be primed about the phenomenological character of the substance. Priming is an important factor to consider when it comes to the phenomenology of DMT. How many of the reported themes or entities emerge in participants that have no established priors of the experience? Nevertheless, these phenomenological reports can serve as valuable data points, particularly in capturing the structure of the DMT experience. As previously noted in section 3.3., focusing on the underlying patterns and dynamics of the experience holds greater scientific significance than focusing entirely on its content.

As with all psychedelic studies, the embedded context; divided into 'set' (defined as a person's worldview, personality, intention, posture, mood etc.) and setting (the person's culture, lineage, environment, comfortability, the facilitators present etc) needs to be taken into consideration as they are essential for the overall experience (Timmermann, Bauer et al., 2023). For example, experiencing anxiety prior to DMT experience could hinder the likelihood of undergoing a mystical-type experience. The limitation of having different settings in naturalistic field studies could be used to examine the effects of context on phenomenology further. Due to anonymity of most of these studies, follow-up questions or longitudinal assessment of data could not be done but could yield important insights into the long-term effects of the DMT experience. What is more, is that most study participants in the selected studies are predominantly Caucasian, white and male people. Further studies across all cultures and ethnicities need to be conducted to limit these biases.

3.5. The boundary problems and the DMT experience

The DMT experience certainly seems to touch upon different boundary problems by seemingly dissolving certain boundaries for a period of time. Regarding the private boundary, there are various reports of feelings of telepathy found across the internet. This phenomenon has not been studied in academic contexts yet, so I will refrain from making too many speculations about this and will only mention that according to a variety of phenomenological reports, the DMT experience - if taken with other people - seems to be potentially able to dissolve the private boundary, leading to perceived non-verbal communication. How far this boundaries dissolve and under what conditions (e.g.: do people need to know each other before? Do they have to be fond of each other? Under what dosage does the phenomenon occur? Does it always occur?) remains open to be studied. To illustrate the experience a report of a Reddit user is included:

"[...] My cousin and friend were there tripsitting, while their friend and I took some Changa. [...] We looked at each other before we left our physical selves, and had a telepathic conversation from across the room. Once back from our trip we both confirmed that it really happened, going as far as to go over specific details of the conversation we

both remembered. Our sitters said we didn't speak a word." (Reddituser: Tacklessmars7, 2010)⁹

Alexander Shulgin - a renowned American chemist and pharmacologist - is often referred to as the 'Godfather of Psychedelics' for his extensive pioneering work of synthesising and documenting the effects of psychoactive compounds. Through self-experimentation conducted primarily between the 1960s and 1990s, he detailed his chemical discoveries and personal experiences with numerous phenethylamines and tryptamines in his books *PiHKAL* and *TiHKAL*. In his short report about his first experiments with 100mg smoked DMT (which is considered to be a very high dose) he wrote:

"As I exhaled I became terribly afraid, my heart very rapid and strong, palms sweating. A terrible sense of dread and doom filled me - I knew what was happening, I knew I couldn't stop it, but it was so devastating; I was being destroyed - all that was familiar, all reference points, all identity - all viciously shattered in a few seconds. I couldn't even mourn the loss - there was no one left to do the mourning. Up, up, out, out, eyes closed, I am at the speed of light, expanding, expanding, expanding, faster and faster until I have become so large that I no longer exist - my speed is so great that everything has come to a stop - here I gaze upon the entire universe." (Shulgin, 1997, p. 417)

This report covers most of the now scientifically identified effects that make up the DMT experience. Shulgin seems to be going through the threshold area until reaching a rapid ego-dissolution as his sense of self evaporated up until reaching a point of perceiving that time has stopped all together. Accordingly, the DMT experience seems thus to be capable of dissolving various boundaries (*higher-level, private and even temporal boundary*) at once in a very short time - at least at a phenomenological level. The next section will explore how the neurophenomenology of DMT can inform EMF based theories of consciousness and how in turn these non-ordinary states of consciousness can be informed by EMF theories.

⁹ Telepathy on DMT: https://www.reddit.com/r/DMT/comments/ds5bv8/telepathy_on_dmt/

4. How can EMF theories and neurophenomenology of DMT inform each other?

4.1. Implications of neurophenomenology of DMT on boundary problems

When studying these phenomena an important analytical distinction should be made between the structural content of the experience (its rudimentary properties: shapes, patterns, textures, i.e. its *topology*) and the representational content (the semantic concepts used to characterise these properties on a level of abstraction). As previously mentioned, phenomenological research should focus on the structural content of these experiences.

4.1.1. The higher-level boundary problem

As described in the previous section, phenomenological reports of DMT include reports of ego-dissolution. This phenomenon is often termed 'DIED' (drug-induced ego-dissolution) in academic contexts. To scrutinise the phenomenon of DIED, the distinction between the narrative, embodied and minimal self is useful (Millière, 2017).

- *Narrative self*: described as an open-ended construction of one's identity, often associated with higher-level cognitive functions and the default mode network, contributing to self-referencing, mind wandering and autobiographical memories, which has been shown to be altered during psychedelic experiences (Gattuso et al., 2023).
- *Embodied self*: this includes sensorimotor engagement, proprioception and interoception and includes the situation or interaction of the body with the environment. According to Lawrence et al. (2022), 17.3% experienced an out-of-body experience like floating, dissociation or their body dissolving altogether. A study found that a reduction in high-beta band activity in the posterior medial cortex (PMC) was correlated with the dissolution of the bodily self (Trautwein et al., 2024) and DMT intake led to beta band reductions (Timmermann et al., 2019), suggesting that DMT leads to a dissolution of the embodied self.
- *Minimal self*: this is closely related to the embodied self, described as an even more basic, pre-reflective experience of being a self rooted in bodily sensorimotor processes in an environment. It requires the experience of spatiotemporal self-location and can be described as the raw, felt sense of being someone in a body in the present moment - as an irreducible sense of selfhood (Millière, 2017).

Minimal phenomenal experiences (MPEs), sometimes also called 'selfless states' are described as a present-moment awareness devoid of a subjective self. MPEs involve a pure, formless awareness, where only the phenomenal state of being aware of being aware remains (Berkovich-Ohana et al., 2020). These contentless states have been found in non-ordinary states of consciousness like deep meditation or as reported by Timmermann's preliminary findings¹⁰, in the phenomenology of 5-MEO DMT. Further research into MPEs can deepen our understanding of the fundamental nature of experience.

¹⁰ Christopher Timmermann - Preliminary findings of the utility of employing 5-MeO-DMT to study MPEs
<https://www.youtube.com/watch?v=iY7hXwr8UyU>

From a predictive processing perspective, psychoactive substances are thought to disrupt the balance between top-down predictions and bottom-up prediction errors in perception. DIED appears to be linked to atypical processing of multisensory endogenous stimuli, leading to a breakdown in the boundary between self and world, as well as self-location. This disruption ultimately results in a profound sense of ego-dissolution (Millière, 2017).

Furthermore, Mason et al. (2020), found that glutamate in the hippocampus is inversely related with ego-dissolution during psilocybin intake and that glutamate levels correlate with the valence of the experience of ego-dissolution (a decrease of glutamate in the hippocampus was associated with a more positive experienced ego-dissolution). They suggest that the specific brain region plays a crucial role in how glutamate levels relate to the subjective experience of ego dissolution. Glutamate thus seems to play a dual role: it is intrinsically involved in the neurochemical mechanisms underlying ego-dissolution and also modulates the subjective or phenomenal experience of an altered state of consciousness, essentially supporting Keppler's TRAZE theory (section 2.2.10.).

4.1.2. The private & temporal boundary problem under DMT

Feelings of private and temporal boundary dissolution under the influence of DMT have been reported, but not scientifically studied yet. A trip report on Reddit illustrates this quite well again:

"Suddenly, it felt as as if time came to a complete halt. We fell into a trance, gazing into eachothers eyes. That broke some kind of barrier in this thought-space. It felt like our consciousnesses broke free of their current constrictions and melded together. 'It' made me into the object, rather than the subject. I started picking out thoughts that weren't mine. ... They were HIS thoughts. I could hear my friend think. I thought to myself: 'Is this really happening, please tell me this isn't real?'. He answered back verbally: 'It is. I... I don't know what's happening.'" (Reddit user [deleted], 2019)¹¹

Some other examples for the possibilities of a dissolution of the private boundary are the concept of emotional contagion and symptom transmission of psychiatric illnesses, which are understudied but well-documented phenomena (Horesh et al., 2021). It has long been acknowledged that one person's psychopathology may significantly affect another's, sometimes to the point of what may appear as full-blown symptom transmission. The transmission of psychotic symptoms for example, has been termed 'Folie a Deux'. A systematic review found that the occurrence of this phenomenon appears to be wider than previously thought, that it most frequently occurs between spouses than siblings. Apparently, physical separation, the presumably recommended treatment, does not always work, specifically when the 'caught' psychosis has triggered an already present psychiatric vulnerability in the secondary patient (Horesh et al., 2021). Another argument for the possibilities of private boundaries being temporally disrupted is the occurrence of 'contact highs',

¹¹ Telepathy on DMT: https://www.reddit.com/r/DMT/comments/bt7p6s/telepathy_on_dmt_story/

in which people feel substance-like effects without consuming the substance but merely being around others who have. These phenomena are well-known among recreational drug users, yet there are almost no studies about this phenomenon to be found (Olson et al., 2020).

What is more, several other Reddit posts explore the concept of time perception being distorted under the influence of DMT, from experiencing the stop of time altogether with no concept of past or future to feelings of travelling backwards or experiencing 'time loops' (Reddituser - justanotherclimber13¹²; Lawrence et al., 2022).

4.2. The higher-level boundary under the EMF topological approach

Before I get into the topological approach of Gomez-Emilsson & Percy (2023), I want to briefly define topology and distinguish the term from topography. Topography describes real-world surface details and measurements, exact physical dimensions or geometry. Topology on the other hand, does not entail precise distances, angles or sizes. Instead, it focuses on the relationships between properties of space that are preserved under transformations like stretching or bending. Topology entails the essence of the structure, it is concerned with the qualitative aspects of geometry rather than the quantitative ones like distances, it is thus frame invariant.

Returning to the topic of boundaries, in their topological approach, Gomez-Emilsson & Percy (2023) emphasise that a strong boundary is necessary for a valid approach of the boundary problem, as from an introspective perspective it at least feels like our 1PP is separated from everything else. Our 1PP appears to be enclosed by a firm and absolute boundary with qualitative differences between what we are aware of and everything else. While fuzzy boundaries seem to be phenomenologically relevant, the authors argue that the phenomenological feeling of a dissolved boundary still needs to be accounted for with a original hard boundary, as multiple pieces of information need to be simultaneously bound. Even if the hard problem is illusory and turns out to be not so hard after all, the processing mechanisms that presents experience as firmly bounded needs to be explained, also from an evolutionary perspective. It is thus necessary to identify mechanisms that result in an ontological boundary that is impermeable to the constitution of the 1PP. In most EMF theories though - if even mentioned - boundaries appear to be continuous and are therefore rather fuzzy, motivated by the decline of EMF strength by distance (e.g. CEMI or the slowest shared resonance principle).

EM fields are continuous by nature, but they can form localised structures what the authors call '*topological pockets*' under certain conditions - a space where EM field lines create confined, stable zones. A possible solution to the boundary problem the authors propose is a topological pocket within an EM field containing 1PP. As most of magnetic field lines occur in closed loops ('Gauss law', p. 14), loops do play an important role in the topological approach of Gomez-

¹² Time perception: https://www.reddit.com/r/DMT/comments/10k1gg5/what_is_time_perception_like_on_dmt/

Emilsson & Percy (2023). If EM fields in the brain form a closed loop, they would create a system where waves reflect off the boundaries, causing the system to act as a unified entity. Once topological segments are formed, EM waves inside these segments lead to resonant modes which represent how the energy within the field organises itself and thus how information is integrated. Resonant modes thus, reflect the topology of the EM field. This is similar to the concept of acoustic resonance, where the relationship between the shape of an instrument and the way it vibrates or resonates is well established¹³. As discussed in McFaddens CEMI field theory (section 2.2.4. & figure 2.1.), EMF loops are the mechanism responsible for conscious awareness. Arrays et al. (2017) provide evidence that it is possible for EM fields to generate knots within themselves, making looping EM fields a realistic possibility of playing a role in consciousness.

With the topological approach of Gomez-Emilsson and Percy (2023) thus, boundaries are determined by the topology of the EM field. By understanding the geometric properties of EM fields it is possible to define closed spaces where information encoded in the field cannot be externally exchanged. By alteration of the topology of the EM fields, boundaries could potentially - if only phenomenally - be distorted, leading to feelings of unity. Aligned to a predictive processing account, topological pockets in the EM field could behave like Markov blankets in the free energy principle (Friston, 2013). Gomez-Emilsson and Percy (2023) suggest that there might be dozens or even billions of these topological pockets in any one system, existing at scales both smaller and larger than the typical human experience. They state that our inability to identify these pockets is currently an empirical question related to analysing and measuring field topology, rather than a firm epistemological boundary. However, they do talk about the possibility of topological pockets existing at various spatiotemporal scales, ranging from the sub-neuronal level up to brain-wide fields and potentially even beyond individual brains, which aligns with Levin's ideas about organisation of biological systems through bioelectrical fields, emphasising a dynamic, multi-level structure that spans across different scales. It also implies a hierarchy of scales at which topological pockets might exist. For example, smaller topological pockets might be nested within larger ones, like sub-neuronal level pockets within a brain-wide pocket which aligns with the third conjecture of GRT ('nested-consciousness conjecture' - p. 24) as well as with the TICL approach by Winters (2020) or the OA approach (section 2.2.12. & 2.2.11.).

In flow-states, the term 'pocket' can anecdotally be used to describe a state where movement and perception feel effortless, synchronised and perfectly timed - instinctively - with no apparent conscious awareness. Examples of this would be a musician effortlessly syncing with the band or an athlete making the right moves without conscious awareness (Antonini Philippe et al., 2022). This is still an under-researched topic though and deserves more academic attention.

Gomez-Emilsson & Percy (2023) furthermore argue that the boundary problem is a non-trivial one: any theory that addresses the binding problem must also address the boundary problem. In EM

¹³ Physics of stringed instruments: <https://exploresound.org/2017/02/physics-stringed-instruments/>

fields, a nontrivial topology means that the field lines form stable, structured patterns (like knots or loops) instead of just diffusing away. In brain dynamics, a nontrivial topology might indicate structured resonant modes, where neural oscillations form stable, self-organising patterns instead of random fluctuations (see 'self-organising harmonic modes' in section 4.10.).

4.2.1. The private boundary problem under EMF theories

In their paper, Young et al. (2022) used EM field interactions as a possible explanation of shared experiences. General Resonance Theory (GRT) is used to describe interpersonal resonant phenomena. They propose a coupled system of spatially distributed EM fields, synchronised through recurrent behavioural interactions. When reached sufficient synchronisation, the emerging system profits from an optimisation of information flow and has causal influence of the conscious states of its merging agents, usually leading to an enriched experience and performance. They mention studies that recorded phase synchronisation of neural rhythms across groups of individuals and found that the establishment of such synchrony relies on mutual attention and the presence of prior empathetic relationships. They propose the mechanism of entrainment - unidirectional coupling of one oscillator to another through the slowest shared resonance (SSR) principle - to be crucial. The phenomenology of 'group flow' differs from regular waking consciousness and even though self-other merging is induced during group synchronisation, merged group members are not extinguished ('nested consciousness conjuncture' of GRT - see p. 24). The phase transition from synaptic (i.e. electrochemical information) to ephaptic (i.e. electromagnetic field exchanges) coupling is characterised by once exceeding the critical point, leading to optimised information flow and the capacity for interpersonal communication by saving computational power through synchronisation within the system. It seems that through the oscillatory approach of EM fields, supervening cognitive systems and interpersonal merging could be described and possibly explained down the road.

The topological approach by Gomez-Emilsson & Percy (2023) addresses the private or higher-level boundary by using an analogy of longitudinal balloons being twisted, where features like bottlenecks or knots prevent movement between different 'pockets' - resulting in dynamics that define inside and outside spaces. The temporal boundary problem is furthermore addressed by considering 4D topological pockets where temporal continuity is being generated by constant referencing to certain neurobiological 'memory modules' of the brain (these are not further described in their paper). This constant referencing creates a sense of persistence.

4.3. Transcranial Magnetic Stimulation (TMS) & boundaries

TMS studies combined with EEG measurements strongly suggest different oscillations across space being a distinctive feature between aware and subconscious states. By observing how TMS disrupts or shifts boundaries of conscious awareness (such as isolating specific sensory inputs or altering awareness of a particular body part), it can provide clues about how the EM field organises and alters phenomenal experience. TMS can thus contribute in getting closer of how

the boundaries of 1PP are formed and maintained. Under the topological solution to the boundary problem (Gomez-Emilsson & Percy, 2023), an electromagnetic field by itself does not alone account for emerging boundaries, it is its topology that determines the formation, stability and functional organisation of these boundaries by constraining how neural and field dynamics self-organise. TMS could thus potentially benefit from investigating different topologies of EM fields and applying them to specific brain regions.

4.4. Visual effects: Hyperbolic geometry, Symmetry & 'Hamiltonian of consciousness'

Perceiving geometric patterns in non-ordinary states of consciousness appear to be a transcultural and transhistorical phenomenon. Individuals across different cultures report seeing tunnels, spirals, grids or fractals, which suggests that these experiences reflect fundamental neural processes rather than cultural conditioning. This could be understood as the brain deconstructing visual perception to its most basic building blocks - pure geometry. Neurons in the visual cortex (V1) are structured by columns in a particular, geometric way, which could be the cause of the perception of geometric patterns under non-ordinary states of consciousness. Klüver, identified four basic geometrical 'form constants' (see figure 4) encountered in these non-ordinary states of consciousness (Bressloff et al., 2002), which align with reported DMT experiences (Lawrence et al., 2022).

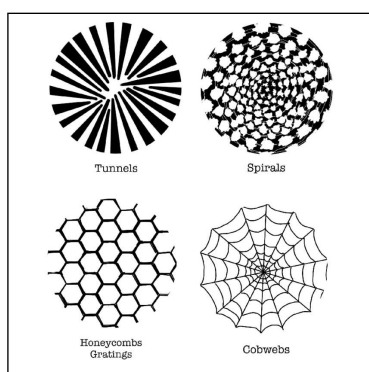


Figure 4: Klüver's form constants (Bressloff et al., 2002)

Since these patterns are perceived with eyes closed and they are able to 'override' the external environment while having the eyes open, it seems likely that the geometry of the brain's visual system influences the patterns that are being perceived. Consistent with mathematical and computational modelling - which have been shown to be an important avenue to illustrate visual effects of psychedelic experiences - Klüver's 'form constants' appear to be universal patterns which may indeed reflect the anatomical structure of the visual cortex as well as reflecting an underlying computational principle of perception (Schartner & Timmermann, 2020) or even of the fractal structure of the physical world itself.

Hyperbolic geometry is a non-Euclidean geometry with constant negative curvature, where parallel lines can diverge infinitely and space expands exponentially. As mentioned on p. 59, seeing hyperbolic geometry is one of the core visual experiences that people report after ingesting DMT. While the brain itself is not hyperbolic, many of its network properties and information processing mechanism can be described by hyperbolic models. Neural connections e.g. follow hierarchical and tree-like pattern, which fit naturally into hyperbolic geometry and are more efficiently modelled in that space than in Euclidian space. Also, functionally similar neurons distant from each other are positioned closer together within this geometric framework (Pitkänen, 2022). More on the brain's geometry and how its activity can be described as wave-like patterns in

section 4.9., when the connectome harmonic decomposition (Atasoy et al., 2016) is being discussed. Interestingly, an EM field can undergo a hyperbolic transformation (such as a 'Lorentz boost') without changing its topology, making them suitable for a possible explanation of these phenomenal accounts (Gomez-Emilsson & Percy, 2023).

What is more, is that the appearance of hyperbolic forms is accompanied by feelings of acceleration (see Shulgin's report on p. 65), often described as *'flying or even bursting through hyperbolic dimensional space.'* This connection to feelings of acceleration is described in Qualia Research Institute's definition of *'Hamiltonian of Consciousness'*: the Hamiltonian¹⁴ is a function in physics that represents the total energy (kinetic and potential) of a system in classical or quantum mechanics. QRI uses the analogy of a 'temperature parameter' to assess consciousness, defining it as the sum of intensity-weighted qualia in an experience. Under the influence of DMT, certain energy patterns become activated, allowing perceptual elements - such as intense colours, kinetic energy or spatial curvature - to morph into one another. In this framework, intensity (aka energy) serves as the fundamental value of experience, manifesting in different forms like colour, movement or geometry. Furthermore, in QRI's glossary¹⁵, *'hyperbolic phenomenal space'* under DMT is defined as:

"So when one raises the energy of the state dramatically (e.g. by taking DMT) the world-sheet tends to instantiate configurations with very high-curvature. The surface becomes generically hyperbolic, which profoundly alters the overall geometry of one's experience. A lot of the accounts of 'space expansion' on psychedelics can be described in terms of alterations to the geometry of the world-sheet."

Furthermore, this framework could potentially account for synesthetic experiences. Synesthetic experiences have been reported on DMT (Lawrence et al., 2022, found a prevalence of 1.2%). Synesthesia is a phenomenon where stimulation of one sensory pathway leads to automatic, involuntary experiences in a second sensory pathway (e.g.: seeing colours when hearing music). Under a predictive processing perspective, synesthesia can be described as leading to uncontrolled, increased cross-modal priors (Safron et al., 2025). When the brain encounters extreme levels of prediction errors, predictions from different networks might be used to explain the incoherent information. Synesthesia is postulated to be a mechanism to deal with prediction errors by using predictions from other networks that usually represent a different modality (Pink-Hashkes et al., 2017). Regarding EM fields, if distinct sensory modalities - like vision and hearing - are represented in nearby brain areas, their EM fields might influence each other, blending sensory inputs. Under the influence of psychedelics, altered neural dynamics may reshape the topology and interaction of EM fields, potentially enabling cross-modal interactions and synesthetic experiences.

¹⁴ <https://www.quera.com/glossary/hamiltonian>

¹⁵ <https://qri.org/glossary>

Psychedelic art, especially DMT related art is characterised by symmetric shapes, similar to harmonic resonance principles or to naturally forming, symmetrical 'Chaldni plate' patterns (see p. 80 and figure 4.2.). Symmetrical shapes or symmetry overall is a core visual effect of the DMT experience ('experienced sacred geometry' - which contains symmetrical attributes - Lawrence et al., 2022). Symmetry is a distinct area of study, with research linking the preference of humans for symmetrical faces and bodies to preference in mate selection. Evidence suggests that symmetry in human bodies is a sign of good health, stable development, and strong genes. Additionally, the attraction to symmetry is often attributed to the way the human visual system processes symmetrical stimuli more easily and efficiently (Leder et al., 2018). Weichselbaum et al. (2018) explored whether the preference for symmetry in art perception is influenced by art expertise by measuring both implicit and explicit preferences. Their findings revealed a strong implicit preference for symmetry, independent of art expertise. In contrast, Leder et al. (2018) found that while non-experts generally prefer symmetrical stimuli, art experts tend to favour asymmetrical ones, challenging the idea that symmetry is a universal principle of beauty. Nonetheless, as mentioned earlier, symmetry continues to play a significant role in evolutionary perception mechanisms. Given these findings, the '*Symmetry Theory of Valence*' proposed by the Qualia Research Institute (QRI) and Detmar's Adaptational Theory of Consciousness (2022) – see section 2.2.7. – appear to be plausible. QRI's theory suggests that if the qualia of a system can be represented mathematically, the degree of symmetry in that structure correlates with how pleasant the experience feels. Similarly, in his *aesthetic argument*, Detmar (2022) proposes that resonating patterns are both pleasurable and evolutionarily beneficial, as they guide organisms through phenomenal experiences. As the only EM field theory addressing meaning and valence, Detmar argues that the EM field immediately signals discomfort from arrhythmic patterns. Like QRI, he contends that the nature of pleasure can be physically explained through different types of EM patterns.

While resonance and symmetry are related concepts, they are not identical. Resonance involves recurring patterns or rhythmic synchronisation, whereas symmetry refers to the balanced distribution of structure or energy. In the context of EM fields, symmetry may determine how energy is organised or conserved, potentially influencing the pleasantness of an experience. Systems with greater symmetry may correspond to more balanced or harmonious qualia, much like how symmetrical musical melodies often evoke stability and positive emotions, whereas asymmetry can introduce tension or unpredictability (Costa & Nese, 2020). Evans et al. (2012), for example, examined human preferences for symmetry and found evidence of a cognitive bias linking asymmetry with feelings of disgust. These findings suggest that symmetry may play a fundamental role in perceptual and cognitive experiences, potentially supporting the idea that the structure of a system's EM field influences its valence. Further research is needed to clarify the role of symmetry in evolutionary perception and how EM field structures may contribute to this process.

4.5. Trembling & Trauma release

Even if trembling or shaking is not reported so commonly (about 1%) during DMT experiences (Lawrence et al., 2022), I still want to discuss this phenomenon, as it is a topic that is poorly understood in a scientific context and ought to be more rigorously studied when it comes to effects of psychedelic substances and trauma in general. It has been shown that psychedelics - such as psilocybin interact with serotonin 2A (5-HT_{2A}) receptors, leading to distinctive shaking behaviours in animal models. A study with awake mice found that these shaking behaviours are preceded by high-frequency oscillations and coincide with low-frequency oscillations in the motor cortex (Buchborn et al., 2023). As briefly mentioned on p. 47, the head twitch response in rodents is being used to assess the subjective effects of psychedelic substances.

The term 'trauma' originates from the Greek word for 'wound' and describes profound disruptions to our bodily and psychological equilibrium, where the memory of a traumatic event overshadows all other experiences (Maté, 2022, p. 16). Trembling is recognised as a somatic therapy method for releasing trauma, exemplified by practices like 'Tension and Trauma Releasing Exercises' (TRE) and 'Somatic Experiencing' (Berceli, 2009 & Payne et al., 2015). While direct scientific studies on humans are limited, it has been suggested that mammals naturally engage in shaking behaviours to discharge stress and trauma (Berceli, 2009). Leading trauma psychologist Peter Levine emphasises the biological nature of trauma, asserting that it is not merely psychological but deeply rooted in our biology. He explains that trauma disrupts the body's natural oscillatory rhythms, causing the nervous system to become stuck in a hyperaroused or frozen state. This dysregulation can manifest as trembling, shaking, vibrations, waves of warmth, deep breaths, slowed heart rate, muscle relaxation, and an overall sense of relief and safety. These sensations indicate the body's ability to self-regulate and return to a state of balance (Levine, as cited in Ives, 2020).

Levine speaks on the belief that somatic therapy works through the body first to help reprogram the mind, which is a 'bottom-up' approach to healing rather than trying to resolve the trauma through talk therapy, a 'top-down' approach. The aim of Somatic Experiencing is to access the body memory of the event - not the semantic story of the experience - and work to heal and release the embodied trauma patterns (Ives, 2020). From an Somatic Experiencing point of view, this trembling or shivering is an opportunity for therapeutic intervention; it is a sign of the system's attempt to begin restoring normal function (Payne et al., 2015). Trembling can be seen as resonant release mechanism, the body engages in spontaneous oscillatory movements that help restore lost rhythm and coherence. Vibration and coherence could be considered as natural healing mechanisms. As the body reengages in natural resonant frequencies, the energy that got originally stuck in the muscles is integrated and eventually released rather than suppressed, leading to an overall nervous system regulation.

Healing through trembling resembles the phenomenon of cats purring (Muggenthaler, 2001). While it has long been believed that cats purr out of contentment, it has been demonstrated that they also do so when they are severely injured or frightened, to calm down their nervous system. Cat larynges can produce sounds in the purr regime with frequencies of 25 to 30 Hz without neural input or muscular contraction (Herbst et al., 2023). This could generate low-level electromagnetic activity, possibly affecting the cat's body and even nearby organisms. Since sound waves are mechanical vibrations, they could also interact with electromagnetic fields within biological tissues, influencing cellular processes. Speculatively, the resonance of purring could help synchronise EM activity in cells, promoting healing, just like in the 'Pulsed Electromagnetic Fields' (PEMF) method (Flatscher et al., 2023).

Regarding DMT experiences, a brief search in the Reddit 'r/DMT'¹⁶ (last accessed on 25th February, 2025) community showed at least seven entries regarding shaking or trembling. For example:

"Can anyone tell me why DMT makes my body shake uncontrollably? Second time I think remember noticing that it felt like my muscles were the ones shaking profusely not my body if that makes sense". (Reddit user: Lookingthruyoureyes, 2023) ¹⁷.

One of the responses explicitly mentioned DMT playing an active role in trauma release mechanisms:

"As dmt opens up and activates deeper levels of your autonomic nervous system that you would not generally have access to, this process is starting to happen naturally. I suggest allowing it to do so as it can be quite healing." (Reddit User: peanutbutterandbacon) ¹⁸.

Notably, hyper-synchronous activity and trembling also play a crucial role in understanding epilepsy and should be differentiated between the trembling of the above mentioned examples. During epileptic seizures, there is widespread neuronal synchrony; however, this excessive synchronisation lacks informational content and correlates with a loss of conscious awareness. This observation challenges IIT - which associates the highest integrated information (Φ) with consciousness, as it struggles to account for unconscious states like seizures. McFaddens' *CEMI Field Theory* offers a compelling explanation by suggesting that while neuronal synchrony amplifies the brain's EM field, excessive synchrony during seizures leads to a uniform field lacking the complex, differentiated patterns necessary for conscious experience. Thus, the quality of consciousness depends not merely on synchronisation but on the richness of information within the EM field. (McFadden, 2020, p. 6).

¹⁶ <https://www.reddit.com/r/DMT/>

¹⁷ https://www.reddit.com/r/DMT/comments/zzs5cb/can_anyone_tell_me_why_dmt_makes_my_body_shake/

¹⁸ https://www.reddit.com/r/DMT/comments/zzs5cb/can_anyone_tell_me_why_dmt_makes_my_body_shake/

A recent study confirmed that breathing influences electromagnetic fields due to changes in the lungs' dielectric permittivity as they fill with air (Vassilyev & Mendakulov, 2024). It might be possible, that *Holotropic breathwork* - a practice involving continuous and repetitive breathing exercises inducing psychedelic-like experiences and on a somatic level, often also including trembling or shaking (Grof, 2014) - significantly impacts endogenous EM fields, potentially contributing to these psychedelic-like and even therapeutic effects. While some have speculated that DMT is produced in the lungs (Berger, p. 88; Chaves et al., 2024), as mentioned in section 3.1., research on human endogenous DMT production remains limited and still inconclusive. Therefore, I avoid further speculation on potential links between DMT, breathing, and EM fields.

To conclude, further studies should address the connection between trembling and psychedelic experiences through the lens of alteration of electromagnetic fields or resonance as a potential avenue for healing as these correlations remain highly speculative for now.

4.6. Attention & EMFS

Attention has often been described as the 'spotlight' that narrows the focus of consciousness, directing awareness to specific possibilities while filtering out others (Hari, 2022, p. 260). It has been a central topic of study and debate in neuroscience for many years. The connection of attentional processes with EMFs could be described by cross-frequency coupling (CFC), specifically phase-amplitude coupling (PAC). As discussed on p. 24, PAC occurs when low-frequency rhythms modulate the amplitude of faster brain oscillations. An analogy from acoustics helps illustrate this mechanism: a slow beat (low-frequency wave) establishes the overall rhythm, while a faster melody (high-frequency wave) adjusts its intensity (louder or softer) depending on its synchronisation within the slow beat's cycle. Similarly, in the brain and overall body, this synchronisation of different frequencies (and therefore different EM fields), seems to enable efficient coordination of cognitive functions such as attention and memory, leading to a dynamic pattern in the brain's EM field, where field lines converge, essentially modulated by underlying resonant modes. It might thus be worth scrutinising the topic of attention and its disturbances - like attention deficit disorders - through the lens of EMF interactions.

4.7. Oscillatory vs. fractal power of EEG measurements during DMT intake

EEG signals consist of both fractal and oscillatory components. The oscillatory component refers to rhythmic (i.e. synchronous, resonant activity between neurons) brain waves, which are more easily linked to different cognitive states such as attention or non-ordinary states of consciousness than the fractal component. The fractal component represents aperiodic activity that reflects the brain's background dynamics and overall complexity. Interestingly, as seen in figure 4.1., when the EEG signals of DMT intake are sliced into their fractal power and a oscillatory power, the fractal component appears to be less functionally relevant than the oscillatory component, especially when it comes to theta and alpha bands (Timmermann et al., 2019).

Oscillatory power appearing more relevant than the fractal component could potentially hint at the importance of synchronous and regular rhythmic activity in shaping subjective experiences. Resonant interactions of specific frequency bands could be a key mechanism during non-ordinary states of consciousness. It seems reasonable to suggest that differences in fractal vs. oscillatory power hint at a potential role for synchronous, resonant activity and thus leading to (EM-)field effects being affected by this. The difference of these powers, the role of synchronised activity in specific frequency bands on affecting on phenomenology or how EM interactions might modulate global brain function could be explored further.

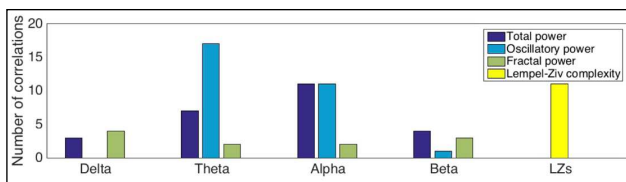


Figure 4.1.: Changes in alpha correlated strongly with the subjective experience when total and oscillatory power was used, while theta changes correlated strongly when only the oscillatory component was employed for analysis (Timmermann et al., 2019).

Furthermore, delta waves are typically associated with deep sleep and unconscious states, yet under DMT, they seem to increase while losing their structured oscillatory patterns. As discussed on p. 51 and in table 3, delta waves under DMT may indicate a disconnection from external reality and a breakdown of hierarchical neural communication (Timmermann et al., 2023).

Also, low-frequency oscillations like delta waves play a crucial stabilising role in coordinating large-scale brain activity (Schroeder & Lakatos, 2009). Within the framework of EMF theories, this destabilization of low frequency oscillations could reflect a disruption in the brain's endogenous electromagnetic field. A loss of oscillatory power in delta waves could thus lead to a more entropic, disorganised field, mirroring the altered perception and cognition seen in DMT-induced states. In essence, the increase in delta power without oscillatory coherence may signal a shift from a stable neural system to a hyperconnected yet unstable state, where information flows more freely but lacks the usual constraints imposed by low-frequency rhythms. The decrease of low frequency oscillations seems to be a key brain signature of the psychedelic state and will be more thoroughly discussed in section 4.9. below. This aligns with both DMT phenomenology and EMF theories of consciousness, suggesting that the brain under DMT might be operating in a fundamentally different mode of information processing. These hypotheses remain speculative, and further research is needed to replicate and validate these findings. The observed loss of delta oscillatory power could also simply stem from artefacts or measurement limitations, rather than reflecting a fundamental neural mechanism.

4.8. Harmonic resonance

Every system has an eigenfrequency at which it naturally oscillates, efficiently absorbing and amplifying energy. A resonant mode is a stable oscillatory pattern that dictates how energy is distributed in space. In acoustics, for example, it corresponds to the shape of sound waves produced when an instrument vibrates at its eigenfrequency. As already mentioned, the sound of

the guitar is thus an expression of the shape of it. More generally, a resonant mode is the spatial pattern of oscillation that emerges when a system resonates at its eigenfrequency. A microwave, for instance, heats food by exciting the resonant mode of water molecules, while the resonant modes within the microwave cavity shape how EM waves propagate inside it. In neuroscience, resonant modes in the brain refer to patterns of electrical oscillations that influence the brain's EM field, as proposed by General Resonance Theory (GRT) (Hunt & Schooler, 2019). Understanding how these resonant modes define the topology of the brain's EM field could possibly provide insights into phenomenological states. Whether in acoustics, electromagnetism, or brain dynamics, resonant modes act as blueprints for how a system behaves in space and time. The resonance of a system determines where energy is concentrated or cancelled out, effectively shaping its topology.

Harmonic resonance describes the property of the coupling between frequency and physical structure (its pattern). Fundamentally, resonances in different resonators unite when they are coupled, producing a single coherent coupled oscillation of a system. These unique emergent properties cannot be fully explained by traditional computational or chemical-based mechanics. Rhythmic motions observed in organisms like caterpillars, snakes, or fish suggest that underlying processes may involve wave-like dynamics that are not entirely reducible to classical computation. In the human body, specific resonances across different axes have already been discussed (see p. 38). Resonance is also characterised by representational invariance - which, as previously mentioned -

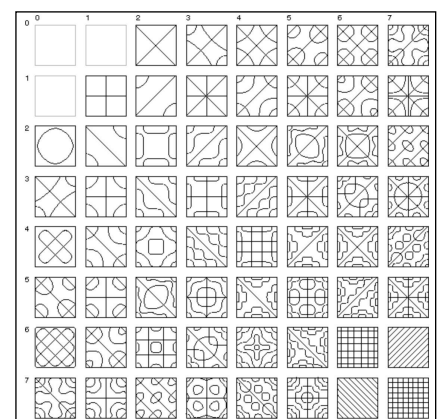


Figure 4.2.: Harmonic Resonances (Lehar, 2005)

supports the formation of topological structures rather than mere topographic mappings. The spatial pattern is encoded as a complex dynamic interaction between the topography of a sphere and its continuous resonating system. Harmonic resonance also naturally leads to mirror-reversed symmetrical pattern formations as seen in figure 4.2.. This could furthermore help explain the phenomenon of perceiving symmetrical geometrical shapes under the influence of DMT as briefly discussed in section 3.4.. Generally, resonance as a principle, exhibits similar properties across different fields (from physical, electrical, chemical to acoustics) which suggests it being a fundamental organisational principle of physical matter.

Steven Lehar¹⁹ suggests that:

"the harmonic resonance theory also offers an explanation for one of the most enduring mysteries of human experience, which is the question of why resonances in musical instruments and the rhythmic beating of drums have such a powerful ability to evoke the deepest emotional

¹⁹ <http://slehar.com/wwwRel/webstuff/hr1/hr1.html>

response in the human soul. The musical instrument represents man's first modest success at replicating the physical principle behind biological computation, and the strong emotional response evoked by these inanimate resonances reflects an unconscious recognition of the essential affinity between mind and music" (Lehar, 2005, last paragraph).

Before delving further into the role of harmonics within the brain in the next section, it is important to mention theories emphasising concepts like phase transitions and criticality. For example, Keppler (2013), in his TRAZE theory (see section 2.2.10.), focuses on phase transitions and criticality in neuronal processing. Similar to other theories, such as the 'Entropic Brain Hypothesis' by Carhart-Harris (2018), neurons are thought to operate in a state of criticality, making them highly susceptible to stimuli that can lead to long-range ordering of neuronal firing. This critical state supports the entrainment of smaller-scale harmonics into larger-scale harmonics (Hunt & Schooler, 2019, p. 7), ultimately forming a cohesive, larger harmonic pattern. Unlike in classic emergentism, these smaller-scale harmonics persist within the larger harmonic structure, allowing the new macro-conscious entity to supervene on and coexist with the micro-conscious entities. This is also a key difference to IIT's *exclusion principle*, stating that consciousness corresponds to the maximum set of information integrated at a particular level, which therefore excludes overlapping subsystems. This ensures that only one integrated whole, the one with the highest amount of integrated information, is considered to be conscious (McFadden, 2023). The proposed hierarchy of resonances in GRT establishes a ground for different degrees of consciousness: the highest level of synchronisation describing awareness, while this can be temporally absent during processes like sleep. Resonance thus reflects the dynamics of the physical structures while the physical structure itself can remain stable (Hunt & Schooler, 2019, p.10).

Klimesch (2018) suggests that brain-body coupling is governed by harmonic phase-to-phase coupling or phase-to-envelope coupling (PEC). Interestingly, a binary harmonic cross-frequency coupling between alpha and theta waves was recorded (Rodriguez-Larios et al., 2020) during effortful cognition, while this coupling decreased during meditation, hinting harmonic CFC to be an important indicator to assess degrees of consciousness, not only within brainwaves but also for brain-body coupling. The heart, as a major generator of electromagnetic activity in the body, plays a crucial role in this dynamic (Burleson & Schwartz, 2005). Its rhythmic contractions produce a strong electromagnetic field, which has been shown to interact with the brain's oscillatory activity and has also been shown to be influenced by external EM fields in rabbits (Misek et al., 2020). As mentioned in table 4, heart-brain entropy increases under the influence of DMT, suggesting a complex interplay between the heart's EM field, brain function, and phenomenal states. If psychedelics disrupt or enhance harmonic CFC patterns between brain and heart activity, this could reflect non-ordinary states of consciousness at a systemic, electromagnetic level. Further research is needed to explore whether increased heart rate entropy during DMT correlates with

shifts in CFC, potentially revealing an EM-driven mechanism underlying psychedelic-induced changes in consciousness.

4.9. The Connectome-Harmonic Decomposition (Atasoy et al., 2016)

Cymatics is the study of how sound and vibrations influence matter, revealing hidden geometric patterns that emerge from resonance. Ernst Chladni, was the first to elaborate on the relationship between frequency and geometry. In the 18th Century, he pioneered the study of vibration by scattering sand on metal plates and using a violin bow to generate sound, revealing intricate geometric patterns now called 'Chladni figures' (similar to these of figure 4.2.) that emerged depending on the frequency the plate was exposed to, ultimately showing how resonances can shape physical structures (Rossing, 1982). Based on cymatics and harmonic resonance principles, Atasoy et al. (2016) developed a novel form of analytic representational language about brain function: the 'connectome harmonic decomposition' to analyse brain activity in terms of its fundamental resonant modes. It involves decomposing neural activity into a set of connectome harmonics, which are the eigenmodes of the brain's structural connectivity network. It is now possible to analyse and describe spatio-temporal patterns of cortical activity based on fMRI and diffusion tensor imaging data (see figure 4.3. below). The method represents a specific representation of cortical activity patterns and dynamics, extending the Fourier basis to the structural connectivity of the thalamo-cortical system. Certain resting state networks (like e.g. the default mode network) seem to overlap with connective harmonic patterns of certain frequencies indicating a relationship between intrinsic brain dynamics and the spatial organisation of harmonic modes in neural activity. The dynamics of the above mentioned process - where smaller-scale neural harmonics synchronise into larger, more cohesive patterns - can be likened to the patterns formed in Chladni plates (visualised as harmonic resonance patterns in figure 4.2.) where physical resonances produce distinct, predictable forms. As shown in Figure 4.4., the eigenfunctions of the Laplacian operator in Atasoy et al. (2016) predict similar harmonic patterns in nature, further supporting the connection between harmonic structures in neural activity and resonant systems in the physical world.

These patterns seem to self-organise from their interplay of excitation and inhibition in coupled dynamical systems. In essence, just as cymatics reveals a hidden order in physical vibrations, the connectome harmonic framework uncovers how the brain's anatomy constrains and shapes neural dynamics through resonance. The framework suggests that the brain's structural connectivity acts like a resonating medium, where neural activity naturally organises into harmonic wave patterns dictated by the brain's eigenmodes. Harmonic patterns are prevalent in various natural phenomena, such as acoustic vibrations and also, electromagnetic interactions, which makes it tempting to assume that human brain activity could also be governed by the same underlying principle. They also indicate that neurophysiological evidence suggests that drug- or sleep-induced loss of consciousness is associated with increasing inhibitory or decreasing excitatory activity, which is accompanied by a transition from the low amplitude, high-frequency patterns to

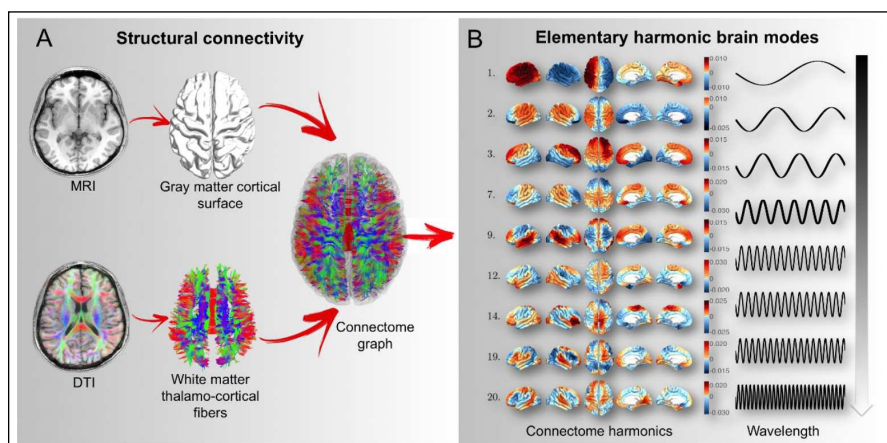


Figure 4.3.: A) Structural connectivity of the human brain defined as the combination of local cortical, grey matter connections. B) Elementary harmonic brain modes defined as fully synchronous patterns of neural activity are estimated as the harmonic modes of structural connectivity, i.e. connectome harmonics. (Atasoy et al. 2017)

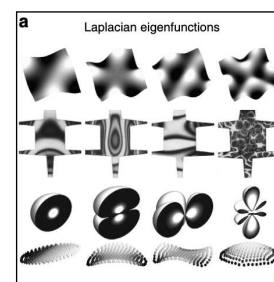


Figure 4.4.: Examples of how the eigenfunctions of the Laplacian operator predict patterns in nature (Atasoy et al., 2016).

low-frequency coherent oscillations in cortical activity. In 2017, the researchers found specific frequency signatures of altered states of consciousness. The psychedelic compound LSD alters the energy and power of individual harmonic brain states leading to an expansion of the repertoire of active brain states (Atasoy et al., 2017). They found a decrease of energy in the low frequency harmonics and an increase in the high frequency connectome harmonics. Also, a significant correlation between loss of energy in low frequencies and emotional arousal has been established. In a more recent paper, Vohryzek et al. (2024), elaborated on the connectome harmonic decomposition under the influence of DMT and demonstrated that measures of energy spectrum difference and thus of certain connectome harmonics can index the intensity of subjective experience, where DMT led to an increase in total power and energy and a shift in the probability distribution from lower to higher connectome harmonics. This shift could also explain why the oscillatory component of delta waves was basically non prevalent under DMT-intake (see figure 4.1.) What is more, is that the same signatures were found with psilocybin (Atasoy et al., 2018) and an opposite pattern (a shift from higher frequency signatures to lower frequencies) was found when participants were put under anaesthesia or in a vegetative or minimal conscious state, indicating a general signature of the psychedelic state of shifting from lower to higher frequencies. This new connectome harmonic language reveals the frequency-specific, unique brain signatures of various states of consciousness. Harmonic resonance indeed seems to be a fundamental organising principle of neural activity.

Studying the psychedelic experience under this methodology can yield more insights into these complex brain dynamics. The framework aligns with EM field approaches by emphasising the role of brain-wide resonant activity in shaping subjective experience. By showing that the brain's large-scale network dynamics can be understood as harmonic wave patterns, it emphasises how

oscillating fields emerge from physical structures, which suggests that alterations in the brain's resonant states - possibly linked to its underlying EM field - play a key role in shaping 1PP.

The fact that CFC has been found to increase for high-frequency connectome harmonics under LSD (Atasoy et al., 2017), indicates towards a reorganisation rather than a random activation of brain activity, as the brain is reorganising its activity into a more flexible yet coordinated state. By again using an analogy of musical notes acting as the connectome harmonics composing a complex musical piece (the overall brain activity), during the psychedelic experience, the brain is not playing random musical notes but rather expanding its repertoire in a structured, non-random way - akin to jazz musicians improvising within an acoustic harmonic framework (Atasoy, Vorhyzek et al., 2018).

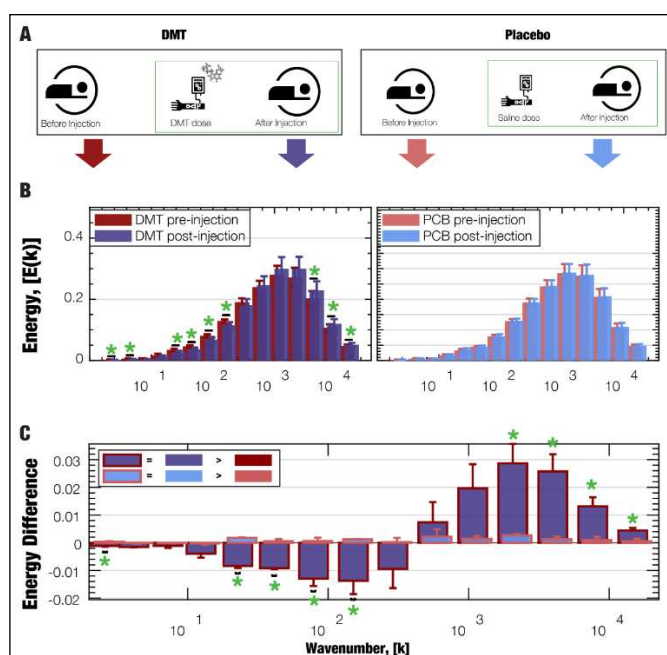


Figure 4.5.: DMT-induced energy changes in the connectome harmonic spectrum: a decrease of energy for low-frequency harmonics and an increase of energy for high-frequency harmonics (Vorhyzek et al., 2024).

This shift in connectome harmonics resembles the temperature-dependent shift in the Maxwell-Boltzmann distribution which describes how the probability of particles occupying different energy states changes as temperature increases. In a gas system, lower-energy states are typically more populated, while higher-energy states occur less frequently. However, as temperature rises, higher-energy states become more populated (Su et al., 2021).

Similarly, the increase in high-frequency connectome harmonics under DMT could be interpreted as a redistribution of energy across brain states, akin to how increased temperature shifts energy levels in physical systems. By modelling brain states as energy distribution states, DMT may be increasing the 'effective temperature' in a conceptual

sense of the brain's harmonic activity, possibly allowing for a greater exploration or description of high-energy states. This analogy furthermore aligns with QRI's definition of '*Hamiltonian of Consciousness*' (see p. 72).

4.10. Self-organising harmonic modes (Safron, 2020)

In his 'Integrated World Modelling Theory' (IWMT), Safron (2020) extends Atasoy's et al. (2016) framework of characterising brain activity as mixtures of connectome harmonics. He introduces the term of *self-organising harmonic modes* to emphasise the dynamic self-organising processes

by which synchronous complexes may emerge. These modes are both attractors and eigenmodes for the system dynamics. These self-organising harmonic modes describe how patterns of neural activity emerge as stable, resonant modes, aligning with how the brain structures and synchronises information flow. His theory suggests that consciousness arises from the brain constructing an integrated model of information, combining its sensorimotor states with environmental data in a structured, causal manner. According to this view - aligned with predictive processing theories (Clark, 2013) - 1PP emerges whenever the brain actively predicts, updates, and integrates its beliefs about the world. In essence, the brain functions both as a creator and an observer of its own reality. Self-organising harmonic modes in the brain could be described as similar to the formation of looping EM fields, as both involve feedback mechanisms to support stable states. While self-organising modes are the neural equivalents of these stable, oscillatory configurations, looping EM fields represent the counterpart that facilitates communication between the brain areas.

Furthermore, *neural field theory* - an established mathematical framework for modelling large-scale brain activity - suggests that the geometry of the brain may represent a more fundamental constraint on dynamics than classic, complex interregional connectivity (Pang et al., 2023). In alignment with Atasoy's framework, by treating the brain's cortex as a continuous surface - rather than dividing it into discrete specialised areas or modes - the focus shifts towards a holistic perspective on how wave-like patterns of cortical activity propagate as geometric eigenmodes - stable, large-scale resonances - across a continuous shape like the human brain. By analysing human magnetic resonance imaging data, Pang et al. (2023), show that cortical activity can be understood as resonant modes of the brain's structural geometry. Instead of using connectome eigenmodes, they use geometric eigenmodes to reconstruct brain activation maps. They postulate that geometric eigenmodes significantly outperform connectome eigenmodes, especially in subcortical activity. Geometric eigenmodes appear to be more invariant compared to connective eigenmodes across subjects. In both frameworks however, global resonance seem to be more predictive of brain activity than activity of a particular region. Pang et al. (2023) conclude that their findings emphasise a close link between geometry and function explained by an important role for wave-like activity, as predicted by a unifying model of brain-wide dynamics.

4.11. Dynamical systems framework

The bidirectional, looping interactions shown in figure 4.6. between neuronal spikes, EM fields, and phenomenological states suggest a dynamical systems framework in which brain activity, EM field fluctuations, and subjective experience continuously influence one another. This aligns with an enactive approach to cognition, which posits that conscious experience emerges through embodied interactions with the world, rather than being a mere byproduct of neural computation (Varela et al., 1991). From this perspective, the brain is not an isolated processor but an embedded system, shaped by sensorimotor states and external interactions. Under DMT, alterations in neuronal firing patterns and thus in EM field dynamics would reshape

phenomenological states, reinforcing a self-organising system of perception and cognition, where experience is dynamically co-constructed rather than passively received (action-perception loop of active inference) (Seth, 2021, p. 112). For simplicity, sensorimotor states are not shown in the figure below, despite their crucial role in enactivism as the system's gateway to its environment. This proposed interpretation of the interplay remains theoretical, requiring further empirical validation, as observed differences in connectome harmonics and thus potentially of local EM field changes under DMT could also stem from measurement artefacts or alternative physiological mechanisms.

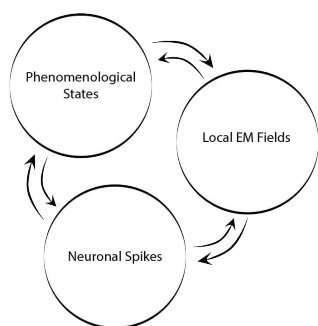


Figure 4.6.: a dynamical systems framework of the reciprocal, looping interplay of phenomenology, local EM fields and neuronal spikes. (Self-made)

4.12. Limitations of the thesis

While the interdisciplinary approach of this thesis enables creative integration, several limitations must be acknowledged. First, many of the connections drawn between DMT-induced phenomenology and EM field theories are more conceptual or metaphorical rather than grounded in mechanistic detail. The lack of a formalised framework linking EMF dynamics to the structure of conscious experience limits the explanatory power of the synthesis and is to be considered with caution. Although emerging research is beginning to explore how EM processes may relate to consciousness, these theories still remain speculative and are not widely accepted in neuroscience. Similarly, while DMT provides a profound window into non-ordinary states of consciousness, direct experimental methods linking these experiences to EM field activity have not been undertaken yet. Additionally, the translation between disciplinary languages - particularly between physics-based theories of consciousness and phenomenological accounts of experience - is still linked to conceptual challenges. The risk of oversimplification or misalignment arises when attempting to synthesise ideas that originate from distinct scientific and philosophical traditions. While recent studies are beginning to explore how EM processes may relate to consciousness and some empirical methods to test these are suggested, the entire field still remains speculative. As a result, some arguments in this thesis necessarily move into theoretical and speculative territory, especially where direct experimental data is still unavailable or underdeveloped.

Finally, the exclusive focus on DMT, while offering depth and specificity, limits the scope of the findings. The neurophenomenology of DMT-intake is definitely well suited for studying processes of consciousness, nevertheless, more extensive research is needed with other non-ordinary states

of consciousness like meditation, flow states or other molecules such as 5-MEO DMT are needed. These limitations highlight the speculative and exploratory nature of the present work. Rather than weakening its value, they underscore the need for future empirical and conceptual research that can build more robust bridges between neurophenomenology and EM field theories or models of consciousness.

5. Conclusion

In summary, this thesis highlights the importance of further exploring EMF theories of consciousness, which merit greater attention within the scientific community. As illustrated in the figure below, electromagnetism plays a fundamental role in all aspects of our reality - it therefore stands to reason that electromagnetism should also be considered central when investigating one of humanity's greatest mysteries: consciousness.

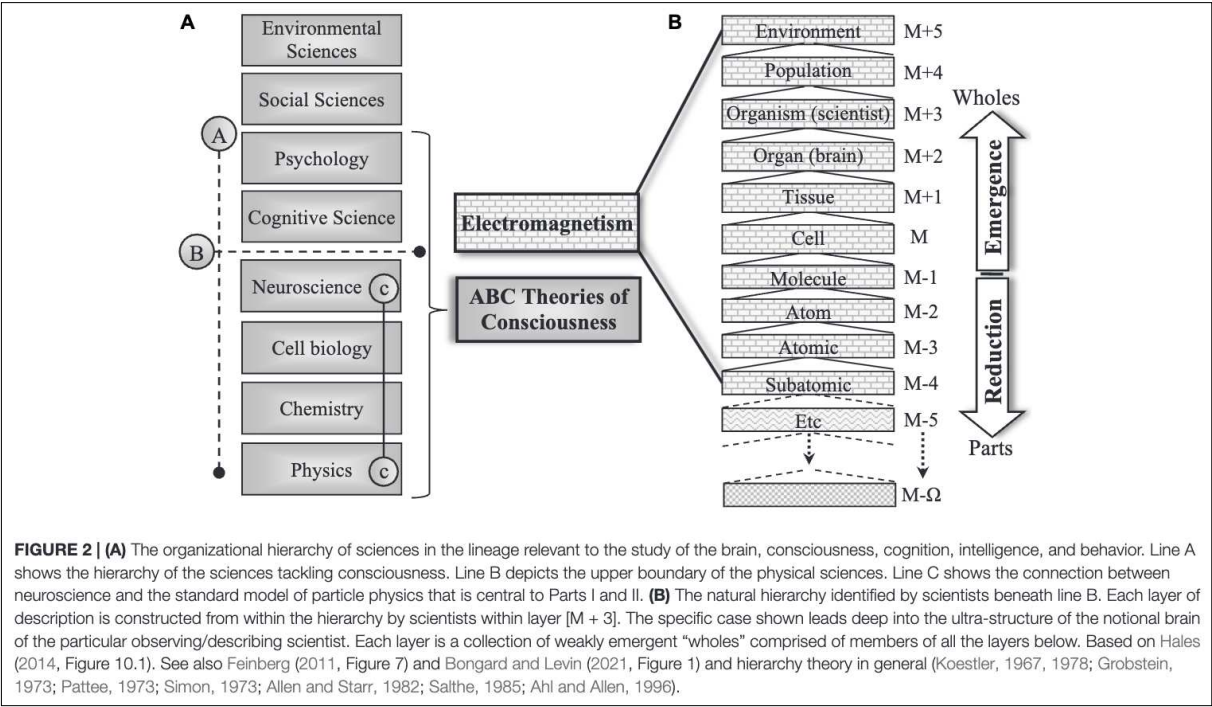


Figure 5: ‘The Electromagnetic Turn’ - electromagnetism touches upon all areas of physical matter (Hales & Ericson, 2022).

The potential for non-local effects in consciousness and the influence of electromagnetic fields beyond local brain activity offer a perspective that warrants serious consideration. This approach, which moves beyond the concept of isolated entities, should not be dismissed as pseudo-science (Gomez-Marin & Arnau, 2021). Furthermore, accumulating evidence underscores the pivotal role of synchrony and resonance in consciousness, some theories touching upon how these lead to awareness and a few others on how these could potentially be involved in the generation of a

first-person perspective (see in the Appendix). The General Resonance Theory (Hunt & Schooler, 2019) represents a significant contribution to the scientific discourse by framing resonance as a central factor in the study of consciousness.

Why is DMT useful for consciousness research and how can this inform EMF theories?

DMT seems to be distinct from other psychedelic substances on a neurophenomenological level. Firstly, the endogenous production of DMT is still a mystery to research. As seen in section 3.2., under the influence of DMT, delta power - which is usually associated with states of unconsciousness or lack of experience (such as dreamless sleep or anaesthesia) - increases. Since this seems to be unique to DMT, further research can help generate insights into how our brains construct the world, how our sense of Self is constructed and how all of these processes can be deconstructed in minutes or even seconds due to a single (endogenous) chemical. The striking changes in visual perception, the short duration and the low health risk factors make DMT a suitable, informationally-rich, safe and cost-efficient tool for the study of conscious perception and phenomenology. As Gomez-Emilsson mentions in an interview²⁰ metaphorically, achieving significant insights often requires moving beyond conventional conditions - paralleling how extreme temperatures in physical experiments yield unique physical or chemical phenomena. Applying this analogy, employing perturbational approaches like DMT administration may offer novel perspectives in consciousness studies.

DMT's capacity to induce significant changes in EEG patterns and potentially reshape connectome harmonics makes it a prime candidate for analysis using the connectome harmonic decomposition method. This framework aligns with EMF theories by emphasising the role of large-scale brain-wide resonant activity in shaping subjective experience. By interpreting the brain's network dynamics as harmonic wave patterns, this approach suggests that alterations in the brain's resonant states - which are possibly linked to its underlying electromagnetic fields - are fundamental to shaping first-person perspectives.

EMF theories can also be informed from studying the neurophenomenology of DMT experiences as the DMT experience seems to be capable of dissolving various boundary problems (*higher-level, private* and even *temporal boundary problem*) at once in a very short time - at least at a phenomenological level. So, DMT research seems to be useful especially for conducting experiments on this possible weakening of different kinds of boundary problems and also, for scrutinising the processes involved in the construction and deconstruction of our reality and the ontological feeling of *realness* further.

²⁰ Gomez Andres: Consciousness, DMT, and Panpsychism: <https://www.youtube.com/watch?v=2CV-LUurIC7k> - timestamp: 26:35

How are EMF theories informing the neurophenomenology of DMT experiences?

While further research is necessary, the neurophenomenology of DMT experiences - particularly those addressing various boundary problems - appears to be able to be more effectively explained by EMF theories than by traditional spike code approaches. Notably, the topological solution to the boundary problem proposed by Gómez-Emilsson & Percy (2023) presents a promising avenue for empirical validation through techniques such as TMS and other EMF-based measurements. Furthermore, by combining the connectome harmonic decomposition with EMF theories and specific EM measurements, more insights about the harmonic organisation of brain states and its implications on consciousness could be addressed. In the (hopefully near) future, further emphasis should be put on harmonic resonances and valence states, meaning-making and attention. This is aligned with QRI's objective of 'developing a mathematical formalisation for subjective experience and its emotional valence'. The role of symmetry in evolutionary perception and how EM field topology may contribute to valence seems to be a promising new avenue to take on.

This thesis calls for neurophenomenological - thin as well as thick neurophenomenological methods (Petitmengin, 2006). approaches to consciousness and psychedelic research as well as a general call to switch from a material based study of consciousness to a field ontology of consciousness. Whether this field is considered to be physical and if so, what kind of physical, remains to be discovered. By postulating the upcoming 'electromagnetic turn', Hales & Ericson (2022) emphasise that no existing theory of consciousness is necessarily automatically lost as most theories of consciousness seem to be merely a particular subset of the totality of an EM field theory. This field based ontology should be examined in light of existing theories and it should be scrutinised if this framework can yield better results in the science of consciousness. Furthermore, science must shift from a horizontal discipline-centric reductive view to a vertical transdisciplinary holistic view (Hales & Ericson, 2022) and could benefit from adopting a dynamical systems approach to consciousness. Additionally, in accordance with a field-based ontology to consciousness the connectome harmonic decomposition method should be employed to dissect existing fMRI data on other non-ordinary states of consciousness. From a philosophical standpoint, this thesis concludes with a non-materialist but physicalist perspective, while remaining curious about ideas like idealism.

Future work should take EMF theories more serious and conduct neurophenomenological studies with non-ordinary states of consciousness and minimal phenomenal experiences - this can be conducted with more pharmacological research with 5-MEO DMT - which seems to produce even more radical changes to our experience than classic DMT. Advocating for global recognition of psychedelic research requires maintaining scientific standards and healthy skepticism to ensure genuine progress. Recent critiques have highlighted concerns over the robustness of current studies, emphasising issues such as small sample sizes and potential biases (Petranker et al.,

2022). Addressing these challenges is crucial for the responsible advancement of psychedelic science.

Generally, Heisenberg's uncertainty principle (Hawking, 2015, p. 71) offers a compelling analogy for the central theme of this thesis. Accordingly, just as we cannot precisely know both the velocity and position of a particle at the same time, current theories of consciousness often focus exclusively on static aspects of the brain (i.e. the 'position'), which has been the norm in materialist approaches for decades. Instead, science should shift its focus toward the dynamic interactions that govern consciousness, akin to the 'velocity' of these processes, and explore field-based movements and their role in shaping conscious experience.

Science is traditionally framed within material, reductionistic or mechanistic paradigms, often confusing our descriptions of how nature *behaves* (in a sense a 'map') with the actual reality (the actual 'territory'). In the context of consciousness, what we *experience* directly might be different from the way we *describe* it scientifically. Drawing on this analogy, if consciousness is the territory, then physical descriptions (brain states, neural activity, or quantum information) are just maps - useful but incomplete representations. Taking the step away from the current materialist framework towards a more holistic perspective can be tough for researchers in academia. The dependence on external funding and the rigid structures within academia appear to impede authentic scientific progress. This dynamic often leads to frustrations among researchers, particularly when it comes to challenging conventional ideas and methodologies - which are essential for making meaningful advancements in science.

To conclude, scientific progress tends to unfold in waves, occasionally marked by sudden leaps. It seems that another wave is on the horizon. Even if we are not yet equipped to understand the full scope of consciousness, it is time to explore new directions. Current paradigms have not yielded sufficient answers, and real progress often involves revisiting foundational concepts and ideas, even if this means looping back to the beginning. Throughout history, phenomena once considered 'magic' or incomprehensible have been understood through careful scientific inquiry. However, for such progress to happen, scientists must be willing to investigate unexplored phenomena and remain radically open to new concepts and possibilities all the while maintaining scientific standards.

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6.4. Additional Ressource Material

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Christopher Timmermann - *The Neurophenomenology of the DMT State* - timestamp: 17:50

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<https://www.siyavula.com/read/za/physical-sciences/grade-11/electromagnetism/10-electromagnetism-02>

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8. Appendix

8.1. Supplementary material of the systematic review of EMF theories -

In all tables below, 'C' stands for consciousness.

Table 7.1: Systematic categorisation of EMF theories: CEMI, GRT & CFT

Categories	Conscious EM Information (CEMI) Theory - 2.2.4.	General Resonance Theory (GRT) - 2.2.5.	Coherence Field Theory (CFT) - 2.2.6.
Representatives	McFadden (2001 - 2024)	Hunt & Schooler (2019)	Bond (2023)
Philosophical standpoint	Physicalism Dual aspect monism: Dualism of matter and energy.	Panpsychism	Physicalism: Quantum Mechanics & Molecular neuroscience
Core idea	C is what physically integrated information in an EM field <i>feels</i> like, from the frame of the photons encoding that information.	Three axioms & three conjectures. Quantitative framework for measuring C in any given system.	Extension of GRT to lower quantum levels. Coherence of EM radiation. Uniquely focuses on <i>light interactions</i> in form of a <i>coherence field (LFPs)</i> .
What is consciousness - fundamental vs emergent property	Awareness emerges from interaction with one EM field. All EM fields can potentially be conscious, but only a subset seems to be: <i>Feedback loops</i> important.	Fundamental - but different degrees of consciousness according to resonance. Resonance between nested EMFs & info processing afforded by EMFs are sufficient & necessary for C.	Emergent - C arises from interaction & synchronisation of carious EMFs with one supervening on the other ones.

Distinction between subconscious & conscious processes (conscious awareness)	Yes, well distinguished and evolutionary explained: parallel vs. serial processing streams. Generating vs. merely transmitting thoughts as information.	Yes - nested hierarchy of conscious entities without extinction & one dominant conscious entity.	Yes, supervenience of one EMF.
Causality of EM fields	Yes, endogenous EM field is causally active for processes of awareness.	Yes, but not sole contributors to C.	Yes. Supervenient EM field causally acting on biochemical pathways
Functioning of EM fields - Reductionism / Connection to Neural Correlates	Critical point of synchronisation needed for awareness: not too little, not too much	EMFs are primary seat of C. Not limited to neurobiological systems.	Coherence of macro-scale EM fields through EM radiation.
Empirical testing	• Can explain split-brain phenomena (2020) • Can account why cerebellum is unaware - cancellation of EM fields through destructive interference (2024, p. 5)	• 'Consciousness-ometer' (Hunt et al., 2022). • Neural Synchronisation • Through SSR across the whole body.	• Developing techniques to measure emission of EM radiation within and from neurons. • Vibration measured as temperature variation.
Problem solved? Main argument	• Binding problem solved. • Does predict a certain kind of boundary but it is not clearly defined. • Provides a possible basis for the feeling of free will (is deterministic though)	Binding problem solved through concept of resonance. Boundary problem only addressed - not solved - through SSR principle.	Phase transitions between coherence & decoherence might influence the establishment of boundaries, potentially addressing aspects of the binding & boundary problem.
Limitations	Empirical testing still inconclusive, limited.	Boundary problem not really solved.	Empirical validation still limited.
Relation to other theories	GRT, CFT, OA	CFT, IWMT,	GRT & CEMI, which also mentions photons
Limited to biological structures?	Yes, until computers allow strange loops (Hofstadter, 2007)	No	No

Table 7.2.: Systematic categorisation of EMF theories - Adaptational Theory, AR, Orch-OR & NP

	Adaptational Theory (ATC) - 2.2.7.	Abstract Realism - 2.2.8.	Orchestrated-Objective Reduction (Orch-OR) - 2.2.8.	Neuroelectrical Panpsychism (NP) - 2.2.9.
Representatives	Detmar (2023)	Sanfey (2023)	Hameroff & Penrose (2014)	Jones (2010 & 2016)
Philosophical standpoint	Evolutionary aspect Dual aspect monism Physicalism	<i>Abstract Realism</i> - field realism - metaphysical principle that wants to connect physical reality with phenomenal experience	Similarity to AR. Panpsychism Physicalism	Panpsychism modulated
Core Idea	• C as an evolutionary adaptation to respond to environment. • C as being a thermodynamic system whose boundary as an EM field is coextensive with the material brain • Meaning is important evolutionary factor	• The interaction and resonance between EM fields are what cause the phenomenal experience of C. • Observation is fundamental to reality. • Time is important to consider. C cannot be detected by anything that requires movement over time.	• C is not a computation. • Brain is rather a quantum computer. • C results through quantum effects in brain's microtubules regulated by objective reduction (i.e.: collapsing of the wave function through quantum gravity)	• Qualia are not merely properties of but are considered neuroelectrical EM substances themselves. • All qualia correlate with different neural proteins. • 1PP everywhere but only united by neuroelectrical processes
What is consciousness - fundamental vs emergent property	Emergent - C evolved incrementally from ephaptic coupling of neurons where organised couplings were favourable.	Fundamental - only metaphysical bridge is possible. Emergent property of a dynamic interaction between abstract fields.	C is both fundamental part of quantum reality but emergent in microtubules.	Fundamental - C is ubiquitous and is matter of degree Qualia resides in the neuronal EM field and maybe also in the neuronal matter

	Adaptational Theory (ATC) - 2.2.7.	Abstract Realism - 2.2.8.	Orchestrated-Objective Reduction (Orch-OR) - 2.2.8.	Neuroelectrical Panpsychism (NP) - 2.2.9.
Distinction between subconscious & conscious (conscious awareness)	Yes, just like in CEMI. Topographic Argument: natural selection arranged neurons in a way that increase the ability of the endogenous EM fields to causally influence the neurons in a feedback loop. Through error correction processes the topographic alignment mutated in just the precise way to allow for (self)-awareness to emerge.	Similar to CEMI: distinguished by the level of resonance between EM fields. When information within the fields is mirrored and synchronised in system memory, it reaches the level of awareness.	<i>Subconscious:</i> classical computation <i>Awareness:</i> quantum states in microtubules collapse at critical moments	Not specifically given, merely concerned with 1PP.
Causality of EM fields	Yes, described as the 'sense of self'.	Yes, EM fields have causal power, meaning they actively shape and influence each other. • 1PP itself causally influences reality.	Not directly mentioned. EM fields are not core driver of C, but may play a role in brain's functioning.	EM field as combination of 1PPs.
Functioning of EM fields - Reductionism / Connection to Neural Correlates	EM fields as originators of meaning: difference between rhythmic patterns vs. arrhythmic patterns.	Consciousness is neither reducible to physical substrate nor to neural substrate - <u>interaction</u> between these leads to 1PP.	Quantum events are primary seat of consciousness. Classical neuronal functions cannot fully explain 1PP.	Qualia identified as proteins.
Empirical testing	Not really, but theoretical explanatory power due to integration of mechanism, function, evolution & development in individual qualia	Theoretically challenging. Perhaps measuring specific resonances between different EM fields	• Effects of anesthesia on microtubule function. • Quantum coherence in brain measurements as soon as tools allow to explore this concept.	Molecular biology: correlation between neural proteins like 5-HT2A with qualia.

	Adaptanional Theory (ATC) - 2.2.7.	Abstract Realism - 2.2.8.	Orchestrated-Objective Reduction (Orch-OR) - 2.2.8.	Neuroelectrical Panpsychism (NP) - 2.2.9.
Problem solved? Main argument	Does not address the binding or boundary problem.	AR addresses the hard problem of consciousness by suggesting that conscious experience arises from the <u>simultaneous</u> causal interaction of EM fields generated by both neurons and microtubules.	Doesn't address the problems. C emerges through collapse of quantum wave function.	Appears to solve hard problem by inversing it and combination problem through neuroelectrical binding Boundary problem not discussed.
Limitations	- Detmar's free energy definition differs from Friston's free Energy definition. - Empirical validation limited	Potentially testable by prediction of strong correlation between bi-directional, mirroring EM fields.	Main argument against theory: quantum processes not possible in warm & wet environments has been refuted (Lambert et al., 2013). Scaling problem: how can micro-level quantum processes lead to macro-level ones?	Panpsychist claims not verifiable (yet?). Strong claims about fundamentality of C.
Relation to other theories	CEMI, GRT, Connectome-Harmonics, Qualia Research Institute's 'Symmetry theory of Valence'	Orch-OR, CEMI but AR focuses on microtubules GRT	AR	GRT but difference of 1PP present everywhere and only united through neuroelectrical processes
Limited to biological structures?	Yes, limited to all beings capable of experiencing meaning.	Yes, AI system do not experience <i>simultaneous</i> presence.	Yes, quantum processes are happening in biological microtubules.	Yes, bioelectrical EM structures are needed.

Table 7.3.: Systematic categorisation of EMF theories: TRAZE, OA, TICL & Topological solution

Categories	TRAZE - 2.2.10.	Operational Architectonics (OA) - 2.2.11.	Temporally Integrated C - landscape (TICL) - 2.2.12.	Topological Solution to the Boundary Problem - 2.4.2.
Representatives	Keppler (2024)	Fingelkurts et al. (2009, 2010, 2013, 2019)	Winters (2021)	Gomez-Emilsson & Percy (2023)
Philosophical standpoint	Panpsychism. Dual aspect monism	Emergent Monism (Fingelkurts et al., 2010): relationship between mental and physical is hierarchical and metastable	Physicalism	Non-material physicalism with a touch of idealism
Core idea	- Assumptions: Zero Point Field (ZPF) is essentially sentient. - neurotransmitter-receptor profile and resonance determines the selection of ZPF modes, shaping the possible phenomenal qualia states, especially glutamate (most abundant neurotransmitter)	- Source and unification of C through nested, dynamic, hierarchical EM field organisation of brain operations. - Incorporating spacetime in a theory of C is crucial. - Every part of the brain is deeply interconnected with its surrounding context, and it is through these <i>relationships</i> that meaning and value emerge.	- C must be looked at through cause-effect relationships across time. - Term 'landscape of causality' to describe the complex web of causal interactions that are processed by the brain. - Five factors of phenomenology	- It is the topological properties of neural networks and their EMFs that contribute to the emergence of conscious experience and 1PP. - qualia arise from structured, bounded regions within a broader field of activity - this could be an EM field, a harmonic resonance pattern, or another yet-to-be-identified field. - Resonant modes within topological pockets facilitate downward causality
What is consciousness - fundamental vs emergent property	Fundamental in the ZPF - formation of phenomenal states requires macroscopic quantum coherence	- Emergent - defined as the emergent result of synchronised global neural operations, coordinated by EM fields and involving both local and global integration. - Qualia emerge from the temporal coupling of EM field-based operational modules.	- Emergent - causal integrated information across time from different Subsystems into one <i>global point of view (POV)</i>. - C is a <i>POV</i> upon contents.	Emergent through topology of brain's EM field(s), not just the field itself.

Categories	TRAZE - 2.2.10.	Operational Architectonics (OA) - 2.2.11.	Temporally Integrated C - landscape (TICL) - 2.2.12.	Topological Solution to the Boundary Problem - 2.4.2.
Distinction between subconscious & awareness	Yes, the capacity to modulate the ZPF through glutamate makes the difference.	Yes, vaguely through nested EM fields: different levels of operational integration & neuronal synchronisation. • Subconscious processes: lower levels of integration, less synchronisation, more fragmented. Global EM fields play a critical role in developing awareness. • Rapid Transition Processes (RTPs) serve as mechanism for transitions between these states by enabling dynamic reorganisation of neural synchrony.	Yes, through temporal integration: if its causally temporally integrated: awareness. • All activities that do not sufficiently contribute to a Subsystem (through temporal synchronisation) are sub-conscious.	Yes, topological segmentation plays a role in creating distinct boundaries within EMFs - 'topological pockets' - potentially facilitating downward causality and differentiating between various conscious states.
Causality of EM fields	Yes, resonating EMFs couple to different ZPF modes, leading to different qualia states	Yes, EMFs synchronise distributed neural assemblies for information integration, and specific configurations of these fields ('operational modules') instantiate qualia but degree of causality not clear.	Yes, EM fields may causally help brain to integrate relationships across time.	Yes, but topological property of field more central.
Functioning of EM fields - Reductionism / Connection to Neural Correlates (NCC)	Resonance of EM fields leads to neuronal coupling to ZPF (which inherently has 1PP).	• Nested EM fields through neuronal synchrony. • Phenomenology arises through temporal coupling of local EM fields.	• A unified thalamocortical EM field structure must co-exist with nested subsystemic EM field structures for C to emerge. • NCC in terms of TIC landscapes containing nested Subsystems (content-specific NCC)	Non reductive connection between EMFs & NCCs: C arises from interplay of neural activity and the EM fields generated by that activity, without reducing one to the other.

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Empirical testing	• Experimental conditions in which resonant glutamate-ZPF is disrupted • Modulating neurotransmitters and observing changes in coherent activity patterns. • Calculation of the necessary critical coupling strengths & neurotransmitter concentrations in cortical microcolumns required for potential resonant coupling to the ZPF.	• Theoretical relationship to quantum mechanics and eastern metaphysics (Fingelkurts et al., 2019). • Classic EMF testing techniques: Neuroimaging techniques to observe the temporal dynamics and synchronisation of neural networks in real time & explore how distributed neural networks and EM field synchrony are disrupted in conditions where consciousness is impaired.	• Agrees with claim that ultimately all NCCs are EMCCs, thus are already being tested. • Verification through measurements of EM fields at spatial and temporal resolution appropriate to System and Subsystem. • Lacks specific empirical testing avenues	• Could be done by altering topologies of EM fields (e.g. in TMS experiments.) • QRI is currently working on empirical testing methods.
Problem solved? Main argument	• Binding Problem solved. • Inverting hard problem: qualia is fundamental	Binding problem: temporal coordination to a global operational pattern of these fields is essential to lead to unified 1PP.	Binding problem solved: thalamocortical EMF synchronises activities. But C cannot exist by itself. It is generated through <i>relationships</i> .	• Boundary problems finally solved • Satisfies their three criteria for a theory of C: frame-invariance, non-epiphenomenalism & weak emergence
Limitations	• Most radical theory: ZPF's fundamental 1PP is unfalsifiable. • Exclusivity to glutamate	• Empirical validation difficult. • Vague distinction of subconscious & awareness. • Hard problem still present: how does 1PP come about?	Not addressing hard problem & boundary problem.	Empirical testing still in early stages.
Relation to other theories	• GRT, • NP: also emphasises importance of molecular proteins	• AR • TICL • Quantum Processes	• OA (nestedness), • GRT (resonance of EM fields) • IIT (integration)	• GRT • IIT • TICL • CEMI: how does EM field <i>feel</i> like?
Limited to biological structures?	Yes, unless AI can couple to ZPF.	Yes, but this is not explicitly mentioned.	No, but temporal integration & causal awareness needed.	So far yes. Topological principles could be extended though.