Neuroscience, space and time[1]

Neurociência, espaço e tempo

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The aim of the present article is to propose possible intersections between contemporary physics and neurosciences, in matters related to space-time. Such scope is of great significance both in "normal" and pathologic situations. In the latter, states like hypermnesia (enhanced capacity to evoke memories, with distortion of information stored in neural circuits) are described, which can be thought of – in a parallel with physics – as space-time scenarios with more than one time-type direction. Dimensions of such category – called Ataiyah-Ward space-time – have been considered in connection with systems of interest in the study of fundamental interactions, and, in macroscopic scale, in association with the issue of gravitational collapse. One has sought to understand physical phenomena in the presence of extra time to then use these studies to propose an attempt to modelling hypermnesia, through the concept that, in certain situations, neuronal system behaves as if immerse in a scenario with two time-type directions.

Keywords: Neuroscience. Space. Time. Physics.

O objetivo do presente artigo é a proposição de possíveis interseções entre a física contemporânea e as neurociências, nas questões relativas ao espaço-tempo. Tal âmbito reveste-se de grande significação, em situações 'normais' e patológicas. Nesse último âmbito, descrevem-se, por exemplo, situações como a hipermnésia (capacidade exagerada de evocação de memórias, na qual há distorção de informações armazenadas nos circuitos neurais), a qual pode ser pensada – estabelecendo-se um paralelo com a física – como cenários espaço-temporais onde há mais de uma direção tipo-tempo. Dimensões desta categoria – denominados espaços-tempo de Atiyah-Ward – têm sido considerados em conexão com sistemas de interesse no estudo das interações fundamentais e, em escala macroscópica, em associação com o problema do colapso gravitacional. Tem se buscado compreender alguns fenômenos físicos em presença de um tempo extra e, então, utilizar estes estudos para propor uma tentativa de modelar o fenômeno da hipermnésia através da ideia de que, em certas situações, o sistema neuronal se comporta como se estivesse imerso em um cenário espaço-temporal com duas direções tipo-tempo.

Palavras-chave: Neurociências. Espaço. Tempo. Física.

1 Introduction

Space and time are essential aspects of human life in its different dimensions – biological, psychological, social, ecological and others one might think of. In fact, the

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very own notion of life only makes sense when thought of in temporal terms – duration – and spatial ones – extension.

Even recognizing the inseparability of space and time in the human experience of existing, the questions about these magnitudes are far from finding simple approaches in different fields of knowledge. Questions about such magnitudes, focusing (1) their nature, (2) their ontological status, (3) their relationships – to mention only the most instigating – remain on the agenda, despite centuries of philosophic thinking, scientific research and technological development. One should add to this the fact that there are important questions concerning the way human brain – space-time limited – is able to deal with such dimensions:

> How and where, for instance, could the human brain, so small in volume, having such brief existence, become capable of dealing with huge expansions of space and time? How and where did such ability start? How and when did humans really "discover" the existence of time and space? How did our brains evolve to perceive and organize the world always within the structure of time and space? (SZÁMOSI, 1994)[2]

Such conjectures point to the relevance of space and time for the fields of philosophy and natural sciences – particularly Physics – but also to the relevance such themes have been acquiring in contemporary Neuroscience studies – with significant implications to the understanding of neurobiological and psychopathological processes – thus opening perspectives for a fruitful dialogue between fields of knowledge. Based on these brief considerations, the following essay aims to present a preliminary proposal of interdisciplinary dialogue between contemporary Physics and Neuroscience – mediated by philosophic thinking – focusing on space and time, weaving up the narrative in five steps: (1) "*Evolution in space and time*" – concerning which the authors recognize great intellectual debt to the work of G. Számozi, (Time and Space: the Twin Dimensions) –, (2) "*The concepts of space and time*", (3) *Extra space-time dimensions*, (4) *Neurosciences, relativity and space-time*, (5) *Extra space-time dimensions: compositions between physics and neurosciences*.

2 Evolution in space and time[3]

Life – probably since its origins – was organized spatiotemporally. In fact, as long as *time* is concerned, most of the experiments investigating biological rhythms corroborate the idea that these have an intrinsic component – with genomic base –

[2] Free translation into English by the authors.

[3] This section is especially dedicated to the presentation of G. Számosi ideas. Thus, the authors publicly acknowledge the debt with his thinking.

manifesting itself independently from the environment. Indeed, in ancestral forms of existence one can observe space-time organization in terms of circadian rhythm, operating in 24-hour periods and determining behaviors such as reproduction, sleep-wake cycles and eating patterns. Some protists (*Paramecium*), for example, have internal biological clocks that regulate reproduction independently from variations in light and temperature. Other rhythms – besides the circadian – are also described, emphasizing the *Leurestes tenuis* (grunion) which live in the coastal waters of California, in the Spring tide, during their reproductive periods. In the small interval of time between two waves these fish fertilize their eggs and hide them in the sand, in the higher water lines on the beach. The incubation of eggs occurs in the two following weeks, out of the reach of the waves. After this period, coinciding with the next high Spring tide of the cycle, the eggs hatch (SZÁMOSI, 1994).

Related observations, consistent with the existence of biological clocks, equally concern the species of hibernating animals – annual rhythm – which keep the activity with little dependence on changes produced in the environment. According to these observations it is possible to propose that adaptation to space developed throughout biological evolution, in a manner very similar to that described about time. Indeed, there are interesting observations concerning the spatial orientation of migratory animals that seem to possess true endogenous compasses – examples of which are many (SZÁMOSI, 1994):

- The use of the sun by *Apis mellifera* (bee) for guidance while searching for food and returning to the hive.
- The return of the salmon (*Salmo salar*) to the river where they were born, for reproduction.
- The displacement of migratory birds – such as the albatross (*Diomedea exulans*) – capable of significant orientation in the environment, including long-distance travel (e.g., between continents).

Such descriptions regarding adaptation to space and time pose the question from the point of view of Neurosciences of how the nervous system – in the case of specimens belonging to the kingdom *Animalia* – organized itself to deal with the multiplicity of stimuli and information coming from the external environment. In other words: *How* did *abstract models develop throughout biological evolution, to deal with space-time reality?* Such abstract models – called *cosmologies* by Számosi (1994) – allowed the exploration of space and time to a greater extent, depending on the development of the brain and long range senses, like hearing and smell, but above all vision (CAMPOS et al., 1997; RIBAS, 2006).

It must be noted that phylogenetic development of the nervous system – particularly the encephalon – made it possible to improve the relations with the environment, based on the development of abstract models of the external environment. In other words, the inscription of living beings in space-time depends precisely on such relations (and not only on biologic or environmental *determinisms* alone). In these terms, the interpretation of the environmental information that reaches a given animal must imply the distinction between relevant and irrelevant information. Classic experiments conducted at the Massachusetts Institute of Technology demonstrated, for instance, that the retina of a frog is highly selective in processing information obtained, being able to react both to small flying objects – e.g., insects – and to the movement of big shadows in its field of vision – e.g., birds (LETTVIN et al., 1961; SZÁMOSI, 1994). Such observations allow the assumption that animal space-time models of perception are highly adapted to survival, from a Darwinian perspective.

These intrinsic models of representation of the "outside world"—organized in terms of space-time perception – evolved with the development of the nervous system (GOULD, 2001; SARNAT et al., 1981) in an interdependent movement:

> [...] the growing of the brain followed pari passu the evolution of an internal model of the outside world, where permanent and distinct objects are perceived in terms of space and time. Obviously a big, complex brain is necessary to perceive the outside world as consisting of 'objects in time and space'. (SZÁMOSI, 1994).

The conceptions of evolution from amphibious and reptilian life to mammalian life may be useful to clarify these points. Indeed, the definitive transition to terrestrial life provoked in the central nervous system a gradual development of both the olfactory lobes – what caused smell to be the first sensorial mode of perception of the external world – and the origins of structures that led to the amygdaloid nuclear complex and hippocampus (RIBAS, 2006; DUVERNOY, 1998). Thus, while the archaic amphibious did not possess any well-developed telencephalic hemisphere, reptiles already presented olfactory lobes, hippocampus, amygdaloid nuclear complex and *septum*, constituted by the septal nuclei (RIBAS, 2006). These – like the amphibious, poikilothermic – were (and still are!) more active during the day, in view of greater ease to keep body temperature (HELAYEL-NETO et al., 2012). Accordingly, sight – probably similar to amphibious sight – was the main long-range sense, information being processed mainly at the retina, with a smaller involvement of the reduced brain (SZÁMOSI, 1994).

With the appearance of the first mammals – small animals – the improvement of spatiotemporal adaptation became feasible. Indeed, these living beings, due to the need to escape from the big reptiles – bigger and stronger – became nocturnal, to which contributed their status as homeotherms – ability to regulate body temperature, keeping it constant despite environmental variations. Their vision, however, was adapted to daytime life in these first moments – similar to that of the reptilian ancestors – consequently of little use to darkness. The evolutionary "response" to this situation was the development of hearing and smell as long-range senses, which made it necessary to expand the brain to interpret data collected by these "new" senses, especially if we consider that information obtained by smell and hearing – the latter linked to the notion of time – would need to be translated in spatial terms (SZÁMOSI, 1994).

In spite of this difficulty, such adaptation eventually happened – according to the ideas of H. Jerison (1973), discussed by G. Számosi (1994) – which concurred to the broadening of possibilities of a *mammalian cosmology*, especially if we consider that the vision of these animals kept evolving, becoming able to see in conditions of lower lighting. Hence, the following consequences are derived:

(1) Information received by multiple "pathways" –hearing, smell, vision – coming from a single source had to be conciliated, being identified as the *same*, i.e., *coming from the same spatial source*; what used to be a series of incoherent information and patterns started to be identified as an object, thus having duration in time and extension in space.

(2) Readaptation of mammals to daily life – motivated among other things by the disappearance of the big reptiles – implied the development of a *new vision*, adjusted to the brightness of daylight, improving the possibilities of mapping space and manipulating temporal sequences. This enabled these animals to follow something in movement in their visual field, now recognizable as the *same object* in displacement.

Based on these conjectures one can see that the "mammalian world" became much more complex, inasmuch as these animals found themselves immersed in a sea of stimuli from different multiple objects, many of which "producing" simultaneous information, sometimes synchronic. Brain development required to give meaning to this "new reality" is remarkable – when we understand that organization of information is consolidated in in *subroutine processing*, the perceptual constancies – relating to the emergence of the thalamus, whose nuclei allowed processing general sensitive stimuli (RIBAS, 2006).

The relevance of object detection from the external environment for animals, in terms of *space-time maps*, is extremely meaningful from the point of view of biological evolution. Indeed, to identify the prey a given carnivorous animal will interpret (i) luminous (sight), (ii) auditory and (iii) olfactory information, gathered in the same *object*. Thus, to hunt the predator must be able to unify all data, interpreting them as something with extension in space and duration in time, which besides, moves. But still more than that is necessary: changes in sensorial *inputs* (for instance, the image that becomes smaller as the prey moves away) must be interpreted not as changes in references and external coordinates from the outside world, but as movements of the same object perceived in consonance with the aforementioned coordinates. If the synthesis is not perfect, the hunt becomes impossible and with it, the survival of the predator (SZÁMOSI, 1994).

The perception of objects by mammals became even more refined with the emergence of the *Homo sapiens sapiens* nervous system. In this case, studies conducted on the evolution of space, time and object perception in childhood can bring light to the matter. A child does not perceive simple objects during his/her first months of life, but sensorial stimuli dissociated from context. He/she perceives and recognizes the presence of people, and associations with his/her direct reactions, like, for instance, crying, so that an absent person returns, in such case, the mother. At the end of the second year, the relations between objects and his/her own body are characterized, the whole context is understood within a general space. The continuity of this process, described by Piaget (2003), will ultimately allow the child to not just perceive objects, but also to create symbols for them, and not only that: "space" and "time" will also be under the symbolic domain. In fact, memory (related to the past) and prediction (related to the future) are examples of symbolic domains of time.

One can understand, based on these brief considerations, that the process of biological evolution – which culminates in *Homo sapiens sapiens* species – produced increasingly complex models of space and time – articulated to the external environment – which are shown below.

3 Concepts of space and time

Space and time are quite polysemic terms (HELAYËL-NETO et al., 2006) which remain controversial despite the antiquity of reflection directed to such magnitudes.

Concerning space, debates focus on the conception of this magnitude as the place – position – of a body in relation to other bodies (e.g., the Cartesian space) and as a receptacle – recipient domain capable of housing material objects (as conjectured by the ancient atomists). Worth mentioning are the conjectures about the reality of space, distinguishing realists – who conceive reality of space (e.g. Aristotle) from idealists – who characterize space as a subjective texture (e.g., Berkeley).

Concerning time, the contemporary discussions link this magnitude to the following conceptions (ABBAGNANO, 2003; LALANDE, 1983).

(1) *Measurable order of movement* – it is the most archaic formulation of time, able to be retrieved from the Phythagorean and Platonic thought, attaining greater refinement in Aristotle. Moreover, in building his mechanics, Newton admits that absolute time and relative time possess, both, order and uniformity, being correlated to movement. A recent contribution to the conception of *time as measurable order of movement* was proposed by Einstein in his General Theory of Relativity (GTR), when he kept the idea of *order of succession*, although subverting the idea that such order was sole and absolute, as discussed below in the section *Time as a participant in the four-dimensional continuum*.

(2) *Intuited movement* – the conception of *time as intuited movement* has close affiliation to the idea that it may be reducible to the soul – or to conscience (SAINT AUGUSTINE, 2000). In the 20th century, Bergson resumed the characterization of a time lived – the duration of conscience – as a fluid stream – *devir*, i.e., *becoming* – where

an uninterrupted continuity is established (BERGSON, 1996). It is in this context that we can consider time as an *eternal present.*

(3) *Structure of possibilities* – in *Being and Time*, Heidegger (1989) defends the idea that time is what is to come, focusing the debate in the *future*, contrary to the traditional propositions focused in the present.

(4) *The four-dimensional continuum* – this formulation was developed by Einstein in the core of the Relativity Theory. The four-dimensional continuum is formulated by adding the time coordinate to the coordinates used by Descartes (axes *x, y, z*), as proposed by Einstein:

> Our physical space, as considered through objects and their movement has three dimensions and the positions are characterized by three numbers. The instant of an event is the fourth number. Four defined numbers correspond to every event; a defined event must correspond to any four numbers. Therefore, the world of events forms a four-dimensional continuum. (EINSTEIN; INFELD, 1962).

In this quote – related to discussions conducted in the Special Theory of Relativity – Einstein resumes the classic notion of space as a place, integrating this magnitude to time. The great "innovation" is in changing the concept of simultaneity, according to which *two events that are simultaneous in a general referential are not simultaneous when observed from another inertial referential, that is, in motion in relation to the first.* Simultaneity depends on position and time, not being an absolute concept (EISBERG; RESNICK, 1979). Therefore, the above mentioned postulates imply the relativity of length of an object or duration of an event, depending on the observer's inertial referential.

The propositions of Einstein imply the contraction of space. Using the same assumptions, it is possible to conclude that time dilation also happens. Imagine an inertial referential R_O where a given event happens during a time interval T_O, always in the same position measured in this referential. Referential R_O moves with velocity v in relation to another inertial referential R. In inertial referential R the same event has duration T, relating to T_O as follows:

$$T = \frac{T_o}{\sqrt{1 - v^2/c^2}}$$

T_o being the proper time, i.e., corresponding to time interval measured always at the same point in inertial referential R_o.

Dilation of time then occurs for the observer in referential *R*. In other words, the observer in referential *R* will have his clock running faster than the clock of the other observer in referential R_o. The measure of time dilation will only be noticeable with *v* close to the speed of light, *c*. This can be used for living beings; after all, any periodic phenomenon may serve as a clock. Heart beats, for instance, may serve as a clock, so we can imagine the body of observers as clocks, thus concluding the observer that lives in referential *R* ages faster than the one in referential R_o.

4 Extra space-time dimensions

Contemporary Physics describes natural phenomena in terms of four fundamental interactions, which, for understanding effects in a context closer to Newtonian physics, can be thought of as force fields. Gravitational and electromagnetic forces are the fundamental interactions that can be felt in the macroscopic world, including human scale. Gravitational force is responsible for planetary movements and for organizing the large scale structure of the universe. Electromagnetic force is the interaction that answers for the formation of atoms, molecular bonds, fundamental biologic processes, like, for instance, neuronal phenomena. The other two forces – strong nuclear force and weak nuclear force – do not appear on the macroscopic level, but only in subatomic scale – actually, as the name implies, in the subnuclear and nuclear scales; therefore at distances as small or smaller than the tenth trillionth of a centimeter (SIQUEIRA-BATISTA et al., 2008b). The strong nuclear force is responsible for the cohesion of protons and neutrons inside the atomic nuclei, and the binding of *quarks* and *gluons* inside hadrons; finally, the weak nuclear interaction is responsible for radioactive processes of decay, that leads to changes between nuclei. It is worth noting that unlike the other three fundamental fields of force, the weak interaction is the only one that does not generate bonded structures in nature: in fact we do not know any kind of aggregate of matter that has its cohesion associated to the weak nuclear force. The latter is characterized primarily by the dissociation of matter.

Works published between 1961 and 1968 helped formulate the theory that unified both electromagnetic phenomena and those ruled by weak nuclear force. Electroweak Theory or Salam-Weinberg-Glashow Unified Model (SALAM, 1968) showed that these two forces, despite presenting markedly distinct experimental characteristics have a common origin, making it possible to propose a scenario of unification for them, where one could describe how both are separated in the regime of nature in which observations are made. It is necessary to emphasize – and this is a key point – that the idea of unification of different fundamental interactions is the starting point to an investigation of new space-time dimensions and to a leading vision of how the space-time structure in which we live should be. In seeking to understand submicroscopic processes, it is necessary to revise the space-time conception proposed at the core of the Special Relativity Theory.

In this scenario of four fundamental interactions duly organized in terms of specific microscopic theories, incorporating the laws of quantum world and Special Relativity Theory, one notices the key concept to formulate them is the idea of symmetry, theoretical framework proposed in the theories of Yang and Mills (YANG; MILLS, 1954) conceived in 1954, which establish the conceptual framework to formulate all fundamental models mentioned throughout this article. From a mathematical point of view, each interaction has a symmetry group associated to it, domain that obeys a set of very specific rules; concerning the characteristics of each interaction field, the symmetry group organizes and systematizes magnitudes of physical nature, like charge distributions, currents and other quantum numbers involved in the interaction.

Electromagnetic phenomena are described in terms of a symmetry group designated by U (1) associated with electric charge; the phenomenology of weak interactions accommodates in the structure imposed by group SU (2), which responds for the so-called weak isospin (or isotopic spin); QCD is formulated in terms of group SU (3) which describes color charge and, finally, the group underneath gravitation is SO (1,3) known as Lorentz group, associated to an intrinsic property of elementary particles, known as spin.

The concept of symmetry, and the corresponding algebraic structure, organizes the conservation laws associated with a given kind of interaction, systematizes the classification of particles and physical states of the theory in terms of very precise specifications – the quantum numbers – and establishes mechanisms for the understanding of the relationship between particle masses and charges involved in the considered interaction. It is worth noting that it was precisely in 1973 – when the specific theories for each interaction were established – that the era of supersymmetry as a basic concept in building a theory of unification of the four fields of force in nature was inaugurated, with the purpose of enabling a theoretical environment to consolidate a quantum theory for gravitation.

The way supersymmetry was introduced in the fundamental interactions theories, in a way compatible with the experimental reality available at then, takes place through the so-called breaking mechanisms. It is proposed that supersymmetry has operated in the universe at its very beginnings, and that, with its cooling, the symmetry between bosons and fermions has been broken (there are specific, independent mechanisms to violate supersymmetry) in such a way that in their current regime the particles introduced by supersymmetry in the physical spectrum have their masses in a scale above the one accessible to existing high energy experiments.

The first ten years of developments in supersymmetry (1974 to 1984) were marked by the incorporation of this symmetry in particle physics, in a program of unification and a project to build up a mathematically consistent theory for gravitation. Several models of supergravity were proposed, and the famous supergravity -N= 8, with a series of aggregated mechanisms, figured for some time in literature as the paradigm of the most suitable theory for the unification of fundamental interactions. The second stage, starting in 1985, presented supersymmetry from another perspective, placing it as a physical and mathematical ingredient necessary to build the Superstring Theory – in this vision, legitimate fundamental theories – which, we hope, may provide the scenario that enables the program of unification, to a consistent quantum theory for gravitation. Supersymmetry was thus definitely incorporated to particle physics and has been increasingly applied to other fields of Physics, like nuclear physics, condensed matter physics and even some biophysical systems. It is opportune to mention that very simple quantum-mechanic systems, like those constituted by particles – charged or neutral, and subject to certain configurations of external magnetic field – exhibit characteristics of a supersymmetry that reveals itself as dynamic symmetry. This is an indication of how supersymmetry can be subjacent to interesting realistic quantum systems. Moreover, with the re-start of the running of experiments in the collaborations of the Large Hadron Collider (LHC), we expect to have enough experimental resources to search and identify supersymmetric particles (which would be a direct test of supersymmetry), possible space-time extra dimensions and other indirect consequences of supersymmetry in the physical world, reinforcing its remarkable role in the formulation of fundamental theories to describe fields of force in nature and for the understanding of space-time itself.

The idea of a complete unification of the four interactions in a scenario dictated by supersymmetry naturally leads to the need to adopt a new approach in the organization of space-time structure. Instead of accepting four dimensions, one must imagine a world with ten dimensions, in which the first is time, and the remaining nine, space: three are known, the other six are extra, of a nature still under discussion. We should point to the close connection between fundamental interactions, the idea of symmetries and the constitution of space-time itself.

One of the main points in this unifying scenario concerns the idea that the ten dimensions have fundamental effects that are better understood if one imagines that nature presents regimes in which, of the four tangible dimensions, two are spatial in nature, while two others are temporal, i.e., under special circumstances, everything takes place as if there were two time axes in the universe. What is the second time, which are its consequences and what does evolution mean according to this new time – these are questions still without a definite clarification. There are actually, different currents of thought and conflicting proposals. The key point in this discussion is the fact that the physics of fundamental interactions needs, in a certain instance of submicroscopic phenomena, to resort to one (or even more than one) extra dimension of time. Such attitude legitimates further discussion about a new temporal notion in other scientific areas where the discussion of time assumes a major role, as in the case of the present contribution, at the core of neurosciences. Standard time, according to quantum view of nature, is complementary to energy; which physical magnitude this eventual second time imposes is still a non-answered question. In any way, the debate introduced here opens the possibility of investigating neurobiological processes, based on the introduction of possible extra temporal dimensions.

5 Neurosciences, relativity and space-time

Perception, by different sensory organs, of objects that make up reality (MAKIN; CHAUHAN, 2014) occurs at distinct times, non-simultaneously, due to finite impulse propagation speed and different neural processing times. Thereby, sounds and images reach sense organs – ears and eyes – and the cortical areas in distinct moments, even if they have simultaneously left the same object. Nevertheless, such relativity is compensated by the brain, which is able to make synchronic stimuli that in their neural pathway become non-simultaneous. Thus, the movement of Eric Clapton hands and the notes produced by his guitar, when interpreting *While my guitar gently weeps* at the Prince's Trust Concert, Wembley arena, seem to be concomitant to the attentive sense organs of those in the audience. The illusion of a simultaneous present is thus generated – both because the temporal content of consciousness emerges with delay in relation to the world and as a result of temporal coherence produced by the brain (BALDO et al., 2006; CAI; CONNELL, 2015). Such simultaneity "imposed" by the brain can however be deconstructed as long as we alter the focus of attention, as discussed by Baldo and collaborators (2006). From this perspective, two concomitant stimuli – auditory, tactile or visual – can be simultaneously perceived or not, depending on the focus, as well as on other psychophysical determinants (BALDO et al., 2006; BUHUSI et al., 2005). In this case for example, when a research subject is put in front of a computer screen and stares at a marked point on the screen, the successive presentation of rapid simultaneous visual stimuli, separated by a certain distance, may be perceived as non-concomitant. In such case, we consider as first stimulus that which appears in the area where attention is focused.

In accordance with these conjectures, studies have shown that changes occur also in temporal perception, which is intimately related to the psychophysic state of the observer. Indeed, according to Weber-Fechner law (NIEDER et al., 2003; DEHAENE, 2003) the perception that a sensorial stimulus suffers variation depends on a minimal increase (or decline) proportional to the initial magnitude of the original stimulus. In this context, the relativity of time perception is widely acknowledged, depending on circumstance: situations of significant stress or anxiety can be felt as an agonizing dragging of time, whereas happy experiences tend to seem quite elusive. Moreover, studies demonstrated that *viewing time* in children – i.e., the time they keep their gaze on a stimulus – gets used, in other words, the more an event is presented to the retina, shorter is the time the gaze rests on it. Similarly, children tend to pay more attention to unexpected stimuli than to expected ones (GAZZANIGA et al., 2006). These observations may help understand why time seems to pass ever faster as one ages (BALDO et al., 2006; BUHUSI, et al., 2005).

Thus, relativity of time and space is established in the dynamic equilibrium process of the close subject-reality relationship, as surmised by Nobre de Melo:

> Alterations in the experience of time and space can certainly be registered, not only in defined pathologic states. But also, in general, every time the close interdependence between the self and the world is disturbed, albeit fortuitously. Thus, a blissful day will leave us the impression of having gone by exceedingly fast. [...] The same happens regarding the experience of space. [...] Because spatiality is not defined simply by material relations of physical proximity or farness, between two or more human realities. (NOBRE DE MELO, 1979)[4]

Currently, the domain of neurosciences/contemporary physics discusses the possibility that perceptions of space and time share circuits that are superposed regarding this processing, composing space-time neural pathways. The description Zihl and collaborators make of a woman with akinetopsia – selective loss of perception of movement – with intact perception of color and shape corroborates this idea. The aforementioned patient, instead of seeing objects in continuous movements – which would be expected with adequate space-time integration – reported to see them in quick snapshots, i.e., in one position, then another one, showing great difficulty to cross the street, since she first noticed a car in the distance, next – when she took the decision to cross the street – she noticed the vehicle very close to her. The patient's neurological evaluation demonstrated serious disorder in the detection of speed and direction of objects in quick movements; image exams found significant bilateral lesions in the temporal and parietal cortexes. In such circumstances, a clear impairment of the space-time relation is characterized – as if the perception of Einstein's four-dimensional continuum had been decomposed in three-dimensional space takes, in instant cuts of time – which leads us to consider the possibility that the perception of these magnitudes may be somehow really integrated in the central nervous system, allowing the establishment of an analogy with space-time of relativity (BALDO et al., 2006; BUHUSI et al., 2005).

These brief considerations allow us to establish a parallel between space-time relations in contemporary physics – Relativity Theory and extra space-time dimensions – and in the activity of neural circuits responsible for the codification of space, time and movement, whether by modulation attention entails, or by intervention of central nervous system lesions.

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4 Free translation into English by the authors

6 Extra space-time dimensions: compositions between physics and neurosciences

Contemporary conceptions about space-time – according to which the world is conceived with ten or more dimensions – allow parallelisms to be thought of within neurosciences framework, particularly if we consider the above comments about relativity and space-time. In this context we can discuss the interesting phenomenon of hypermnesia (HELAYËL et al., 2012) which refers to (1) *Exaggerated memory activity* and to the (2) *unusual capability to evoke memories* (HOUAISS, 2001).

From the point of view of psychopathology, hypermnesia is detected in situations when casual memories are evoked with more accuracy and vehemence than usual, or when we recall singularities that typically do not come to consciousness (MULLIGAN, 2005; DUARTE et al., 2012). In general hypermnesia does not mean a true increase in memory, what is observed is greater ease in the evocation of mnemonic elements – these usually limited to certain periods or specific events – chiefly if there is involvement in a situation of strong emotional appeal (HURLEMANN, 2006; MACNAUGHTON, 2003). Traditionally the following are recognized as important causes of hypermnesia: febrile infectious diseases – situations in which we experience a recall either of old memories (from childhood or youth, e.g.) or of facts we could not remember existed – and hypnosis, moment when the reminiscences of complex events are accurately relived.

Instant recall of events of a lifetime is equally described in certain situations, but in an uncommon way. Such events occur in conditions of significant emotional impact, generally in contexts of unbearable suffering and/or great threat to life, as in cases of imminent death[5]. After the cessation of the threatening factor, subjects report the experience of having remembered, in an instant and with absolute clarity – in great detail – the unfolding of their own biography, as if watching a movie.

Such occurrences allow us to conjecture about the "decompressing" of time, i.e., it would be as if time "opened" in a very special way, to the point that the long period of a lifetime would "fit" in a few seconds. Furthermore: one could think of the access to a second and extremely compact regime of time, impenetrable in the very movements of everyday life.

One of the possible keys to think these two regimes of time can be found in the phenomenological distinction between the "time of the self" (*Ich*-Zeit) and the "time of the world" (*Welt*-Zeit). The first one refers to the immanent time of experience, interior, characterized as the "duration of consciousness" (BERGSON, 1996; JOHANSON, 2004), whereas the latter, the time of natural sciences, is divisible and measurable, or, as Bergson remarked, it is *spatialized*, it may be taken

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5 As specified on the site Psiquiatria Geral (http://www.psiquiatriageral.com.br/glossario/h.htm), "hipermnesia, that may occur in states that precede death when a person is faced with situations extremely threatening to survival. In psychiatric literature, there are references to cases in which the person recalls, in few moments, all of the events of a lifetime with absolute clarity". Free translation.

for a line, motionless (BERGSON, 1996).

Hypermnesia – based on these preliminary elucubrations – from the point of view of considering it as the evidence of *two coexisting times* – opens the perspective to establish one more parallel between contemporary physics and neurosciences, when considering that, in both fields, it is possible to propose the existence of space-time extra dimensions. In this context, it would be worth calling the attention to two lines of thought from contemporary physics of fundamental interactions: (1) the existence of a planar system for electromagnetic interactions, responsible for biologic processes and thus, for the processes of neuronal transmission; and in parallel (2), the possibility to describe natural phenomena in a space-time scenario where two time directions coexist.

In the case of the so-called planar electromagnetism, it is interesting to observe the character of higher spatial correlation of the very electromagnetic interaction. This means that space regions that could not usually connect through three-dimensional magnetism, in a situation where correlation plans are configured, we observe that electromagnetic interaction intensifies. This could be responsible for the release of information stored in regions of the brain apparently disconnected from those points linked to sensorial experience immediately perceived (MOURA-MELO, 2001).

On the other hand, the discussion about supplementary temporal dimensions is of harder correlation with the phenomena we experience. One must define – and there still lacks a clear vision – exactly which of the possible times really parametrizes the temporal evolution of physical systems. In the present contribution, we simply present the information that the physics of fundamental interactions points to the possibility of existence of an extra time coordinate, which can lead us to a deeper reflection on the matter in the neuroscience field. However, it is still impossible to make a systematic proposition of a mechanism to connect this extra time to hypermnesia, in both mathematic and physiologic terms. Certainly, this is a subject to be reflected in depth and forwarded in future works the authors plan to develop and report.

7 Final considerations

The current article presents the following hypothesis: (1) there is an interrelation between issues addressed by neuroscience and concepts and ideas developed by high energy theoretical physics in its approach to fundamental interactions; (2) the current thinking is that interactions found in the universe must have a common origin in a multidimensional space-time scenario; from these extra spatial relations should emerge the different interactions that truly elementary particles experience; (3) the electromagnetic sector responsible for atomic cohesion, for molecular and atomic bonds and, ultimately, by the formation of life is the one that commands neuronal interactions and connections; (4) thus, it is reasonable to propose that neurons may somehow reveal, albeit indirectly, reminiscences of the extra dimensions where the fundamental forces of nature have origin.

A more delicate issue is whether another temporal axis may figure among these supplementary dimensions. Usually one accepts that time, in reality four-dimensional, is not accompanied by any extra time dimension; typically one maintains that all other dimensions are of a spatial nature. Nevertheless one can consider the possibility of an extra time dimension in the context of neurosciences, considering the case of hypermnesia. Indeed, one assumes the possibility that the brain can trigger, in very special conditions, experiences related to an extra temporal dimension – the same way physics systems perceive the so-called extra time in very high energy regimes – accessible in psychological markedly severe situations. Such perspective – ultimately a hypothetical parallelism – deserves to be duly investigated, not only from the point of view of physics fundamental interactions, but also from the perspective of neurosciences, perhaps allowing new variations on the theme *space* and *time*.

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Contribution of authors

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