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Cognitive paradoxes and brain design

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Abstract

It is generally agreed amongst philosophers and neuroscientists that the main obstacle between the science of the brain and the conscious nature of the mind is rooted in an objective-subjective dichotomy. It is further common to classify natural sciences in terms of their epistemological values and their ontological existential attributes. As a result, one concludes that a computer that is useful for studying nature, such as the conscious mind, is not itself part of nature, or as phrased differently by the noted philosopher, John Searle, 'there are no Turing Machines in nature! However, the great physicist John Archibald Wheeler, by declaring the famous dictum, 'it from bit', did impart a somewhat different approach to the true nature of reality. To reconcile the two contrasting portraits, a different picture, based on the principle of self-reference, will be presented, and applied to the brain-mind problem. It is demonstrated how this principle imparts a thermo-qubit syntax, i.e., 'bit from it', for communication between increasingly more complex physical systems. Altogether, the steady state situation produces negentropic pockets for quantification and storage of information. The communication protocol entails cognition mechanisms that display unexpected equivalences that prompts fundamental interpretations of general optical illusions such as Necker's cube, the Rubin vase, and the Spinning Dancer. The derived syntax also embodies an interesting deconstruction of the recently observed dodecanogram brain signal, experimentally elucidated by Anirban Bandyopadhyay and his team.

Keywords: Panexperiential materialism, Gödelian self-references, Rubin vase, Communication Simpliciter, It from Bit, polygram

l. Introduction

Neuroscience explores the structure and function of the human brain, and the principal objective is set on biological processes relating to constitutional activities and cognitive processes. A contrast or dilemma appears here, cf. similar debates between construct or form occurring in linguistics or between genotypic information versus phenotypic morphology in biology. In fact, these dichotomies resonate all the way from straightforward contrapositions to the fundamental duality controversy between the physical and the mental. The latter deliberates on the protean gap between the body and the mind, promoted as substance dualism theory, defended by the great neuroscientist Sir John Eccles (Eccles, 1951).

In general, the presentation of dichotomies, such as subjective-objective or local-global etc., leads to metaphysical thinking, ingenuity, and creativity. As a result, new concepts regarding the relationship between consciousness and the physical processes in the material brain were realized, principally by John Searle (Searle,1980), who strongly denied Cartesian dualism. His philosophical vernacular has notably been expressed in the arguments concerning artificial intelligence (AI) for instance, in defining the distinction between the notions of strong and weak AI.

However, there is a rather important difference between the glossary of philosophy and the usage of concepts and definitions in physics and chemistry. The axiomatic structure of the latter derives deductive theories, objective by choice as an interplay between the experiment and the role of observations (Löwdin, 1992). For instance, the laws of physics are supposed to be independent of the practicing scientist, whether one defines the nature of research from an epistemological or an ontological standpoint. This is a common view that incorporates what one usually, perhaps sloppily, refers to as natural science. Consequently, it has been customary to recognize computation as a physics enterprise, particularly in view of Landauer's principle considering the thermodynamic costs associated with the erasure of a binary digit (Landauer, 1961).

Now, the philosophical thesaurus, albeit inadvertently often like the language of modern reductionism, can be very deceptive that might cause severe misunderstandings. Returning to the mind-body problem, later presented under the name of *Biological Naturalism* (Searle, 2007), refers to the latter as an understanding essentially based on the evolutionary theory of biology. Within this scenario, *viz*. what is the characteristic property of research concerned with the *knowledge of nature*, he further concludes that computation is not a natural science. The computer has no mind since it is only a tool for studying it, and as the argument goes, computations are observer relative, and hence any technological device lacks intelligence – the gist of his celebrated '*Chinese Room'* thought experiment. The qualitative distinction of traits such as observer-dependent/independent, whether in the epistemic or in the ontological sense, carries a mudskipper. Even if human creations, albeit observer-relative, might not be so by themselves, there is always the Gödelian enigma, i.e., that the decision to claim an entity to be observer-independent must depend on an observer.

In this setting, information is relative to its interpreter and therefore, depends on the observer. Here is a fundamental logical distinction between a computer program and human intelligence. Searle clarifies that AI, specifically the program in a computational process, is at most syntactic. Since the syntax has no causal powers, the conclusion is that information computation is not intrinsic to physics – *there are no Turing machines in nature* – and hence the key query is whether the manipulation of binary symbols is sufficient for thinking? The answer is obviously no since the semantics of the human mind is absent. As hinted earlier, there will be an unavoidable confrontation between the philosophical style and the deductive attributes of reductive science. In addition to Landauer's principle (Landauer, 1961), linking the costs of computation with thermodynamics, the eminent physicist John Archibald Wheeler (Wheeler,1982), contrived the popular dictum '*it from bit*', promoting a closer link between computation, engineering, and the physical laws of nature. To make nature more complicated one also needs to come to terms with the various interpretations of quantum mechanics, e.g., the standard collapse scenario, the many words theory etc., see for instance the review from the proceedings of Nobel Symposium 104 (Karlsson & Brändas,1998). Obviously, the two portraits of nature are contradictory.

The most direct way to reconcile the differences would be to simply implement a strategy that goes beyond the distinctions, made above, between physics-chemistry-biology and the engineering sciences and to find the actual mechanism behind the workings of the brain. Such a program must relate to the Gödel-Turing *Entscheidungsproblem* (Gödel, 1931; Turing, 1951) as well as contain a demonstration that also the syntax '*bit from it*' is part of nature. Below we will give such an approach. Parts of this proposition has been presented in various publications (Brändas, 2021a,b) and references therein, but we will also add some new features along the way. The first step has been to add *the principle of self-reference* to the table. This imparts that NATI, i.e., *Nature is All There Is,* includes all and nothing, the mental and the physical, and the conscious mind and the material brain. It would also include any type of simulations of NATI, including the simulations themselves, as the self-referential subtlety will end the ensuing infinite regress, more details is given in section 5. As will be seen, this innocuous addition provokes interesting and deep-going consequences with a significant bearing on the boundaries between organic and live matter (Poznanski & Brändas, 2020).

The substance dualism of Sir John Eccles has its opposition in neutral monism, or the materialistic thesis known as physicalism. A modern answer to these contraries is the prototypical view described under dual-aspect monism (DAM). A noted advocate of the latter is the neuropsychologist Mark Solms, who, with his psychoanalyst background, together with the prominent neuroscientist Karl Friston, have brought forward the latter's free energy principle (FEP), as a monistic explanation of both physiological and psychological phenomena (Solms & Friston, 2018) – a view that will be discussed in the next section. For a recent defence of DAM (see also Benovsky, 2015). The presentation below will demonstrate the unexpected consequences of adding the precept of self-references to the laws of physics. After a short re-examination of dual aspect theories, we will establish a bottom-up strategy of NATI, including the proof that syntax for communication is part of physics or '*bit from it*', i.e., the fruition or obverse of Wheeler's dictum. This conclusion fosters a closer link to Friston's free energy principle as well as provides a novel interpretation of the work by Anirban Bandyopadhyay and his team. The resulting polygram syntax enunciates a coherent and intelligible account of cognitive paradoxes and general optical illusions such as Necker's cube, the Rubin vase, and the Spinning Dancer, suggesting extended readings of neuronal dynamics.

2. Dual aspect theory

One of the current most popular approach to the mind-body problem is dual aspect monism, DAM, while most practitioners of the hard-core sciences, such as physics and chemistry, persist in the thesis that everything is physical. In launching his first major publication, The Conscious Mind, the philosopher, David Chalmers promoted a very thorough argument for a naturalistic dual view (Chalmers, 1996). As a quantum chemist educated at the crossroads between the historically established areas of mathematics, physics, chemistry, and biology (Brändas, 2017), I am not able, nor is this the right place, to engage in a philosophical discourse comparing in detail the latter with a monistic stance. However, for a topical overview, with some new propositions, (see Poznanski & Brändas, 2020). A simple illustration, as a framework for the various renderings concerning the metaphysics of dualism contra monism, will be of particular focus in this study. The exemplar will nevertheless be a bit different and unorthodox as will be seen below.

Consider for instance the widespread metaphor of nature as a coin or banknote, with the two sides referring to the mental and the physical aspects of all there is. The two sides have a connection, i.e., the coin or bill, representing simultaneously money made from metal or in the form of paper and currency as legal tender for payment. For instance, a Swedish coin carries a portrait of Carl XVI Gustaf, as a unifying symbol of the country in the north, and an opposite flat side referring to material heraldic achievements, such as shields and coats of arms and other embellishments. Further the various notes celebrate e.g., the film-director Ingmar Bergman on front, displaying a rauk field from his 'Fårö' on the back, or the former Secretary-General of the United Nations, Dag Hammarskjöld, adverse, with the world heritage Laponia and the National Park Sarek displayed on the reverse. It is noticeable that the two sides of the money refer to different realms, i.e., the material constituents of the physical world and the immaterial inherent expectations of a country communicating and sharing information with its environment. The two sides are linked together via the abstract notion of currency and the substance of the manufactured coinages. From an ontological point of view there is no mystery to deduce that a change in the mental image of a particular country supervenes on spatiotemporal individual facts, e.g., that the lower ranking of a football nation supervenes on the actual scores of separate independent matchups.

However, from an epistemological perspective such an evaluation may be a problematic task. Take for instance the burning of a holy script, sparking condemnations in the world. While the ontological connections are forthright, the epistemic situation is not pronounced, i.e., whether the impaired reputation of a democratic country, with a constitutional law of free speech, supervenes on the combustion of a slice of coded paper. The dualist position (Chalmers, 1996) is that biology does not logically supervene on physics. What about DAM? In a recent commentary on Mark Solms' *New Project for Scientific Psychology* (Solms, 2017; Friston, 2010; Brändas & Poznanski, 2020), it was discussed whether the free energy principle, FEP (Friston, 2010), as a unifying principle would provide a monistic explanation of both physiological and psychological phenomena. In the answer Solms (2020) rightly pointed out that his asserted dual aspect theory was not commensurate with the alleged general dualistic view.

To clarify this point further, the situation above will be revisited from a more succinct mathematical perspective. The crucial point is to combine the epistemology of FEP, with the metaphoric 'coin' replaced by a Markov Blanket, in terms of its active and sensory states, combined with a predictive model of the external world, the external states, registering and adjusting the relevant quantities, predicting the error, quantified as free energy. In this scenario, where both the free energy and the entropy is minimized, the method bears down on a steady state situation, where the surprisal, actualizes through constraining boundary conditions far from thermodynamic equilibrium. Now the critical question arises. Will the Markov Blanket, from an epistemological perspective, be sufficient as a unifying notion of dualistic conceptions, i.e., to be the final vindication of DAM? One knows that a complete knowledge of the 'slice of paper', in the example above, is not possible, unless one has access to its full evolution history, which includes the origin of the universe, the evolution of life, common descent, gradual transformations, multiplication of species, natural selection, the appearance of intelligence, culture, politics, religion, etc. This, in a sense, is biological naturalism (Searle, 2007) but then we have already disposed of the 'coin' hiding the gap between the physical and the mental by an ontological trick. Obviously, traditional physicalism lacks closure to fully incorporate monism, and this also contaminates DAM.

3. Physicalism and monism

In this section, monism will be addressed from the view of physicalism, but with the addition of the law of self-references. The conceptual formulation, while appearing harmless, in order to include nature as all there is, NATI, seems at first sight to include unwelcome complications, for instance the famous contradictions, such as Epimenides-Russel-Pinocchio type paradoxes or the Gödel-Turing limits of knowledge. However, rather than, as usual being the practice, trying to avoid these inconsistencies by introducing additional quantifiers and stronger semantics, the course of direction is instead to find a legitimate translation of the Gödelian branchpoint into the parlance of set theory.

A very simple argument can be given as follows, by translating a truth-functional propositional calculus to linear algebra terminology, for more details see e.g., (Brändas, 2015). For instance, assign to each proposition one or the other of the truth value symbols, *truth or falsity* (provable or non-provable) by considering the proposition $\mathfrak{P}$ and not $\mathfrak{P}$, i.e., $\mathfrak{P}$ and $\mathfrak{Q} = \neg\mathfrak{P}$. This leads to the following logical negation table: if $\mathfrak{P}$ is true (and $\mathfrak{Q}$ false), then the first row below 'asks' whether $\mathfrak{P}$ is true (yes!) and $\mathfrak{Q}$ is true (no!), while the second row 'asks' whether $\mathfrak{P}$ is false (no!) and $\mathfrak{Q}$ is false (yes!),

$$\text{Logical negation:} \quad \begin{array}{c c} & \begin{array}{cc} \text{true} & \text{false} \end{array} \\ \begin{array}{c} \text{true} \\ \text{false} \end{array} & \begin{pmatrix} \mathfrak{P} & \mathfrak{Q} \\ \mathfrak{P} & \mathfrak{Q} \end{pmatrix} \end{array} = \begin{pmatrix} \text{yes} & \text{no} \\ \text{no} & \text{yes} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \tag{1}$$

In a linear algebra formulation, with only two orthonormal basis elements, $|\text{true}\rangle$ and $|\text{false}\rangle$, one finds in obvious quantum mechanical notation the traditional identity relation for the unit operator *I:*

$$I = |\text{true}\rangle\langle\text{true}| + |\text{false}\rangle\langle\text{false}| \tag{2}$$

This simple result incorporates the standard deductive formulation of quantum mechanics for isolated systems entrusted with a positive definite metric. The corresponding density matrix ρ with p the probability for $\mathfrak{P}$ to be true reads:

$$\rho = |\text{true}\rangle p\langle\text{true}| + |\text{false}\rangle(1-p)\langle\text{false}| \tag{3}$$

with a von Neumann entropy in units of k given by, choosing e.g., $p = 1/2$,

$$S = -\text{Tr}\{\rho \ln \rho\} = -[p \ln p + (1-p)\ln(1-p)] = \ln 2 \tag{4}$$

However, in open system dynamics, this will not be a sufficient description that will exhaust all the possible alternatives. Choose for instance $\mathfrak{P} = \mathfrak{G}$, where $\mathfrak{G}$ is Gödel's formally undecidable proposition, "this statement is unprovable", leads to the appearance of terms such as $|\text{true}\rangle\langle\text{false}|$ or $|\text{false}\rangle\langle\text{true}|$, i.e., if it is true it is false, and if it is false it is true, or, translated into a matrix representation

$$|\text{true}\rangle\langle\text{false}| = (|\text{true}\rangle, |\text{false}\rangle)\begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix}\begin{pmatrix} \langle\text{true}| \\ \langle\text{false}| \end{pmatrix} \tag{5}$$

The matrix introduced in Eq.(5) is a Jordan matrix of order two, an irreducible degenerate block containing a geometric multiplicity, known as a Jordan block with a Segre characteristic equal to the degeneracy, here being two. The importance of this understanding is deep going and profound, the most fundamental prerequisite being a non-positive definite metric. While every matrix can be reduced to its general Jordan form, Hermitian matrices, representing self-adjoint operators, can always be diagonalized. Hence it is obvious that pioneering quantum mechanics will never be sufficient to confront situations that lead to representations, such as the one exemplified in Eq.(5). In contrast, biological systems, being open and self-referential, exchanging energy-entropy with its environment, the appearance of Jordan blocks of various dimensions are legion. The point in question becomes: how and when do they occur, and what are the ensuing dynamical consequences? These requirements demand the full machinery of energy-time, momentum-space conjugate observables and the entropy-temperature conjugate relationship and a rigorous formulation of so-called resonance states, i.e., quasi-bound states embedded in the continuum, see e.g., references (Brändas, 2021a,b), for more details.

To give an adequate insight into the basic details of the workings of microscopic processes in a biological organism, such as a neuron or other key structure in a human brain, supported at absolute temperature, T, it is a good idea to examine the relevant energy and time scales of the description. A human body, at normo-thermia, provides a chaotic environment of enacted thermal fluctuations, with energies of the order kT, where k is Boltzmann's constant, exactly defined by the 2019 redefinition of the SI base units. The thermal energy scale, at 310K, equals 0.0267eV, corresponding to about 6.3THz and time cycles smaller than picoseconds. However, neural brain oscillations, caused by electrical activities, as measured by EEG, corresponds to time periods in the millisecond region. This begs a theoretical formulation that incorporates a tremendous range of process lead times that are vital for living entities and their ongoing communication within its milieu. For instance, a higher order relaxation process in the millisecond region, characterized by a relaxation process time t_{rel} at temperature, T, is related to the thermal correlation times $t_{\mathrm{corr}} = h/kT$ via the relation[1]

$$t_{\mathrm{rel}} = nh/kT \tag{6}$$

where n is the dimension or degrees of freedom separating the terahertz-normothermic region from the slow conformational dynamics of the recognized brain waves. Such a requirement calls for boundary conditions of the type:

$$t_{\mathrm{rel}} = (l-1)t_l\,;\;\; (l-1) = 1, 2, 3..n \tag{7}$$

i.e., a set of connected quantum-thermal time scales that will play a key role in the steady state universal biological evolution. These estimates have crucial consequences for the qualitative understanding of the necessary theoretical strategy. To begin with, we are interested to construe biological processes that are commensurate with the proliferations and dissipations taking place at thermal correlation times and their subsequent longer intervals in exercising self-organization, see Eq.(7). It is clear that the Schrödinger equation is not applicable here. Pure quantum effects are completely washed out by the observed classical thermal motion, a condition also known as the decoherence problem in quantum mechanics. That said, this difficulty nevertheless has a resolution. This work has a long history (Brändas, 2021a,b; Reid & Brändas, 1989; Chatzimitriou-Dreismann & Brändas, 1991), but we will give a short review below. A few characteristic quantum chemical developments will be integrated to produce a surprising result, i.e., a chain of objective interactions and correlations between complex enough systems, projecting a syntax for higher-order communication and associated semantic evolution, covering the approach from external objectivity towards internal subjectivity. The extension of Wheeler's dictum '*it from bit*' to '*bit from it*' will contribute a physicalistic perspective on monism as a panexperiential materialistic view (Poznanski & Brändas, 2020) that establishes a conjugate link between the material brain and the conscious mind (Brändas, 2021b). Those mostly interested in the semiotic consequences of the derivation of a syntax for intelligent communication might jump the next two sections and return to it later.

4. Dissipative systems and quantum thermal correlations

This section will consider the microscopic molecular motion of complex enough systems, building up a biological system, such as a cell, with its chemical processes, program, and communications with its environment. The brief review contains primarily three steps. *First*, one needs to understand the configurations behind macroscopic long-range correlations as described by quantum mechanics at zero temperature. *Second*, one requires a consistent non-Hermitian formulation of open, dissipative systems, dynamics in concert with the objectives stated in the previous section, and *third*, a thermalization procedure that engrains the biological system within a liveable temperate milieu. The underlying conditions advance several adjustments, i.e., to retain the long-range order while prohibiting decoherence into classicality, to provide the boundary conditions for the negentropic gain under steady-state conditions and to find the transformations that bring the extended representation of the Schrödinger-Liouville equations to classical canonical form. An overall principal consideration is the synergism between the light fermionic carriers as they transverse a fluctuating nuclear skeleton of a combined neutral open system.

[1]A more detailed derivation of Eq.(6) from scattering theory, see e.g., (Brändas, 2021a), contains a dimensional constant, $1/4\pi$, indicating integrations over solid angle.

First it is clear that to overcome the thermal noise one needs to consider a thermodynamic system with incomplete knowledge, i.e., one might focus on the density matrix $\rho = \sum_{k,l=1}^{n} |\psi_k\rangle \gamma_{kl} \langle \psi_l| = |\boldsymbol{\psi}\rangle \boldsymbol{\gamma} \langle \boldsymbol{\psi}|$, represented by the matrix $\boldsymbol{\gamma}$ in the orthonormal basis ψ_k, with $\langle \psi_k | \psi_l \rangle = \delta_{kl}$. Note that ρ, ψ_k obtains from the Schrödinger-Liouville equations, and under the axioms of quantum theory, the Hermitian system operator ρ can always be diagonalized. There are many ways to determine the probabilities γ_k, for instance via the theory of reduced density matrices (Coleman, 1963; Sasaki, 1965), linking the extreme correlations with superfluidity and superconductivity (Yang, 1962). The story behind the discovery that the second order reduced density matrix exhibits a large eigenvalue is interesting, leading up to several Nobel Prizes in Physics, while some fundamental work has escaped the centre stage, see e.g., (Brändas, 2017) for more details.

We will start by discussing the pure quantum correlations at zero temperature, introducing the second order, reduced density matrix, normalized to the number of pairings:

$$\Gamma^{(2)}(x_1, x_2 | x_1', x_2') = \binom{N}{2} \int \Psi(x_1, x_2, x_3, \dots x_N) \Psi^*(x_1', x_2', x_3, \dots x_N) dx_3, \dots dx_N \tag{8}$$

where the total electronic wave function $\Psi(x_1, x_2, x_3, \dots x_N)$ represents N fermions, x_i is the combined space-spin variable, and the electronic energy, for the reduced Hamiltonian, is given by $E = \mathrm{Tr}\{H_2 \Gamma^{(2)}\}$. Note that the nuclear degrees of freedom are not yet written out, as they normally are specified in most molecular applications lending support to the adiabatic approximation. The latter will not be valid here, since the nuclear motion, represented by the *n* nuclear sites, will be of crucial importance. This is true even at very low temperatures, where the actual pairing mechanism in e.g., the celebrated Bardeen-Cooper-Schrieffer, or BCS, theory, is mediated by the electron-phonon interactions. In fact, the light fermions moving in a nuclear skeleton must obey a fundamental mirroring symmetry in that the consecutive mappings between the electron and the nuclear dynamics and vice versa exhibits the same classical canonical forms. We will return to this further below. For more details regarding pair condensation in BCS, and in more complex situations, such as alternate cuprate- and iron-based lattices, see Dunne et al. (2017).

The reduced dynamics, defined by Eq.(8), can also be viewed from the Brussels-Austin-Prigogine star unitary formulation (Prigogine et al., 1973), but we will instead follow the pathway based on $\Gamma^{(2)}$, and ask what happens at zero temperature when quantum mechanics rules. Isolated quantum systems are characterized by electronic correlations forming delocalized structures in a nuclear matrix. Extreme correlations instigate fermionic pairings that prompts an overall wavefunction, Ψ, as an anti-symmetrized product of two-electron functions, g_1, being also an eigenfunction of $\Gamma^{(2)}$, see Coleman (1963). This geminal, g_1, can be represented as an expansion in a preferred basis $|\boldsymbol{h}\rangle$, of dimension *n*, with each basis element consisting of a product of two localized spatial orbitals, each centred at a particular nuclear site, and coupled to a spin singlet, i.e., $h_i = (\varphi_i \varphi_i) 1/\sqrt{2}(\alpha\beta - \beta\alpha)$. Since the two fermions, as described by two separate spatial degrees of freedom in h_i, can avoid each other, a linear expansion in basis $|\boldsymbol{h}\rangle$ will generate a geminal, which exhibits long range quantum correlations. Note that this Off-Diagonal Long-Range Order, ODLRO, see Yang (1962), is qualitatively different from the standard quantum mechanical build-up of the periodic system, where e.g., the interactions of the two electrons in a helium atom ground state are forced into a $1s^2$ configuration close to the nuclei. The paired fermions, correlated by ODLRO, show bosonic character, and will pile up into a condensate of highly correlated phases, if the temperature is low enough. As a result, the diagonal-canonical form of $\Gamma^{(2)}$, in the preferred basis $|\boldsymbol{h}\rangle$, will display a macroscopically large eigenvalue, corresponding to the eigenfunction g_1, with the remaining ones forming a degenerate set of small ones.

The first derivation of the reduction process, from $|\Psi\rangle\langle\Psi|$ to $\Gamma^{(2)}$, was carried out by Sasaki (1965), see also Coleman (1963), by proving a formula for the study of a system of symmetric bosons or antisymmetric fermions composed of two subsystems via a combinatorial counting argument. Note that this proof only rests on the symmetry properties of the actual particles – here the electrons. However, it is easier to recognize this mechanism from the mirroring dynamics, i.e., from a nuclear vibrational perspective. Returning to the problem of a nuclear skeleton, and the question of distributing $N/2$ electron pairs equally over the *n* locations. Obviously, this probability is $p = N/2n$, while an empty site equates with $(1-p)$. Hence the probable event that a pair moves from site "i "to site "j" becomes $p(1-p)$, defining a simple $n \times n$

matrix, with a large eigenvalue and an $(n-1)$-degenerate small eigenvalue

$$\lambda_{\mathrm{L}} = np - (n-1)p^2 = N/2 - (n-1)p^2; \quad \lambda_{\mathrm{S}} = p^2 = (N/2n)^2 \tag{9}$$

Note that $\lambda_{\mathrm{L}}, \lambda_{\mathrm{S}}$ approaches $N/2$, and 0, as $n \to \infty$. and that $\lambda_{\mathrm{L}} = \lambda_{\mathrm{S}} = 1$ for $n = N/2$, i.e., when the number of nuclear sites equals the number of pairs. The surprising circumstance is that the fermionic pair dynamics, based on $\Gamma^{(2)}$ and the simplistic nuclear model above, displays identical classical canonical forms at the extremely correlated motion of the light carriers at zero temperature. The bottom line here is that the light fermionic carriers are in a mirroring relationship with the nuclear dynamics, a situation, which will be of paramount importance in the thermalization process, for more details see (Brändas, 2004). In summary we have a system operator expressed as,

$$\rho = \Gamma^{(2)} = \sum_{k,l=1}^{n} |h_k\rangle \gamma_{kl} \langle h_l| = |\boldsymbol{h}\rangle \boldsymbol{\gamma} \langle \boldsymbol{h}| = |\boldsymbol{g}\rangle \boldsymbol{d} \langle \boldsymbol{g}| \tag{10}$$

where the diagonal form $\boldsymbol{d}$ of the matrix $\boldsymbol{\gamma}$ reads, with $|\boldsymbol{g}\rangle = |\boldsymbol{h}\rangle \boldsymbol{B}$ – the transformation will be discussed in more detail below[2],

$$\boldsymbol{d} = \begin{pmatrix} \lambda_L & 0 & \cdots & 0 & 0 \\ 0 & \lambda_S & & 0 & 0 \\ \vdots & & \ddots & \vdots & \\ 0 & 0 & & \lambda_S & 0 \\ 0 & 0 & \cdots & 0 & \lambda_S \end{pmatrix} \tag{11}$$

Note that the matrix $\boldsymbol{\gamma}$ can be interpreted either as a fermionic representation in a basis set with the electronic coordinates centred at particular nuclear locations or as a mirroring epitome, described by the degrees of freedom of the structure at each nuclear site, as perturbed by the electron pairs.

In order to complete the picture, it is necessary to realize that biological systems evolve as open systems at finite temperatures. This entails another fundamental problem, as quantum mechanical states may not withstand decoherence, i.e., might be washed away by disordered thermal fluctuations. This calls for the needs of (1) a rigorous formulation of open system, non-Hermitian, quantum mechanics and (2) a consistent thermalization procedure. Fortunately, both requirements can be met. The first concern has been rigorously addressed by the honoured theorem, due to Balselv & Combes (1971), providing many original applications in chemical physics. The method, also known as complex scaling, is particularly suited for atomic and molecular physics, since it applies to the Coulombic interaction underlying most macroscopic forces. It has the following effect on the spectral properties of the Hamiltonian. The bound states remain ‘untouched’ by the ‘complex scaling’ operation, while the continuum opens the lower complex energy plane, thereby uncovering complex resonance states, shown by a complex eigenvalue $\varepsilon = E - i\Gamma/2$, with E the position and the width Γ being related to the lifetime t of the state through the relation $\Gamma = h/t$. As examples one might mention Gamow’s mechanism of nuclear disintegration, e.g., the process of alpha decay, or the Stark effect[3] on the hydrogen atom (Hehenberger et al., 1974). Although the methodological modifications to incorporate the operation of complex scaling appear straightforward there is a fundamental difference when extending the dynamics to complex symmetric representations. One such modification, as was already mentioned above, relates to the theorem that any square matrix is similar to a symmetric matrix, see the classic work of Gantmacher (1959). For the present outline an explicit derivation of an original form of a symmetric Jordan block was carried out in Reid & Brändas (1989). Since this form will be significant for our development, we give the substance of the proof, i.e., that:

$$Q_{kl} = \left(\delta_{kl} - \frac{1}{n}\right) e^{\frac{i\pi}{n}(k+l-2)} \tag{12}$$

is nothing but a complex symmetric representation of a Jordan block, $\boldsymbol{J}$, via the transformation

$$\boldsymbol{J} = \begin{pmatrix} 0 & 1 & \cdots & 0 & 0 \\ 0 & 0 & & 0 & 0 \\ \vdots & & \ddots & \vdots & \\ 0 & 0 & & 0 & 1 \\ 0 & 0 & \cdots & 0 & 0 \end{pmatrix} = \boldsymbol{B}\boldsymbol{Q}\boldsymbol{B}^{\dagger} \tag{13}$$

Note that transformations to classical canonical forms are commonly expressed as $\boldsymbol{U}^{\dagger}\boldsymbol{Q}\boldsymbol{U}$ with the columns of $\boldsymbol{U}$ containing the canonical vectors of the initial matrix. In formula (13) the relation becomes $\boldsymbol{U} = \boldsymbol{B}^{\dagger}$. We will

[2] The transformation $\boldsymbol{B}$ is the same as the one occurring below in Eq.(13).

[3] Although the Stark effect is not covered by the Balslev-Combes theorem, complex scaling nevertheless will work due to Weyl’s limit point theorem, see (Hehenberger et al., 1974) for more details.

come back to the actual form of the transformation in the next section[4].

Finally, we must discuss the extension of the Balslev-Combes theorem to the thermalization problem, for more details see Obcemea & Brändas (1983); Husimi (1940). The integration of quantum- and thermal correlations follows now basically from the standard Bloch thermalization procedure (Husimi, 1940), adapted to the present density matrix formulation, i.e. with $\mathcal{L}_{\mathrm{B}}$ being the Prigogine energy super-operator (Prigogine et al., 1973), $\beta = 1/kT$,

$$-\frac{\partial\rho}{\partial\beta} = \mathcal{L}_{\mathrm{B}}\rho;\;\; \mathcal{L}_{\mathrm{B}}\rho = \frac{1}{2}(H\rho + \rho H) \tag{14}$$

The thermalization procedure entails that the quantum-thermal correlations, at the various nuclear sites, display a set of successive ascending/decaying vibrations, commensurate with

$$\Gamma_l = h/t_l \tag{15}$$

where t_l might define the time scales of a particular process as specified by Eqs. (6,7). The remarkable result is that the application of the Bloch thermalization procedure to the system operator Eq.(10), with the boundary conditions (6,7) leads to, $\boldsymbol{\gamma} \to \boldsymbol{\gamma}_{\mathrm{term}}$ and $|\boldsymbol{h}\rangle = |\boldsymbol{f}\rangle\boldsymbol{B}$

$$\begin{aligned}\rho_{\mathrm{tr}} = e^{-\beta\mathcal{L}_{\mathrm{B}}}\rho = |\boldsymbol{h}\rangle\boldsymbol{\gamma}_{\mathrm{term}}\langle\boldsymbol{h}| = |\boldsymbol{f}\rangle\boldsymbol{B}\boldsymbol{\gamma}_{\mathrm{term}}\boldsymbol{B}^{\dagger}\langle\boldsymbol{f}| \\ = |\boldsymbol{f}\rangle\boldsymbol{d}_{\mathrm{term}}\langle\boldsymbol{f}|\end{aligned} \tag{16}$$

with, cf. Eq.(11)

$$\boldsymbol{d}_{\mathrm{term}} = \begin{pmatrix} 0 & \lambda_S & \dots & 0 & \lambda_L \\ 0 & 0 & & 0 & 0 \\ \vdots & & \ddots & & \vdots \\ 0 & 0 & & 0 & \lambda_S \\ 0 & 0 & \dots & 0 & 0 \end{pmatrix} = \lambda_L \boldsymbol{J}^{\mathrm{n}-1} + \lambda_S \boldsymbol{J} \tag{17}$$

The key transformation, $|\boldsymbol{f}\rangle = |\boldsymbol{h}\rangle\boldsymbol{B}^{\dagger}$ has still not yet been defined except only being referred to in the proof of the general similarity theorem for symmetric matrices, (Reid & Brändas, 1989), in connection with Eq.(13). The explicit forms, and properties, of $\boldsymbol{B}^{\dagger}$, $\boldsymbol{B}$ are significant, specifically in providing a *bit from it* structure for communication between complex enough systems. The law of self-references bears fundamental consequences for the nonequilibrium thermodynamics turning Off-Diagonal Long-Range Correlations, ODLRO, into Off-Diagonal Long-Range Correlative Information, ODLCI (Brändas, 2021a); (Poznanski & Brändas, 2020), inducing a syntax for *communication simpliciter*[5], i.e., creating channels for microscopic negentropic quantum-thermal fluctuations, epitomi-izing iconicity, while promoting a monistic world view. It transcends DAM in that the focus, rather than concentrating on the neural correlates (Crick & Koch, 1990), or reconceptualizing the functional role of the FEP in terms of the Markov-Blanket-states (Solms, 2019), lies in the realization of open systems, and their associated physical and chemical processes, generated by universal explicit temperature-time-scale boundary conditions.

5. Steady states, self-organization, and Poisson statistics

In the previous section an open system formulation has been presented regarding microscopic processes in a biological system with particular considerations to extending molecular correlations to higher order communications, in principle applicable to chemical substrates such as enzymes, cells, organs and organisms. This concerns in particular the activities of the neurons in the various parts of the brain, e.g., the cerebral cortex or the reticular activating system, the latter specifically promoted as an important source of consciousness by Solms (2019). Rather than specifically referring to particular areas in the brain, we will initially first consider general biological processes with particular reference to long-range order that will constitute the basis for communication, self-organisation, Darwinian evolution and ultimately intelligence. This program is indeed a tall order, but the derivations contributed in the section above give an indication towards possible solutions. For those who skipped it for later, here is a short summary.

An important lesson, when investigating open system processes, is the realization that the relation between the temperature and the actual time-scales, Eqs.(6,7) indeed contributes a fundamental set of boundary conditions by constraining the thermodynamic equilibrium. This will form the principle of a non-equilibrium steady state situation, creating negentropic pockets for information at the expense of heat production, all in agreement with the second law of thermodynamics. We will return to this below

[4] It is an interesting coincidence that the same transformation occurs again, see footnote 2, however with $\boldsymbol{B}^{\dagger}$, and $\boldsymbol{B}$ interchanged.

[5] The communication hypothesis, *Communication Pure and Simple*, is taken in a restricted sense in that it refers to an unbiased syntax for use in the semantic pursuit of information.

however, pointing out the understanding of an open system as a process driven entity, i.e., that the energy and entropy that goes into it must be equal to what goes out and the energy-entropy changes acquired by the system during its activities. The query now becomes what de facto goes on inside a somatic cell. How is the actual bookkeeping of the activities kept and accounted for and what are the costs? How is it stored in the system? A first clue comes from the realization that the generalized transformation theory, derived above, essentially converts a self-adjoint density matrix, ρ into a Jordan block, i.e., of the type below, in terms of some, here unspecified, orthogonal functions ψ_k,

$$\rho \rightarrow \rho_{\mathrm{tr}} = \sum_{k=1}^{n-1} |\psi_k\rangle\langle\psi_{k+1}|$$

This was the main topic of explanation in the section above, starting with the formulation of zero temperature correlations in an extreme situation generating a macroscopically large eigenvalue in $\Gamma^{(2)}$, Eq.(8), of the electron pair quasi-boson, cf. superconductivity or superfluidity. In order to make this situation relevant to chemical processes associated with living organisms, the formulation must reproduce open state dynamics commensurate with the analytic extension due to the theorem of Balslev & Combes (1971), followed by proper thermalizations of the corresponding Liouville-Bloch equations. With the compliance of conditions (6,7), noting the necessity to establish a fundamental change to complex symmetric representations during the analytic continuation, the result, identifying the symmetric block with Jordan's normal form, one obtains, recognizing the crucial transformation $|\boldsymbol{f}\rangle = |\boldsymbol{h}\rangle\boldsymbol{B}^{\dagger}$, (for a derivation of this result (see Reid & Brändas (1989)):

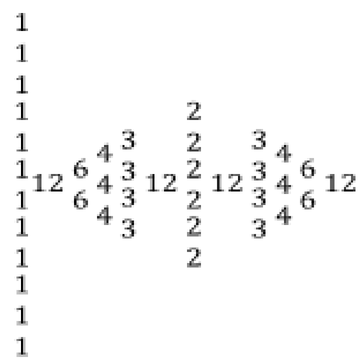
$$\rho_{\mathrm{tr}} = \lambda_L |f_1\rangle\langle f_n| + \lambda_S \sum_{k=1}^{n-1} |f_k\rangle\langle f_{k+1}| \tag{18}$$

This is a very compact and simple relation, which we will discuss in more detail later, that puts the focus on the unitary matrix transformations, $\boldsymbol{B}^{\dagger}$ and $\boldsymbol{B}$. The unitary matrix $\boldsymbol{B}$ that provides the crucial identification of the interrelated dynamics between the nuclear matrix and the long-range correlations of the electron pairs, has a very interesting form (Reid & Brändas, 1989).

In passing one notes that the precise transformation, i.e., the one containing the canonical vectors as columns, obtaining the classical canonical form

$$\boldsymbol{B} = \frac{1}{\sqrt{n}} \begin{pmatrix} 1 & \omega & \omega^2 & \cdot & \omega^{n-1} \\ 1 & \omega^3 & \omega^6 & \cdot & \omega^{3(n-1)} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 1 & \omega^{2n-1} & \omega^{2(2n-1)} & \cdot & \omega^{(n-1)(2n-1)} \end{pmatrix}; \ \omega = e^{i\pi/n} \tag{19}$$

of ρ_{tr}, see (18), is $\boldsymbol{B}^{\dagger}$. These are simply obtained from $\boldsymbol{B}$ by taking the complex conjugate of each row and making it into a column. One observes directly some very interesting symmetry properties, for instance that the columns of $\boldsymbol{B}$ factorizes according to the value of n and depending on the fact that all powers of ω are situated on the unit circle in the complex plane. Further, the rows of $\boldsymbol{B}$, or columns of $\boldsymbol{B}^{\dagger}$, are pairwise complex conjugate, while the columns of $\boldsymbol{B}$ display another symmetry, complex conjugacy, and multiplication by $e^{i\pi} = -1$. An indication of the structure of the matrix $\boldsymbol{B}$ can be illustrated by considering the case $n = 12$, where the dimensions of the factorized columns are displayed.



First, the interpretation is that the basis $|\boldsymbol{h}\rangle$, referring to the specific sites in the nuclear matrix, after the transformation, $|\boldsymbol{f}\rangle = |\boldsymbol{h}\rangle\boldsymbol{B}^{\dagger}$, has generated a canonical basis $|\boldsymbol{f}\rangle$, which are linear combinations of the localized set, where the coefficients are made up from the elements of the columns in $\boldsymbol{B}^{\dagger}$, for instance one gets for the canonical vector corresponding to the large eigenvalue λ_L,

$$|f_1\rangle = \sum_{k=1}^{n} e^{-i\pi k/n} |h_k\rangle = |f_n^*\rangle \tag{20}$$

Note that these coefficients, for all canonical vectors, given by the powers of $\omega^* = e^{-i\pi/n}$, are situated on the complex unit circle, representing the various time steps of the actual units of the given process time, which are divided into discrete time intervals according to Eqs.(6,7). Note also that the pairing symmetry of the columns of $\boldsymbol{B}^{\dagger}$ exhibits bilateral symmetry, which leads to interesting conclusions regarding cognitive paradoxes, such as Necker's cube, Rubin's vase and the pirouette dancer. For a preliminary discussion and explanation, see Brändas (2019), but we will come back to it in the next section. One is usually careful to distinguish between optical- and visual illusions, with the first occurring between two possible perspectives while the latter is viewed as a cognitive or logical paradox caused by the brain, see (Khalil, 2021) for recent discussions. In our explanation of the aforementioned cognitive paradoxes, this distinction disappears. A more graphic and illustrative argument will be given in the next section, but first some words regarding the thermodynamic situation. The concern is to incorporate the various time scales from Eq.(6), i.e.,

$$t_l = t_{\mathrm{rel}}/(l-1);\ \ (l-1) = 1, 2, 3..n \tag{21}$$

into a steady state scenario, as stated above. The well-known Boltzmann formula, $S = k \ln \Omega$, displays maximum entropy at equilibrium, where Ω is the number of microscopic states corresponding to a given macro-state. One way to determine Ω is to consider the convex function $-x \ln x$ studied by Gibbs and being also the basis for von Neumann's ensemble theory. Since this function has a maximum at $1/e$, one finds for a thermal system, with n degrees of freedom, that Ω is given by e^n. Consequently, the maximum entropy of the thermal system becomes $S = nk$. However, a biological system evolves under constraining conditions. The entropy changes per unit time, $dS = 0$, can be divided into two parts (Prigogine et al., 1973); (Glansdorff & Prigogine, 1971), i.e.,

$$dS = dS_{\mathrm{e}} + dS_{\mathrm{i}}$$

where dS_{e} is the entropy flux due to exchanges of energy-matter with the environment, dS_{i} the entropy production due to the irreversible processes inside the system. The second law admits $dS, dS_{\mathrm{i}} \geq 0$. Under steady state condition, $dS = 0$, one might find a negative entropy flux, $dS_{\mathrm{e}} = -dS_{\mathrm{i}}$. Introducing the constraints, see also Eqs.(6,7) and the footnote 1, where $t_{\mathrm{corr}} = h/kT$, one finds

$$n = (l-1)t_l/\mathrm{t}_{\mathrm{corr}}$$

and

$$0 = \frac{dS}{S} = \frac{dn}{n} = \frac{dt_l}{t_l} + \frac{dT}{T};\ dS_e = -dS_i = -SdT/T < 0 \tag{22}$$

From Eq.(22) follows that a biological system, such as a cell, recognized by its duties and activities, under steady state conditions, will lower its entropy, provided there is entropy production, i.e., heat generated under the processes exercised in the overall organisation. Note that dT/T corresponds to the efficiency index in the classical Carnot process (Brändas, 2024). Obviously, this conclusion begs the question what type of information results from the negentropic gain? This will be the theme of the next section.

Before leaving this passage, one might wonder how the open system evolves in time, its relation to self-organization and how one might consider scaling up the nuclear skeleton to include higher order structures such as neurons, organs, and organisms. In principle this is not too difficult to do. One way is to build higher level structures based on the Liouville equation, (see e.g., Brändas,2021a; Obcemea & Brändas,1983). At the same time one can continue to extend the quality number, the dimension n, to a set of capabilities $(n_1, n_2, n_{3,} \cdots)$, corresponding to key cycles, discriminating or matching every cells position and duties in the systemic order of the organization. Take for instance a cell with a specific duty, such as the phosphorylation reaction related to ATP synthase from ADP, characterized by a process time, t_{rel}, of the order of milliseconds. At T =310 K, t_{corr} is about 10^{13} s, indicating a dimension, $n{\sim}10^{11}$, i.e., the covering of an immense number order of time scales. Nevertheless, there are two main points to be made. The first is the simple consequence that if the generator of the time evolution contains a Jordan block one obtains a finite polynomial factor in front of the exponential decay, i.e., leading to a Poissonian time evolution. The second is that the ensuing result is microscopic self-organization and increased lifetimes.

To see this, let us first consider the generator of time evolution, cf. the standard protocol of considering the Hamiltonian as the generator of time in quantum mechanics. Here we must take care of the generalizations, discussed above, i.e., maintain the extensions to the complex plane. For each cell that takes part in a collective, common organization, where the syntax for communication is the condition[6] $t_{\mathrm{rel}}/t_{\mathrm{corr}} = n$, defining a consistent quality number for each cellular activity, one needs to establish its open state dynamics. For instance, considering an organization of m cells, with the dimension of the actual transformation matrix $\boldsymbol{B}^{\dagger}$, increased to nm, one can build up a simple Liouvillian generator $\mathcal{P}$ as follows. For simplicity one utilizes dimensionless variables, with I, J being the corresponding identity and Jordan operators:

$$\mathcal{P} = (\nu_0 t_{\mathrm{rel}} - i)I + i\alpha J \tag{23}$$

with $\nu_0 = 1/t_{\mathrm{corr}}$, and the process time for the individual cell, t_{rel}. As proved above the boundary conditions of the type Eq.(21) imparts Jordan blocks of higher orders, nm, i.e., n times the number of cells involved. The parameter α might depend on the actual situation, but we will choose $\alpha = 1$ for simplicity, but see Eq.(18) for different choices. The evolution equation in dimensionless variables reads for the propagator $\mathcal{G}$

$$\begin{aligned}\mathcal{G}(t) &= \mathrm{e}^{-i\mathcal{P}t/t_{\mathrm{rel}}} \\ &= e^{-i\nu_0 t}\, e^{-t/t_{\mathrm{rel}}} \sum_{k=0}^{m-1} \left(\frac{t}{t_{\mathrm{rel}}}\right)^k \frac{1}{k!} J^k\end{aligned} \tag{24}$$

It is easy to prove that the standard microscopic decay law $dN(t) = -1/t_{\mathrm{rel}} N(t)dt$, where $N(t)$ is the transition probability[7], proportional to the absolute value of the propagator, working on the appropriate set of density matrices, Eq.(23), will be modified e.g., by considering the highest power $m-1$, i.e.,

$$\begin{aligned}&dN(t) = t^{-1}(m - 1 - t/t_{\mathrm{rel}})N(t)dt; \\ &dN(t) > 0;\;\; 0 < t < (m-1)t_{\mathrm{rel}}\end{aligned} \tag{25}$$

Hence it follows that $N(t)$ grows in agreement with the appearance of a cellular communication timescale, t_{org}, due to the irreducible perturbation J above, with $t_{\mathrm{org}} = (m-1)t_{\mathrm{rel}}$, or adding the decay time, mt_{rel}. Thus, the higher order dynamics introduces additional time scales in addition to those ranging from t_{corr} to t_{rel}. Note that the syntax is set by the quality numbers n, while the process of self-organization concerns the collective disposition of m cellular entities, yet they are invariably integrated.

In brief, open system dynamics requires self-references, in a set theoretic language Jordan blocks, determined by the boundary conditions that links the temperature, the time scales and the dimension of the system. In a sense the transition matrix ρ_{tr} acts as a channel for the signal, defining a syntax for communication, with the mean and variance equal to $t_{\mathrm{org}}/t_{\mathrm{rel}}$, yielding the band width and optimizing the possible length of the message m. Hence the cell can be imagined as a tuning fork, Eq.(23), coupled to a resonance box for each duty or task in the organization. At the same time the derived distribution suggests the metaphor of a telephone call centre. Note however that it is not the frequency of the signal, as displayed e.g., in Eqn.(23), that supports the semiotics of the information content provided. It is the infrastructure of the networking activity, transferred through the 'Jordan channels' that sustains the communications, from objective molecular interactions and correlations to '*bit from it*' and further the evolution of subjective experiences shaped by linking the material brain with the conscious mind (Brändas, 2021b). In the next section we will focus the attention on the actual qualities of the syntax.

6. Polygrams, syntax and iconicity

For those who have jumped sections 4 and 5, here is a quick background information. The path from the microscopic formulation, i.e., a quantum description for isolated systems, to open system dynamics, where the system exchanges energy and entropy with its surroundings, has been derived within steady state conditions, i.e., at $dS = 0$, where dS is the total entropy change per unit time. This condition comes with boundary conditions of generic time scales, linked with thermal correlations, Eq.(21), creating negentropic pockets, matching entropy production, Eq.(22). The final result is the derivation of a specific pair of unitary transformations, $\boldsymbol{B}^{\dagger}, \boldsymbol{B}$, which brings the open system density matrix from a spatiotemporal configuration at absolute temperature, T, to classical canonical form, represented by an n-dimensional Jordan block[8], equal to the number of sites in the nuclear matrix, as the latter are subject to long-range correlations via thermally correlated fermions. The matrix $\boldsymbol{B}^{\dagger}$ contains the canonical vectors as columns, where each element, expressed in terms of powers of

[6] The relation should include an integration over solid angle, see footnote 1.

[7] The standard decay law corresponds to the first term, $k = 0$.

[8] Note that Jordan blocks do not occur in the traditional quantum mechanical representation of stationary states.

$\omega^* = e^{-i\pi/n}$, is restricted to be situated on the unit circle in the complex plane, see **Fig. 1** below.

The n localized nuclear centers actualize vertices for a molecular clock, serving as the brain's timekeeper. However, this clock, as we will see, mixes a very large range of timescales. For instance, since the present picture is process driven, see above, these vertices are visited once, as programmed by each canonical column, but in each case running off a given number of rotations in the polygon, cf. the appearance of winding numbers in the Fourier-Laplace analysis (Brändas, 2021b). This calls for a 3D architecture of the clocks, see e.g., recent discussions on self-operating time crystal models by Singh et al., (2020), investigating the communication between artificial- and human brains[9]. These studies focused on timescales, ranging from conventional EEG signals to kHz, MHz, and THz. The new filament firings organize the dimensions dynamics of the neuron resonators, suggesting different brain maps. In particular, the brain appears as a timekeeper from femtoseconds to a million of years. The dimension $n = 12$ suggests a temporal platform, the DDG (dodecanogram), linking apparent symmetries, the pattern of primes, to the brain's cognitive response. However, there are here some important differences, in addition to the directly proven relation between the syntax and open system dynamics. Observing that the transformation $\boldsymbol{B}^\dagger$ can be represented by a polygon clock, **Fig. 1**, each vertex on the complex unit circle represents a nuclear site, here they are numbered from zero to 12, i.e., $'0' = '12'$. The clock metaphor is even more realistic as it takes 24 steps to complete a full 360-degree turn, see **Fig.1**. Note also that the various columns of the transformation correspond to counting up each site only once, but in a ordering fashion so that the polygon might be looped several times. However, the bilateral symmetry of $\boldsymbol{B}^\dagger$, i.e., the pairwise complex symmetry between its columns, indicate that, while the first half, corresponding to a clockwise move around the clock, the second half corresponds to a time reversed move in the other direction. Since the present formulation is invariant under combined parity-time-reversal operations, the two directed polygons have different parities with respect to each other, cf. the discussion[10] in Brändas (2019). The conclusion is that the brain is designed with a double set of ambiguous information, which in the cases, such as Necker's cube, the Rubin vase, the spinning dancer, where the two competing parity directions are crucial, will cause repeated reversals of the perceived orientation.

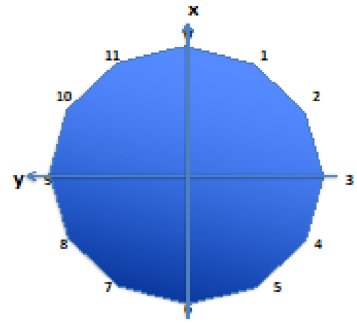


Figure 1. The unit circle in the complex plane model of the brain's clock as a polygon. Although purely temporal, it has a spatial connection in that each time step is represented by the associated entity of a particular column of $\boldsymbol{B}^\dagger$ referring to a particular site depending on its order in the list. Note also that the clock has to move around twice to complete the full 360 degree turn of the argument of the phase of ω^*, cf. am and pm.

However, the brain's timekeeper, the clock in **Fig. 1**, is not a practical device for coordinating the basic tasks and assignments between the fundamental entities of a biological system. We will here present a solution, although different in nature, still bears some deeper relation with the Crystal Model or the dodecanion manifolds (Singh et al., 2020; Singh et al., 2023). The trick is to interpret the vertex properties of the columns of $\boldsymbol{B}^\dagger$ as channels for transmitting communication to a receiver, while the edge morphing of information on a derived syntax comes with the columns of $\boldsymbol{B}$, see Eq.(19). With the genetic code as a tutelage, the case $n = 12$ remains an interesting example. By removing the one's in the first column the remaining 11 columns have the pronounced factorizations, Eq. (26), while also displaying a bilateral symmetry, similar but different as compared to the 12 columns of $\boldsymbol{B}^\dagger$.

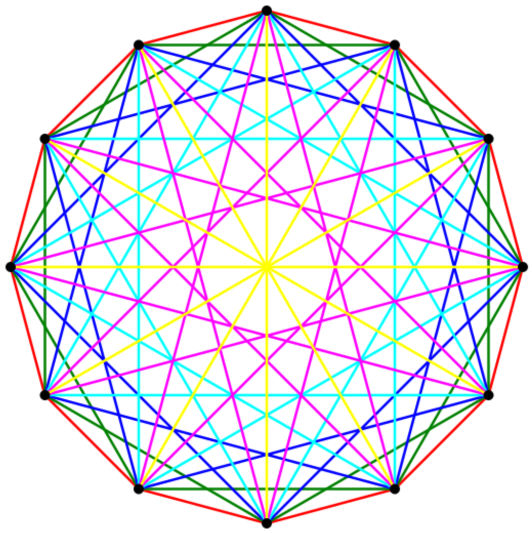
$$12\ \begin{matrix}6\\6\end{matrix}\ \begin{matrix}4\\4\\4\end{matrix}\ \begin{matrix}3\\3\\3\\3\end{matrix}\ 12\ \begin{matrix}2\\2\\2\\2\\2\\2\end{matrix}\ 12\ \begin{matrix}3\\3\\3\\3\end{matrix}\ \begin{matrix}4\\4\\4\end{matrix}\ \begin{matrix}6\\6\end{matrix}\ 12 \qquad (26)$$

The first observation, in addition to the symmetric structure above, suggests various ways of encoding,

[9] The most recent experiments were presented at the Science of Consciousness Conference, Encinitas 2023.

[10] Note that **Fig. 5** in Brändas (2019) refers to $n = 6$.

e.g., via Gödel numerals or by other systems (Brändas, 2011). The second is quite surprising as one recognizes that the algebraic structure displayed by the matrix $\boldsymbol{B}$ translates into the geometric structure K_n, i.e., a complete graph of polygons and polygrams, see **Fig. 2** for $n = 12$.



black: the twelve corner points (nodes)
red: {12} regular dodecagon
green: {12/2}=2{6} two hexagons
blue: {12/3}=3{4} three squares
cyan: {12/4}=4{3} four triangles
magenta: {12/5} regular dodecagram
yellow: {12/6}=6{2} six digons

Figure 2. Complete graph of all the dodecagons and dodecagrams[11], i.e., the complete graph K_{12}. Note that the Schläfli symbol {p/q} corresponds exactly to the factorized columns in Eq.(26).

The columns of $\boldsymbol{B}$, in Eq.(26), are pairwise related through complex conjugation and multiplication with (-1), the latter a rotation of π radians in the complex plane. The symmetric relationship suggests again a doublet set up of information, corresponding both to *what there is* and *its upside down*. Since the operations connecting them, corresponds to a reversal of all the three geometrical directions the brain design is here again characterized by a choice between two visual versions for the interpretations of its environment. This suggests why it is possible to learn how to orient oneself with a pair of glasses that turns everything up-side down, while the optical illusion, such as Necker's cube still remains.

[11]https://en.wikipedia.org/wiki/Dodecagram#Regular_dodecagram, Creative Commons Attribution-ShareAlike License 4.0

The isomorphic relation between a syntax, 'bit from it' (Brändas, 2024), derived from open system generalized transformations, inducing Jordan's normal form, and its geometric interpretation, generated by the polygraph (K_n), suggests a Darwinian evolution, where linguistic and visual forms provide expanding cognitive domains for communication. Since the visual representation, an icon, can represent something else than an arbitrary numerical table, the present correspondence alludes to the principle of iconicity (Givón, 1985), i.e., that it might go beyond the arbitrariness of language, i.e., cross the bridge between syntax and semantics (Perniss et al., 2010). From a chemical angle, the neurotransmitters and neuromodulators, guide the strengths of the neuron firing, in patterns that are, for instance constrained through the structure of the nuclear matrix and the traversing chemicals. Eq. (18) displays a typical neuronal spike, with the magnitude given by λ_L, see Eq.(9), and the pulse actualized and halted by $|f_1\rangle = |f_n^*\rangle$, see Eq.(20). The digon of the pulse, and the polygram syntax of the λ_S-part of ρ_{tr} in (18), characterizes the long-range order maintained at the temperature *T*, while communicating properly with its environment. Since the thermo-syntax derives from *it* under a steady state non-equilibrium mise-en-scène, there is no particular instant in the history of our universe, when a reflecting brain birthed, either from natural selection and/or from accidental random events. This insight suggests an interesting query: what is the maximum level of 'consciousness' or understanding that can be established by man-made machines (Poznanski et al., 2024).

7. Conclusions

For those that skipped section 5 for later, the steady state scenario under discussion, see Eqs.(21,22), entails a more radical and engrained complicacy than first anticipated. As an illustration let us return to the Chinese Room by modernizing the experiment, e.g., by replacing John Searle, including the book of English instructions etc., with a modern mobile telephone with direct access to the latest version of ChatGPT. Instead of sending unfamiliar characters through slots in the door of the room, messages are sent from a matrix of cell phones to the mobile device, which after a due process time by the AI program returns the required information to the senders. So far this is in line with the famous thought experiment in that it displays no intentionality or understanding since the ChatGPT is a man-made device that does not think. This experiment is also consistent with thermodynamics and a steady state scenario, $dS = 0$, where the steady flow of entropy in the environment of the open system, the latter consisting of the matrix of cell phones, the channels for sending emails, the particular phone in direct contact with the AI device and the program, will not change. As a result, cf. Eq. (22), the open system in communication with its environment will lower its entropy by matching the entropy production in the device[12].

However, a closer study of the situation requires more detailed expositions of the time scales involved, for instance one needs to examine the material substrates of the devices, invoking the properties of matter, their chemical reactions, with the associated complexity of time scales. Furthermore, this will not be enough, since the substances created by nucleo-synthesis in the stars will, as a necessity, take us all the way back to the big bang. Finally, there is the gathering of the components that permits the hardware of a computer to house a man-made program or software. Even if artificial, the existence of the device imparts an exploration of the time scales of its creator, which takes us back to biological Darwinian evolution. A similar argument entails the epistemic connection between the public desecration of a holy script and the progress of public security risks all in all depending on the ability, or inability, of the lawmakers to understand whether burning books is a civilized method or not to exercise communication. In fact, all prescriptions of law enactment depend on the rationales of an epistemological nature.

The thought processes have taken us all the way back to black hole thermodynamics with all its inherent intricacies. These aspects will also briefly readdress the introduction, i.e., the two conflicting views of nature[13]. To support a possible synthesis, three remarks will be offered (1) the addition of the principle of self-references to the laws of nature, (2) the absence of arbitrarily chosen boundary conditions, (3) the importance of time. The first point has a surprising side effect in that gravitational interactions are self-referential. As this being a fundamental property of gravity, traditional quantum theories for isolated systems cannot be wedded to black hole dynamics without the inclusion of (1), see Brändas (2022) for a viable argument where notably black hole dynamics is shown to be commensurate with a steady state scenario within generalized open system quantum formulations. The second point demonstrates that the present formulation of an evolving universe is not dependent on any specific arbitrary boundary condition, such as the standard metaphor of winding up a clock and letting the mechanism run its distance. Although seemingly comparable with Sir Fred Hoyle's classical Steady State Theory (Hoyle, 1948), it is not, since our universe is characterized as an open self-referential system, commensurate with its expansion, with no cosmological constant and with the black hole singularity providing channels between our and other universes.

Finally, the degree of freedom called time is essential for the present formulation. The universe is built on time scales (Quack, 2022) and they provide the evolution history of NATI. The constructive role of quantum thermal fluctuations supports self-organization, feeding energy and entropy into living systems under steady state conditions, maintaining life processes at specific time scales, while communicating chemical signals to its environmental ontogenetic workmates. A particular example is the patterns of communication or the syntax between the members of the neuronal system, for instance the reticular activating system, a lobe in the cerebral cortex or a more complex embedded structure like the hippocampus. The structure of the syntax and the associated design in the occipital lobe, is tied to a doublet set of information that in certain cases operates in such a way as to give rise to a cognitive paradox, e.g., Necker's cube. This bipartite function transcends the brain's timekeeper with a pair of directed polygrams that nurtures a measure for increasing time scales of the evolving brain and its history, the latter as an optimal model for artificial intelligence.

Conceding John Searle's argument that a computer cannot think, a corollary to Panexperiential materialism (Poznanski & Brändas, 2020), given the epistemic history behind the development of the computer, asserts that its subsistence supervenes logically on physics. However, this is an existence that goes beyond the present physical laws of nature in want of the law of self-references, with its associated substrate dependent time scale complexities and the possible appearance of intelligence. In reverse, the

[12] This argument can be given a more detailed formulation, see e.g., section 5 and footnotes 1 and 5.

[13] For a related, but slightly different perspective, see the Special Issue of International Journal of Quantum Chemistry celebrating the pioneering work of Ilya Prigogine, Antoniou et al. (2004).

philosopher David Chalmers could perhaps claim that NATI is a simulation (Chalmers, 2022). Yet, discussions of the type initiated in section 3, will inevitably lead to infinite regress and a confrontation with the Gödelian enigma. The sims would for instance develop a syntax for communication and possibly be as 'intelligent' as any generative AI. However, they could not be able to simulate a substrate dependent world before establishing its full epistemological knowledge or whether it ontologically does exist. The simulation would always be 'behind' Darwinian evolution, because the universe, or rather NATI, including us, sims etc., do not, or perhaps never will, experience the time scales necessary to complete the final picture, whatever this might turn out to be. In this sense we will continue to bear up a universe in our brain.

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