Quantum dissipation and information: A route to consciousness modeling

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ABSTRACT

In the dissipative quantum model of brain memory recording is modeled as coherent condensation of certain quanta in the brain ground state. The formation of finite size correlated domains allows the organization of stored information into hierarchical structures according to the different life-times of memories and the size of the corresponding domains. The openness of the brain to the external world (dissipation) implies the doubling of the brain system degrees of freedom. The system obtained by doubling, the *Double*, plays the role of the bath or environment in which the brain is permanently embedded. It is suggested that conscious as well as unconscious activity may find its root in the permanent *dialogue* of the brain with its Double.

1 Information, Function and Structure

In this paper I will summarize the main features of the dissipative quantum model of the brain and discuss some aspects of the memory recording process which seem to have implications in the study of consciousness. The line of thought is the one which I have presented in my book "My Double Unveiled" (Vitiello 2001) and in a series of more technical papers. Some of the remarks I will make in the following may be of some interest to problems of information processing and related issues.

The experimental work by Lashely in the forties has shown that many functional activities of the brain cannot be directly related to specific neural cells, rather they involve extended regions of the brain. Pribram's work, confirming and extending Lashely observations, brought him in the sixties to introduce concepts of Quantum Optics, such as holography, in brain modeling (Pribram 1971; 1991). These results have been subsequently confirmed by many other observations and it is now well established that neural connectivity, rather than the single neuron cell activity, is of primary importance in the brain functional development (Greenfield 1997a; 1997b).

The description of the observed non-locality of brain functions, especially of memory storing and recalling, was the main goal of the quantum brain model proposed in the 1967 by Ricciardi and Umezawa (Ricciardi and Umezawa 1967; Stuart et al. 1978; 1979). This model is based on the Quantum Field Theory (QFT) of many body systems and its main ingredient is the mechanism of spontaneous breakdown of symmetry. In QFT spontaneous breakdown of symmetry occurs when the dynamical equations are invariant under some group, say G, of continuous transformations, but the minimum energy state (the ground state or vacuum) of the system is not invariant under the full group G. When this occurs, the vacuum is an ordered state and massless particles (the Nambu-Goldstone bosons (NG) also called collective modes) propagating over the whole system are *dynamically generated* and are the carriers of the *ordering information* (long range correlations): *order manifests itself as a global, macroscopic property which is dynamically generated at the microscopic quantum level*. For example, in ferromagnets the magnetic order is a diffused, i.e. macroscopic, feature of the system. In crystals the atoms are *trapped* in their sites by exchanging phonons, which are NG quanta establishing the inter-atomic long range correlation. Ordering in the crystalline structure, in the ferromagnetic one, in the superconductive one and in other ordered systems is thus achieved by the presence (condensation) of the collective modes in the vacuum state.

Since the NG collective mode is a massless particle, its condensation in the vacuum does not add energy to it: the stability of the ordering is thus insured. As a further consequence, infinitely many vacua with different degrees of order may exist, corresponding to different densities of the condensate. In the infinite volume limit they are each other physically (unitarily) inequivalent and thus they represent possible, different physical phases of the system: this appears as a complex system equipped with many macroscopic configurations. The actual phase in which the system sits is selected by some external agent among the many available minimum energy states. In other words, such an agent acts as a trigger of the spontaneous breakdown of symmetry process with the consequent condensation in the ground state of the NG modes, and in this way it induces the dynamical process of the ground state ordering.

Different external inputs or agents may thus lead to different degrees of vacuum ordering, namely to different phases of the system. The order parameter is a measure of these different degrees of ground state ordering. It is a label specifying the system phase.

In summary, the external agent can be viewed as the *source* of the information *channeled* by the NG modes in the system of elementary constituents (the *receiving* system). Different external inputs may lead to different orderings, or to different degrees of ordering in the system: the system gets thus ordered under the action of the external agent. In this sense, conventionally I talk of *ordering information*.

I would like to stress that in Quantum Mechanics (QM) the von Neumann theorem states that the spaces of the system states are all unitarily, i.e. physically, equivalent. This theorem does not hold in QFT since there the number of the degrees of freedom is infinite and thus there exist infinitely many unitarily inequivalent (i.e., physically inequivalent) state spaces. QM is thus not adequate for the description of the dynamical generation of ordered states for systems with many different phases. One needs QFT.

In the case of open systems, i.e. systems interacting with the environment and therefore possibly subjected to external actions, transitions among inequivalent vacua may occur (*phase transitions*). Dissipation, namely the energetic exchange with the environment, leads thus to a picture of the system "living over many ground states" (continuously undergoing phase transitions) (Del Giudice et al 1988c). Note that even very weak (although above a certain threshold) perturbations may drive the system through its macroscopic configurations (Celeghini et al 1990): (random) weak perturbations thus play an important role in the complex macroscopic behavior of the system.

The observable quantity specifying the ordered state, called order parameter, acts as a macroscopic variable since the collective modes present a coherent dynamical behavior. The order parameter is specific of the kind of symmetry into play. The value of the order parameter is related with the density of condensed NG bosons in the vacuum and specifies the phase of the system with relation to the considered symmetry. Since physical properties are different for different phases, the value of the order parameter may be considered as a *code* specifying the system state.

All of this is a well known story and the conclusion is that stable long range correlations and diffuse, non-local properties related with a code specifying the system state are *dynamical* features of *quantum* origin.

These features suggested to Ricciardi and Umezawa that a QFT model of the brain based on the mechanism of spontaneous breakdown of symmetry could be formulated in a such a way to account for the observed diffused character of the brain functions.

I remark that there is an *identification* in the QFT of ordered systems among *information, function and structure*. Consider, e.g., the crystal. The particles it is made of are not only the atoms sitting in their lattice sites, but also the phonons. These are real particles living in the crystal which can be observed for example by the scattering with neutrons. However, if the crystal is destroyed, e.g. by melting it at high temperature or by acting with some mechanical agent, the phonons are not found among the left out particles (the atoms): the phonons live as long as the crystal exists, they are indeed *dynamically generated* in the process of symmetry breakdown, as said above. They are the quanta of the long range correlation ordering of the atoms in the lattice sites. Thus the system *function* of being a crystal cannot be *separated* from the phonon *structure*. There is no crystal without phonons, and vice-versa. Similarly, the phonons are the carriers of the *ordering information* over the whole system. Without phonons the atoms would not *know* if and in which lattice site to sit, they would not be *trapped* in their sites by *exchanging* phonons. The *information* about the crystal lattice is thus *intrinsic*, *not detachable* from the crystal structure, and therefore it cannot be *separated*, made *distinct* from the crystal function. Information, function and structure are the *same* thing. And this identification has a *dynamical origin*.

2 The Early Quantum Model of Brain

In the quantum model, the brain elementary constituents are not the neurons and the other cells (which cannot be considered as quantum objects), but, in analogy with the QFT approach to living matter (Del Giudice et al 1985-1988b), they have been identified (Jibu et al 1994-1996) with the vibrational electric dipole field of the water molecules and other biomolecules present in the brain, and with the NG bosons (called the dipole wave quanta (dwq)) generated in the breakdown of the rotational symmetry of the electrical dipoles.

Memory printing is achieved under the action of external stimuli producing the breakdown of the continuous phase symmetry. The quantum model of the brain thus imports all the machinery of the spontaneous breakdown of symmetry introduced in the previous Section. The information storage function is thus represented by the coding of the ground state (the lowest energy state, or vacuum) through the coherent condensation of dwq collective modes (Stuart et al. 1978; 1979). The non-locality of the memory is therefore derived as a dynamical feature rather than as a property of specific neural circuits, which would be critically damaged by destructive actions or by single neuron death or deficiency.

The stability of memory demands that the dwq must be in the lowest energy state (the ground state), which also guarantees that memory is easily created and readily excited in the recall process. The long range correlation must also be quite robust in order to survive against the constant state of electrochemical excitation of the brain and the continual response to external stimulation. It is shown (Del Giudice et al.1988b) that the time scale associated with the coherent interaction of electrical dipole fields for water molecules is of the order of 10 to -14 *sec*, thus much shorter than times associated with short range interactions, and therefore these effects are well protected against thermal fluctuations. At the same time, the brain electrochemical activity must be coupled to the dwq. It is indeed the electrochemical activity observed by neurophysiology that provides a first response to external stimuli. The brain is then modeled (Stuart et al. 1978; 1979) as 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. It is an open problem to know the specific interactions relating these two levels. According to some studies (Jibu et al. 1994-1996; Vitiello 2001), the quantum, long range dipolar correlation in the water matrix plays a crucial role in the electrochemical activity. This points to the role of the glia cells in the biochemical brain activity (often overlooked in favor of the neuronal activity) and may constitute the link between the two levels. However, much work still has to be done in such a direction. For the sake of brevity I will not comment more on this still open crucial question.

The recall process is described as the excitation of dwq modes under external stimuli of a nature similar to the ones producing the memory printing process. In the words of Ricciardi and Umezawa, upon excitation of dwq from the ground state to higher energy states the brain "consciously feels" the pre-existing order (recall). This is similar to scanning a crystal by phonon excitation in order to read out its specific crystalline structure.

Long term memory is printed in the lowest energy state (the vacuum), which ensures its stability. Short-term memory is instead associated to metastable excited states of dwq condensate (Ricciardi and Umezawa 1967; Sivakami and Srinivasan 1983) and therefore it has a finite life-time. I will not, at this point, further discuss short-term memory. Let me instead observe that once some external input triggers the ground state ordering and memory is recorded in the ground state, a successive different input, in turn, produces a different ordering corresponding to the associated different memory recording. Such a successive input thus overwrites the previously recorded memory. This is similar to successive recording on the same portion of a magnetic tape: the last recorded voice or sound destroys the previous records. We have *overprinting*, or, in different words, we have a problem of *memory capacity*. We cannot store more than one memory at a time. The reason for this is that that portion of the tape may only be found in one single vacuum at a given time. Vacua labeled by different code numbers (different values of the order parameter, as explained in the previous Section) are accessible only through a sequence of phase transitions from one to another one of them. Thus in the Ricciardi and Umezawa brain model, where one single code (one single memory) is associated to each vacuum, each recording process destroys the previously stored information (*overprinting*): under a sequence of external different inputs the brain sets in a sequence of different vacua, only the last one surviving. This is a strong defect in the model.

A solution to such a problem of *memory capacity* could be found by assuming a huge number of symmetries for the brain system (a huge number of code classes for the brain Lagrangian) (Stuart, 1978; 1979). In such a case, one could have different classes of inputs associated with different symmetries. One could then have different memory recordings associated with the processes of the breakdown of the different symmetries. However, one still would not have solved the overprinting problem for inputs in the same class. In any case, Stuart, Takahashi and Umezawa (Stuart, 1978; 1979) were pointing out that such a theory, with such a huge, practically infinite, number of symmetries, would be completely out of any computational control, and therefore it would be not physically acceptable. The model would be completely useless.

However, there is another possibility of solving the overprinting problem without recourse to the introduction of a huge number of symmetries. In the next Section we will see how dissipation provides such a solution.

3 The Dissipative Quantum Model of Brain

The memory capacity can be enormously enlarged by considering (Vitiello 1995) the intrinsic dissipative character of the brain dynamics: the brain is an *open system* continuously coupled to the environment.

Let me denote the dwq by A(k) (here k generically denotes the field degrees of freedom, e.g. spatial momentum). As said in the previous Section, the dwq are the NG modes generated in the symmetry breakdown process under the external stimuli action. The number N(A) for all k of the A(k)-modes, condensed in the vacuum $|0(N)\rangle$, constitutes the *code* of the information.

In order to set up the proper canonical formalism for dissipative systems a standard result in QFT (Celeghini et al. 1992) requires the doubling of the A(k) operators by introducing their *time-reversed* copies, say Ã(k). I will come back soon to this point. Let me first observe that the crucial point of dissipative dynamics is that the vacuum state is now defined to be the state in which the *difference* N(A)-N(Ã) = 0, for all k. This means that also the state for which N'(A)-N'(Ã) = 0, with $N'(A) \neq N(A)$, is a vacuum state, and thus there are infinitely many simultaneous ground states, each one corresponding to a different value of the code N(A). Each of these ground states of code N(A) is thus associated to a correspondent memory. It can be shown (Vitiello 1995) that each of these states is unitary inequivalent to the other ones, and thus *protected* from unwanted interference (*confusion*) with other memory states. The unitary inequivalence among the degenerate vacua, i.e. the non-existence in the infinite volume limit of unitary transformations which may transform one vacuum of code N into another one of code N', guarantees that the corresponding printed memories are indeed *different* or *distinguishable* memories (N is a good code).

The brain (ground) state is then represented as the collection (or the superposition) of the full set of memory states $|0(N)\rangle$, for all N: The brain is described as a complex system with a huge number of (coexisting) macroscopic quantum states (the memory states). The dissipative dynamics introduces N-coded *replicas* of the system and, contrary to the non-dissipative quantum model, information printing can be performed in each replica without reciprocal destructive interference. A huge memory capacity is thus achieved (Vitiello 1995).

In the non-dissipative case the memory states are stable states (infinitely long-lived states): there is no possibility of forgetting (I am not considering here short-term memory states). To the contrary, in the dissipative case the memory states have finite (although long) life-times (Vitiello 1995). At some time t = t' the memory state $|0(N)\rangle$ is reduced to the *empty* vacuum $|0(0)\rangle$ where N(k) = 0 for all k: the information has been forgotten. At the time t = t' the state $|0(0)\rangle$ is available for recording a new information. It is interesting to observe that in order to not completely forget certain information, one needs to *restore* the N code (Vitiello 1995), namely to *refresh* the memory by brushing up on the subject (external stimuli maintained memory (Sivakami and Srinivasan 1983)).

In the dissipative model the recall mechanism is described in the same way as in the early quantum model and the unitary inequivalence among the differently coded memory states also avoids unwanted interferences (confusion) among memories.

I remark now that the Ã(k)-modes can be shown (Umezawa 1993; Celeghini et al. 1992; Vitiello 1995) to represent the environment. This is a mathematical consequence of the formalism, which, at a first sight, could be difficult to see since at the same time the tilde-modes are the time-reversed copy of the system. However, one can understand this point by noticing that the canonical formalism only deals with closed systems. Therefore in the study of an open system one must include the environment in the treatment in order to "close" the system. The point is that, *for such a task* it is not required to consider any detail of the environment, nor its coupling to the system. In order to "close" the system one only needs to "balance" the energy fluxes, and this is why the environment can be simply, but efficiently, represented by the exact copy of the system, exact except for the exchange of the "in-coming" with the "out-going", namely the time-reversed copy. The copy needs to be "exact" since we want "balance". I also remark that since the environment cannot be neglected in the formalism, so the Ã(k)-modes cannot be neglected. Moreover, for different systems, we have different Ã(k)-representations of the environment: this is a simple mathematical implication of the canonical formalism which requires full equivalence (a part time-reversal) of the A and Ã systems (in this sense, A is the time-reversed copy of the environment). The reader should not be upset if I will refer to the Ã's as the system's *subjective* representation of the environment. Although I only refer with this term to the just mentioned mathematical implication, nevertheless the way is open to some conjectures which I will present in the Section 6. Let me also stress that the tilde-modes also enter in the memory states (and therefore in the brain state), as said above. They are indeed described as the *holes* of the A-modes (Umezawa 1993), in a way very similar to the description of particle-hole couples in condensed matter physics, where holes are observed as real excitations (e.g. in a semiconductor).

4 Finite Size Memory Domains

Consider now the case in which the dwq frequency is assumed to be time-dependent (the parametric dissipative model). The time-reversed copy Ã of the dwq can be still introduced. One finds that the couple of equations describing the dwq A and the doubled modes Ã is equivalent to the spherical Bessel equation of order n (n integer or zero) (Alfinito and Vitiello

2000b) . The coupled system A-Ã is then described by a parametric oscillator of frequency $f(n(k,t))$. There is no need to give here the specific mathematical expression of this frequency (see Alfinito and Vitiello 2000b for that). I only need to remark that the time-dependence of this frequency means that, in this parametric case, energy is not conserved in time and therefore that the A-Ã system does not constitute a fully closed system (Ã is a non-complete, partial representation of the environment, something of the environment is left out). However, when $n \to \infty$, $f(n)$ approaches to a constant, i.e. in such a limit the energy is conserved and the A-Ã system gets closed (Ã becomes in that limit the representation of the full environment). Thus, as $n \to \infty$ the system A is described as *fully* coupled to the environment. This suggests that n represents the number of *links* between A and the environment. When n is not very large (infinity), the system A (the brain) has not fulfilled its capability to establish links with the external world. Moreover, n *graduates* the rate of variations in time of the frequency, i.e. the *rapidity* of the system response to external stimuli. The time span useful for memory recording (the ability of memory storing) is found to grow as the number of links with the external world grows: the more the system is open to the external world (the more links), the better it can memorize (high ability of learning). The ability in learning may be different under different circumstances, at different ages, and so on.

One can show that the memory recording can occur only when the frequency $f(n(k,t))$ is real. This happens only when the momentum k is greater or equal to some momentum q which depends on n, t, and on some characteristic parameter L of the system, $q \equiv q(n,t, L)$. In turn this implies that only wave-lengths $\lambda \leq 1/q$ are allowed: $1/q$ plays the role of a cut-off. Thus (coherent) domains of sizes less or equal to $1/q$ are involved in the memory recording. The cut-off shrinks in time for a given n. On the other hand, a growth of n opposes such a shrinking. These cut-off changes correspondingly reflect on the memory domain sizes. It is thus expected that, for a given n, *more impressive* is the external stimulus, i.e. the greater the number of high momentum excitations produced in the brain, the more *focused* the *locus* of the memory.

The finiteness of the size of the domains implies that transitions through different vacuum states at given t become possible. As a consequence, both the phenomena of *association of memories* and of *confusion of memories*, which would be avoided in the regime of strict unitary inequivalence among vacua (i.e. in the infinitely long wave-length regime), are possible (Vitiello 1995; Alfinito and Vitiello 2000b). I also note that, due to finiteness of the size of the domains, the irreversibility of the dynamics is not strictly enforced as it would be in the infinitely long wave-length regime. In particular, modes with larger k are found to have a longer life with reference to time t. Only modes allowed by the cut-off are present at a certain time t, for the other ones have decayed. This introduces a hierarchical organization of memories depending on their life-time: memories with a specific spectrum of k mode components may coexist, some of them dying before, some other ones persisting longer. The (coherent) memory domain sizes are correspondingly larger or smaller.

I further note that, as an effect of the difference in the life-times of different k modes, the spectral structure of a specific memory may be *corrupted*, thus allowing for more or less severe memory *deformations*. This mechanism adds up to the memory decay implied by dissipation.

Finally, I observe that the finiteness of the domain size is known to imply a non-zero effective mass of the dwq. Such a mass acts as a threshold in the excitation energy of the dwq so that, in order to trigger the recall process, an energy supply equal or greater than such a threshold is required. When the energy supply is lower than the threshold a *difficulty in recalling* may be experienced. However, the threshold may also positively act as a *protection* against unwanted perturbations (e.g. thermalization) and cooperate to the stability of the memory state. In the case of zero threshold (infinite size domain) any replication signal could excite the recalling and the brain would fall in a state of *continuous flow of memories* (Vitiello 1995).

5 Dissipation and Information

I remark that once certain information has been recorded under the action of some external stimulus, then, *as a consequence*, time-reversal symmetry is also broken (Vitiello 1995; 1998; 2001): *After* information has been recorded, memory stability implies that the brain cannot be brought to the state in which it was *before* the information printing occurred. This is, after all, the content of the warning: *NOW you know it!...* Once you come to know something, you are another person. This means that in brain modeling one is actually obliged to use the formalism describing *irreversible* time-evolution. Due to the memory printing process time evolution of the brain states is *intrinsically* irreversible: The same fact of getting information introduces *the arrow of time* into brain dynamics, namely it introduces a partition in the time evolution, i.e., the *distinction* between the past and the future, a distinction which did not exist before the information recording. Before the recording process time could be always *reversed*.

It can be shown that dissipation implies that time evolution of the memory state is controlled by the entropy variations (Vitiello 1995; Alfinito and Vitiello 2000b): this feature reflects, indeed, the mentioned irreversibility of time evolution, namely the choice of a privileged direction in time evolution. We thus recover, in a completely unexpected way, a strict connection between information and entropy. This holds true also in the case of the formation of finite size coherent domains which smooths out, but does not eliminate the strict irreversibility of the dynamics.

In particular, we have seen that the intrinsic dissipative nature of the brain dynamics guarantees the existence of infinitely many degenerate vacua, namely the *possibility* of having a huge memory capacity. But it is indeed such a *possibility,* the characterizing feature of information which is in fact computed, according to Shannon, in terms of the *possible choices* among the available alternatives. I stress, however, that, while in the latter the possibilities are referred to the information *source*, in the dissipative quantum model the information source, i.e. the environment, is represented by the Ã system which at the same time is also the *copy* of the brain, i.e., in some sense the source *coincides* with the *receiver*. Moreover, we have seen above that, when the dwq frequency is assumed to be time-dependent, finite size coherent domains are generated, which smooth out the strict inequivalence among the degenerate vacua, thus reducing the number of possible choices (some of the vacua may have non trivial overlap). Such a feature, as already observed, is of advantage in the memory storing and retrieval, since it allows *paths* or *associations* leading from memory to memory, thus improving the *handling* of the huge memory storing and retrieval. In information theory it is known that the adoption of coded restrictions (a conventional set of *rules* or *restrictions*) on the full set of possible choices present in the source improves the information transmission. In the dissipative model these restrictions are *dynamically* introduced through the finite size domain formation. In the following Section I will comment on how the input (*the signal*) may acquire, for the receiving subject (the system A), a *significance* (it acquires a *sense* or *meaning*). It is an interesting question asking about the relation between the dissipative quantum model of brain and semiotics from one side, and linguistics from the other side (Stamenov 1997).

Finally, let me observe that the stationary condition for the free energy functional leads one to recognize the memory state $|0(N,t)>$ to be a finite temperature state (Umezawa 1993), which opens the way to the possibility of thermodynamic considerations in the brain activity. In this connection, I observe that the *psychological arrow of time* which emerges in the dissipative brain dynamics turns out to be oriented in the same direction of the *thermodynamical arrow of time*, which points in the increasing entropy direction. It is interesting to note that both these arrows, the psychological one and the thermodynamical one, also point in the same direction of the *cosmological arrow of time*, defined by the expanding Universe direction (Alfinito et al. 2000a; Hawking and Penrose 1996).

6 Dissipation and Consciousness

In this Section I will present some conjectures and interpretations suggested by the mathematical features of the dissipative quantum model. Much work is still needed in order to clarify many questions related with the interpretations and the comments presented below. It is, however, interesting that some mathematical features of the model may have, already at this stage of the research, surprisingly far reaching, although qualitative, implications on consciousness study and related issues. In what follows I will not consider conclusions derived by other theoretical approaches and all the statements are always restricted and referred to the framework of the dissipative quantum model.

The coupling of A with Ã describes nonlinear dynamical features of the dissipative model. The nonlinearity of the dynamics describes a self-interaction or back-reaction process for the A system. Ã thus also plays a role in such self-coupling or *self-recognition* processes. The Ã system is the *mirror in time* image, or the *time-reversed copy* of the A system. It actually duplicates the A system, it is the A system's *Double* and since it can never be eliminated, the A system can never be separated from its Double. The role of the Ã modes in the self-interaction processes leads me to conjecture that the tilde-system is actually involved in consciousness mechanisms (Vitiello 1995; 2001). Dissipation manifests itself as a *second person*, the Double or *Sosia* (Plautus, 189 B.C.), to dialogue with.

Consciousness seems thus to emerge as a manifestation of the dissipative dynamics of the brain. In this way, consciousness appears to be not solely characterized by a subjective dynamics; its roots, on the contrary, seem to be grounded in the permanent *trade* of the brain (the subject) with the external world, on the dynamical relation between the system A and its Sosia or Double Ã, permanently joined to it. Consciousness is reached *through* the opening to the external world. The crucial role of dissipation is that self-mirroring is not anymore a *self-trap* (as for Narcissus), the conscious subject *cannot* be a monad. Consciousness is only possible if dissipation, openness onto the outside world is allowed. Without the *objective* external world there would be no possibility for the brain to be an open system, and no Ã system would at all exist. The very same existence of the external world is the *prerequisite* for the brain to build up its own *subjective simulation*, its *own representation* of the world. It is an interesting question to ask about the possible relation of the dissipative quantum model, and of the doubling of the degrees of freedom, with the "two worlds" or the dyadic reality analyzed in Taborsky 2000.

The informational inputs from the external world are the *images* of the world. Once they are recorded by A they become the *image* of A : $\tilde{A}$ is the *address* of A, it is identified with (is a copy of) A. We have seen that such a memory recording process implies a *breakdown*, a *lack* of symmetry: memory as *negation* of the symmetry which makes things indistinguishable among themselves (Vitiello 1998; 2001); memory as *non-oblivion*, literally the αληθεια of the ancient Greeks. It is interesting that the same word was used by them to denote the *truth*.

As already mentioned in Section 4, the finiteness of the size of the correlated domains implies that recording memories requires some expense of energy (the one required by the non-zero effective mass of the dwq). This suggests that, unavoidably, we are led to make a *choice*, an *active* selection among the many inputs we receive: we record only those that we judge worthwhile to expend some energy for. In other words, the ones to which we attribute a *value*, which involve our *commitment* (*emotion*). It is the specific information received through those selected inputs which then becomes *our memory*, it becomes *our truth* (αληθεια, indeed). It is here, in the map of such values, that our memory depicts our *identity*. In fact, mathematically speaking, in the model the brain state is *identified* by the collection of the memory codes. It will be interesting to consider these suggestions of the dissipative model in connection with the mechanisms involving values and emotion in other theoretical models (see, e.g. Perlovsky 2001). I leave this to a future analysis.

The dissipative model also excludes any rigid *fixation* or *trapping* in certain states. Such a plasticity implies that we are not simply spectators or victims of *passive perceptions*. Active perceptions, our active choices have also a part in our continuous interplay with the world. Freeman stresses that brain actually processes *meanings* rather than information (Freeman 2000). In his view meanings are *intended actions*, namely the meaning belongs to, *is in* the subject and arises from the active perception of that subject, which includes intentionality. The brain as an adaptive system permanently conjugates the memory of the past, namely the knowledge of the causes, which deterministically pushes forward, with the goal-oriented activity (Freeman's intended actions) of the present, which teleologically attracts to the future. The conjecture is here that tilde-modes express meanings or *meaningful representations* rather than just representations.

The dissipative model thus seems to suggest that one reaches *an active point of view* of the world (Vitiello 1998; 2001; Desideri 1998), which naturally carries in it the *unfaithfulness* of subjectivity. But such unfaithfulness is precious. It is exactly in such an unfaithfulness that the map of the values which *identify* the subject has to be searched. It is in the above discussed processes that the external *signal* acquires a *sense*, a *meaning.* The comparison of the dissipative model with other theoretical schemes (e.g. with Perlovsky 2001) on these issues would be very interesting but beyond the tasks of the present paper.

Note that the above mentioned self-recognition process includes reflection loops as well as control loops of the subject-environment interaction. Due to the self-identification process these loops are self-reference loops (Cordeschi et al. 1999).

Finally, the dissipative quantum model seems to imply that the conscious identity emerges *at any instant of time*, in the *present*, as the minimum energy brain state which separates the past from the future, that *point* on the *mirror of time* where the conjugate images A and Ã join together. In the absence of such a mirroring there is neither consciousness of the past, nor its projection in the future: the suggestion is that consciousness does not arises solely from the subject (*first person*) inner activity, without opening to the external world. In the dissipative quantum model the intrinsic dissipative character of the brain dynamics strongly points to consciousness as *dialogue* with the inseparable own Double (Vitiello 1998; 2001). Clarifying these issues in future studies will be a challenging task.

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