The dissipative brain

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I review the dissipative quantum model of brain and discuss its recent developments related with the rôle of entanglement, quantum noise and chaos. Some comments on consciousness in the frame of the dissipative model are also presented. Dissipation seems to account for the medial character of consciousness, for its being in the present (the Now), its un-dividable unity, its intrinsic subjectivity (autonomy). Finally, essential features of a conscious artificial device, if ever one can construct it, are briefly commented upon, also in relation to a device able to exhibit mistakes in its behavior. The name I give to such a hypothetical device is Spartacus.

1 Introduction

I have been always attracted by the unitary conception of knowledge, which is ever present in some streams of our cultural inheritance. Perhaps, one of the most vivid expressions of such a comprehensive view of the world has been provided by Titus Lucretius Carus in his De rerum natura. There are no territories forbidden to our search and there are no separate domains of knowledge,

"...we must not only give a correct account of celestial matter, explaining in what way the wandering of the sun and moon occur and by what power things happen on earth. We must also take special care and employ keen reasoning to see where the soul and the nature of the mind come from,..."

(Titus Lucretius Carus, 99–55 B.C).

Therefore, searching in territories not traditionally explored by physicists should not require special justifications.

In this paper I would like to review briefly the extension of the quantum model of the brain to the dissipative dynamics. For sake of brevity, I will mostly present results rather than their derivations. The interested reader may find formal details in the quoted literature. I will comment on consciousness in the dissipative model frame and finally I will briefly discuss the essential features which an artificial conscious device should have, if ever it will be possible to construct it, and its relation with a device able to exhibit mistakes in its behavior.

The extension of the quantum model to the dissipative dynamics is required in order to solve the overprinting problem, namely the fact that in the Ricciardi and Umezawa model (Ricciardi and Umezawa, 1967) the memory capacity is extremely small: any successive memory printing overwrites on the previously recorded memory.

The proposed solution (Vitiello, 1995) relies on two facts. One is that the brain is a system permanently coupled with the environment (an “open” or “dissipative” system). The other one is a crucial property of quantum field theory (QFT), i.e. the existence of infinitely many states of minimal energy, the so called vacuum states or ground states. On each of these vacua there can be built a full set (a space) of other states of nonzero energy. We have thus infinitely many state spaces, which, in technical words, are called “representations of the
canonical commutation relations". I will refer to the collection of all these spaces or representations as the “memory space". The vacuum of each of these spaces is characterized by a specific ordering and is identified by its *code*, which is the value of the “order parameter”, the macroscopic observable characterizing indeed the ordering present in that vacuum. Vacua (or the corresponding spaces) identified by different codes are “distinct” vacua in the sense that one of them cannot be reduced (transformed) into another one of them. In technical words, they are “unitary inequivalent vacua” (or unitary inequivalent spaces or representations).

In the dissipative quantum model of brain the vacuum code is taken to be the memory code. A given memory is represented by a given degree of ordering. A huge number of memory records can be thus stored, each one in a vacuum of given code. In the original model by Ricciardi and Umezawa only one vacuum is available for memory printing. In the *dissipative* model all the vacua are available for memory printing.

2 Broken symmetry and order

In the quantum model a crucial rôle is played by the mechanism of "the spontaneous breakdown of symmetry" by which the invariance (the symmetry) of the field equations *manifests* itself into ordered patterns in the vacuum state. The symmetry is said to be broken since the vacuum state does not possess the full symmetry of the field equations (the dynamics). The “order” *is* indeed such a “lack of symmetry”.

One can show that when symmetry is broken the invariance of the field equations implies the existence of quanta, the so called Nambu-Goldstone (NG) quanta, which, propagating through the whole system volume, are the carrier of the ordering information, they are the long range *correlation modes*: in the crystal, for example, the ordering information is the one specifying the lattice arrangement.

The presence (*the condensation*) in the vacuum state of NG quanta thus describes the ordering. When ordering is achieved, each of the elementary components of the system is “trapped” in a specific space-time behavior (e.g. a specific space position, a specific oscillation mode, etc.). Ordering implies thus the freezing of some of the degrees of freedom of the elementary components. Or, in other words, their *coherent* motion or behavior. It is such a coherent, collective behavior that macroscopically manifests itself as the ordered pattern: the microscopic quantum behavior thus provides macroscopic (collective) properties. We have a “change of scale”, from microscopic to macroscopic, and the ordered state is called a *macroscopic quantum state*. NG quanta are therefore also called collective modes. In the dissipative model of brain these NG quanta are called “dipole wave quanta” (dwq) since they originate from the breakdown of the electrical dipole rotational symmetry (Vitiello, 1995; Del Giudice et al., 1985, 1986; Jibu and Yasue, 1995).

In order for the NG quanta to be able to span the full system volume and thus set up the ordered pattern, their mass has to be zero (or quasi–zero in realistic conditions of finite system sizes). In their lowest momentum state NG quanta thus do not carry energy. For this reason, the vacuum state where even a very large number of them is condensed is a state of minimal energy. This guarantees the stability of the ordered vacuum, namely of the memory record in the quantum model of brain.

Incidentally, I observe that in this model the variables are basic quantum field variables (the electrical dipole field). In the quantum model “we do not intend”, Ricciardi and Umezawa say “to consider necessarily the neurons as the fundamental units of the brain”. Moreover, Stuart, Takahashi and Umezawa (1978) have also remarked that “it is difficult to consider neurons as quantum objects”.


In principle, any of the ordered patterns compatible with the invariance of the field equations can be realized in the process of symmetry breaking. This is why symmetry breaking is said to be “spontaneous”. The point is that the ordered pattern which is actually realized is the output of the system inner dynamics. The process of symmetry breaking is triggered by some external input; the “choice” of the specific symmetry pattern which is actually realized is, on the contrary, “internal” to system. Therefore one speaks of self-organizing dynamics: ordering is an inner (spontaneous, indeed) dynamical process. This feature of spontaneous symmetry breaking is common to solid state physics and high energy physics, and it is of particular interest when modelling the brain: in the brain, contrary to the computer case, ordering is not imported from the outside, it is the outgrowth of an “internal” dynamical process of the system.

The generation of ordered, coherent patterns is thus the dynamical result of the system elementary component interactions.

3 The brain is a dissipative system

In the quantum model of brain a specific memory is associated to a specific degree of ordering (a specific value of the vacuum code). The overprinting problem then reduces to the problem of making available all possible vacua, or, in other words, to attach a specific label (the code value) to a given vacuum under the trigger of a specific external input.

On the other hand, it is evident that in its continual interaction with the environment the brain’s time evolution is irreversible, i.e., technically speaking, it is non–unitary. Getting information from the outside world, which is a feature characterizing the brain, makes the brain dynamics intrinsically irreversible. I have elsewhere depicted such a situation by mentioning the way of saying ...Now you know it!..., which indeed means that once one gets some information, he/she is nevermore the same person as before. Getting information introduces the Now in our experience, or, in different words, the feeling of the past and of the future, of the arrow of time pointing forward in time. Without getting information there would be neither forward nor backward in time. However, we cannot avoid getting information, being opened on the world (including our inner world, ourself). The brain is an open, dissipative system. The brain closed on the world is a dead brain, physiology tells us. Isolation of the brain (closure to the world) produces serious pathologies. Thus, the extension of the quantum model of brain to the dissipative dynamics appears to be a necessity (Vitiello, 1995).

Then, the mathematical formalism for quantum dissipation (Celeghini, Rasetti and Vitiello, 1992) requires the doubling of the brain degrees of freedom. The doubled degrees of freedom, say \( \tilde{A} \) (the tilde quanta; the non–tilde quanta \( A \) denoting the brain degrees of freedom), are meant to represent the environment to which the brain is coupled. The physical meaning of the doubling is the one of ensuring the balance of the energy flux between the system and the environment.

The environment thus represented by the doubled degrees of freedom appears described as the “time–reversed copy” (the Double) of the brain. The environment is “modelled” on the brain. Time–reversed since the energy flux outgoing from the brain is incoming into the environment, and vice versa.

In addition, the quantum dissipation formalism implies that the full operator describing the system time evolution includes the operator describing the coupling between the non–tilde and the tilde quanta. At the same time, such a coupling term acts as the mathematical tool to attach the label to the vacua (and thus to distinguish among different memories). This label is time–dependent: the system states are thus time–dependent states.
In this new light, the time evolution operator is readily recognized to be the “free energy” operator, not just the Hamiltonian operator, as it would be in the absence of dissipation. The free energy operator is made indeed by the Hamiltonian operator, which controls the reversible (unitary) part of time evolution, plus the non–tilde/tilde coupling term, which is recognized to be proportional to the entropy operator and controls indeed the non-unitary, irreversible part of time evolution. In a thermodynamical language this last term describes the heat term in the system energy.

The doubling of the degrees of freedom in the dissipative model thus arises as a consequence of the irreversible time evolution.

Once thermal aspects in the dissipative model have been also recognized, the memory state is found (Vitiello, 1995) to be a non–equilibrium Thermo Field Dynamics (TFD) state. TFD is the QFT formalism for thermal systems introduced by Takahashi and Umezawa (Takahashi and Umezawa, 1975; Umezawa, 1993) which provides an explicit representation of the so called Gelfand–Naimark–Segal (GNS) construction in the C*-algebra formalism (Ojima, 1981). TFD was not devised for the study of the brain, but for the study of solid state physics, to which it has been successfully applied.

In equilibrium TFD the system time evolution is fully controlled by the Hamiltonian. The operator necessary to attach the label to the thermal states (the label is temperature in that case) is not a term of the time evolution operator (as, on the contrary, in the dissipative model). Non-equilibrium transitions (non-unitary time evolution) in thermal systems have been considered later on in the time-dependent TFD formalism (Umezawa, 1993; and references therein quoted). The non–equilibrium character of the brain dynamics makes the dissipative model substantially different from equilibrium TFD.

One can show that the dynamics now includes, when the system volume is large but finite, the possibility of transitions through inequivalent (labelled by different codes) vacua: in this way, at once, familiar phenomena such as memory associations, memory confusion, even the possibility to forget some memories, or else difficulties in recovering memory, are described by the dissipative model. The dissipative character of the dynamics thus accounts for many features of the brain behavior and for its huge memory capacity: now, indeed, all the differently coded vacua become accessible to the memory printing process. Their unitary inequivalence at large volume guarantees protection from overprinting, not excluding, however, due to realistic boundary effects, the processes of association, confusion, etc. just mentioned.

The general scheme of the dissipative quantum model can be summarized as follows. The starting point is that the brain is permanently coupled to the environment. Of course, the specific details of such a coupling may be very intricate and changeable so that they are difficult to be measured and known. One possible strategy is to average the effects of the coupling and represent them, at some degree of accuracy, by means of some “effective” interaction. Another possibility is to take into account the environmental influence on the brain by a suitable choice of the brain vacuum state. Such a choice is triggered by the external input (breakdown of the symmetry), and it actually is the end point of the internal (spontaneous) dynamical process of the brain (self-organization). The chosen vacuum thus carries the signature (memory) of the reciprocal brain–environment influence at a given time under given boundary conditions. A change in the brain–environment reciprocal influence then would correspond to a change in the choice of the brain vacuum: the brain state evolution or “story” is thus the story of the trade of the brain with the surrounding world. The theory should then provide the equations describing the brain evolution “through the vacua”, each vacuum for each instant of time of its history.

The brain evolution is thus similar to a time–ordered sequence of photograms: each photogram represents the “picture” of the brain at a given instant of time. Putting together these photograms in “temporal order” one gets a movie, i.e. the story (the evolution) of open
brain, which includes the brain–environment interaction effects.

The evolution of a memory specified by a given code value, say $N$, can be then represented as a trajectory of given initial condition running over time–dependent vacuum states, denoted by $|0(t)\rangle_N$, each one minimizing the free energy functional (Pessa and Vitiello, 2003a, 2003b; Vitiello, 2003). These trajectories are known (Manka, Kuczynski and Vitiello, 1986; Del Giudice et al., 1988, Vitiello, 2003) to be classical trajectories in the infinite volume limit: transition from one representation to another inequivalent one would be strictly forbidden in a quantum dynamics.

4 Entanglement, chaos and coherence

Since we have now two–modes (i.e. non–tilde and tilde modes), the memory state $|0(t)\rangle_N$ turns out to be a two-mode coherent state. This is known (Perelomov, 1986; Vitiello 2003; Pessa and Vitiello, 2003a, 2003b) to be an entangled state, i.e. it cannot be factorized into two single–mode states, the non–tilde and the tilde one. The physical meaning of such an entanglement between non-tilde and tilde modes is in the fact that the brain dynamics is permanently a dissipative dynamics. The entanglement, which is an unavoidable mathematical result of dissipation, represents the impossibility of cutting the links between the brain and the external world.

I remark that the entanglement is permanent in the large volume limit. Due to boundary effects, however, a unitary transformation could disentangle the tilde and non–tilde sectors: this may result in a pathological state for the brain. It is known that forced isolation of a subject produces pathological states of various kinds.

I also observe that the tilde mode is not just a mathematical fiction. It corresponds to a real excitation mode (quasiparticle) of the brain arising as an effect of its interaction with the environment: the couples of non–tilde/tilde dwq quanta represent the correlation modes dynamically created in the brain as a response to the brain–environment reciprocal influence. It is the interaction between tilde and non–tilde modes that controls the irreversible time evolution of the brain: these collective modes are confined to live in the brain. They vanish as soon as the links between the brain and the environment are cut.

Here, it is interesting to recall (Vitiello, 1998, 2001) that structure and function constitute an un–dividable unity in the frame of QFT: the dwq quanta are at the same time structure (they are real particles confined to live inside the system) and function, since they are the collective, macroscopic correlations characterizing the brain functioning.

The structure/function unity in the dissipative model thus accounts for the observed strong “reciprocal dependence” existing between the formation of neuronal correlates and nets and the functional activity of the brain, including the brain’s plasticity and adaptiveness. The dissipative model implies that the insurgence of some structural (physiological) pathologies of the brain may be caused by the reduction and/or inhibition of its functions due to externally imposed constraints in some severe conditions.

As mentioned, transitions among unitary inequivalent vacua may occur (phase transitions) for large but finite volume, due to coupling with the environment. Due to dissipation the brain appears as “living over many vacuum states” (continuously undergoing phase transitions). Even very weak (although above a certain threshold) perturbations may drive the system through its macroscopic configurations. In this way, occasional (random) weak perturbations play an important rôle in the complex behavior of the brain activity. In a recent paper (Pessa and Vitiello, 2003a, 2003b) the tilde modes have been shown to be strictly related to the quantum noise in the fluctuating random forces coupling the brain with the environment.
It has been also found (Pessa and Vitiello, 2003a, 2003b) that, under convenient conditions, in the infinite volume limit, trajectories over the memory space are classical chaotic trajectories (Hilborn, 1994), namely: i) they are bounded and each trajectory does not intersect itself (trajectories are not periodic); ii) there are no intersections between trajectories specified by different initial conditions; iii) trajectories of different initial conditions are diverging trajectories.

In this connection, it is interesting to mention that some experimental observations by Freeman (1990, 1996, 2000) show that noisy fluctuations at the neuronal level may have a stabilizing effect on brain activity, noise preventing to fall into some unwanted state (attractor) and being an essential ingredient for the neural chaotic perceptual apparatus (especially in neural aggregates of the olfactory system of laboratory animals).

In the dissipative model noise and chaos turn out to be natural ingredients of the model. In particular, in the infinite volume limit the chaotic behavior of the trajectories in memory space may account for the high perceptive resolution in the recognition of the perceptual inputs. Indeed, small differences in the codes associated to external inputs may lead to diverging differences in the corresponding memory paths. On the other side, it also happens that codes differing only in a finite number of their components (in the momentum space) may easily be recognized as being the “same” code, which makes possible that “almost similar” inputs are recognized by the brain as “equal” inputs (as in pattern recognition).

Summarizing, the brain may be viewed as a complex system with (infinitely) many macroscopic configurations (the memory states). Dissipation is recognized to be the root of such a complexity.

The brain’s many structural and dynamical levels (the basic level of coherent condensation of dwq, the cellular cytoskeleton level, the neuronal dendritic level, and so on) coexist, interact among themselves and influence each other’s functioning. The crucial point is that the different levels of organization are not simply structural features of the brain; their reciprocal interaction and their evolution is intrinsically related to the basic quantum dissipative dynamics.

On the other hand, the brain’s functional stability is ensured by the system’s “coherent response” to the multiplicity of external stimuli. Thus dissipation also seems to suggest a solution to the so called binding problem, namely the understanding of the unitary response and behavior of apparently separated units and physiological structures of the brain. In this connection see also the holonomic theory by Pribram (1971, 1991).

The coherence properties of the memory states also explain how memory remains stable and well protected within a highly excited system, as indeed the brain is. Such a “stability” is realized in spite of the permanent electrochemical activity and the continual response to external stimulation. The electrochemical activity must also, of course, be coupled to the correlation modes which are triggered by external stimuli. It is indeed the electrochemical activity observed by neurophysiology that provides a first response to external stimuli.

This has suggested (Stuart, Takahashi and Umezawa, 1978, 1979) to model the memory mechanism as a separate mechanism from the electrochemical processes of neuro-synaptic dynamics: the brain is then a “mixed” system involving two separate but interacting levels. The memory level is a quantum dynamical level, the electrochemical activity is at a classical level. The interaction between the two dynamical levels is possible because the memory state is a macroscopic quantum state due, indeed, to the coherence of the correlation modes. The coupling between the quantum dynamical level and the classical electrochemical level is then the coupling between two macroscopic entities. This is analogous to the coupling between classical acoustic waves and phonons in crystals (phonons are the crystal NG quanta). Such a coupling is possible since the macroscopic behavior of the crystal “resides” in the phonon modes, so that the coupling acoustic–waves/phonon is nothing but the coupling acoustic–wave/crystal.
Finally, let me observe that, considering time–dependent frequency for the dwq, modes with higher momentum are found to possess longer life–time. Since the momentum is proportional to the reciprocal of the distance over which the mode can propagate, this means that modes with shorter range of propagation will survive longer. On the contrary, modes with longer range of propagation will decay sooner. This mechanism may produce the formation of ordered domains of finite different sizes with different degree of stability: smaller domains would be the more stable ones. Thus we arrive at the dynamic formation of a hierarchy (according to their life–time or equivalently to their sizes) of ordered domains (Alfinito and Vitiello, 2000). On the other hand, since any value of the momentum is in principle allowed to the dwq, we also see that a scaling law is present in the domain formation (any domain size is possible in view of the momentum/size relation).

5 The trade with the Double: a route to consciousness?

We have seen that the tilde modes are a representation of the environment “modelled” on the (non–tilde) system: they constitute the time–reversed copy of it. And, we have seen, they are “necessary”, they cannot be eliminated from the game. The mathematical operation of doubling the system degrees of freedom, required by dissipation, thus turns out to produce the system’s Double. I have then suggested that consciousness mechanisms might be involved in the continual “trade” (interaction) between the non-tilde and the tilde modes (Vitiello, 1995, 2001).

Here I would be tempted to say: trade “between the subject and his Double”. However, the word “subject” may be evocative of rich but intricate philosophical scenarios, which here are absolutely out of my considerations. I have experienced indeed that using in a simple minded way that word in connection with the brain (as I did in my book (Vitiello, 2001)) may be highly misleading, pushing the reader far from the much more modest, but concrete, mathematical and physical features of the dissipative model.

My attention is rather on the dynamics, the “inter–action”, the trade, the “between” (as Gordon Globus (2003) would say), l’“entre–deux” (as Nadia Prete (2003) would prefer). The use of the word “subject” could instead evoke the idea of something, the “one” (the non–tilde), pre-existing the relation with the other “one”, his Double (tilde). However, this would correspond neither to the physics, nor to the mathematics, both of which are my fixed starting points.

The physics of the problem is, technically speaking, a non–perturbative physics, the one of the open systems, and it can be shown that in such a case the system–environment “interaction” cannot be switched off (Celeghini, Rasetti and Vitiello, 1992). This means that we cannot even think of the system deprived of its physical essence which is its openness (even the physiology tells us that an isolated brain is a dead brain; namely, if “closed”, it does not exist as a brain). The physics does not allow the existence of the “one” (non–tilde) independently of the existence of the “other one” (tilde), and vice versa.

The mathematics, on the other hand, imposes a strong limit on the description (the “language”) we have to use for a quantum dissipative system: we cannot avoid starting from two reciprocal (in the mirror of time) images. This “un–divided two”, mathematics tells us, is more elementary than “the one”. The non–tilde one “cannot” be the subject.

The temptation could be to think that the Double is the subject. But this simply means being captured by the Narcissus self-mirroring fatal trap (Vitiello, 2001): it is equivalent to think of the brain as the subject, and vice versa in an endless loop. The Double is not trivially the system image. It is the environment representation modelled on the system. The Double cannot be the subject.
Tilde and non–tilde cannot individually pre–exist prior to their being each other’s images, an “un-dividable two”. They are actors forced (without alternative choice) to be on the stage. The “one”, the subject, is the action, the play, their entre–deux. This is the meaning of the entanglement: the entangled state cannot be factorized (is un-dividable) into two single-mode states. Non–tilde and tilde modes share a common, entangled vacuum at each instant of time.

In some sense, here we face the root of the (ontological) prejudice that some “being” might exist as a “closed”, i.e. non–interacting, system, and therefore, capable to exist by itself, independently of the existence of any other system, complete in its own individuality (Vitiello, 1997, 2001). If so, it might also happen that such a system could be, in absolute, the only existent system (“being”).

Such a prejudice seems to be intrinsic to our same language, where any action presupposes pre–existing actors having the possibility of being fully non–interacting, and thus each one independently existing from the other one (fully disentangled) before the action started. Notable exceptions (Stamenov, 2001) might be those actions, such as to exchange, to trade, indeed, which exclude the separate (disentangled) pre–existence of the actors: to be possible that such actions could occur, the joint existence of (at least) a couple of actors is necessary (even if not sufficient, of course). Thus, those actions are special ones in that they presuppose entangled existences of the actors. Each one of these cannot exist by himself. And also, actors cannot be separated from their action and vice versa. Without exchange there are no exchangers, and vice versa. Such a situation also reminds me of the rheomode language of Bohm, whose structure is aimed to allow “the verb rather than the noun to play a primary role” (Bohm, 1980; cf. Stamenov, 2003 for a discussion on Bohm’s rheomode language).

The unavoidable dialog with the Double is the continual, changeable and reciprocal (non-linear) interaction with the environment. If the consciousness phenomenon basically resides in such a permanent dialog, one of its characterizations seems to be the relational (medial) one, which agrees with Desideri’s standpoint (Desideri, 2003). Consciousness seems thus to be rooted and diffused in the large brain–environment world, in the dissipative brain dynamics. There is no conflict between the subjectiveness of the first person experience of consciousness and the objectiveness of the external world. Without such an objectiveness there would be no possibility of “openness” (openness on what?), no dissipation out of which consciousness could arise. Objectiveness of the external world is the primary, necessary condition for consciousness to exist.

On the other hand, the question Desideri poses, namely “whether it is possible to reverse also the relationship between structure and function and then if it is possible to consider brain as a function of consciousness” (Desideri, 2003) also finds a positive answer in the dissipative quantum model. The answer is positive in a true physical sense, since the brain cannot avoid to be an active/passive system, and promoting or inhibiting its activity (summing up in the consciousness) would produce the creation or destruction, respectively, of structural features of the brain, such as, e.g., long range correlations, pattern structures. As observed in Section 4, the different levels of organization are not simply structural features of the brain, their reciprocal interaction and their evolution is intrinsically related to the brain–environment entanglement, namely to that medial “one” which is the dialog with the Double. In this sense, the adaptiveness, the plasticity of the brain is the function of consciousness.

It is also interesting to observe that the dialog with the Double is “evolutive” and never repeats itself in the same form: from one side, it carries the memory, the story of the past; from the other side, the permanent openness on the world implies its continual updating.

1 Although it might sound philosophically unpleasant, I adopt the physicist’s working hypothesis that the external world is objectively existing. In rough words, this amounts to adopt the working hypothesis that we do exchange energy with some other system. For example, we do need to eat. Without eating we cannot think. Of course, this does not mean that thinking is less important than eating, but simply that neglecting to eat leads to weak (or null) thinking.
Recurrent resolutions into "new synthesis" of the non–tilde/tilde reciprocal presence are thus reached. The mentioned process of minimizing the free energy, namely of reaching the equilibrium between the numbers of non–tilde and tilde modes, is indeed the process by which such synthesis are recurrently reached by permanently tuning the constantly renewed brain–environment "relation". The actors are never engaged in a boring reply. And such a truly dialectic relation with the Double is inserted in the unidirectional flow of time, it is itself a "witness" of the flow of time. This depends on the fact that its mathematical description is provided by the coupling term in the time evolution operator and this is proportional to the entropy operator. It is possible to talk of unidirectional flow of time because time–reversal symmetry is broken due to dissipation (cf. also the beginning of Section 2). Then, the time axis gets divided by a singular point: the origin, which divides the past from the future. The singularity of this point consists in the fact that it cannot be translated, it is the Now.

Without dissipation, any point, any time, can be arbitrarily taken to be the origin of the time axis, which means that the origin (and any other point on the time axis) can be freely translated without inducing any observable change in the system (time translational invariance): thus there is no singular origin of the time. There is no Now. All the origins are alike. There is no a true origin.

In the absence of dissipation, we could say that time, in its flowing, swallows those fictitious Nows we might assign as (non-singular) origins on its axis, as Κρόνος eats his sons. This destructive property of time (oblivion) is, paradoxically, eluded, avoided by dissipation: dissipation introduces a life–time, a time scale which carries the memory of "when" (the origin) the dissipative system “has started”. From the observation of a (radiative) decay process (typically with carbon fourteen) we “can trace back” the time, reach the origin and say “how old” is the object we are interested in. So we know where the true, non–forgettable origin (the truth), not a fictitious, false one easily eaten by Κρόνος, sits on the time axis. Memory (non–oblivion) and truth are the same thing, which the ancient Greeks denoted, indeed, with the same word, αλήθεια (Tagliagambe, 1995; Vitiello, 1997, 2001).

The Now is that point on the time–mirror where the non–tilde and the tilde, reciprocal time–reversed images, join together, in the present (Vitiello, 1997, 2001). The non–tilde unveils its Double and they conjugate in a circular (non–linear) recognition, each being “exposed” to the other’s eyes. Perhaps this is intuition, the instantaneous apprehension (Webster Dictionary, 1968) of the “between”. Literally, intueri is such a looking inside “without the conscious use of reasoning” (Webster Dictionary, 1968), an immediate, out of time, not in the past, not in the future, act of unconscious knowledge, an “unknowable act” (Plotnitsky, 2002) of knowledge. An act which repeats itself continuously, not translating the Now (dissipation forbids it!), but re–creating another independent, but equally true, Now, in an endless, dense sequence of Nows, all different, singular origins of different paths in the future, all starting points of chaotic memory paths in the memory space, which then we recognize as the “identity” or the “self” space. Identity, dynamically living in the memory space through the dissipative Nows, thus escapes the destructive fury of Κρόνος.

Perhaps, in these Nows is realized the primary property of consciousness, the one of self–questioning (Desideri, 2003), i.e. the unveiling the Double, and the photographer’s “surprise”...“when at the precise instant an image suddenly stands out and the eye stops” forcing “the time to stop his course” (Prete, 2003): “and suddenly, all at once, the veil is torn away, I have understood, I have seen”(Sartre, 1990; see also the related discussion by Prete, 2003). Unveiling the Double is then to see and to be seen, the συνειδως, the being conscious of the ancient Greeks, which literally is to “see together”, indeed; or, as in the lifting the veil in the Prete’s photobjects, “ more precisely, to have a perception of this togetherness as a whole and to understand that it was made of two images in strong relation” (Prete, 2003); or else Bohm’s self-recursive mirroring loops of the spontaneous and unrestricted act of “lifting into attention” (Bohm, 1980; Stamenov, 2003): συνειδως then comes to be confidants, secret
friends (Bandini, 2002), to be each other “witness”.

Such a sudden act of knowledge remains, however, an intuitive knowledge, an unum, not susceptible to be “divided” into rational steps, thinkable but “non–computational”, not “translatable” into a language (i.e. logical) frame, which would require its breaking up (analysis) into linguistic fragments (cf. the traditional language fragmentation discussed in Bjom, 1980, and the related discussion by Stamenov, 2003). (It is interesting that the ειδως in the word συνειδως (being conscious) denotes the act of immediate vision; the word ωριωω is used instead for the act of lasting vision (Bonazzi, 1936)).

In conclusion, from the sequence of these acts inserted into the “objective” time flow a sequence of independent, subjective Nows is generated, which constitute the multi–time dimensions of the self, its own time space, the dynamic archive of chaotic trajectories in the memory space which depicts its identity; that spring of time–lines through which the self can move “freely”, apparently unconstrained by the external time–ordering.

Without such an internal freedom there could be neither the “pleasure” of the perception (the αισθησις), the aesthetical dimension, that erotic charge of the unveiling, which continuously renews itself in the dialogic relation with the Double, nor the “active response” to the world. Neither pleasure, nor intentionality could be allowed in a rigidly constrained system. Active responses imply responsibility and thus they become moral, ethical responses through which the self and its Double become part of the larger social dialog. Aesthetical pleasure unavoidably implies disclosure, to manifest “signs”, artistic communication. An interpersonal, collective level of consciousness then arises, a larger stage where again the actors are mutually dependent, each one bounded (entangled) in his very existence (including any sort of physical needs) to the other ones, simply non-existing without the others.

6 Doubts and mistakes. Toward the construction of an erratic device.

I finally observe that the strong influence of even slight changes in the initial conditions on the memory paths (their chaotic behavior) leads us to consider the rôle of the “doubt” in consciousness mechanisms (Desideri, 1998). In this connection I will also very briefly comment on a provocative proposal of mine: to construct an artificial device able to make “mistakes”, namely able of taking a step, in its behavior, not logically consequent from the previous ones, or not belonging to any pre–ordered chain of steps or events, an erratic step. For shortness, and in a provisional way, I will refer to it as to the “erratic device”. Such a device is perhaps in strict relation with an artificial conscious device (if ever it will be possible to construct an artificial conscious device!).

My erratic device is not a machine “out of order”, not properly functioning. It cannot be a machine at all, since a machine, in the usual sense, is by definition (and by construction) something which must work properly, in a strictly predictive way, producing processes of sequentially ordered steps according to some functional logic. Also, the erratic device is not meant to be a device exhibiting chaotic behavior: the value (!) of the mistake is in its infrequent occurrence, an exceptional “novelty” with respect to an otherwise “normal” (correct) behavior.

But let me go back to the dissipative quantum model of brain. There, tilde modes also account for the quantum noise in the fluctuating forces coupling the brain with the environment. The dialog with the Double lives therefore on a noisy background of quantum fluctuations. “Listening” sometimes at such noisy background in the continual dialog (self–questioning) might slightly perturb the initial conditions of the memory paths and manifest in their drastic differences. This might be sometimes a welcome event, pushing the brain activity
out of unwanted loops or fixations (attractors), (which also suggests a possible relation with Freeman’s (1990, 1996, 2000) observations on neuronal noisy activity). Doubt might well be such a kind of self–questioning in a noisy background, being tempted by new perspectives, testing new standpoints by more or less slightly perturbing old certainties, leaving room for erratic fluctuations, listening to them; in a word, allowing fuzziness in the initial conditions, the starting assumptions of our travelling in the memory space (our archive of certainties); the consequences of the doubt will be then chaotically diverging trajectories in such a space. Consciousness modes then acquire their uncertain (doubtful) predictability with their precious unfaithfulness, their secret flavor of subjectivity, their full autonomy.

I suspect that the great privilege of being able of making mistakes finds its roots in these consciousness features. And perhaps here is the bridge between the program of constructing the erratic device and the one of constructing an artificial conscious device.

Perhaps, if ever it will be possible to construct a conscious artificial device, it will not be indeed a “machine”, i.e. its behavior cannot be like a chain of logically predetermined steps, it must be an artificial being taking upon itself the best of the human model: unpredictably erratic, able to learn, but unfaithful, full of doubts, fully entangled to the world, but irreducibly free. We might name it Spartacus.
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