The time in cognitive neuroscience: For a physics of mind focused

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QVO NON ASCENDAM?

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Abstract

Can physics provide satisfactory answers to the main questions posed by cognitive neuroscience? Does it make sense to seek such answers through this way? What is the role of time in cognitive processes? Is there a real physical proper time of the mind, distinct from the time of external things? Can mastering the physics of the mind contribute to learning? These are some of the issues discussed in this article, from which I believe it is possible to advance not only in neurosciences, but also in our way of seeing the world through the eyes of contemporary physics.

Keywords: Cognitive Neuroscience, Physics, Brain, Mind, Time.

Resumen

¿Puede la física dar respuestas satisfactorias a las principales cuestiones planteadas por la neurociencia cognitiva? ¿Tiene sentido buscar tales respuestas de esta manera? ¿Cuál es el papel del tiempo en los procesos cognitivos? ¿Existe un tiempo físico real propio de la mente, distinto del tiempo de las cosas externas? ¿Dominar la física de la mente puede contribuir al aprendizaje? Estas son algunas de las cuestiones que se abordan en este artículo, a partir de las cuales creo que es posible avanzar no sólo en las neurociencias, sino también en nuestra manera de ver el mundo a través de los ojos de la física contemporánea.

Palabras clave: Neurociencia Cognitiva, Física, Cerebro, Mente, Tiempo.

I. INTRODUCTION

I usually write my solo works in first-person, especially when it comes to neuroscience and physics, as it is essential to take responsibility for what is said, and also because in many situations referring to cognitive neuroscience only personal experiences narrated with clarity can awaken someone's interest and attention for similar events that eventually happened within that someone. As an admirer of Hofstadter, I like to remember and make my own his words on this point in the memorable book "I Am a Strange Loop":

"If I tell many first-person stories in this book, it is not because I am obsessed with my own life or delude myself about its importance, but simply because it is the life I know best, and it provides all sorts of examples that I suspect are typical of most people's lives. I believe most people understand abstract ideas most clearly if they hear them through stories, and so I try to convey difficult and abstract ideas through the medium of my own life. I wish that more thinkers wrote in a first-person fashion." [12]

In present essay, not only do I keep this principle, but at times I add the concept of self-research, a simultaneously cerebral and mental investigation of myself, quite in the spirit of Maturana (certainly not as in Husserl's egology — for whom the first-person study of the "self" boils down to a handful of trivial accounts —, but as illustrations that seek to facilitate understanding from self-referential interaction of myself with my own, perhaps the only way to circumvent Descartes' "infernal" observer.)

First of all, my considerations about the mind emphasize consciousness in processes of focused intellection. There is no way to talk about the time of the mind without talking about consciousness, since in my personal view time is the preponderant physical entity for the emergence of what we understand by consciousness. The assumption of an individual's proper mind-physical-time, the core of this work, plays the main role of throwing the intellect on the issue of understanding consciousness, a kind of harbinger of considerable changes in the way we evolve throughout life and also in the way we use our existence. It is certainly a thorny topic, but as physicist I feel obliged to tackle it — whilst within the wary scope of the educated guesses (in fact, it is also competence of neuroscience to research phenomena not yet recognizable in laboratory, or not accessible with current technologies, including thoughts and emotions) —, at the same time fighting the obscurantist postmodernism that floods the 21st century media with quantum foolishnesses.

Neuroscience constitutes a way of submitting to logical reasoning the neuronal-mental system with the aid of a synthesis arising mainly from physics, biology and chemistry, comprising several subfields as behavioral

neuroscience, cognitive neuroscience, neurophysiology, neuroanatomy, neuropsychology, and, more recently, neurotheology [16] (the correct approach to this last one subfield epitomizes the investigation of what happens in the brain when the mind experiences the divine from the personal contemplation of existence, and not doing reverse engineering — as the positivist biologists want — looking for biochemical reasons for the mysteries of faith). My approach is fundamentally concerned with cognitive neuroscience. As it is a subfield with many open questions, serendipity discoveries are expected. For this reason, it is absolutely essential that I make plausible conjectures in search of the immense possibilities that the brain-mind relation offers us, from which I hope to find elements that help us keep it healthy the whole lifetime, among other prospects referring to learning and scientific education. As once Sagan brilliantly put it, "Science is much more a certain way of thinking than a body of knowledge."[21] Since physics seems to have an appreciable weight in understanding the mind, it's up to me to warrant rationality of that way of thinking in applying physical principles to this fascinating domain.

To reflect on physics and cognitive neuroscience, there is nothing better than a peaceful environment with pleasant climate, a small town with almost deserted streets, forests and mountains in the background motivating a deep contemplation of existence. The city of Teresópolis, State of Rio de Janeiro – Brasil, “where time passes slowly” (as I use to say), has been the geographic place of my good reflections for decades, including thoughts about the nature of time itself, thermodynamics, cosmology and quantum field theory. As the years go by, I feel I need to experience this "psychological" stretching of time more often (maybe it's a consequence of aging, although this seems to contradict the common belief that time seems to pass faster with age!). But is it possible that, someway, the mind truly alters physical time? This is a question that arises with naturalness from the acceptance that we are in the final analysis made of space-time (thinking in terms of Einstein’s relativity). Therefore, it is a question of knowing whether the word “consciousness” resumes a mind activity that has something to do with the space-time continuum, since the brain is logically part of this continuum.

In my works, I always emphasize the urgent need to retake the disruptive way of science, the only one that leads us to advance as a civilization. If, on one hand, the excessive focus on mathematical stunts accounts for a considerable parcel of the stagnation of physics in recent decades, on the other hand it is necessary to make a *mea culpa* of pure physical thought, sometimes fictional, sometimes obstinate by ideas that offer little hope of success. There is, however, a deeper semantic cause for that stagnation: the insistence on taking representations as identical with the concrete facts of the material world[1]. Much of the conundrum generated as a result of this insistence is due to the growing number of questions that arise the more the representative images of the physical world become fragmented. Descartes' "infernal" observer is really the “infernal” fragmenter of the universe.

From my point of view, such fragmentation does not lend itself to a comprehensive approach to many things, one of which is the human mind (not the brain). There is nothing more basic than space-time, the physical continuous structural entity that composes all things, even elementary particles. Let matter be divided into as many particles as desired; in the end, only space-time will remain. In fact, particles and waves are constructs that attend certain stages of mathematization of experience. Naturally, dividing the world into parts has successfully gotten us quite far. We owe a lot to quantum mechanics in our most advanced technological solutions. But I don't believe that the essential answers we are looking for can be born from a discontinuous conception of reality. Something tells me there must be a continuum underlying all the diversity that the mind processes as copies. Unlike the brain, with its reasonably well-known basic functional regions, the mind is an ever-going physical process with no well-defined boundaries within the brain's structure. The mind cannot be compartmentalized as the ancient positivists would certainly have liked; it is closer to the field construct than to the cluster construct. Here lies the great problem of cognitive neuroscience, as is insinuated in Uttal's speech [32] and later in the compilation of Vacariu & Vacariu:

“The parts of the brain are all somehow interconnected; it is not possible to isolate the neural patterns that correspond to any cognitive process; consciousness and all its relatives (thinking, reasoning, decision-making, problem solving, and intelligence) are the most problematic notions in cognitive neuroscience, etc. There are no clear definitions of some mental states like emotion, attention or consciousness and probably such states are general functions and not modules of cognition.”[33]

Indeed, if it is already difficult to understand the origin and complexity of the simplest biological systems, imagine the effort (perhaps futile!) required to try to understand the human mind! Undoubtedly, there are wonderful efforts in search of models that bring us closer to a preliminary physical understanding of the chain of processes involved in the manifestation of life as the “vital field” of Sánchez and Battaner [22], governed by equations of continuity and “vital flow”, to which the characteristic scalar physical magnitude is the so-called “vital density” defined for all space-time.

Certainly, it is expected that there is a more essential physical architecture of the mind beyond brain matter and neural networks, and, as is to be also expected, the further we descend into the unimaginably small, the more voids we find. But what I mean by void does not belong to naïve realism. Here, the void is just the scale where space-time manifests itself in an absolutely indistinct way (taking the common materialist view of what we mean by “distinction”), however contradictory this may seem. Choosing this way, I must admit that the only thing left is the very variable dynamics of expansion-shrinkage of

1 This is rooted in a substantialist avidity characteristic of common human understanding, as Bachelard rightly observed: "The need to substantiate qualities is so great that metaphorical qualities can be proposed as essential." [1] (author’s free translation).

space-time, constituting a kind of tessellation from which everything becomes more complex (it doesn't sound like much, just what I see as possible). I'm afraid I share with Schrödinger a somewhat skeptical perspective on how far we can go:

"From all that we have learnt about the structure of living matter, we must be prepared to find it working in a manner that cannot be reduced to the ordinary laws of physics." [23]

Being a physical approach to the mind based on the notion of space-time continuity, whilst in a limited way, then it will be useful to return to Einstein's theories. There is a dramatic philosophical[2] consequence of replacing the Newtonian view with Einstein's relativity — in particular, general relativity —, something that is never discussed, at least in the most closed circles (I like to think that, as Chalmers and Sklar [5, 29], many scientists recognize the importance of philosophy in scientific investigation). There is not a receptacle filled with matter and indifferent to time direction as in classical mechanics, but a space-time continuum that forms the primordial nature of all matter. The space-time woof is expanding at all scales, although the expansion has no measurable effect on us; thinking of the expansion of the universe as a necessary condition of its very nature, and putting aside speculations about its future, thinking of our own bodies and the objects around, that expansion occurs since subplanckian domains. Evidently, this expansion does not happen equally in all regions. Although the binding forces between the coupled bodies compensate the expansion (just enough for us not to implode!), this does not mean that the trend has ceased to exist, but that we can rest safe about our physical integrity, at least for a while, insofar as the entire universe expands maintaining basically the same relative proportions between bodies. From this assumption, now thinking about the brain/mind system, as space-time moves in itself, there is a drag effect of expansion along the entire neuronal trajectory of an electric signal (including the electric signal itself).

Whatever the theory, there is always concern about the human threshold of reading a temporal variation, as Conway *et al*. underlined:

"*Relatedly, and more importantly, is the fact that non-Newtonian space-time effects would seem on the surface to be so small that they would appear to be outside the human capacity to perceive*." [6]

The drag effect of expansion referred above is certainly a tiny effect, but, being amplified in some way over a large succession of signals in a sequential neuron assembly, it can form a pervasive effect, while relatively small. If this is indeed possible, we will need to investigate which mental states favor such an effect.

When it is admitted that everything — effectively everything we know, particles, fields, societies, cities, etc. — is made up of space-time in its ultimate content, it becomes difficult to completely separate things. It can be assumed that, in this line of reasoning, the potential connections of mind and matter are far from known, even more so the connections between time and consciousness. This is a topic that needs to be treated with great caution, as it is very susceptible to pseudoscientific approaches. The objective of this essay is just to discuss the hypothesis of a physical proper time of the mind — along with a subjective time — of each individual, susceptible to random stretching according to singular mental states. To verify completely this hypothesis, it will be necessary to establish a hybrid program, including measurement apparatus and specific reports of individuals submitted to the tests. Lastly, the proposed discussion is useful because it raises a number of interesting philosophical questions. I hope the reader will appreciate and choose to pursue studies that bring physics and neuroscience closer together.

II. THE ETERNAL QUANDARY

The true nature of time is a thought-provoking subject; Aristotle's invariable time, Newton's absolute time, time as Kant's a priori category, time in Husserl's phenomenology, Einstein's relative time, and so on. In Plato, the negation of time by the idea that it is an "movable image of eternity" led to accept that the only real thing is timeless eternity, the basis for the positivist notion of time as simply an epiphenomenon of human perception. In recent times, numerous works discuss the perception of time under different approaches [3, 6, 10, 13, 14, 15, 35]. Furthermore, the millennial discussion has led some authors to consider time as a fundamentally social construction. It is true that the notion of time evolved socially in the context of the most primitive perceptions and ideas of humanity. It is also true that we can see history as an institute that alleviates human frustrations, especially Christian ones, in relation to prophecies and myths about the end of human suffering with death, and about the end of the world, substituting progressively the relationship between heaven and earth for the relationship between past and future [7]. In addition, events of anthropic nature were decisive to gradually change the demarcations of the old temporal conception. Ancient calendars, full of prophetic visions, and rustic hourglasses gave way throughout history[3] to prognostics more related to human actions and accurate clocks than to divine designs. The understanding of God became much more cosmological[4], while personal experiences with God became the subject not only of erudite theology but also of a new discipline, the neurotheology. But, at least as far as

[2] It is important to understand that the major role of philosophy is not to prove something, but rather to eliminate from reasoning what does not make any sense, allowing us to improve our representations of the world.

[3] Here it is not the case of a critical analysis of historicism, only a historical view as a sequence of cultural records subject to interpretations according to epoch social contexts.

[4] I really have the impression that we come closer to Ambrose's statement in the First Book of *Hexaemeron*: "Almost all pagan pretend that the world is co-eternal with God, as it were a shade of divine power. And though they confess that God is their cause, it is not, however, a question of a cause by the disposition of the will of God, but as a body is the cause of the shadow and the brightness the cause of the light." (free translation of the author).

science is concerned, in the intense light of indisputable facts, time is far more than a clock-based convention; it has, so to speak, its own "humor" in playing tricks on us. Its “passage” is felt in our existence and in the objects that surround us through its inseparable partner, the entropy. Time may have been socially perceived, which does not mean that it has no physical reality. We can recognize the notions of succession and continuity in all physical processes and astronomical observations. More than that, bodies tend towards regions where time passes more slowly; when a body falls it approaches the source of space-time warping, where duration “flows” most slowly. Among the heavens, there is always a gravitational attractor pulling everything nearby inexorably onto itself.

A. The Pranks of the Time: *Tempus Fugit*

The problem I identify in most of the discussions about time is that there is no possibility to dissociate it not only from space, but also from energy and entropy. All these magnitudes are perfectly defined and interdependent. A time interval, that is, an ideal piece of the temporal facet of the four-dimensional continuum, "delimits" a quantity of energy, and therefore, a flow of entropy; the duration referring to this time interval depends on the space that separates it from a massive object — which, in turn, is an expression of the curvature of the continuum —, or on the speed of the moving body to which this duration refers. The primordial energy of the continuum is the expansion energy of space-time itself, intrinsically linked to its own evolution. Thus, to explain time based on idealistic phrases such as "in fact, time does not pass, because everything happens now" and “time is nothing more than an illusion created by our limited way of perceiving reality“ is to want to deny physical concreteness based on the fragility of language, since expressions like "the flow of entropy follows the arrow of time" and "time runs from the past to the future" are usual in general communication with the effect of "so to speak", the way we found to mentally represent the real and inexorable consummation of a succession of facts that exist independently of our presence in the world. Bearing in mind what I said earlier, the frequent confusion between language (representation) and phenomenon is at the heart of the stagnation of physics.

As Wheeler once said, "time wears different clothes for each role it plays in our thinking." This is a fact, and it is precisely this fact that complicates everything, for we have no way of stripping time of its subjective attire in order to separate the physical from the psychological. We know that in our universe time — like entropy correctly understood according to the Second Law of Thermodynamics — cannot go backwards; we can stretch it or compress it, but never make it go back. We saw earlier that variations in duration depend on the speed of the object that lasts, or on the object's proximity to a source of gravitational deformation. But imagine that the so-called "psychological time" is more than that; there is a real physical duration specific to each individual under determined circumstances of focal concentration. Wouldn't talking about "psychological time" be also a way of simplifying a physical fact whose gear we are yet to know? It is easily understood that the psychological experience of time is closely linked to the spatial domain of our daily actions, that is, to the boundaries of our day-to-day activities, such as going to the market or taking the children to school. The closer to our homes are the services we need, the more time seems to slow down because we can do more things in the same amount of time (to say it another way, the high density of sensory data recorded in a short period of chronological time generates the feeling that the temporal extension of an event has increased). In our day-to-day lives, we use to say that “time flies”, "the day paid off", or that "the hours don't pass", expressing our particular experiences in time. Thus, time is always associated with the yield of energy we consume to act in some spatial domain. Therefore, the question is whether the stretching of time — the proper time — may be a real physical phenomenon influenced by the individual's mind, so constituting the dynamics of that proper time itself. I'm not denying at first the existence of subjective perceptions of time, just hypothesizing that certain mental states can physically alter duration.

In most of the existing literature there remains the belief that the perception of an instant is a subjectivity (in the sense of being particular to each individual). In some cases, this subjectivity is supposed measurable by the ratio between the brain energy spent and the chronological longness of an event, hinting at the intimate relationship between time and energy. It turns out that this energy can participate partially — if not completely — in a real physical influence on mental duration.

So, the enticing discussion is whether there are only pure sensations of the passage of time, or if mind beyond sensations is capable of objectively interfering with the individual's own passage of mental time, considered from the perspective of a physical proper time. Certainly, this ability would be associated with a much greater complexity of connections between neurons. In fact, it would not be so surprising a mental control of one's proper time in parallel with a physical control of the advance rate of one's proper entropy (something we do while maintaining healthy habits). Would there be conditions to test such a hypothesis? I believe so, organizing groups of individuals with good intellectual focus capacity during periods of at most one hour of continuous study. In addition, I see great theoretical support from a deepening of Günther’s polycontexturality, which provides logical means to identify paradoxical observations and to describe them soundly [11].

III. THE STRANGE SYMMETRIES OF TIME

Many scientists talk about complex things as if everything was very clear. In fact, not much can be said clearly in contemporary physics and neuroscience. In Smythies' interrogative saying, “…what is the exact nature of a neuron’s activity that leads to a conscious experience?”[30] It is preferable to walk calmly without waiting for

crystalline statements. That is what I have been trying to do, not always successfully.

We are used to a Cartesian macro-world of squares and rulers delimiting our spaces, while quartz clocks count with extreme precision the hours of everyday life. We travel inexorably into the future with our belongings, our homes, our planet. At the quantum scale, however, things look different. Phenomena that escape common sense appear, such as the entanglement between particles. First, as Bunge noted, quantum entanglement confirms the thesis that "once a system, always a system."[4] According to my way of seeing, what changes are the relationships between the components of the system. Two interlaced particles can relate under a different geometrical framework. While in our macro-world information diffuses in space in any direction, but only to the future, in the micro-world the message exchanged between two entangled photons freely navigates in time between past, present and future (three temporal components), but only in one dimension in space, the single one-dimensional line that connects both photons like a kind of umbilical cord, a particular broadcast channel not in a bolt shareable by any other particle, an entail that will disappear under a sudden perturbation, disengaging the photons initially entangled[5]. This approach was modeled on a set of quaternions, introducing a quartic imaginary unit ε in four matrices as

$$\mathrm{E}_1=\begin{bmatrix}\sqrt[4]{-1} & 0\\ 0 & \sqrt[4]{-1}\end{bmatrix}=\begin{bmatrix}\varepsilon & 0\\ 0 & \varepsilon\end{bmatrix};\qquad \left(\varepsilon=\sqrt[4]{-1}\right)$$

$$\mathrm{E}_2=\begin{bmatrix}0 & -\sqrt[4]{-1}\\ -\sqrt[4]{-1} & 0\end{bmatrix}=\begin{bmatrix}0 & -\varepsilon\\ -\varepsilon & 0\end{bmatrix};$$

$$\mathrm{E}_3=\begin{bmatrix}0 & -\sqrt[4]{-1}\\ \sqrt[4]{-1} & 0\end{bmatrix}=\begin{bmatrix}0 & -\varepsilon\\ \varepsilon & 0\end{bmatrix};$$

$$\mathrm{E}_4=\begin{bmatrix}\sqrt[4]{-1} & 0\\ 0 & -\sqrt[4]{-1}\end{bmatrix}=\begin{bmatrix}\varepsilon & 0\\ 0 & -\varepsilon\end{bmatrix}.$$

That quartic imaginary unit represents the signature of a "fifth direction" embedded in the fourth dimension that is neither time nor space, connecting four-dimensional slices of the continuum by the so called "bridges" built with E_i matrices. It is possible that gravity's weakness compared to other interactions is due to the fact that most of its influence is restricted to this "fifth direction" that we do not perceive precisely because it is embedded in the fourth dimension; that is to say, most of the gravitational power is hopelessly hosted on the "bridges". There would be no way to reproduce the complete theory here in all its complexity, so that the reader will find the complete work in reference [24]. There is, therefore, a private space-time of communication between the twin photons. This kind of virtual space-time companion of common space-time is spontaneously created. While interlaced, the photons communicate by a "swiveling" of our space-time, an operation of natural symmetry transformation that converts three components of space into three of time, and one of time into one of space (let's say, more precisely, space-time "swiveling" is what entangled particles can do; it is not a product of entanglement). Why the relationship between entangled particles is the way I have described it is a great mystery, as is the very law that governs the transformation of four-dimensional signatures. We know the symmetry, but not the *prima causa*. However, it is common to say that if we know the symmetry, we understand the theory. This is certainly unsatisfactory, but the quantum world is full of unsatisfactory things, as well as the precariousness of the notion of psychological time. In typical quantum mechanical terms, the entangled photons are in both real space-times, until an "observation" takes place and fixes them separately in our ordinary world (the loss of interlacing, or decoherence). Evidently, this is a way of speaking limited by the fact that we still use the idea of particle here, something that, once understood, should lead us to a complete withdrawal from the corpuscular model as a valid tool.

It is pertinent to question whether this model of entanglement would contradict Law II. The answer to this question is relatively simple because entropy is a quantity strictly referring to thermodynamics, and not to information theory as so many wanted and made huge analogical confusion. The space-time of entanglement is mainly communicational, and restricted to the twin particles. We may say that the interaction (communication) between the twin photons assumes a temporal *palindrome* (a new course), explaining a new context of geometrophysical relations. Physically, the pair of photons remains subject to the standard laws of thermodynamics in conventional space-time (and not in a Hilbert space!), the geometrophysical "place" where relationships give meaning to the concept of entropy.

On this last point it is necessary to be quite clear. It is curious how one transfers to something called "information" all the difficulty in dealing with matter and energy in processes that escape first intuition. But this is a misleading subterfuge and, at best, provisional, since information is codified energy, and, as such, in the woof of the fourth-dimensional continuum, it is connected, intrinsic, pervasive to everything and in everything that exists. Information is a set of signals endowed with a structure and capable of inducing a certain behavior in a given system. A signal is a kind of "snap" of energy, so information is a crackle of snaps in a certain pattern or arrangement. Therefore, the *palindrome* assumed by the twin photons belongs to a space-time as real as the conventional space-

[5] Interestingly, four years after the publication of my PhD paper in theoretical physics [24], working with quaternions in a 4-D model of spontaneous symmetry transformations for entangled particles, in which three space coordinates are transformed into three time coordinates and one time coordinate into one of space, a group of researchers formulates a hypothesis according to which, if we could travel at superluminal speeds, we would see bizarre phenomena taking place, such as the transformation of relativistic four-dimensional space-time into a universe with three dimensions of time and one space dimension (see **Andrzej Dragan *et al* 2023 Class. Quantum Grav. 40 025013**). Evidently, my approach does not require superluminal velocities, since it proposes to model the relationship between entangled particles, showing how they exchange information freely from the future to the past and *vice versa*.

time, although configured from different ontological relations.

In conclusion, the role of this section is to bring the reader a correct perspective on the concept of information so that its nature can be evidenced when considering it in the study of the mind and its connections with the brain. Furthermore, time also comes to be understood as an entity that integrates the form of relationship established between physical objects, which, as we have seen, is not necessarily limited to the way we are used to perceiving the world.

IV. THE INSCRUTABLE MIND

There is still no consensus on what consciousness is. Neuroscience community, as pointed out by Smythies, understands "consciousness" as "identical with the electrical activity of assemblies of neurons in the cortex arranged in a series of interconnected network." And it gets worse when we are compelled to investigate it physically; a big puzzle arises from the moment we look for a physical understanding of the mind. I would like to transcribe a passage from Ukachoke, which brings some interesting insights for my argument:

"*Because the mind is a composite of information-processing processes, it is an informational entity — a non-material entity that is composed of information and information processing, and because the information processing processes that form the mind are innumerable in number and involve information that ranges from simple to very advanced, the mind is an informational entity in a highly advanced form. And, because the mind is a non-material, informational entity, it is not a conventional physical entity (or mechanical entity) like mass, energy, or force; that is why it is so different from the conventional physical entities.*" [31]

The text makes a huge effort to understand mind, whilst without much precision. This stems from the hindrance in dealing with time as a fundamental physical entity to be considered in mind processes. Faced with the impossibility of representing time figuratively, unlike the case of space, we claim for a deeper and more essential approach, which is feasible by assuming a universal continuity behind the fragmented appearances of ordinary matter. Borrowing from Popper [18] his excellent discussion of the three worlds that house human creations and everything else that exists, we will be able to see the roots of this difficulty. Human creations belonging to Popper's world 3, such as Bach's partitas and Magritte's paintings, assume physical representations in world 1 (musical scores and paintings), but remain inhabitants of world 3. These inhabitants are born from complex mental associations and intellective interactions between emotions and images of objects in the world 1, the latter often dissolved or deformed in erratic thoughts. If, however, we accept time as a legitimate inhabitant of world 1, its participation in insights from world 3 will hardly find concrete counterparts in world 1 such as musical scores and paintings.

The need for concrete counterparts in world 1 comes from common didactic errors such as in the first classes on vector algebra, in which one starts aprioristically with the generalized notion that a vector has size, direction and pointing, when in fact vectors are quantities composed of n components over which, fundamentally, an operation called scalar product is definable. Size, direction and pointing are features of vectors in three-dimensional space. So, disruptively deconstructing the crude ideas of traditional teaching, the expression "composite" from Ukachoke seems to me quite adequate to indicate the mixture of space and time. However, the understanding of the mind as a "composite" of physical nature can only occur if we consider the implications of the time intrinsic to neuronal processes, as long as we assume neurons and synapses as one and the same thing regarding the spatio-temporal woof. In my opinion, consciousness does not occur in time, it is predominantly time in its own course, with the neuronal architecture as the organism that registers this course through the apprehension of external world by mental copies of facts in succession, a process known as "perception". Contrary to popular belief, space and time combine in different ways, i. e., a conscious process is a copy-slice of external world (predominantly "duration") recorded in a neuronal structure (predominantly "extension") through an opaque blend of duration and extension called "perception". All these combinations are space-time composites. I really like to summarize all this in a definition that is both philosophical and a little poetic: Consciousness is the awakening of primigenous time-face of the space-time composite in the brain activity of a sentient and rational entity, the ineffable movement that realizes the mind. Therefore, the discontinuous model of the universe has taken a back seat, being evoked only as a convenient heuristic artifact in certain situations in which scientific discourse remains at the level of naïve realism, or in some systems of hypothesis like the Penrose–Hameroff theory [17, 17-a], namely "orchestrated objective reduction" (Orch OR), in which discrete conscious moments are identified with quantum computations in microtubules inside neurons (although here discontinuity can still be overcome by understanding it as a mere linguistic artifice to facilitate general communication at first approximation).

The concrete problem is that every explanatory construction presupposes an "infernal" observer, and none include observer variables. Even the confused operationalist rhetoric that identifies the observer with a sensor apparatus cannot ignore the fact that a external subject is needed to interpret the registers of such an apparatus (i.e., the human observer himself), otherwise there would be no epistemological sense in building apparatuses. Fortunately, not everything we imagine as part of the so-called real world is observable or experienceable in labs at first glance, leastwise within the limits of what we currently consider technologically possible. The anachronistic excuse that science, dependent on objectivity, could not include something as subjective as consciousness, does not survive the fact that any subjective event is embedded in the objective world we are trying to describe, and as such must

physically connect with that world. We can live with some inscrutable aspects of consciousness, but we cannot accept that the whole subjective characterization of conscious acts is reduced to psychological facts without physical support. This leaves us a margin for abstract work more sheltered from naïve realism. Of course, there is a true technological paraphernalia at the service of the regionalization of brain functions that add little or nothing to the understanding of the mind as a physical process in itself. For example, as it is said, deliberations and decision-making take place in the prefrontal cortex, while feeling afraid runs on account of the amygdale; but they are all processes running from a highly complex material structure, and although they may somehow be linked to the brain regions indicated, we have no way of identifying which arrangements of neuronal assemblies would serve a specific cognitive event. In addition, various experiments are possible, such as measuring changes in behavior by Transcranial Magnetic Stimulation (TMS) [4]. Also neuroimaging findings on time perception and many results on neural integration have been reported since the early 2000s [19, 34]. None of this, however, ensures that mind can be associated with a precise location in the brain.

Some attempts to advance the investigation of the connections between physics and mind can be found in Buhusi & Meck [3] and Ghaderi [9-a]. In particular, Ghaderi's approach on the ratio between the entropy inside the brain and the entropy outside the brain is interesting but needs an accurate revision on the concepts of entropy and irreversibility in light of my inspection of the Second Law [25, 27]. Conversely, his approach suggesting relativistic neuronal broadcast speeds affecting time perception doesn't seem to correspond to the facts [9] (I will return to this subject later). A very interesting work by Conway *et al*. [6] discusses the possibility that human beings have space-time-like mechanisms — as space-time-like processors — for perceiving the intrinsic relativistic relation between space and time, perhaps indicating, based on research by other authors which have already received some empirical support, that neural underpinnings are shared in mental representations of space and time (soever such an overlap, even though suggestively consistent with the defended hypothesis, does not warrant that we have a relativistic space-time processor). However, the approach remains on a plane that focuses the mechanism for slowing time down as being purely psychological. Another interesting recent work from Signorelli *et al*. [28] explores the layer-cake representation of states of physical systems in configuration spaces with increasing complex structure to propose an analogous hierarchy for a meta-model of space-time cognition, a work that can help to build a clearer understanding of how brain functions operate the representational fusion of space and time. A curious attempt, whilst somewhat vague, can be found in Le Bihan [15], in which the author seeks to treat the brain as a four-dimensional manifold whose geodesics would be the neuronal transmission pathways. At the end of the work, he admits that the analogy has its limitations, but I believe that the main problem is in dealing with the continuum that would certainly have to be considered in all its consequences in the brain manifold, which leads, according to my theory, to a discussion of time, mind and consciousness within a clever and suitable framework. More than that, even if the idea of curvature *lato sensu* is more broadly applicable when talking about evolution of complexity, in order to be feasible to consider the Ricci tensor it is necessary to accurately and consistently describe the energy context specified on the right hand side of Einstein's equation and its connection with the geometry to form a plausible explanation about how consciousness occurs (I'll return to this subject later on). These questions still seem to be obscurely dealt with in this sort of approach. Therefore, the general appearance of the research leads me to believe that there is a long way to go before it becomes intelligibly applicable. Lastly, among many other authors, Isbister *et al*. [13], approaching how information in the nervous system is encoded, analyzed the temporal variability of spike encoding. In short, working together to encode information quickly and make decisions, neurons produce sequences of "dots" called "spikes". It was verified by the authors that the level of cortex excitability affects the evolution of those sequences. A less exciting cortex leads to spike sequences stretching and evolving slowly in time. Contrarily, for a more exciting cortex, spike sequences are compressed, evolving quickly in time. This approach is particularly interesting in the sense of empirically identifying a direct association between a mental state, equivalent to the level of excitation of the cortex, with the degree of time stretching for the assembly of spike sequences. Nevertheless, as far as is known, there are no concrete initiatives operating in search of an intrinsic physical connection between mind and time lapses (although I do not presuppose that physical space-time and psychological space-time directly and necessarily overlap in one-to-one correspondence), perhaps because the professional schooling of the public which is mostly interested in the subject as psychologists, neurologists and neuroscientists with background in biology. Still, it seems that there is a certain embarrassment in discussing beyond the merely psychological, arriving at the possibility of the physical actually happening. Anyway, the mind science — bringing together here the specific branches of neuroscience and brainless psychology in what it can benefit from the formers — lacks a robust axiomatics. This is one of the problems of psychology, whose future advances in the direction of constituting a true science will depend on our ability to understand the mind and to formally recognize physical processes associated with the emotional responses we give to the facts that affect us (when it comes to formalization, it is not necessarily about mathematics[6]; there are other formal languages such as those of logic and chemistry). It is difficult to say now whether a program of this magnitude may be fully realized, so the best we can do is to make some plausible assumptions guided by a lot of intuition and a few well-established physical principles. After all, educated guesses are part of scientific thinking when making predictions, even for the remote future.

[6] Evidently discarding Lacan's topological guff.

V. THE MIND'S EXPERIENCES AND THE EXPERIENCES WITH THE MIND

It is commonly accepted that the expansion of "psychological time" happens every time we perceive an amount of sensory data at a greater speed than usual (at least that is what is said according to the limitations of current knowledge). The high density of data recorded in a shorter chronological interval produces the sensation that the temporal dimension of an event has been extended. But, intellectual focal concentration has nothing to do with the speed of perceiving a certain amount of sensory information; on the contrary, in a focused intellectual state, everything else is abstracted. So, does a highly complex neuronal activity slow down the time so that one can process much more data if needed (the proper time flowed slower than the outer time)? One might object that a physical clock would not be applicable to a real measurement of the internal proper time, which in fact is true; it is much simpler to reduce everything to a matter of subjective intensity. However, if we abandon the debate, we will suppress the idea that effectively everything is made up of space-time, a fact that will always cause an inevitable discomfort in face of Einstein's general relativity. Indeed, the hypothesis is testable by creating several groups of individuals known to be able to conduct studies with focused intellect during periods of approximately one hour without interruption. By setting a clock as an external reference system, through inference, evaluation of energy expenditure, and personal report of each participant in the test group, it will be possible to reveal the verisimilitude of the hypothesis.

VI. THE TIMES THEY ARE A-CHANGIN' (WITH ENTROPY!)

Excluding any mention of internal mental processes, as in 20th century behaviorism, science was slow to dare to discuss the mind from a physical point of view, although a merely functionalist description still predominates. Chalmers drew attention to this in his eloquent review:

"*Even if each of the cognitive and behavioral functions related to consciousness were explained, there would still remain an additional mystery to be explained: why the performance of these functions is accompanied by a conscious experience? It is this additional enigma that makes the hard problem be hard.*" [5]

And proceeds further on the physical approaches:

"*The problem is that physical theories serve to explain why systems have a certain physical structure and how they perform their various functions. Most scientific problems take this form; to explain life, for example, we need to describe how a physical system can reproduce, adapt, and do its metabolism. But consciousness is a completely different kind of problem, insofar as it is beyond the scientific explanation of structure and function.*" [5]

I think that the first step to overcome the barrier of simple functionalism and defeat reductionist subjectivism is to review the foundations of applied physics. I have tried to reduce the stubborn impositions of subjective character that often confuse us in our explanatory constructions, especially when human limitations of understanding are linked to stochastic descriptions, as is the case with the concept of entropy. Here, more than in any other field of knowledge, analogies are really problematic, insofar as they ignore how unreal they can be in face of the vast complexity of the universe. I wish it were simpler; however, if we want to understand what entropy is, we must forget about playing cards and boxes with colored balls. The same must be done about time, leaving aside the tricks playing on us by word games that make it seem an epiphenomenon connected to consciousness. For example, time appears as the structure of consciousness in Husserl, with consciousness being the systemic condition of the brain or mental state that allows the apprehension of the world of external things in a succession of facts. Anyway, unlike Bergson, for whom physical time would be nothing more than the projection onto things of our own subjective perception of duration, I think — trying to be incisive without being redundant — consciousness is essentially what space-time is in terms of its temporal constitution, and, simultaneously, supported by the neuronal architecture, a mental disposition that helps us to perceive the duration as a facet of reality, even though we are constantly in an inner conflict between theory and reality. But if we don't learn to deal with this natural conflict, we will renounce knowledge by reaching sterile conclusions about the essence of the beautiful and fantastic universe in which we are the thinking part that perceives itself in four dimensions.

A. Relations and Objects

My point is that the idea of being immersed in a "gelatin" of space-time [20] sounds incoherent, if not absurd; we are part of the gelatin, we expand with it — although imperceptibly — towards the future. Space and time are physical signatures of the way in which *relationships* between objects are established, including the mind and the copies of external facts and phenomena it create to run consciousness. They are independent of our existence, whether we are conscious or not. By physical signatures we understand the ultimate structure, the *fundamentum naturalis* that enables the emergence of *relationships*. They cannot be separated, and from the point of view of general relativity, I understand that the "gelatin" of space-time does not represent a reality external to us, but constitutive of ourselves. Hence the relevance of the central question of this essay.

Likewise, I find the association of entropy with a "blurred" (statistical) view of reality inconsistent. Entropy is a perfectly clear and focused concept, requiring no stochastic-subjective connotation. Think of the Big-Bang,

the lowest entropy stage imaginable; why that? Because "immediately before" the "Big-Bang fact" there were no *relationships*; neither did objects exist, since objects are only defined by the *relationships* they maintain with one another. Such *relationships* are established in different and intricate ways, all of them, in one way or another, involved in energy exchanges and thermal dissipation. It is precisely these *relationships* that drive entropy from the complexities that are being created. In short, the Big-Bang started from an absence of *relationships*, therefore, an absence of objects. Hence the need to admit total ignorance about that "pre-Big-Bang". At the post-Big-Bang first stages, the early universe was very different from the universe of now, consisting primarily of hydrogen and helium. The relations at that period were, therefore, very restricted. The first stars, called Population III, now extinct, were completely consumed at young ages with very little chance of interaction. Entropy was just starting to increase, changing the features of time as well.

B. Some Additional Physical Thoughts

There is a topological approach to entropy (referring to the order of the time sequence) that I developed based on the Lagrangian and Hamiltonian formalisms, namely, respectively,

$$\mathfrak{L}_1 = \delta Q_{int} \left\langle \tau - \tau_0 \right\rangle^0 + \left\langle \tau - \tau_0 \right\rangle^1 \frac{\delta Q_{ext}}{\tau_{ref}}, \qquad (1)$$

$$\mathcal{H}_1 = -\left\langle \tau - \tau_0 \right\rangle^1 \frac{\delta Q_{ext}}{\tau_{ref}}.$$

Sub-Planckian time intervals in brackets are singularity functions that "encapsulate" certain amount of energy[7]. These intervals characterize a method of analysis by neighborhoods, not corresponding to a real fractioning of the continuum. Internal and external heat variations with respect to these intervals, and the characteristic (reference) transition time interval $\boldsymbol{\tau}_{ref}$ of the system are present. As noted in reference [27], intrinsic and extrinsic analytic operations are applied to the Lagrangian function under consideration, according to the mathematization instance. This means, in short, that it is possible to show different facets of he running physics, i. e., representations of distinct features of a single process. The final conclusion is the entropic interaction relation precisely on the boundaries between neighboring intervals given by

$$\frac{\delta \dot{Q}_{int}}{T} = \frac{\delta Q_{ext}}{T \tau_{ref}},$$

an expression that defines the flow of entropy at the borders (note that entropy is decoupled from the "history" $\left\langle \tau - \tau_0 \right\rangle^1$, but not the thermal energy expressed by the Lagrange function). Again, the reader has access to the complete theory in Serpa & Fernandes [25]. Scientifically, what matters is to understand that the fewer *relationships*, the fewer objects and the lower entropy. Entropy increases precisely because with the expansion of the universe the number of *relationships* increases, therefore increasing the number of objects. There is no doubt that the evolution of the mind depends directly on this increase in *relationships*.

VII. FOR A RELATIVISTIC THERMODYNAMICS OF THE MIND

For a brief period, a subject that seemed controversial was the speed of neuronal transit. As the speed of thought is admittedly high for everyday standards, there were those who imagined the presence of relativistic effects in our perception of time. In accordance to Einstein's theory, time intervals can undergo dilation under the action of intense gravitational fields or when referring to bodies moving at speeds appreciably close to that of light. On this latter case, let's think about this way. Our upper atmosphere shields us from cosmic rays. When interacting with atmospheric atoms they generate highly energetic muons. Under natural conditions, these muons would be ephemeral and would not have time to reach Earth's surface. However, because they were accelerated to speeds very close to that of light, their lifetimes expand so that some of them reach the ground, confirming once again the correctness of Einstein's theory. Having in mind relativistic effects related to high speeds, Ghaderi supposed that the velocity of neural information transfer through the cortical paths in the human brain may be close to the speed of light. According to him, the velocity of integration of the assemblies in a neuronal network is too high [9]; he suggested that time perception is related to these high speeds. But, compared to the speed of electricity — for instance in a copper wire —, nerve impulses through the axons (the neural "wires" as long leaky tubes of fluid) are extremely slow, traveling at a maximum of 100 meters per second, depending mainly on axon's diameter and myelination. There is nothing similar to the atmospheric interactions that accelerate muons. For physicists in general, it is very implausible that nerve impulses could reach speeds close to that of light. However, although neural tissue are much worse at conducting electricity, increased nerve impulse conduction speed may be partly responsible for sensory and cognitive improvements.

Particularly, intending to create a description inspired by mechanical systems in general relativity, Le Bihan, as I mentioned earlier, takes a somewhat extravagant approach:

"*With General Relativity Einstein showed that the metric of the Universe space-time was related to the stress-energy tensor of the sources it contents (including gravity) through field equations, giving the space-time a curvature […]. By*

[7] Recently, to more accurately express the arbitrary character of the finite time interval, I replaced the *bra* with

$$\left\langle \forall \right|,$$

so that

$$\left\langle \forall \right| \tau - \tau_0 \rangle^1$$

means "whatever scale is considered for the time interval". In this way, the physical sense of continuity is ensured, no matter the order of magnitude of the chosen neighborhood [27-a].

analogy, we might consider that the "trajectories" (brainlines) followed by neural activity in the brain 4D-space-time are determined by its metric, which, in turn, is determined and shaped (curved) by its sources, that is by brain nodes activity ("energy"), and existing connections ("field") between them […]. Note that the situation is a little bit easier for the brain than the Universe where the mass concept had first to be converted to energy (and then a stress-energy tensor) through the Relativity theory […]. However, reciprocally one may also virtually associate node activity (energy) level to a "neural mass" (actually, neuronal activity might be really accompanied by changes in local mass considering that neural swelling and influx of water occur, notably within dendritic spines, upon activation […], but this is out of the scope of this essay)." [15]

All this sounds hit-and-miss and portentous, even if metaphorical. Special care is needed here: is it a question of describing the brain in terms of general relativity, or of describing the relativistic functioning of the mind? About the first alternative, I don't see a reasonable prospect of approaching the understanding of the mind. In Einstein's theory, geodesics are world lines that curve in the vicinity of massive bodies, like a beam of light coming from deep space near the Sun. May be helpful a little of the fundamentals of the Lagrangian approach to relativity so that we can better understand the serious difficulties of the crude representation proposed by Le Bihan.

A. Lagrangian Forms in Einstein's Theories

When looking for a Lagrangian representation of a given physical system, one seeks to establish some kind of math algorithm (the Lagrange function) for extracting the evolution equations of the system — equations of motion in mechanics jargon —, ensuring, from the specification of the energy involved by means of that algorithm, an action which must be minimal. In other words, the Lagrange function, or simply Lagrangian, is such that the resulting scalar of the action integral during a certain time interval has the smallest value. So, between two moments, the energy cost of the evolution of the system needs to be as small as possible[8]. It turns out that in general relativity the Lagrangian of a system includes a metric tensor that describes how space-time deforms on a scale where matter densities become relevant, something of the general form

$$\mathcal{L} = \alpha\, g_{\mu\nu}\dot{x}^{\mu}\dot{x}^{\nu} \tag{2}$$

parameterized by the arc length between the two considered instants of the action integral (α is an arbitrary constant); so the energy is associated with the geometry of space-time. Indeed, in luminous metrics [26] we can write

$$\mathcal{L} = \frac{1}{2} g_{\mu\nu}\dot{x}^{\mu}\dot{x}^{\nu}. \tag{3}$$

Applying this equality in Euler-Lagrange equation

$$\frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \dot{x}^{\mu}}\right) - \frac{\partial \mathcal{L}}{\partial x^{\mu}} = 0,$$

$$\frac{d}{dt}\left(g_{\mu\nu}\dot{x}^{\nu}\right) - \frac{1}{2}\frac{\partial g_{\nu\eta}}{\partial x^{\iota}}\dot{x}^{\nu}\dot{x}^{\eta} = 0, \tag{4}$$

which leads us further to the final form of the geodesic equation [26].

Instead, in a situation free of such relevant densities, we fall back into special relativity, in which the Lagrangian takes the form

$$\mathcal{L} = -mc^2\sqrt{1-\frac{v^2}{c^2}}; \tag{5}$$

here, the energy depends on the speed v of the system in motion.

To transpose general relativity's way of thinking to brain lines and brain nodes would be a huge distortion of physical representation unless there was the consideration of a new modeling of structures, perhaps even including at a sub-Planckian level, evidently without appeal to discontinuous constructs, in addition to a complementary theory that explains the role of gravity compatible with the Euclidean scale of the brain, something that could only be obtained through a way similar to that of the model I briefly described in Section 3. In the way discussed by Le Bihan, frankly, I don't know how the brain could be matched to a Riemannian (or pseudo-Riemannian) manifold having in mind Einstein's equations in a way that is convincing and coherent to the point of translating relativistic deformations at the scale of matter and energy we are dealing with. Nor do I see how such a representation would shed light on the question of the mind's physical connection with the brain.

B. The Mind Heat in Pseudo-Lorenzian Theory

Surely, thinking of the mind as a singular manifestation of space-time seems inevitable, but, by its own characteristics, we must assign it a plausible relativistic model. For that, due to its scale, its material frontiers established by the brain (*mentis imaginari per cerebrum*), and its intangible essence, I consider the mind embedded in its own time whose dynamics is grounded in special relativity, however, in a way that certainly goes back to thermodynamics (considering time and energy as closely associated quantities), not to mechanics. This hypothesis requires two germane specific postulates for the mental action, namely:

- *Postulate 1*

  The time interval registered in a conventional external clock, covered by two individuals on the same event of

[8] In this way, from a classical view, we can understand a temporal interval as a kind of "reservoir" of minimal energy, just as the corresponding spatial interval is in a sense a "reservoir" of minimal mass.

intense mental focus, however, with distinct dissipations of heat, matches different durations (proper times) for each mind (frame of reference).

- *Postulate 2*

The energy consumed in focused mental effort during one hour never exceeds the maximum complement of basal brain/mind energy consumption for the same period.

- *Corollary 2.1*

There is a maximum stretching of the fundamental time interval.

These postulates guide the formalization that will follow. To proceed, we need the already well-established knowledge about brain metabolism. The brain works under a constant energy consumption around 20% of the total metabolic energy, even while the mind is at rest. Accordingly Bruckmaier *et al* [2], "*the brain may handle challenging tasks by diverting energy away from other functions, and prioritizing the focus of our attention*", that is, the material brain manages energy in order to meet the priority demands of the abstract brain (the mind) when there are imperative needs for focus. So, neurons running outside the focus of attention receive less energy. The research of neuroscientists and biomedical engineers measuring cerebral metabolism used broadband near-infrared spectroscopy to analyze the energy metabolism in brain cells' mitochondria.

Personal experiences of temporal expansion, however, may be related to the quota of energy redirected to the focus of mental concentration. Thereby, if we are going to think of the mind inscribed in a relativistic model, we will certainly need to investigate how this model would be adapted to an exceptionally complex phenomenon, which does not take place under luminous velocities, nor under gravitational interactions that could affect duration. Also, it is necessary to pay attention to the fact that this is not a mathematical problem, but a physical one. In other words, it resolves very little to assume a sophisticated mathematical representation that does not correspond to the "mind" phenomenon; it is not about associating the brain with an exotic geometry, but conceiving a description of mental processes as physical manifestations that, although originating in the brain, have their own nature and dynamics. As far as I can see, it does not seem feasible, or even justifiable, to evoke Einstein's equations for an explanatory construction of the brain/mind relationship, not so much because of the type of figurative association that is intended, but for the related energy levels. Rather, we can assume a simple relativistic relationship between time and energy.

From *Postulate 1*, the fundamental proposition to be formalized is that mental duration τ is relative to the exceeding energy consumed by the mind in the frame considered, such that the relativistic expression of time is,

- *Definition 1.1:*

$$\tau = \frac{\tau_o}{\sqrt{1-\frac{\mathcal{Q}_{mind}^2}{\mathcal{Q}_{brain}^2}}}, \tag{6}$$

where $\mathcal{Q}_{mind}$ is the surplus energy spent by the mind, and $\mathcal{Q}_{brain}$ is the maximum total energy spent by the brain/mind complex. The quantity τ_0 is the initial time interval considered congruent with conventional external clock time, and $\frac{1}{\sqrt{1-\frac{\mathcal{Q}_{mind}^2}{\mathcal{Q}_{brain}^2}}}$ is the modified Lorenz factor.

From *Postulate 2* and expression *(6)*, I proposed the "focal well function",

- *Definition 2.1:*

$$\Pi = sin\left(\frac{\tau_o}{\sqrt{1-\frac{\mathcal{Q}_{mind}^2}{\mathcal{Q}_{brain}^2}}}\frac{1}{u^2}\right), \tag{7}$$

where *u* is a cyclic dimensionless variable of temporal matching. This function establishes a representation of the time well of confinement of the focus excitations. Graphic 1 shows that the greater the energy consumed in the mental process, the greater the temporal width of the time well.

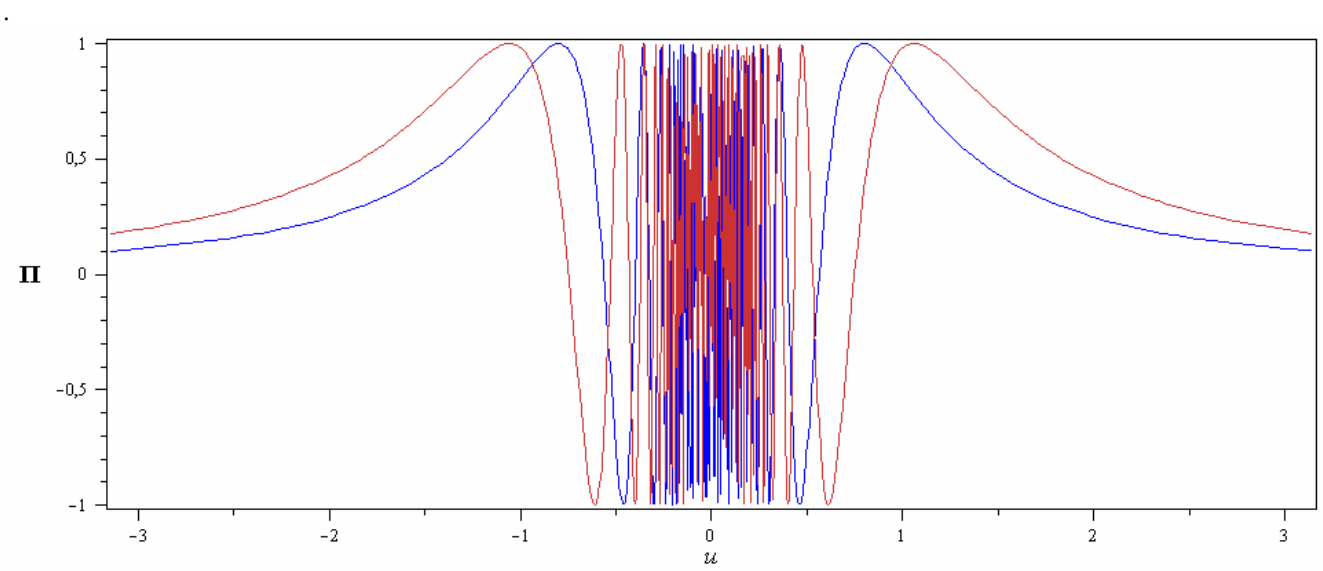
In basal state we expend *in toto* a maximum about $80\ \mathcal{K}cal/h$, depending on weight, age and general health conditions. As I noted before, it is assumed that 20% of the total amount of energy needed to the human body is consumed by the brain under any circumstances (sleeping, alert or thinking). So, at rest, we need for the brain

$$\mathcal{Q}_{brain} = 16\frac{\mathcal{K}cal}{h}. \tag{8}$$

The temporal reference I use as a standard to demarcate the limit of intensity of mental focus is one hour, as pointed out by Ericsson when he talks about deliberate practice in the training of experts [8]. He argues that to keep deliberate practice effective, one needs to push himself beyond his comfort zone and keep his focus, but these are mentally exhausting activities. So, experts do two things that can help. The first is getting enough sleep and staying healthy. The second is to limit the practice to approximately one hour; no one can keep intense concentration for much longer than that.

It is known that, during one hour of intensely focused intellectual work, a brain/mind consumption of $90\ \mathcal{K}cal$ can be reached. It is reasonable to admit that, having the energy of $16\ \mathcal{K}cal/h$ as the brain's functioning groundstate, $74\ \mathcal{K}cal/h$ would be the surplus necessary for

purely mental processes (completing $90\ Kcal/h$), since it would be very difficult to quantify with precision what portion of the $16\ Kcal/h$ is included in erratic mental processes. Reasoning in seconds, let's take $\tau_0 = 1\ s$ and admit the maximum expense of $0.020555556\ Kcal/s$ of the focused mind (which corresponds to $74\ Kcal/h$).



Graphic 1. The focal well function. Blue line matches the lower level of energy consumed in the focused mental process. Red line shows a wider temporal hollow of the well, referring to the higher level of the energy spent.

The maximum total mind expense ($90\ Kcal/h$) corresponds to $0.025\ Kcal/s$. Applying the pseudo-Lorenzian expression (6), each second is dilated by $0.756954901\ s$ according to

$$\tau = \frac{1s}{\sqrt{1-\frac{(0.020555556\ Kcal/s)^2}{(0.025\ Kcal/s)^2}}} \cong 1.756954901\ s.$$

Thus, in extreme ideal conditions, one hour of intense intellectual concentration ticked in the external clock will correspond to a mind's proper time of $2048.999663\ s$ ($\cong 0.569166573\ h$). This was the basis for plotting Graphic 1. As it is clear, in the basal state (i. e., without focused intellectual activity), $\tau = \tau_0$.

VIII. A BRIEF DISCUSSION

We have seen that, with seconds dilated under exceptional conditions of focused concentration (during one hour by the external conventional clock), the mind's proper time corresponds to little more than half an hour. Being more pragmatic, theoretically, one hour counted by the external conventional clock is enough for a productive study (which, supposedly, even for a competent and disciplined individual, would require much more time taken from the schedule of other day-to-day work demands), provided that maximum concentration is established. The well function measures the dilation of the symbolic temporal "hollow" during which the intense oscillations that represent focused and elaborative mental activity occur.

Evidently, my personal experiences with the expansion of mind's proper time are not enough to be conclusive, but I believe they can be reproduced by individuals with high capacity for intellectual focus. It is important to point out that the ability to fully concentrate for one hour of study is an attribute that requires a lot of training, being nowadays much more exception than rule.

One might ask whether it is not just a matter of personal ability to make the study faster than what normally would take well over an hour. Note, however, that this is not about competence to conduct studies on a particular subject, but about being wieldy to focus for a long period. It is the focusing power that is discussed here, not proficiency.

Lastly, the time I discuss appears as an ergogenic entity of conscious processes. Reading Eddington in his brilliant explanation of general relativity, it is possible to extract an illuminating overview of what we can understand as purely psychological time:

"*Our minds are immediately aware of a "flight of time" without the intervention of external senses. Presumably there are more or less cyclic processes occurring in the brain, which play the part of a material clock, whose indications the mind can read. The rough measures of duration made by the internal time-sense are of little use*

for scientific purposes, and physics is accustomed to base time-reckoning on more precise external mechanisms. It is, however, desirable to examine the relation of this more primitive notion of time to the scheme developed in physics. Much confusion has arisen from a failure to realize that time as currently used in physics and astronomy deviates widely from the time recognized by the primitive time-sense. In fact the time of which we are immediately conscious is not in general physical time, but the more fundamental quantity which we have called interval (confined, however, to timelike intervals)."[9]

This fragment is crucial for the correct comprehension of the presented theory. There is a primitive time-sense that refers to the understanding provided by the human mind. It serves to elaborate "imaginary experiments", constructs and explanatory constructions (such as the time-like interval construct), absolutely necessary, however, without confusing them with what we actually deal with in physics. Thus, it is "*desirable to examine the relation of this more primitive notion of time to the scheme developed in physics*", as observed by Eddington, which sounds to me as we should find ways to depriving our time-like construct from the impressions provoked by consciousness, leaving their physical status exempt from the psychological one. Therefore, what I hypothesize is the existence of a time apart from "*the rough measures of duration made by the internal time-sense*", perfectly within the framework of physics, but logically and inevitably implied in the time-sense of consciousness (otherwise we would not have how to develop the concept of time).

IX. CONCLUSION

Present essay raised the hypothesis that not all personal experiences of time stretching are of purely psychological nature, discussing the possibility of a physical proper time structuring the mind. Unlike the stretching of psychological time, usually associated with dramatic or distressing situations, physical proper time dilates not because of the mental chaos which imprints a sensation that a given event takes longer, but because of the energy cost required by the effort of mental concentration. The defended theory presupposes a composite of space-time structuring the brain, the mind, and everything else that exists, a four-dimensional continuum that constitutes the "void" that remains when descending to sub-Planckian domains (it is not the case here to discuss physics in sub-Planckian domains, something I do in reference [27-a]).

I sought to build a relativistic model for the mind in focused mode, considering the energy spent as a key factor influencing the duration of a mental process under intellectual tension. This hypothesis was settled on two major fundamentals: 1) my personal experiences, taking into account a series of considerations about the structure of the universe and the emergence of complexity; 2) to be *accurate*, the physicist has to account for every millisecond ticked by the standardized external clock. However, to be *really accurate*, he needs to go beyond appearances[10]. So, in present context, it was necessary to guess different reference systems, that is, different minds and brain/mind relationships. Proper times refer to the mind's internal clocks, each setting a particular frame of reference.

The work begins what could become one of the most relevant branches of cognitive neuroscience, with meaningful contributions to teaching/learning. Even those who, endowed with a lot of discipline, embrace research challenges, may find it difficult to concentrate the mind over a long period. Indeed, a meticulous testing program will have to be organized for application by several research groups. Undoubtedly, there is much work ahead, but the perspective of temporal stretching in the focused mind opens not only a new perspective of consciousness training, but also a wide area of investigation of techniques to increase the capacity for attention and reflection within an external time interval considered small in the everyday, if we take into account the dispersive lifestyle that humanity decided to choose. In addition, I believe that distance learning would greatly benefit in terms of quality as media resources were implemented that favored the individual's focal intensity — dilating the mind's proper time —, most likely with the help of artificial intelligence.

We live the "civilization of spectacle", recalling Vargas Llosa [34]: the globalized society of consumption and search for maximum material comfort and delight, entertained by scandals and bizarre events. Such a scenario of life has not favored teaching/learning, and what we understood by culture seems to have vanished. It is difficult to concentrate efforts on an intellectual focus when surrounded by dispersive stimuli. In face of so much hedonistic appeal, so many showcases and deleterious experiences, it is not surprising that the average intellectual capacity is in sharp decline at the 21st century. I think there is a long way to go before we really understand the nature of the mind reasonably enough. However, starting from some point, I think this is the indisputable milestone of the beginning of everything: the physics that governs the cosmos. Just so can we be sure that we are not flirting with the realms of fantasy and pseudoscience.

"*Consciousness is something that there is no one who can explain and no one who does not understand*."

Cecília Meireles

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[9] See **Arthur S. Eddington 1923/1930 "The mathematical theory of relativity" Cambridge University Press Fetter Lane, London, pp 23-25**.

[10] See **Arthur S. Eddington 1945 "La naturaleza del mundo fisico" Editorial Sudamericana, Buenos Aires, pp 56-57**.

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