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# Brains, Minds, and Science: Digging Deeper

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## ABSTRACT

Nowadays scientific challenges require us to work together not only across disciplines, but also in large teams often scattered around the globe. To understand the intrusive inefficiencies present when we deal scientifically with the dazzling natural and social challenges facing us, I have previously proposed to consider the scientific milieu itself as a primary subject of study. Since any collective action related to knowledge involves communication, brains, and minds, a central point in this plan is to understand the role our brains play in this scenario.

This paper describes the beginnings of a many-step modelling process that aims to build a brain-aware scientific culture, starting from a model of the scientific milieu itself displaying associations of the brain-mind complex with its many components. The description of the scientific milieu embraces all its aggregation and individuation levels, while highlighting channels, procedures, conditionings, and phenomenological characteristics through which our brains may interfere in the process of knowledge production, preservation, and transmission.

It extends previous efforts by sketching models that separate anatomical from physiological changes in brains; by highlighting the interplay of both these facets; by discussing next steps necessary to advance towards a more encompassing model; and by clarifying how agreements about elementary cross-disciplinary communication tokens seems to be initially achieved.

**Keywords**: Brains, Minds, Thinking, Reasoning, Scientific knowledge, Collective knowledge production.

## 1. INTRODUCTION

Huge trans-national and trans-continental challenges stand before humankind, threatening its very existence as a biological entity. Most of them require multiple perspectives just to be identified and verbalised, not to say investigated. They also bind, from the general systems perspective, to what is considered as complex organised phenomena [5], complex but not *a fortiori* complicated. These challenges require us to work together not only across disciplines but also across cultural boundaries, and often in large teams scattered around the globe; wherefrom multi-national stakeholders, logistics and factors associated with institutions and organisations are brought into play. As a follow-up of this threatening scenarios, it became nowadays common word stating that humankind is in trouble. Is it? Really? If so, why? Why can we not overcome our conundrums, or think more clearly about them? Have problems suddenly become too complicated and awfully difficult, or did we become so badly intellectually equipped that we cannot understand the challenges associated with them, finding even partial solutions? Why our creative pillars, Logos, Pathos, Ethos, are not helping us to think differently and invent a better future for us? Where are the drawbacks?

In multi-individual components of the scientific milieu, Logos requires sympathetic resonant thinking, Pathos requires empathy, and Ethos, synergy. To understand our inefficiencies while acting collectively across cultures and intellectual disciplines or when dealing with the dazzling natural and social challenges facing us, I have recently proposed the scientific milieu itself as a primary subject of study [6] due its social nature, world-wide distribution, and intellectual characteristics. I suggested also to investigate it using an integrative approach that stems from considering the scientific milieu as a collective living organism, along the guidelines laid down by JG Miller [7] during the last century, but reading them as organisations [8] instead of simply as systems.

Proposing the scientific milieu as a starting point of enquiry, is backed-up by a few key points. Being virtually global, we can consider the scientific community to be a representative part of humankind, retaining a good deal of its intellectual and cultural diversity. Moreover, it is putatively the most prepared and inquisitive of all human social groups. Hence, it is the portion of humanity that should firstly face novel and disruptive menaces and challenges from an understanding perspective, proposing solutions, detours, or palliatives. It grounds also on the perception that the scientific milieu amasses (not exclusively) a good deal of our intellectual tools but, despite the differences in thinking and perception among researchers in various disciplines and cultures, there is an intellectual thread keeping their thinking, investigative moods, and arguing rigour close together — the scientific method.

The integrative approach to be used in its study is centred on the concept of organisation [8] a straightforward generalisation of the system concept that, nonetheless, possess formally many properties often required for systems but treated only informally or decoratively whenever referring to systemic objects. For instance, organisations can pertain to either the *thing-hood* or *system-hood* domains [4] of systems thinking [9] [10]. That is, organisations can be either actors (cells, sensorial organs, scientists, teams, groups, labs, boards, etc) or whatever glues actors together into a behaving whole (cell-architecture, signals, tissues, intercellular matrix, organic systems, communication systems, institutions, etc).

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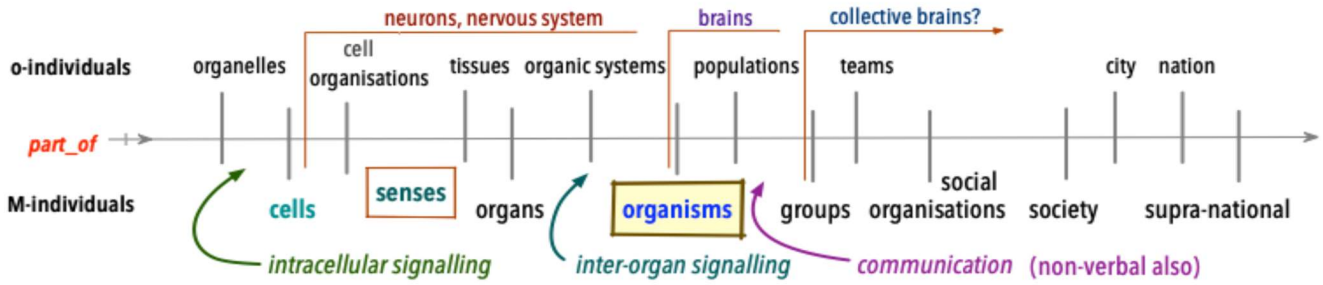


*Figure 1 – Brain-aware Scientific Milieu and Sensorial Components*

From the in-formation/organisation perspective, our biological brains may have agonistic-antagonistic effects on intellectual sophistication, learning, adaptation, or imagination, as well as, on communications, collective memory directives, protocols, or whatever glues scientific actors together. As a consequence, any biological constrain on brains or minds, does affect and may hinder the process of scientific knowledge construction, and needs also to be mapped if we are to help clarifying any lack of cooperation or understanding in teams and collective entities.

***Figure 1*** depicts components of the scientific milieu representation proposed in [6], together with the elements just identified. All elements along the *part_of* chronicle line [11] are embodied organisations (synexions) in the sense of [8]; even organelles, pathways, tissues and signals are synexions. They have volumes, vibrate, can be flows or may be *alive (quick)* as well. Those below the line have been addressed by JG Miller, as detailed in [12], and abide to his definition of living systems, displaying all Miller functions. It is an open question whether all those above the chronicle line also conform to Miller's characterisation of living systems, although all of them do abide to the characterisation of living entities implicit in [8], e.g., of being representable as synexions. All components along the line to the left of 'organisms' entry can be parts of organisms, while those to its right are formed by multiple individual-organisms interconnected and held together in several manners. Not with standing, all connections between components to the right of *organism* at any level containing individuals involve communication [13] [14], which is directly affected by the activity of our brain-mind complex.

To advance along these lines, gathering knowledge, we need to perform various intertwined modelling tasks. A central one is to conveniently describe brains and minds. Given that *mind* is still a controversial and ambiguous concept, let us remain humble and bind to the anatomical and physiological facets of brains instead. The first facet refers to changes and dynamics in the organisation of the anatomical brain (cells and substances inside skulls, for instance), while the second refers to changes in spike patterns, modules, and connections between stabilised spike-modules. The characteristic times of basic events (observed changes) in either class are rather distinct although deeply coupled. Hence, brains should be represented as a dual entity—together and intertwined but retaining both identities and being individually addressable. We need also to precise which would be the right Miller's functions on these dual objects, and how and by which kind of organisations these functions could be performed within skulls and how they extend into the science-related milieu. This article starts a discussion about these issues.

In the next two sections, I discuss how to represent brains from the anatomical, physiological, and signalling stands, highlighting their couplings; suggest what in this picture may be consider as mind; and how "signalling" and communication between their parts and components occur. The fourth section addresses the justification of options and decisions in the suggested models, while the fifth set up a path for next steps that look necessary from my actual perspective. Concluding remarks close this article.

## 2. BRAINS, MINDS, AND SIGNALLING

Present day knowledge allows us to hypothesise that all signals arriving at brains come through our bodies and are modulated by our physiological processes [15] [16]. Even signals which provenance is not a specific sensory system, like the diffusive senses of magnetic fields, proximity, gravity, and equilibrium, do come through nerves to the brain. For neuropsychologists, the later signals originate not just in human sensorial organs but come from many points in our bodies. In general, nervous signals arriving at the brain contain an amalgam of all sensations endured by our bodies during the time a given signal is started and travel to the brain, resulting in multi-sensorial *imprints* [8] in the brain. Stimuli provoking bodily signals exist continuously and stem from inside or outside our bodies, as in the perception of diffusive signals of equilibrium, gravity, or well-being. Incoming signals start to be intertwined and modulated into an integrated composite signal, long before reaching the brain. They are also organised, presenting the hierarchy and connectivity intrinsic to any organisation, and reflecting the organisation of their provenances. Signals with different provenances, and not necessarily associated with a single sense, may arrive at the brain in parallel, at the same time, offering more than just a primary or singular stimulus to it.

The following picture (***Figure 2***) summarises, in my understanding, what is currently accepted as paths of neural signals (pulses) and their flow through nervous tissues in our bodies and into our skulls from a general and integrative stand. It is important to note, though, that pulse flows are enchainments of entailed neurone-firings that, in observational apparatuses appear as propagating lines or surfaces. Since pulses always propagate from central parts of cells (their soma) toward dendrites, where they bifurcate and spread, neural activity has locally a single direction of propagation being almost completely constrained by the connection topology of brain anatomy. Nevertheless, not much is known or consensual about firing, coupling of firings, and the flux of pulses on neurone-axons, networks, or amid neurones. That is, about which firing-trails are provoked by a given thought, reasoning, or sensorial perception.

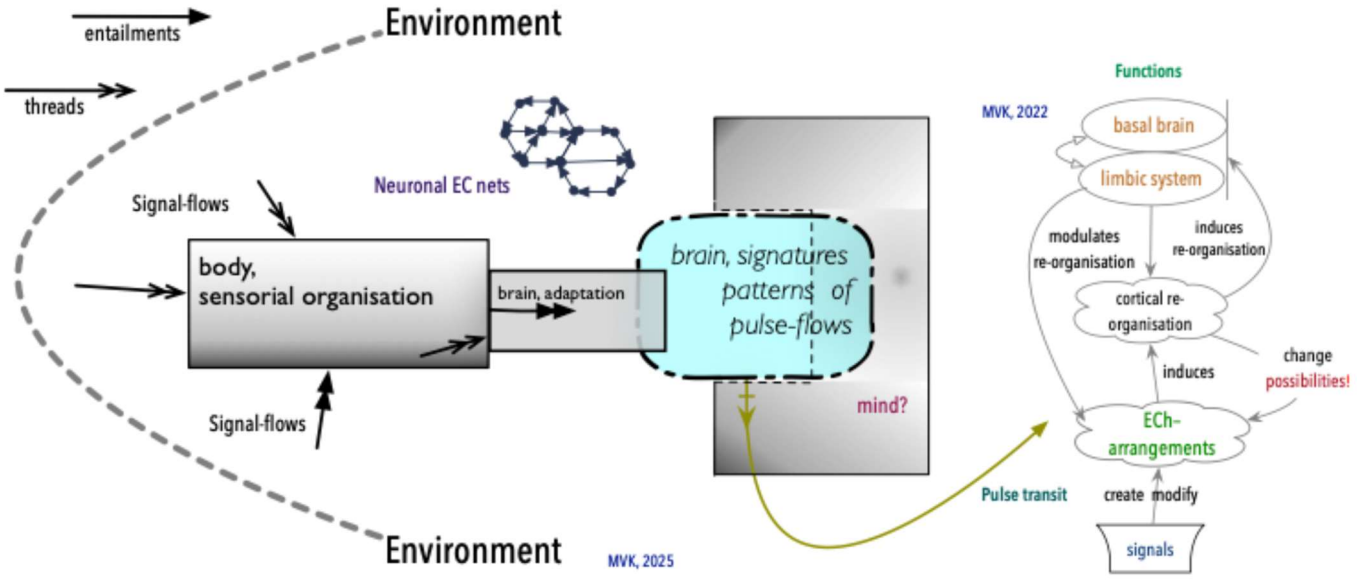


*Figure 2: Sensing, Signals, and Brains*

This lack of precision is reflected in ***Figure 2*** by its ontologically nebulous or fuzzy parts, highlighted by a non-uniformly coloured background. This impreciseness is in part observational and in part behavioural [15] [17]. It is largely associated with inaccurate localisation of firing cascades on the neuronal organisation (mainly cortex), with difficulties in the comparative observation of the topological structure of neuronal connections, and with the representation of concepts grounded on other concepts in the physiological and anatomical components of the brain-mind complex. It is not certain that the same thought in the same person maintains its localisation exactly.

Otherwise, our body is a collection of integrated, intertwined, and interrelated sensors, not always identifiable by conspicuous or specialised input-organs. It senses the environment in a structured manner, provoking imprints of organised sensations in our brains. Sensorial-signals flow from our bodies into specific parts of the brain and often stabilise into patterns of pulse-flows that become available to posterior mental manipulation. Stabilised imprints of sensorial signals will be called signatures. Signatures are mental organisations induced by sensorial signals and act as models (representations) of these signals in our minds. They thus reflect what has been immediately perceived and how it was perceived. They are instantiated in brains as modular organisations of EC-pulses, that are sustained by the perennial physiological dynamics of brains. Any organisation of ground-level pulses is autopoietically maintained by the basal neuronal activity and any pulse-organisation may be a component (node) of a hierarchically higher organisation of mental elements. Anyway, although going to the same region, it is unclear whether the same sensorial-signal attach to exactly the same neurones in any given organism.

Moreover, signatures of any imprint contain parts associated with all provenances of a signal and are often distributed throughout the brain. For instance, when perceiving a stimulus originating from an image through optical senses, the signal finally imprinted in the brain contains spikes other than those coming from the sensed image through the visual sub-system and intertwines with all signals arriving in the brain at that moment. The various binding intensities may depend on tastes, attention, memories, expectations, and many other modulatory mental processes, states, and abilities. Therefore, it is unlikely that brain-imprints, or signatures, formed simultaneously in two persons standing side by side and subject to signals from the same source will ever be equal, the same, or even homologous. Signatures in distinct individuals may though have the same meaning [16]. Moreover, the boundaries between the many parts of the brain handling our many psychological moods (rational, emotional, tensional, etc) are fuzzy and lack precise localisation in the brain. Further yet, signatures may oscillate between several organisational states, as in the case of illusions and ambiguous images.

## 3. BRAIN DUALITY

The following lines describe improved version of a model sketched earlier this year [17]. The greatest depart being the postponing of mind descriptions to a further and much deeper stage of elaboration.

The statements below originate and are supported by advances in neuropsychology and other sciences surrounding investigations about cognition, during the last decades. Yet, they are described here through spectacles provided by the organisation/in-formation/communication perspective. Please, refer to the minimalist snapshot about organisation and in-formation in [17] or its full account in [8]. To understand the following, though, its only necessary to know that in-formation can only be defined, and perceived, by means of synexions or embodied organisations. Synexions are organisations instantiated in a physical space grounded on space, time, and other observables. Synexions can be seen as hierarchically arranged ever-changing volumes or as orbits (orbit envelopes) of hierarchically coupled dynamical systems. Hence, they are "living" versions of organisations that change quicker or slower without changing their organisational identity, e.g., moving or growing organisms. Moreover, in-formation is anticipatory from its very core requiring observers to acknowledge phenomenological propensities to identify it.

The improved sketch below, put also forward a slight distinction between brains and minds grounded on observed biological

behaviour. This distinction brings brains closer to anatomy and physiology while minds attach to processes of further organising signatures and modules attached to brain physiology. The options below conform partially to difficulties in observing cognitive facts, events, and things. All intervening fields of knowledge referred below are under active development and mutating fast. Therefore, be gentle and consider the words herein not as a final proposal but as an inquisitive initial dialogue.

The brain creates the basic elements through which minds manifest themselves: trains of electro-chemical pulses. But brains does that in two stages: the anatomical and the physiological. Brain-cells and their protrusions have volume, spark electro-chemical pulses (EC-pulses), and vibrate. They are thus represented as synexions in the sequel, even though apparently being static for most of the time (except for the EC-pulses that are immaterial). Brains change very slowly chiefly by synaptic reorganisation, while EC-pulses are much quicker. Let's start with two definitions.

***Definition 6.1.*** The anatomical brain consists of all material entities inside human skull together with their organisation. Brain-cells (neurones, glia, micro-glia, and other cells residing within human skull) map to nodes of this platonic organisation while connections between them (axons, dendrites, neurotransmitter channels, or whatever modulates or propagates EC-pulses or neurotransmitters within the skull) bind to arcs in this organisation, the organisational hierarchy being established not just by anatomy but also by the details in study requirements. Anatomical brains map closely but not strictly to the physical brain. Moreover, these representations are fluid, and change depending on inquiry demands.

***Definition 6.2.*** The physiological brain consists of stabilised modules of EC-pulse trains and their actual and possible organisations. At lower organisation-levels, EC-pulse trains and modules are fully conditioned and constrained by the anatomical brain. This mould is gradually loosened towards higher levels of EC-pulse organisation (memories dependent on other memories, images composed of other images, and so on), identified as manifestations in brain physiology of reasoning and immaterial thoughts. These modules may become organised through associations between them and through mental transformations.

Mental transformations have not yet been clearly observed or neatly identified from the electro-chemical point of view, due to technological and comfort hindrances. Nonetheless, they have been observed, recorded, and studied for centuries from the psychological and philosophical stands. From this point of view they are well known and widely used. It is in this sense that they are being offered and considered in the above definition [16] [18] [19] [17] [20] [21] [22]. Under this perspective, signatures and more down-to-earth modules, closer to sensorial imprints, pertain to both brains: the anatomical and physiological.

The idealised mind of organisms with brains should be thus represented by a synexion or a collection of synexions, some of them dually connected. Physiological-nodes map either to anatomic-nodes (firing-neurones) or onto stabilised and resilient pulse-modules. Pulses between these nodes map to synexion-arcs. The mind is thus more fluid, a more embodied (quick) than disembodied (stable) organisation in the mathematical sense implicit above, relying on signatures, modules, and concepts that are already stable [17] [26]. ***Figure 3*** is an attempt to convey what have been stated in a more integrative form.

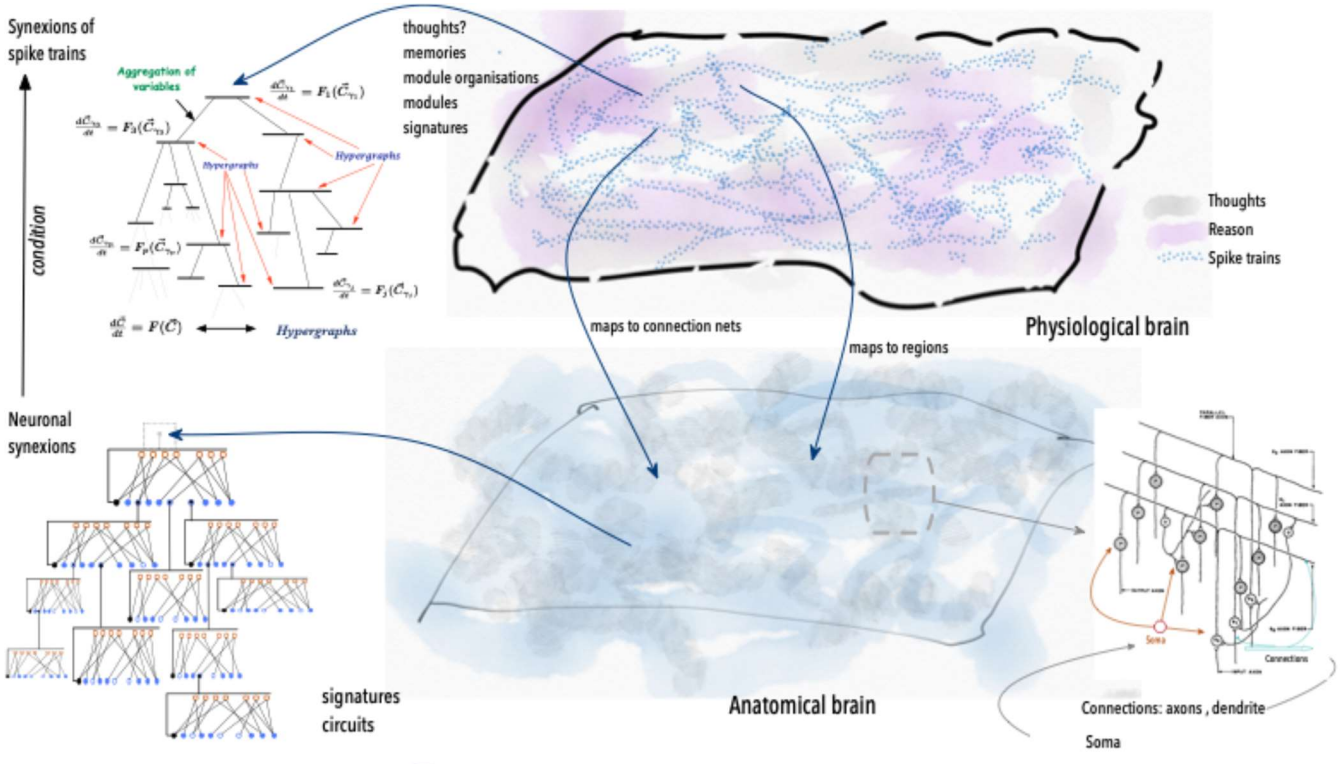


*Figure 3: Anatomical and Physiological Brains — do they blend and Mind?*

## 4. MODEL JUSTIFICATION

As explained in [23], scientific models have a known and primary purpose and need to be justified, with respect to achieving or approaching their purpose. The primary purpose of the models just sketched is to address the possibility of putting data-driven and thought-driven cognitive studies side by side, in equal stands, and collaborating. The very first argument in support of the picture above is that it proposes an initial separation of the anatomical and physiological aspects of a brain. The fast our brain-minds apparently go when we interact with each other, there are many physical and physiological reasons pointing to substantial differences in the characteristic times and space intervals of phenomena in/on the anatomic and physiological brains.

Moreover, this separation allows for a clearer and sharper perspective about minds, even if still tentative. If we consider the electro-chemical pulses composing the physiological brain to be mind's raw stuff, the organised stable modules of EC-pulses closer to the neurone organisation as its basic elements, i.e., signatures and modules at the lower and initial organising levels, and organisations over them as mental objects that last (thoughts, images, ideals, reasonings, memories, and so on), we have an scheme that allow for potentially infinite levels of abstraction and construction of mental objects. This perspective establishes a bridge between our biological brain and what we usually call mind in an easier and more seamless way.

Besides aiding cognitive investigations by separating and confining concerns, the model scheme just sketched allows also for going in other directions. To show this, let's make a humble parallel, at times rough, at times poor, but valuable. Computers have a processing unit, memory, and input-output modules that are made of electronics, but which boundaries go each day fuzzier due to advances in technology and Boolean calculus. Turning a computer on, will energise each and all electronic components but this will provoke essentially no change in its organisation or its response. Not even upon receiving inputs will the computer situation change, unless some special memorised element, a program, activates the processing unit, starting a computation. The program in the memory may be considered as computer's intention. The electronic computer elements are sorted out into each of the modules above on a more than less immutable manner. Noting that a computer program may reside anywhere in the computer memory, we can ask cognitive scientists "why is it so important to determine where in the brain a certain pulse configuration resides?". Wouldn't it be much more interesting to know how is this module activated, and how does it stimulate other brain or mind modules? If we relax in considering localisations important, wouldn't physiological cognition come synergistically closer to psychological cognition?

Brain-organisations, though, are alive and 'quick'. They are permanently creating EC-pulses, moving them around, and transforming them, even when their sensorial parts (input) are 'off' (during sleep or unconscious stasis, for instance). This is basal neuronal activity. These ground pulses are the stuff that gives existence and life to minds. They are the mind's raw 'material'. Given this, it is not difficult to accept that minds are much swifter and plastic than brains, despite their tight coupling and the fact that brain-pulses provenance come ultimately from sensorial and body organs, thru the nervous system and the anatomical brain. Pulse-flows in brains exist by themselves, permanently stimulated by signals from the environment and the body. Notwithstanding, since pulse flows seem not to be fully determined by anatomic details, it is possible to consider the basal pulse activity as the substance giving life to minds under the above definitions. Typically, pulse modules may be identified from an ontological [2] or theoretical [3] standpoints.

## 5. NEXT STEPS

Creativity in collective disciplinary, cross-disciplinary, or multi-disciplinary scientific ambiences [6] are grounded and utterly dependent on communication [12]. Furthermore, cooperation and co-working among scientists and other (non-scientific) communities that surround scientific production, belonging notwithstanding also to the scientific milieu [6], strongly depend on trans-disciplinary communication. Gathering consensus about the most basic communication tokens is in general non-trivially dependent on establishing meanings for signatures and other ground-level pulse-modules associated with basic communication signals.

Therefore, initiating multi-disciplinary efforts strongly rely on profound mental adaptations, reaching levels of neuronal plasticity and low hierarchy spike reorganisation [12] [16] [18]. This suggests that the concur of neuropsychologists in multi-disciplinary teams at these early stages of communication could greatly speed up comprehension convergence. This happens either in relation to understanding a message (semantics), achieving consensus [19] about specific and key terms or ideas, and blending towards other ways of thinking. To continue, the work here described should be further advanced and the construction of a framework supporting a comprehensive and in-depth study of communication, inside our skulls and among scientists with background in distinct fields of knowledge, should be undertaken. This framework should also address communication between scientists and non-scientists [12] [16], acknowledging cultural differences.

## 6. FINAL COMMENTS

If we are addicted to chemical substances, acknowledge it, and want to get rid of our dependence on them, we go to a specialised clinic. There, dedicated people will keep us physically apart from troublesome substances and help us to clean ourselves from their dependence. If we are addicted to an idea, ideal, or way of thinking, we generally are not aware of it. But, if we become aware of an addiction of this kind and want to get rid of it, for instance, to unleash imagination, find unorthodox solutions, or be more creative, what can we do? How can we isolate a mental configuration and not be influenced by it in any manner? How can we be masters of our brains instead of being their slaves?

Understanding the issues addressed above is critical to answer these questions and keep our minds open to novelties and never yet seen challenges. For sure, this understanding doesn't by itself answer these critical questions. Nonetheless, they can suggest innovative training methods that may contribute to minimise the strength of our mental dependencies.

## 7. ACKNOWLEDGEMENTS

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**Disclaimer:** The invitation I received from JSCI was encompassing, this meaning: charges free and no directives or reviewing. Frightening, the last one. I hope to have matched the editors' expectations.

I hereby declare no conflict of interest.

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