ISSN 1063-7796, Physics of Particles and Nuclei, 2010, Vol. 41, No. 3, pp. 425–451. © Pleiades Publishing, Ltd., 2010.

Quantum Information, Oscillations and the Psyche[1]

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Received February, 2009

Abstract—In this paper, taking the theory of quantum information as a model, we consider the human unconscious, pre-consciousness and consciousness as sets of quantum bits (qubits). We view how there can be communication between these various qubit sets. In doing this we are inspired by the theory of nuclear magnetic resonance. In this way we build a model of handling a mental qubit with the help of pulses of a mental field. Starting with an elementary interaction between two qubits we build two-qubit quantum logic gates that allow information to be transferred from one qubit to the other. In this manner we build a quantum process that permits consciousness to "read" the unconscious and vice versa. The elementary interaction, e.g. between a pre-consciousness qubit and a consciousness one, allows us to predict the time evolution of the pre-consciousness + consciousness system in which pre-consciousness and consciousness are quantum entangled. *This time evolution exhibits Rabi oscillations that we name mental Rabi oscillations*. This time evolution shows how for example the unconscious can influence consciousness. In a process like mourning the influence of the unconscious on consciousness, as the influence of consciousness on the unconscious, are in agreement with what is observed in psychiatry.

DOI: 10.1134/S1063779610030032

1. INTRODUCTION

For more than twenty years quantum models of consciousness have grown in number (see references [1–9] among others). Most of these models presuppose the existence in the brain of a quantum physical phenomenon that leads to the emergence of consciousness. For some of them, this phenomenon is Bose-Einstein condensation which shares with consciousness the property to be global.

However, about sixty years ago, following a different approach, in the framework of theories considering dual-aspect approaches of the mind-matter problem, Jung and Pauli had already assumed that the human unconscious obeys quantum laws [10–13].[2] It is in this framework that Baaquie and Martin [9] proposed a quantum field theory of the human psyche, this theory applying more to mental states than to physical states of the brain.[3]

Let us notice that dual-aspect approaches to mind and matter as manifestations of one underlying reality in which mind and matter are unseparated go back to the holistic reality, *unus mundus*, the "one world" of the 16th century alchimist Gerhard Dorn. This *unus mundus* could be related to Plato's world of ideas.

The observation of correlations at a distance between several minds, just as the observation of *synchronistic* phenomena, lead us to postulate a non-localization of unconscious mental states. These states are not exclusively localized in the human brain. Mental states are correlated (probably via quantum entanglement) to physical states of the brain but they are not reducible to those physical states.

With regard to *synchronistic* phenomena, i.e. meaningful coincidences between a mental state (subjective) and an event occurring in the external world (physical state; objective), those phenomena corroborate the fact that the limit between the observed object and human consciousness does not really exist. In this respect we are going further than Stapp [4].

In previous articles [15, 16] we tried to model the awareness of unconscious components from the present theories of quantum measurement, consciousness acting like a measuring device. We con-

[1] The article is published in the original.

[2] Concerning this subject we shall read with interest the review of H. Atmanspacher, *Quantum Approaches to Consciousness*, in the Stanford Encyclopedia of Philosophy [14]. This paper reviews the situation on present quantum theories of consciousness.

[3] Nevertheless one does not exclude the other.

cluded that the model of quantum information of Cerf and Adami [19], in which there is no collapse of the wave function, seems to fit better to the phenomenon of awareness, because it does not alter so much the state of the unconscious. Let us notice that Everett's "Relative State" or "many-worlds" theory [20–22] can also serve the purpose.

In papers [15] and [16] we also tried to build up a quantum model of the correlations at a distance appearing between several minds, for example between two people (e.g. Alice and Bob) or in a group of people (group correlations).

Several authors studied conscious and unconscious mind [17, 18]. The states of unconsciousness are defined by these authors as quantum states, and the states of consciousness as attractors of the dynamical system—a classical system. In fact this kind of consciousness could be such as when you ask to a person what he is thinking about "right now": answering the question results in introspection and in the collapse of a superposition of states into a single thought. The thoughts are in quantum superposition until you answer the question. But this kind of consciousness is only a part of consciousness. It is the part of consciousness that, through an act or a choice, leads to the illusion of the collapse of the wave function. It is a simplification of the more complex consciousness that permits a person to live a "normal" life where people need to think, understand and connect several thoughts at the same time.

Present theories of quantum measurement presuppose quantum entanglement of the observed quantum system with a measuring apparatus also considered as a quantum system. This quantum entanglement can be achieved through several *ancillae*. Eventually the created system quantum entangles itself with the environnement and with the observer. Analogically, in articles [15] and [16], we have assumed that a quantum state of the unconscious becomes quantum entangled with consciousness, this entanglement being also achieved through several *ancillae,* constituted, in this case, by the *insight* or by quantum states of pre-consciousness. The quantum entanglement of this system with the environnement, or with other parts of the unconscious, leads consciousness to have access not to a pure quantum state, but to a (statistical) mixing. Indeed, a great number of information, to which consciousness has no access, gets loose in the environnement or in the unconscious. However that may be, among "classicaly" possible quantum states that can reach consciousness, i.e. pointer-states, only one reaches the consciousness of one human being at a given time. Presently the uniqueness of this state remains a mystery. Does consciousness make a choice? Is it a spontaneous symmetry breakdown that leads to this uniqueness of a conscious state? As postulated by Michael B. Mensky, is awakened consciousness, by definition, the separation between the various quantum states that are "classicaly" possible, the separation between the various "pointer-states" [22–25]?

Let us emphasize that in the works of Everett [20], Zurek [21] and Mensky [22–25], the observer's consciousness is considered as a quantum state and not as a classical one. In these works classicality, and consequently the collapse of the wave function, are considered as illusions. It is this point of view that we follow in this article.

In this paper, taking the theory of quantum information as a model [26], and more specifically nuclear magnetic resonance theory (NMR) [28, 29], we investigate interaction processes between unconscious, pre-consciousness and consciousness. Those processes lead to quantum entangled states of the three systems. For simplicity we restrict ourselves to interactions between two qubits, a qubit corresponding to a binary situation. This limitation does not undermine the generality of our reasoning since a certain amount of information contained, for example in the unconscious, could be embodied in a set of qubits. As an example of a mental binary situation we consider the process of mourning [15], [30].

We also study how the interactions that we investigate could allow us to predict the time evolution of the quantum entangled systems, e.g. unconscious-(pre-consciousness)-consciousness. In this way we are able to predict how the unconscious can influence consciousness and vice versa, the implementation being considered in the case of the mourning process.

Still by analogy with the theory of quantum information and nuclear magnetic resonance (NMR), we study how to control a qubit of the unconscious, pre-consciousness or consciousness. This control technique carried out in NMR with the help of magnetic fields is, in our case, carried out with the help of a psychic field emitted by consciousness, by our unconscious, or by the unconscious of another person, ... The implementation of a two-qubit quantum gate, the controlled-NOT gate, essential in quantum information, is investigated. We consider also the exchange between two qubits (swapping), for example the swapping of a qubit of the unconscious with a qubit of pre-consciousness.

In this article we also build an explicit model of interaction between the unconscious of two different subjects (e.g. Alice and Bob) which, as suggested in papers [15] and [16], leads to the quantum entanglement of the two unconscious. As written above this quantum entanglement of the two unconscious could explain the long-distance correlations that appears between several individual minds. But it could also explain how an unconscious can interact with another unconscious, for example during a seance of psychoanalysis.

Let us notice that, in all processes that we investigate (unconscious/unconscious, pre-consciousness/consciousness, ...), quantum information theory

and the analogy with NMR lead to Rabi oscillations. Those oscillations can be of paramount importance for mental systems. Thus neuroscientists discovered "oscillations" as interhemispheric switchings in the brain in the case of binocular rivalry (see for example references [31, 32]).

The outline of the article is the following: in Section 2, as a preamble, we consider analogies between unconscious processes as studied by Jung and some quantum physics processes. In Section 3, we investigate the analogy between a mental qubit and a NMR qubit. From the control of a qubit in NMR we deduce the control of a mental qubit. In Section 4, we consider the possible interactions between two qubits. We implement a controlled-NOT logic quantum gate in NMR as well as for two mental qubits. In Section 5, we study the interaction between pre-consciousness and consciousness as inferred from an elementary interaction between two qubits in quantum information theory (or in NMR). Thanks to one or several swappings between the unconscious and pre-consciousness we deduce the influence of the unconscious on consciousness. We investigate various cases due to various initial states of the unconscious and consciousness, whereof the general case. In Section 6, we say a few words on reciprocity, i.e. on the influence of consciousness on the unconscious. In Section 7, we study the interaction between two unconscious as a consequence of the elementary interaction considered between two qubits. In Section 8, we carry out a discussion of the consequences of these interactions. We finish this article with conclusions and prospects (Section 9).

2. ANALOGY BETWEEN UNCONSCIOUS PROCESSES BY JUNG AND QUANTUM MECHANICS

2.1. Amplification

According to Jung "the amplification is the extension and the deepening of a dream-like image by means of associations centered on the dream theme and parallels based upon social studies and history of symbols (mythology, mystique, folklore, religion, ethnology, art, etc.). Thanks to this the dream becomes accessible to interpretation" [33].

In quantum physics, during a measurement, there is an amplification of a microscopic process which results in a macroscopic physical phenomenon. This is so for example for the track of a particle which goes through a bubble chamber. It is thanks to amplification that we can do the interpretation of a microscopic quantum process. It is only after an irreversible act of amplification that a microscopic quantum process can be called a physical phenomenon.

The fact that, according to Jung, a dream becomes accessible to interpretation only after amplification, is similar to the fact that, in quantum physics, a microscopic process also becomes accessible to interpretation only after amplification. Therefore unconscious mental processes like dreams can be considered, in an analogous way, as "microscopic" quantum processes. This argues in favour of the fact that the unconscious could be a quantum system.

In quantum physics, the amplification of a microscopic process, such as a particle which goes through a bubble chamber, is implemented by a sequence of quantum entanglements which, when their number is big enough (of the order of Avogadro's number: 10^{23}), appears as a macroscopic phenomenon. It is the quantum entanglement with environment, a part of the amplification process, which leads to decoherence and as a result to "the reduction (or collapse) of the wave function". Let us notice that the amplification process does not necessarily imply the collapse of the wave function. This process also occurs in the framework of Everett's "Relative State" or "many-worlds" theory [20, 21].

"The extension and the deepening of a dream-like image" which is achieved "by means of associations centered on the dream theme and parallels based upon social studies and history of symbols" does not necessarily represent an interaction of the psyche with the environment, for, when we sleep, this interaction is very weak. On the other hand, it could be an interaction with the collective unconscious or with the sleeper's "memory stocks". Whatever is the interaction between the dream-like image and its "environment" (which therefore is not necessarily the sleeper's "environment"), this interaction leads, by a sequence of quantum entanglements, to an amplification process and to a unique image of the dream which reaches the sleeper's consciousness. Let us notice that, as in quantum physics, this unique image of the dream does not imply necessarily the reduction or the collapse of the wave function, which are classical illusions. This unique image of a dream could well be included in the definition of consciousness as the separation between the various (classicaly) possible quantum states [22–25]. If it is so the various images of a dream will continue to coexist, although only one of these images reaches the sleeper's (subjective) consciousness.

2.2. Anima, Animus and Persona

"The natural function of *animus* (as well as of *anima*)[4] consists in implementing a relation between individual consciousness and the collective unconscious" [34].

Therefore *animus* and *anima* operate as "ancillae", enabling the "measurement" of the collective unconscious by individual consciousness.

[4] *Animus* and *anima* epitomize respectively the male nature of the woman's unconscious and the female nature of the man's unconscious.

"In an analogous way the *persona* represents a midzone between the ego consciousness and the objects of the external world" [34]. As a result, in a similar way, the *persona* operates as an "ancilla" which characterizes the interaction between individual consciousness and the environment.

"*Animus* and *anima* should work as a bridge or a porch heading for the collective unconscious images, following the example of the *persona* which builds up a kind of bridge toward the world" [34].

Therefore, according to Jung, *animus* and *anima* carry out the "amplification" of the collective unconscious components which become "accessible to interpretation by an individual consciousness." Thus they make up the "ancilla" which becomes quantum entangled with the collective unconscious and with consciousness, allowing the awareness (the measurement) of collective unconscious components. Consequently *animus* and *anima* could be related to what we call *"insight."*

In the same way, still according to Jung, the *persona* could be the "ancilla", or the sequence of ancillae (the sequence of quantum entanglements) which characterizes the interaction of consciousness with the environment, and thus enables either "the reduction (or collapse) of the wave function of an individual consciousness", or the emergence of consciousness as the separation between the various quantum states that are "classicaly" possible, the various "pointer-states". As C.G. Jung wrote: "The *persona* is the system of adaptation or the way through which we communicate with the world", i.e. with the environment.

Thus the *persona* characterizes the interaction between consciousness and the environment. It works both ways. In one way it measures the contribution of the environment to our personality. In the other way it characterizes how our personality (our consciousness) responds and behaves in relation to the environment.

2.3. Archetypes

"The archetypal representations which appear in fantasies, dreams, delirious thoughts and illusions of individuals have their origin in the archetype which in itself eludes representation, pre-existent and unconscious form which seems to belong to the inherited structure of the psyche and therefore can manifest itself spontaneously everywhere and for all time" [35].

The fact that the archetype eludes the representation appears to be similar to the quantum object, e.g. the atom, which eludes any representation and can only be "depicted" by a mathematical object such as a wave function or a quantum field.

"I always find again this misunderstanding which presents the archetype as having a specified content; in other words one makes it a kind of unconscious "representation", if I may put it that way. Therefore it is necessary to make clear that archetypes do not have a specified content; they are only determined in their *form* and yet to a very limited extent. A primary image has a specified content only when it becomes conscious and is consequently filled with the material of conscious experience" [36].

This appears very similar to the fact that in quantum physics a particle does exist as such only when it has been recorded by a detector. Then, and only then, it acquires a "specified content", while before the detection (which corresponds to "a reduction of the wave function" or "a choice of a classically possible quantum state") it has no "effectively specified content", except in terms of wave function or quantum field.

Jung continues: "Maybe one could compare its *form* to the axial system of a crystal which in a way "pre-forms" the crystalline structure in the residual water ("eau mére") although it has no material existence by itself" [36].

A wave function and a quantum field have no material existence. They gain one only after a measuring process (an amplification process) has recorded, for example, the position or the velocity of the particle in an irreversible and indelible way.

"The archetype in itself is empty; it is a pure formal element, nothing more than a *facultas praeformandi* (a possibility of pre-formation), a form of representation given *a priori*" [36].

In some way a wave function or a quantum field are "empty of matter". They only exist as *Potentia*, allowing the apparition in the "real world" of a material form, the elementary particle.

Jung goes on: "The representations themselves are not inherited: only their forms are; thus considered they correspond entirely to instincts which are also themselves only specified in their form. One cannot prove the existence of archetypes more than the existence of instincts, as long as they do not manifest themselves in a concrete manner" [36].

This looks similar to the fact that a particle does not exist as a particle as long as it is not recorded "in a concrete manner", i.e. in an irreversible and indelible way, by an amplification process (the "measurement").

Jung writes: "It seems likely that the true essence of the archetype cannot become conscious; it is transcendent: this is why I call it *psychoid*[5] [37].

Similarly, the true essence of matter (the quantum field or the wave function) cannot become conscious. It appears in the physical world through its effects: particle detection, interference effect, ... However the true essence of matter does not elude representation since mathematical entities such as quantum fields or wave functions are representations of this essence. In this sense "the true essence of matter becomes con-

[5] "Like the soul, quasi-mental. Jung thus characterizes the very deep layer of the collective unconscious and its contents, the archetypes, which elude representation" [33].

scious". In a similar manner, we can conceive that there exists a (mathematical) representation of archetypes in terms of quantum fields. This is what Belal Baaquie and one of us (FM) have postulated and studied within the framework of a quantum field theory of the human psyche [9].

Like Jung we do not think that the true essence of matter, or of the unconscious (e.g. archetypes), could become fully conscious. However when we build a mathematical representation of them which fits with the real world (this representation being classical or quantum), then some part of the essence of matter or of the unconscious (e.g. archetypes) becomes conscious.

Jung writes: "At all time we should not give up to the illusion that in the end we shall succeed in explaining an archetype and thus "liquidate" it. The best explanatory attempt itself will ever be nothing else than a translation more or less achieved in another system of images" [38].

3. NUCLEAR MAGNETIC RESONANCE FORMALISM: APPLICATION TO THE UNCONSCIOUS

In this paper we will try to make the interaction between the unconscious, the insight (pre-consciousness) and consciousness, more refined. In this way we will be inspired by quantum information theory [26] and more specifically by what takes place in nuclear magnetic resonance (NMR) or in nuclear magnetic resonance imaging (NMRI) [28, 29].

The formalism of NMR is the formalism of quantum information. It is for this reason that this formalism comes to be useful in the description of mental phenomena which are phenomena of information measurement and information transfer. Therefore we will consider the space of mental states as an abstract space of information [39, 40].

Moreover, experimental conditions and the interaction with the environnement are such that in both circumstances, i.e. in NMR and in mental phenomena, time scales vary very importantly.

Thus, in NMR, the energy relaxation rate can vary from "tens of seconds for well-chosen molecules and liquid samples with good solvents to times of days for isolated nuclei embedded in solid samples" [41]. In the same manner, in the case of spin polarisation of nuclear targets [42, 43], "specific time scale of establishing internal equilibrium in the spin-spin system is much shorter (10^{-5} second) than for a Zeeman subsystem of spins in an external magnetic field (10^{-1} second)" [44].

Those various considerations show that in NMR [28, 45] and in spin polarisation of nuclear target experiments there is a great sensitivity of the results to the experimental conditions such as the choice and the size of the target along with the tuning of the magnetic fields brought into play (static and micro-wave fields). Let us put the emphasis on the fact that the tunings of those magnetic fields, and more particularly of microwave fields, should be extremely accurate.

In Subsection 4.2 we will see that the interaction times between the various layers of the psyche can be very different, depending on the type of interaction and the presence (or not) of a mental field. Likewise we will see in Section 8 that the time scale of a direct coupling between two unconscious can be much shorter than the time scale brought into play in the interaction between the unconscious and consciousness of one person. This can be an analogy between physics and psyche.

However, precision of tunings needed in NMR or in the experiments of spin polarisation of nuclear targets shows that it is difficult to compare what occurs in physics with what happens in the human psyche. Nevertheless in mental phenomena we can also refer to a need of "*tuning*" between the various layers of the psyche and between the unconscious of several individuals.

In quantum physics, and more specifically in the experiments of nuclear spin polarisation, the control of spin sets as quantum systems requires very often extremely low temperatures (a few degrees Kelvin) and intense magnetic fields (several Teslas). However Nature does not seem to need those very low temperatures, nor those intense magnetic fields, so that quantum phenomena appear for mental states and for physical states of the brain that are correlated to them. We talked above about the very precise tunings to which physicists should proceed in order to obtain some results. By contrast, concerning phenomena of life (biology) and mental phenomena (neurophysiology and psychology), it seems quite true that Nature undertakes these tunings by herself. Contrary to physics for which physicists do the tunings, Nature carries out self-tuning.

As elements of an abstract space of information we assume that the unconscious and consciousness of a human being can be represented by quantum states [9, 15, 16]. These quantum states, respectively $|U\rangle$ and $|C\rangle$, are vectors of Hilbert spaces H_U and H_C. Moreover we are led up to assume the existence of an intermediate quantum system between unconscious $|U\rangle$ and consciousness $|C\rangle$. This intermediate system interacts both with unconscious and consciousness and thus allows awareness of unconscious components. We suppose that this intermediate system is the insight, the intuition, the perspicacity, that makes us aware of something. The insight is represented by a quantum state $|I\rangle$ vector of an Hilbert space H_I. According to measurement theory in quantum physics we assume that there is creation of a quantum entangled state involving unconscious and insight: $|U, I\rangle$, followed by a quantum entanglement of this new state with consciousness $|C\rangle$. Let us notice that insight can play the part of pre-consciousness, a state close to emerge to consciousness.

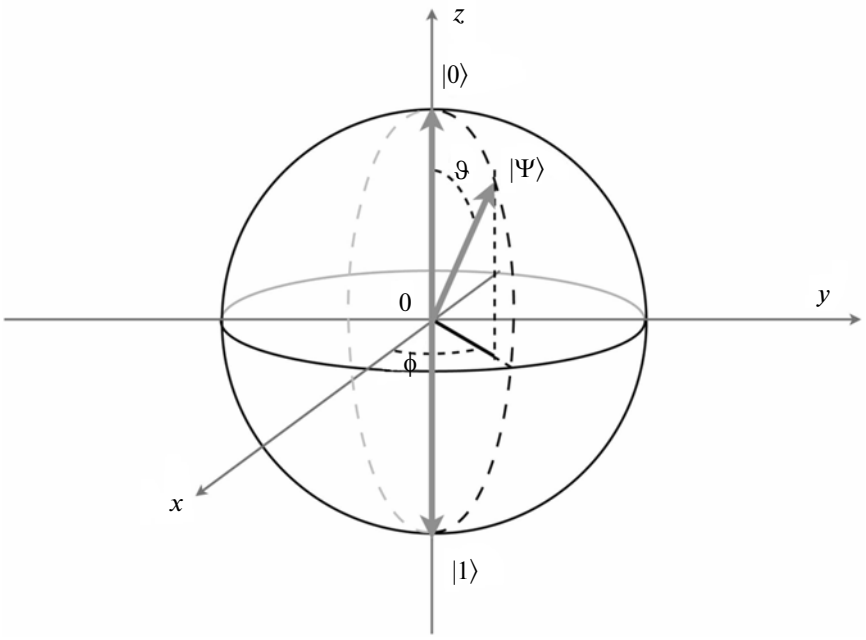

Fig. 1. Bloch's sphere which enables to represent the qubit $|\Psi\rangle$ by a vector of polar angles ϑ and ϕ.

We consider the simplest case of a binary situation corresponding in quantum physics to a qubit (quantum bit or quantum binary element). A qubit represents, among other things, the state of a spin 1/2. In psychology it could correspond to a mourning state (e.g. the bereavement of Bob after his father's death) [15], [30].

3.1. Qubits

In quantum physics a spin-1/2 state is represented by a vector on the Bloch's sphere (Fig. 1):

$$|\Psi\rangle = e^{-i\phi/2}\cos(\theta/2)|0\rangle + e^{i\phi/2}\sin(\theta/2)|1\rangle. \quad (1)$$

In a similar way we represent the unconscious of a person in a mourning process by the quantum superposition:

$$|U\rangle = e^{-i\phi/2}\cos(\theta/2)|U0\rangle + e^{i\phi/2}\sin(\theta/2)|U1\rangle, \quad (2)$$

Pointer-states of mental qubits related to mourning

	"Father is dead" (achieved mourning)	"Father is alive" (non achieved mourning)
consciousness	$\|C0\rangle$	$\|C1\rangle$
pre-consciousness	$\|I0\rangle$	$\|I1\rangle$
unconscious	$\|U0\rangle$	$\|U1\rangle$

where $|U0\rangle$ is the state corresponding to a mourning that is accomplished and $|U1\rangle$ the state corresponding to a mourning that is not achieved.[6]

Table shows the notations of pointer-states of various mental qubits (consciousness, pre-consciousness and unconscious) related to mourning.

In NMR the state $|0\rangle$ corresponds to the spin (of the proton) pointed along the Oz axis direction. Regarding the state $|1\rangle$ it corresponds to the proton spin pointed along the direction $-Oz$. These directions of the proton spin can be "brought to light" (or selected) by a magnetic field $\vec{B}_0$ pointed along the Oz axis.

In a similar way, in the Bloch's representation of qubit $|U\rangle$, corresponding to the unconscious of a person in process of mourning, state $|U0\rangle$ points toward the Oz axis while state $|U1\rangle$ points toward the direction $-Oz$. We will assume that the Oz axis of the Hilbert space H_U is "selected" by a psyche field $\vec{B}_{U0}$ considered as the analogue of the magnetic field $\vec{B}_0$.[7] The psyche field defined here could interact with the mental qubits that we will introduce later like an ordinary magnetic field. We consider the qubit without position in physical space, but only as elements of an abstract information space, at least at this point of our elabora-

[6] We have slightly modified the notations of references [15] et [16] so as to use the same notations as in NMR. In particular, here, the angle θ equals $\pi - \theta$ the angle used in reference [16].

[7] From a quantum point of view a psyche field "pointed along the Oz axis" is a field of which creation operator of a field quantum is proportional to σ_z (see formulae (5)).

tion. This is similar to quantum entanglement of physical (e.g. spin) qubits. Before any measurement those qubits are not localized in space-time. It is only after measurement that they are localized in space-time. The same is true for unconscious and conscious mental qubits. It is only when they reach the observer's consciousness that they are localized in the brain (or the body) of the observer. There is certainly a dependence of unconscious mental qubits, or of the psyche field, with space coordinates. But it is irrelevant, and we do not consider them, at this point of our study. As for the geometrisation of consciousness of Penrose [27] that we do not consider here.

Let us notice that the Oz axis direction is nothing else but the pointer-state directions $|U0\rangle$ (father is dead) and $|U1\rangle$ (father is alive). So the psyche field $\vec{B}_{U0}$ that "selects" this direction is a field related to the external reality and consequently to the environment.

3.2. Rotations of a Qubit

The time evolution of a spin-1/2 particle in a magnetic field $\vec{B}_0$ pointing along the Oz axis is governed by the Hamiltonian [28]:

$$\mathcal{H}_0 = -(h/2\pi)\gamma B_0 I_z = -h(\omega_0/2\pi)I_z, \qquad (3)$$

where h is Planck's constant, γ the gyromagnetic ratio of the particle, $\omega_0/2\pi$ the Larmor frequency, and I_z the momentum operator in the Oz direction. The angular momentum operators I_x, I_y, and I_z are related to Pauli matrices by the relations:

$$I_x = \sigma_x/2, \quad I_y = \sigma_y/2, \quad I_z = \sigma_z/2, \qquad (4)$$

with the usual Pauli matrix notations:

$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad \sigma_y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \quad \sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}. \qquad (5)$$

From equation (3) we deduce an energy difference between the states $|1\rangle$ and $|0\rangle$ equal to $h\omega_0/2\pi$. This energy difference is known as the Zeeman splitting.

When the Hamiltonian $\mathcal{H}$ is time independent, the unitary operator $\mathcal{U}$ which gives the time evolution of the state $|\Psi\rangle$ (Eq. (1)) is:

$$\mathcal{U}(t) = \exp(-i\mathcal{H}t2\pi/h). \qquad (6)$$

When the Hamiltonian is $\mathcal{H}_0$ (Eq. (3)) this time evolution is a precessing motion of the Bloch vector $|\Psi\rangle$ around the Oz axis. This precessing motion which occurs with the frequency $\omega_0/2\pi$ is known as Larmor precession. The θ angle of formula (1) does not vary with time. By contrast the ϕ angle varies linearly with time:

$$\phi = \phi_0 - \omega_0 t. \qquad (7)$$

Actually this leads to a rotation of the Bloch vector $|\Psi\rangle$ around the Oz axis in the opposite way of the trigonometrical way with the frequency $\omega_0/2\pi$.

In NMR we can manipulate the quantum state of a spin-1/2 particle in a static magnetic field $\vec{B}_0$ along the Oz axis by applying an electromagnetic field $\vec{B}_1(t)$ which rotates in the (Ox, Oy) plane with frequency $\omega_{rf}/2\pi$, this frequency being equal or close to the Larmor frequency $\omega_0/2\pi$.

The Hamiltonian of a spin-1/2 particle in such a radio-frequency (RF) field is analogous to the Hamiltonian (3):

$$\mathcal{H}_{rf} = -(h/2\pi)\gamma \times B_1[\cos(\omega_{rf}t + \eta)I_x - \sin(\omega_{rf}t + \eta)I_y], \qquad (8)$$

where η is the phase of the radio-frequency field and B_1 its amplitude. The frequency defined by $\omega_1/2\pi = \gamma B_1/2\pi$ is called the Rabi frequency.

The motion of a spin-1/2 particle subject to both a static magnetic field $\vec{B}_0$ and a rotating magnetic field $\vec{B}_1(t)$ is rather complex. However it takes a simple form when we study it in a coordinate system rotating about the Oz axis with frequency $\omega_{rf}/2\pi$.

In such a coordinate system the complete Hamiltonian is:

$$\mathcal{H}^{\text{rot}} = -h((\omega_0 - \omega_{rf})/2\pi)I_z - h(\omega_1/2\pi) \times [\cos(\eta)I_x - \sin(\eta)I_y]. \qquad (9)$$

If $\omega_{rf} = \omega_0$, i.e. if the rotation of the new coordinate system corresponds to the Larmor precession about the Oz axis, the first term of the Hamiltonian (9) vanishes. Thereby an observer in this rotating frame will see the spin of the particle simply precess around $\vec{B}_1$, a motion called *nutation*. This is a resonance phenomenon between the spin and the magnetic field $\vec{B}_1(t)$, both rotating. The choice of the η angle defines, in the rotating (Ox, Oy) plane, the direction of the axis around which the *nutation* occurs.

The basic logical quantum gates acting on only one qubit are rotations on the Bloch's sphere. The most general rotation of angle θ_1 around an axis defined by the unitary vector $\vec{n} = n_x\vec{e}_x + n_y\vec{e}_y + n_z\vec{e}_z$ on the Bloch's sphere is implemented by the operator:

$$\mathcal{R}_{\vec{n}}(\theta_1) = \exp[-i\theta_1\vec{n}\cdot\vec{\sigma}/2], \qquad (10)$$

where $\vec{\sigma} = \sigma_x\vec{e}_x + \sigma_y\vec{e}_y + \sigma_z\vec{e}_z$ is a Pauli matrix vector.

The rotation of a qubit in the rotating frame can be implemented by a radio-frequency pulse (RF pulse). From the control Hamiltonian (9) we deduce that a RF field of amplitude ω_1 and rotating frequency $\omega_{rf} = \omega_0$ implemented during a time t_p makes the spin $|\Psi\rangle$ (Eq. (1)) evolves from $|\Psi\rangle$ to $\mathcal{U}|\Psi\rangle$ thanks to the unitary operator $\mathcal{U}$:

$$\mathcal{U}(t_p) = \exp[it_p\omega_1[\cos(\eta)I_x - \sin(\eta)I_y]]. \quad (11)$$

Comparing (11) with formula (10) we see that $\mathcal{U}(t_p)$ describes a rotation of angle $\theta_1 = \omega_1 t_p$ about an axis located in the (Ox, Oy) plane and making an angle $\pi - \eta$ with the Ox axis. Such a RF pulse is called a Rabi pulse.

3.3. Rotations of a Mental Qubit

By analogy we see that for a mental qubit representing mourning (formule (2)), or for any binary mental state, a pulse of a psyche field "along the Oz axis", which is definied by the pointer-states $|U0\rangle$ and $|U1\rangle$[8], modifies the ϕ angle without modifying the θ angle, a fact which is not very interesting concerning the evolution of mourning, this one being "measured" by the variation of the θ angle.

By contrast a psyche field pulse "located in the (Ox, Oy) plane" will modify the θ angle and therefore will make mourning evolve.[9] For simplicity let us assume that the ϕ angle is equal to 0. Therefore in such a case a psyche field pulse pointing along the Oy axis will modify the θ angle by a quantity proportionnal to the duration t_p of the pulse (without modifying the ϕ angle). Effectively, in order for mourning to evolve in the "good" way, i.e. that the θ angle tends toward 0, it is necessary for the psyche field to point along the direction $-Oy$.

4. INTERACTIONS BETWEEN TWO QUBITS

An example of interaction between two nuclear spins in a molecule is the *scalar coupling* or *J coupling*. It is a (Fermi) contact interaction between two nuclear spins of which the Hamiltonian is [28]:

$$\mathcal{H}_J = hJ\vec{I}^1 \otimes \vec{I}^2, \quad (12)$$

where $\vec{I}^1 = I_x^1\vec{e}_x + I_y^1\vec{e}_y + I_z^1\vec{e}_z = \vec{\sigma}^1/2$ is the angular momentum operator vector of spin 1, $\vec{\sigma}^1$ being the Pauli matrix vector acting on the quantum states of spin 1. The same is true for $\vec{I}^2$, the angular momentum operator vector of spin 2. The J constant is the coupling strenght between the two spins.[10]

The symbol $\otimes$ represents the tensor product of the two operators $\vec{I}^1$ and $\vec{I}^2$ which acts in the space tensor product of the two Hilbert spaces of qubits 1 and 2. By using the relation between the angular momentum operator vector and the Pauli matrix vector we obtain the formula:

$$\vec{I}^1 \otimes \vec{I}^2 = (\sigma_x^1 \otimes \sigma_x^2 + \sigma_y^1 \otimes \sigma_y^2 + \sigma_z^1 \otimes \sigma_z^2)/4. \quad (13)$$

For nuclear spins in a static magnetic field $\vec{B}_0$ along the Oz axis, and under some conditions, the Hamiltonian (12) simplifies to:

$$\mathcal{H}'_J = hJI_z^1 \otimes I_z^2. \quad (14)$$

The interactions considered so far are internal interactions between two qubits. They lead to a quantum entangled state of the two qubits. Contrarily to external magnetic fields, that can be manipulated, it is very difficult to manipulate internal interactions. However if it is a short-distance interaction it is possible to move the qubits closer, to let them interact, and then to move them away.[11]

In NMR the interaction Hamiltonian (14) proves very useful to implement logical two-qubit gates. However as far as mental qubits are concerned we will prefer the non-simplified Hamiltonian (12).

For psyche the simplified Hamiltonian (14), which in NMR, as we say it again, is nothing other than the interaction Hamiltonian (12) in the presence of a strong static magnetic field along the Oz axis, allows us to consider the interaction of two mental qubits located in a field of which the analogue of the magnetic field would be a psyche field [9].

Further on (Section 8) we will see that the interaction Hamiltonian (12) which, in NMR, does not require the presence of a magnetic field, can be interpreted as the interaction Hamiltonian of a qubit (e.g. qubit 1) with the magnetic field created by the other qubit (e.g. qubit 2).[12] The analogy for mental qubits is

[8] See footnote 7.

[9] On a quantum point of view a psyche field "located in the (Ox, Oy) plane" is a field of which field quanta creation and annihilation operators respectively create and annihilate the quantum states $|0\rangle$ and $|1\rangle$. Such operators are proportionnal to the operators $\sigma_+ = (\sigma_x + i\sigma_y)/2$ and $\sigma_- = (\sigma_x - i\sigma_y)/2$.

[10] The fact that Planck's constant h appears in a Hamiltonian supposed to describe a mental process looks meaningless, this constant being involved *a priori* only in microscopic matter processes. Moreover until proved otherwise we have not clearly define what is mental energy. However that may be, be in Schrödinger's equation or in the time evolution operator $\mathcal{U}(t)$ (formula (6)), only the operator $\mathcal{H}/h$ takes place. Therefore Planck's constant does not appear in quantities that interest us, i.e. the time evolution operators. Let us notice that, according to Lotka [46], Planck's constant could intervene in the phenomenon of emergence of (subjective) consciousness.

[11] For mental qubits the "rapprochement" or the "remoteness" will be done thanks to swappings with intermediate qubits (see Subsection 4.2).

[12] In reality in NMR the interaction Hamiltonian of spin 1 in the magnetic field created by spin 2 (*magnetic dipole-dipole interaction*) is more complex than formula (12) (see formula (5) of reference [28]).

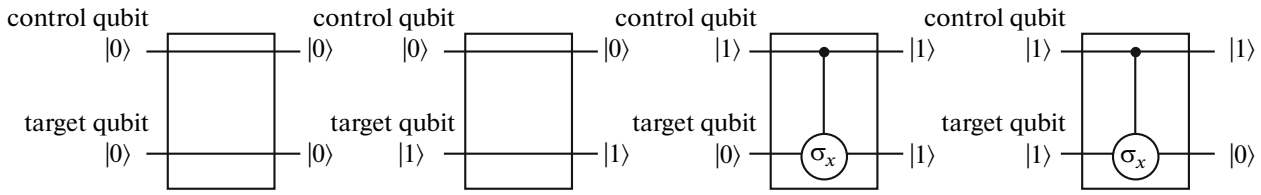

Fig. 2. Representation of the $CNOT_{12}$ gate for base qubits (see formula (16)).

straightforward: the interaction Hamiltonien (12) represents the interaction of a qubit with the psyche field created by the other qubit.

Thus the psyche field created by the qubit 2 will be proportionnal to $\vec{I}^2$ the "angular momentum operator vector" of qubit 2, the proportionality constant including a kind of "gyromagnetic ratio" γ_2 of qubit 2.[13] This "gyromagnetic ratio" γ_2 of qubit 2 will get involved in the coupling constant J, which thus will be proportional to the product of the two "gyromagnetic ratio" $\gamma_1\gamma_2$ respectively of qubits 1 and 2. From this we conclude immediately that the larger the "gyromagnetic ratio" γ_2 is, on one hand the larger the coupling constant J will be, and on the other hand the larger the intensity of the psyche field created by the qubit 2 will be. In summary *the larger the respective intensities of the psyche field created by each of the two qubits are, the larger the coupling constant J will be*.

The interaction described by the simplified Hamiltonian (14) could explain the numerous transfers between the various layers of the unconscious, going from the deepest unconscious to pre-consciousness closest to consciousness. It could explain as well, in a reciprocal manner, the transfers going from consciousness to the deepest unconscious. As we will see further on (Subsection 4.2), in the end this interaction implies "long" interaction times[14], and a reciprocal exchange of information of the various layers, one layer taking as such the information of the other layer.

The interaction described by the Hamiltonian (12) can also explain the numerous transfers between the various layers of the unconscious. However it is more direct than the previous interaction. Indeed it needs, for the transfer of information from one layer to the other, an interaction time at least three times shorter than the time of interaction (14), as we will see later. Like the previous one this interaction can guarantee the complete transfer of a quantum information from one layer to the other.

[13]Let us notice that unlike what happens in NMR, where the notion of distance from spin 2 gets involved in the magnetic field created by this spin, in the abstract space of mental qubits we have not defined so far any notion of distance.

[14]"Long" in comparison to the interaction time necessary for only one transfer of information to take place from one qubit to the other.

Interaction (14) is formulated in this Section (Section 4) whereas interaction (12) is formulated in Sections 5, 6 and 7.

4.1. Implementation of Two-Qubit Logical Quantum Gates

The basic two-qubit logical quantum gate is the controlled-NOT (CNOT) gate. In the basis $|00\rangle$, $|01\rangle$, $|10\rangle$, and $|11\rangle$ in which the first index refers to qubit 1 (spin 1), whereas the second one refers to qubit 2 (spin 2), this gate is represented by the matrix:

$$\mathcal{U}_{\mathrm{CNOT}} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}. \tag{15}$$

The matrix notation of base qubits $|00\rangle$, $|01\rangle$, $|10\rangle$, and $|11\rangle$ is the following:

$$|00\rangle = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \quad |01\rangle = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}, \quad |10\rangle = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}, \quad |11\rangle = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}. \tag{16}$$

The $\mathcal{U}_{\mathrm{CNOT}}$ transformation flips qubit 2 (target qubit) if and only if the quantum state of qubit 1 (control qubit) is $|1\rangle$ (Fig. 2).

A basic theorem of quantum computation states that up to an irrelevant overall phase, any unitary transformation $\mathcal{U}$ acting on two qubits can be factorized into a $\mathcal{U}_{\mathrm{CNOT}}$ gate and rotations $\mathcal{R}_{\vec{n}}(\theta_1)$ acting on each of the two qubits [47].

In NMR the spin-spin coupling Hamiltonian (14) (valid in the laboratory frame as well as in the rotating frame defined in Subsection 3.2) leads to a unitary time evolution operator of the two-qubit system:

$$\mathcal{U}_J(t) = \exp[-i2\pi J I_z^1 \otimes I_z^2], \tag{17}$$

in matrix notation:

$$\mathcal{U}_J(t) = \begin{pmatrix} e^{-i\pi tJ/2} & 0 & 0 & 0 \\ 0 & e^{+i\pi tJ/2} & 0 & 0 \\ 0 & 0 & e^{+i\pi tJ/2} & 0 \\ 0 & 0 & 0 & e^{-i\pi tJ/2} \end{pmatrix}. \quad (18)$$

When the interaction time between the two qubits is $t = 1/(2J)$, after having done in addition 90° rotations of each of the two qubits about the $-Oz$ axis, and up to an irrelevant overall phase, we obtain a transformation known as the *controlled phase gate*:

$$\mathcal{U}_{\mathrm{CPHASE}} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}, \quad (19)$$

(see formula (30) of reference [28]).

This two-qubit logical quantum gate is equivalent to the CNOT gate (15). To show this it is sufficient to make a base change of the target qubit (qubit 2) (a 90° rotation about the Oy axis) and to shift the phase of the control qubit (qubit 1) (see formula (31) of reference [28]).

Therefore in NMR, thanks to a spin-spin interaction acting between the two qubits during a given time, and thanks to radio-frequence pulses acting on each of the two qubits also during a given time, we are able to implement any unitary transformation on a two-qubit system.

4.2. CNOT Gate Properties

The CNOT quantum gate (15) in which qubit 1 is the control qubit and qubit 2 the target qubit will be designated by CNOT_{12} (Fig. 2). When qubit 2 is the control qubit and qubit 1 the target qubit it will be the quantum gate CNOT_{21}.

Let us consider the CNOT_{12} quantum gate and let us suppose that qubit 1 is given by formula (1):

$$|\Psi_1\rangle = e^{-i\phi/2}\cos(\theta/2)|0\rangle_1 + e^{i\phi/2}\sin(\theta/2)|1\rangle_1. \quad (20)$$

As for qubit 2 let us suppose that it is in the quantum state $|0\rangle$:

$$|\Psi_2\rangle = |0\rangle_2. \quad (21)$$

Initially the system of the two qubits is in the factorized state $|\Psi_1\rangle|\Psi_2\rangle$. After going through the CNOT_{12} gate the state of the two-qubit system will be:

$$\mathrm{CNOT}_{12}|\Psi_1\rangle|\Psi_2\rangle = e^{-i\phi/2}\cos(\theta/2)|0\rangle_1|0\rangle_2 + e^{i\phi/2}\sin(\theta/2)|1\rangle_1|1\rangle_2. \quad (22)$$

It is a *non-separable* two-qubit system. The two qubits are (quantum) entangled. In some way the target qubit is brought into alignment with the control qubit. It has "measured" the control qubit. Let us notice that when performing a CNOT quantum gate, the control qubit is measured in a nondestructive way (QND: Quantum Non-Demolition) by the target qubit which plays the role of a meter. This is a consequence of the fact that the state (22) is a pure quantum state. The final detection of the target qubit collapses the control qubit in the state corresponding to the measurement result (with a given probability). In such a case the pure state (22) is transformed into a (statistical) mixing of pure quantum states. Moreover let us notice that the non-destructive operation "CNOT gate" can be repeated as many time as we want, with N target qubits. When N is large the final state can be "seen" as a "Schrödinger's cat" [48].

In a similar way let us assume that after his father's death Bob's unconscious is represented by the quantum state $|U\rangle$ given by (2), whereas his pre-consciousness is in the state $|I0\rangle$ (the father is dead; information obtained from consciousness). Initially the system made up of his unconscious and pre-consciousness (both related to mourning) is the factorized state $|U\rangle|I0\rangle$. Going through the CNOT_{12} quantum gate leads to a quantum entangled state analogous to (22):

$$\mathrm{CNOT}_{12}|U\rangle|I0\rangle = e^{-i\phi/2}\cos(\theta/2)|U0\rangle|I0\rangle + e^{i\phi/2}\sin(\theta/2)|U1\rangle|I1\rangle. \quad (23)$$

In the same way as formula (22) it is a *non-separable* two-qubit system describing Bob's unconscious and pre-consciousness, both related to the father's mourning. This quantum entangled state of Bob's unconscious and pre-consciousness is completely equivalent to the quantum state (32) of reference [15] or to the quantum state (4) of reference [16]. The unconscious plays the part of the control qubit. As for pre-consciousness, it plays the part of the target qubit. Like for (22) we can say that in some way pre-consciousness is brought into alignment with the unconscious. Pre-consciousness "measures" the unconscious.

Let us state some remarkable properties of CNOT gates. First if we apply the CNOT_{12} gate to the quantum entangled states (22) or (23) we will recover the initial factorized states $|\Psi_1\rangle|\Psi_2\rangle$ or $|U\rangle|I0\rangle$. This is a consequence of the fact that the product of the CNOT gate $\mathcal{U}_{\mathrm{CNOT}}$ (15) by itself gives the identity operator (or the identity matrix) (Fig. 3). Therefore if a CNOT gate enables to entangle two qubits, then the same CNOT gate enables to disentangle them. Let us emphasize that this is true only if the two-qubit system is not modified during the time interval between the two transitions through the CNOT gate.

Another remarkable property of CNOT gates is the fact that the product of the three CNOT gates: $\mathrm{CNOT}_{12}\mathrm{CNOT}_{21}\mathrm{CNOT}_{12}$ exchanges the states of qubits 1 and 2 whatever the states of those qubits are. This is called a swapping (Fig. 4). Let us notice that it is also possible to swap the states of qubits 1 and 2 in

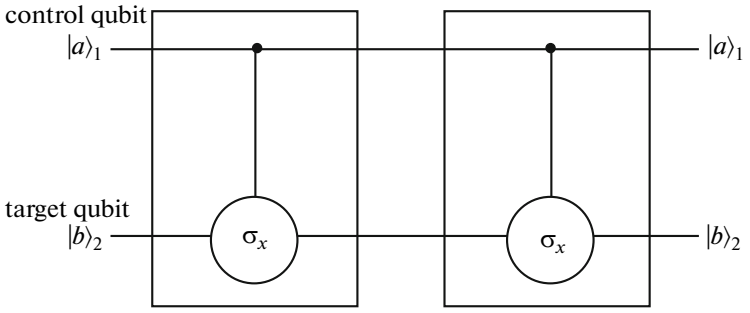

Fig. 3. Product of the $CNOT_{12}$ gate by itself giving identity.

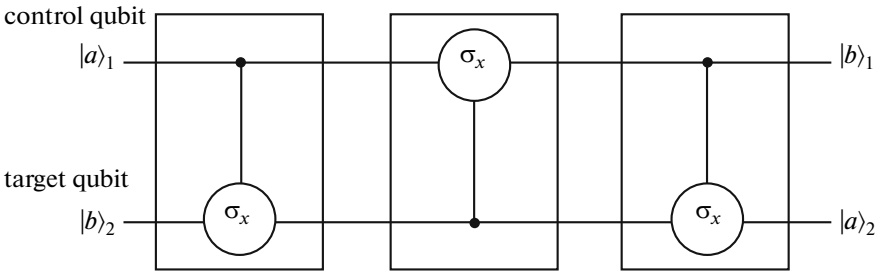

Fig. 4. Gate sequence $CNOT_{12}CNOT_{21}CNOT_{12}$ giving a swapping.

another way. We will see this in Section 5. We will see that to swap qubits 1 and 2 we just have to let them interact via the interaction Hamiltonian (12) during an interval of time $t = 1/(2J)$ (see formula (74)).

Swapping is especially interesting for mental qubits. Indeed let us assume that Bob's unconscious related to his father's mourning is described by qubit:

$$|U\rangle = e^{-i\phi_U/2}\cos(\theta_U/2)|U0\rangle + e^{i\phi_U/2}\sin(\theta_U/2)|U1\rangle. \quad (24)$$

and that his pre-consciousness (also related to his father's mourning) is described by qubit:

$$|I\rangle = e^{-i\phi_I/2}\cos(\theta_I/2)|I0\rangle + e^{i\phi_I/2}\sin(\theta_I/2)|I1\rangle. \quad (25)$$

A swapping between unconscious and pre-consciousness consists in exchanging in formulae (24) and (25) the θ_U angle with the θ_I angle and the ϕ_U angle with the ϕ_I angle. After a swapping between unconscious and pre-consciousness it results that pre-consciousness is precisely in the quantum state of the unconscious. As for unconscious it is in the quantum state of pre-consciousness.

We can suppose that initially a qubit representing a state of the unconscious is so much burried in it that it is not coupled to consciousness and therefore cannot interact with it, this preventing the unconscious state to emerge to consciousness. Then we can suppose the existence of a sequence of qubits coupled to each other (just "nearest-neighbour" couplings[15]) and representing the mental states going from the deepest unconscious to pre-consciousness closest to consciousness. This "pre-consciousness closest to consciousness" state will be coupled to consciousness. We can call this sequence of states making a connection between unconscious and consciousness: sequence of "pre-consciousness" states. Thus a sequence of swappings starting from unconscious and exchanging gradually the quantum states allows to put the closest to consciousness pre-consciousness state in precisely the quantum state of unconscious and therefore allows this latter to interact with consciousness. Let us notice that a sequence of swappings is nothing other than a (longer) sequence of CNOT gates or a sequence of

[15]Let us notice that for mental qubits the notion of "nearest-neighbour" does not take place in space-time. Mental qubits belong to an abstract space of information. "Nearest-neighbour" qubits just means that they can interact.

interactions between qubits coupled to each other described by Hamiltonian (12).

We can suppose that this sequence of qubits going from the deepest unconscious to pre-consciousness closest to consciousness can be correlated with a set of neural connections.

Let us emphasize that since unconscious and consciousness cannot interact directly (or very seldom) swappings are absolutely necessary. As we have seen before they allow unconscious to come closer to consciousness (and vice versa) and from then on they allow those two quantum systems to interact. The number of swappings necessary to a "rapprochement" of unconscious with consciousness (N') can be large. In such a case this requires an interaction time between $N' + 1$ mental qubits at least equal to $t = 3N'/(2J)$ for swappings due to passages through N' CNOT gates[16], and equal to $t = N'/(2J)$ for swappings due to N' interactions between $N' + 1$ qubits coupled to each other, represented by Hamiltonian (12), and making the connection between unconscious and consciousness.

The sequence of swappings going from the deepest unconscious to pre-consciousness closest to consciousness allows unconscious to modify consciousness. We will study this in Section 5. Likewise we can consider a sequence of reverse swappings going from consciousness to unconscious. This last sequence of swappings allows consciousness to come closer to unconscious and thus allows consciousness to modify unconscious.

4.3. Awareness

There are several manners to consider the coupling of consciousness with unconscious and awareness by an individual of components of his (or her) unconscious. We will consider one of these manners in Section 5.

We have already studied this problem in references [15] and [16]. There we supposed that starting with the above quantum entangled state $|U, I\rangle$ (23), which is called an EPR doublet[17], in a second period of time the interaction with consciousness $|C\rangle$ led to the formation of an EPR triplet:

$$|U,I,C\rangle = e^{-i\phi/2}\cos(\theta/2)|U0\rangle|I0\rangle|C0\rangle + e^{i\phi/2}\sin(\theta/2)|U1\rangle|I1\rangle|C1\rangle. \quad (26)$$

Like for pre-consciousness $|I\rangle$, if consciousness is initially in the quantum state $|C0\rangle$ (father is dead), we obtain formula (26) from formula (23) by transformation of the $|U, I\rangle|C0\rangle$ system through the CNOT ($|U, I\rangle|C0\rangle$) quantum gate.

When we trace over the degrees of freedom to which consciousness has no access, e.g. the degrees of freedom of the unconscious $|U\rangle$, formula (26) leads for consciousness to a (statistical) mixing of pure states $|C0\rangle$ (father is dead) and $|C1\rangle$ (father is alive) with statistical weights $\cos^2(\theta/2)$ and $\sin^2(\theta/2)$ which are the statistical weights of the states $|U0\rangle$ and $|U1\rangle$ when unconscious is not thought as a pure quantum state but as a (statistical) mixing. Then we conclude that formula (26) allows consciousness to "measure" the unconscious. A choice occurs that makes either the state $|C0\rangle$ (father is dead) with statistical weight $\cos^2(\theta/2)$, or the state $|C1\rangle$ (father is alive) with statistical weight $\sin^2(\theta/2)$, reach consciousness.

Another way to formulate awareness, due to Michael B. Mensky [22–25], is to assume that (awaken) consciousness IS by definition the separation between the two "classically" possible quantum states $|U0\rangle|I0\rangle|C0\rangle$ and $|U1\rangle|I1\rangle|C1\rangle$. Then subjective consciousness makes a choice between those two states, making either the state $|C0\rangle$ or the state $|C1\rangle$ reach consciousness.

We can also consider the interaction between the quantum state $|U, I, C\rangle$ (formula (26)) and the environment $|E\rangle$ and thus obtain an EPR quadruplet:

$$|U,I,C,E\rangle = e^{-i\phi/2}\cos(\theta/2)|U0\rangle|I0\rangle|C0\rangle|E0\rangle + e^{i\phi/2}\sin(\theta/2)|U1\rangle|I1\rangle|C1\rangle|E1\rangle. \quad (27)$$

The loss of information in the environment causes the decoherence of the state $|U, I, C, E\rangle$, i.e. its transformation from a pure quantum state to a (statistical) mixing [50]. Likewise, following Mensky [22–25], we can assume that (awaken) consciousness IS the separation between the two "classically" possible quantum states (the two pointer-states) $|U0\rangle|I0\rangle|C0\rangle|E0\rangle$ and $|U1\rangle|I1\rangle|C1\rangle|E1\rangle$, subjective consciousness making a choice between those two states.

Be that as it may, whatever the manner in which we formulate the phenomenon of awareness that concerns us here, environment plays an important role since it defines the pointer-states (the "classically" possible quantum states). Indeed it is the environment (or the classical "reality") that determines if the father is alive (state $|C1\rangle$) or else if he is dead (state $|C0\rangle$).

5. INFLUENCE OF UNCONSCIOUS ON CONSCIOUSNESS. INTERACTION BETWEEN PRE-CONSCIOUSNESS AND CONSCIOUSNESS

In this Section to study the interaction between unconscious and consciousness we will assume that first, thanks to one (or rather to several) swapping(s),

[16] A time to which one should add all the durations of Rabi pulses necessary to the implementation of the N' CNOT gates (e.g. $t_p = \pi/(2\omega_1)$ for a 90° rotation of a qubit about a given axis).

[17] EPR stands for Einstein–Podolsky–Rosen [49].

pre-consciousness closest to consciousness is turned into the quantum state of the unconscious and therefore is described by the qubit:

$$|I\rangle = e^{-i\phi_U/2}\cos(\theta_U/2)|I0\rangle + e^{i\phi_U/2}\sin(\theta_U/2)|I1\rangle, \quad (28)$$

which is the qubit representing the unconscious related to mourning.

Generally speaking consciousness (related to mourning) will be represented by the qubit:

$$|C\rangle = e^{-i\phi_C/2}\cos(\theta_C/2)|C0\rangle + e^{i\phi_C/2}\sin(\theta_C/2)|C1\rangle, \quad (29)$$

Let us recall that the swappings considered in Subsection 4.2, which are more or less numerous (N'), thus allow the information carried by the deepest unconscious to be transferred to pre-consciousness closest to consciousness.

Then we will study the interaction between the two qubits (28) and (29).

Above we have seen that it is possible to modify the θ_U angle measuring mourning in the unconscious and the θ_C angle measuring mourning in consciousness with Rabi pulses of a psyche field "located in the (Ox, Oy) plane". (Concerning psyche fields and mental qubits see the paragraph at the end of p. 430 and at the beginning of p. 431.)

However we can ask the following question: is it possible to modify the θ_U and θ_C angles measuring mourning, without the intervention of a psyche field, but with a direct interaction between the two qubits (28) and (29)? The answer is yes.[18] But as we have said above, rather than the Hamiltonian (14) it is better to consider that the interaction between qubits 1 and 2 is given by the Hamiltonian (12)[19]. Similar to nuclear spin-1/2, qubits 1 and 2 are respectively qubits (28) and (29).

Implementing formula (6) with Hamiltonian (12), the unitairy operator which controls the time evolution of the two-qubit system is the following:

$$\mathcal{U}(t) = \exp[-i2\pi tJ\vec{I}^1 \otimes \vec{I}^2]. \quad (30)$$

The matrix notation of this unitary time evolution operator is more complex than matrix (18). We will make appear this matrix notation. In order to do this let us make explicit the operator $\vec{I}^1 \otimes \vec{I}^2$ with the help of formula (13) and name F the operator matrix $(\sigma_x^1 \otimes \sigma_x^2 + \sigma_y^1 \otimes \sigma_y^2)/2$ and G the operator matrix $\sigma_z^1 \otimes \sigma_z^2$. Thus we obtain: $\vec{I}^1 \otimes \vec{I}^2 = (2F + G)/4$. After some computation we get the following matrices:

$$F = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}, \quad (31)$$

and

$$G = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}. \quad (32)$$

A remarkable property is that matrices F and G commute. This allows us to rewrite the unitary operator (30) as:

$$\mathcal{U}(t) = \exp[-i\pi tJ(2F+G)/2] = \exp[-i\pi tJF]\exp[-i\pi tJG/2] = \mathcal{U}_{\mathcal{F}}(t)\mathcal{U}_{\mathcal{G}}(t). \quad (33)$$

The matrix $\mathcal{U}_{\mathcal{G}}(t) = \exp[-i\pi tJG/2]$ is nothing but matrix (18). As for matrix $\mathcal{U}_{\mathcal{F}}(t) = \exp[-i\pi tJF]$ we obtain it by making an expansion of the exponential as a function of the matrix variable $-i\pi tJF$. Thus we obtain the following matrix:

$$\mathcal{U}_F(t) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(\pi Jt) & -i\sin(\pi Jt) & 0 \\ 0 & -i\sin(\pi Jt) & \cos(\pi Jt) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}. \quad (34)$$

The product of the two matrices $\mathcal{U}_{\mathcal{F}}(t)\mathcal{U}_{\mathcal{G}}(t)$ gives

[18] In fact the direct interaction between the two qubits (28) and (29) modifies the θ_I and θ_C angles since it is an interaction between pre-consciousness and consciousness. To modify the θ_U angle we must consider for example a direct interaction between pre-consciousness and the unconscious (Section 6).

[19] However let us notice that unlike Hamiltonian (14) Hamiltonian (12) is not invariant when we consider it in rotating frames about the Oz axis with Larmor's precession. For NMR we will study the effect of Hamiltonian (12) in the absence of magnetic fields $\vec{B}_0$ et $\vec{B}_1$. As for the interaction between pre-consciousness and consciousness we will assume that this interaction, given by Hamiltonian (12), will not occur simultaneously with psyche field pulses.

for the operator $\mathcal{U}(t)$:

$$\mathcal{U}(t) = \begin{pmatrix} e^{-i\pi Jt/2} & 0 & 0 & 0 \\ 0 & e^{+i\pi Jt/2}\cos(\pi Jt) & -ie^{+i\pi Jt/2}\sin(\pi Jt) & 0 \\ 0 & -ie^{+i\pi Jt/2}\sin(\pi Jt) & e^{+i\pi Jt/2}\cos(\pi Jt) & 0 \\ 0 & 0 & 0 & e^{-i\pi Jt/2} \end{pmatrix}. \quad (35)$$

If we know the quantum state of the two-qubit (1 and 2) system at time $t = 0$, the operator $\mathcal{U}(t)$ given by matrix (35) allows to predict the quantum state of the two-qubit system at time t. First we will consider several special cases corresponding to various initial conditions of the two-qubit (1 and 2) system. Then we will consider the general case corresponding to any initial conditions.

5.1. Special Cases

5.1.1. Special case I. In the first special case that we consider the initial quantum state of qubit 1 is $|1\rangle$ and the initial quantum state of qubit 2 is $|0\rangle$. As far as qubits (28) and (29) are concerned it corresponds to an initial quantum state $|I1\rangle|C0\rangle$. Regarding mourning, consciousness of the person knows that his (or her) father is dead, quantum state $|C0\rangle$, while for his (or her) unconscious his (or her) father is still alive, quantum state $|I1\rangle$ (or $|U1\rangle$). At time t the two-qubit system is represented by the state $|I, C\rangle_{(t)} = \mathcal{U}(t)|I1\rangle|C0\rangle$, i.e.:

$$|I,C\rangle_{(t)} = \mathcal{U}(t)|I1\rangle|C0\rangle = e^{+i\pi Jt/2}[\cos(\pi Jt)|I1\rangle|C0\rangle - i\sin(\pi Jt)|I0\rangle|C1\rangle]. \quad (36)$$

Whereas initially the two-qubit system of qubits (28) and (29) is a separable system (there is factorisation of the two states $|I1\rangle$ and $|C0\rangle$), at time t there is quantum entanglement of states $|I\rangle$ and $|C\rangle$. This is indicated by the fact that there is no more factorisation of states $|I\rangle$ and $|C\rangle$ (except at time $t = k/(2J)$, k being an integer). So, generally speaking, at time t, the two-qubit system of qubits (28) and (29) is a non-separable system. This is obviously a consequence of the interaction between pre-consciousness and consciousness. We remember that we are describing an abstract information Hilbert space of qubits and any attempt to relate this Hilbert space to the physical space is premature at this point of our elaboration.

Formula (36) shows that the quantum entangled state $|I, C\rangle_{(t)}$ is subjected to Rabi oscillations between the states $|I1\rangle|C0\rangle$ and $|I0\rangle|C1\rangle$. The frequency of those oscillations (Rabi frequency) is J. After a time $t = 1/(2J)$ pre-consciousness is disentangled from consciousness:

$$\mathcal{U}(t = 1/(2J))|I1\rangle|C0\rangle = e^{-i\pi/4}|I0\rangle|C1\rangle. \quad (37)$$

Moreover we observe a swapping between the quantum state of pre-consciousness, which is initially the quantum state of the unconscious, and the quantum state of consciousness. With regard to the initial state, up to an overall (and thus irrelevant) phase, $|I1\rangle$ becomes $|I0\rangle$ and $|C0\rangle$ becomes $|C1\rangle$. We infer that at time $t = 1/(2J)$ consciousness is in the initial state of pre-consciousness, i.e. in the quantum state of the unconscious $|U1\rangle$. The information "$|1\rangle$", corresponding in mourning to the information "father is alive", reaches consciousness. So at this moment consciousness measures the unconscious and its resistance to achieve mourning.

After time $t = 1/J$ the quantum entangled state $\mathcal{U}(t)|I1\rangle|C0\rangle$ is again in the initial state $|I1\rangle|C0\rangle$ up to an overall irrelevant phase equal to $-\pi/2$.

Now let us examine how we can determine the influence of pre-consciousness (and consequently of the unconscious) on consciousness (and vice versa), after time t, by considering the state (36). In order to do this, let us consider a quantum system $A + B$ composed of two quantum entangled parts A and B, which is the case of the system described by the state (36). In addition let us suppose that the $A + B$ system is in a pure quantum state $|\Psi\rangle_{AB}$. This is also the case of the system described by the state (36). If we want to describe the part A alone, then there is no pure quantum state that describes it. It is necessary to introduce a density operator for A. This density operator is:

$$\rho_A = Tr_B(|\Psi\rangle_{AB\ AB}\langle\Psi|), \quad (38)$$

which is obtained by calculating the trace of the operator $|\Psi\rangle_{AB\ AB}\langle\Psi|$ over the states of system B.

Likewise if we want to describe the part B alone, it will be described by the density operator:

$$\rho_B = Tr_A(|\Psi\rangle_{AB\ AB}\langle\Psi|). \quad (39)$$

Let us notice that the degree of entanglement between the parts A and B is given by the entropy of entanglement S_{AB}:

$$S_{AB} = -Tr[\rho_A\log(\rho_A)] = -Tr[\rho_B\log(\rho_B)]. \quad (40)$$

In our case the system A is the pre-consciousness $|I\rangle$. As for the system B it is the consciousness $|C\rangle$. The quantum state of the system $A + B$, i.e. $I + C$, i.e. pre-consciousness + consciousness, is the state (36) which exhibits quantum entanglement between pre-consciousness and consciousness. Consciousness C is not described by a pure quantum state but by the density operator ρ_C (39) in which $|\Psi\rangle_{IC}$ is given by (36). A calculation, thanks to definition (39), leads to:

$$\rho_C = Tr_I(|\Psi\rangle_{IC\ IC}\langle\Psi|) = \cos^2(\pi Jt)|C0\rangle\langle C0| + \sin^2(\pi Jt)|C1\rangle\langle C1|. \quad (41)$$

This density operator corresponds to the density operator of a (statistical) mixing of pure quantum states (29) in which the $\theta_C(t)$ angle would be equal to $2\pi Jt$. On the other hand we do not obtain any result on the $\phi_C(t)$ angle, which corresponds to a phase shift between the states $|C0\rangle$ and $|C1\rangle$. This is normal because we are in the presence of a (statistical) mixing. But in a (statistical) mixing, phase shifts between quantum states disappears and are meaningless. It is what is called decoherence.

The influence of unconscious, for which the father is still alive, is to modify consciousness through pre-consciousness by making it get a component "the father is still alive". Whereas initially for consciousness "the father is dead", the consequence of the interaction with pre-consciousness, which is initially in the quantum state of the unconscious, is that consciousness cannot remain in this quantum state. It acquires a component "the father is still alive". Then consciousness is a (statistical) mixing of quantum states "the father is dead" and quantum states "the father is still alive." The (statistical) weight of the component "the father is still alive" ($\sin^2(\pi Jt)$) depends on time t during which pre-consciousness and consciousness interact. As a fonction of time the θ_C angle varies from 0 to $2\pi Jt$, t being the time of interaction between consciousness and pre-consciousness.

Likewise if we want to describe pre-consciousness alone in the quantum entangled state (36) we calculate the density operator ρ_I:

$$\rho_I = Tr_C(|\Psi\rangle_{IC\ \ IC}\langle\Psi|) = \cos^2(\pi Jt)|I1\rangle\langle I1| + \sin^2(\pi Jt)|I0\rangle\langle I0|. \quad (42)$$

This density operator corresponds to the density operator of a (statistical) mixing of pure quantum states (25) in which the $\theta_I(t)$ angle would be equal to $\pi - 2\pi Jt$.[20] On the other hand, likewise for consciousness, in such a (statistical) mixing, the phase shift $\phi_I(t)$ between the states $|I0\rangle$ and $|I1\rangle$ is meaningless.

The influence of consciousness for which the father is really dead is to modify pre-consciousness by making it get a component "the father is dead". Whereas initially for pre-consciousness, which is initially in the quantum state of the unconscious, "the father is still alive" the consequence of the interaction with consciousness is that pre-consciousness cannot remain in this quantum state. It acquires a component "the father is dead". Then pre-consciousness is in a (statistical) mixing of quantum states "the father is dead" and "the father is still alive". The (statistical) weight of the component "the father is dead" ($\sin^2(\pi Jt)$) depends on time t during which pre-consciousness and consciousness interact. Therefore the influence of consciousness is to allow mourning to proceed at the level of pre-consciousness. As a fonction of time the θ_I angle varies from π to $\pi - 2\pi Jt$, t being the time of interaction between consciousness and pre-consciousness.

Let us notice that if the initial state of the two-qubit (28) and (29) system is $|I0\rangle|C0\rangle$, i.e. that for consciousness and pre-consciousness (which has swapped with unconscious) "the father is really dead", the operator (35) applied on this quantum state does not modify it. The quantum state of the two-qubit (28) and (29) system remains $|I0\rangle|C0\rangle$ for all values of time; this is true up to an overall phase. This is understandable because, mourning being achieved both at the level of unconscious and consciousness, nothing changes.

The entropy of entanglement S_{IC} between pre-consciousness and consciousness is given by formula (40):

$$S_{IC}(t) = -(\cos^2(\pi Jt)\log[\cos^2(\pi Jt)] + \sin^2(\pi Jt)\log[\sin^2(\pi Jt)]), \quad (43)$$

which corresponds to von Neumann's entropy for consciousness or pre-consciousness, each considered as parts of the pre-consciousness + consciousness system (see reference [15]).

5.1.2. Special case II. In the second special case that we consider the initial quantum state of qubit 1 is $|0\rangle$ and the initial quantum state of qubit 2 is $|1\rangle$. As far as qubits (28) and (29) are concerned it corresponds to an initial quantum state $|I0\rangle|C1\rangle$. Regarding mourning, the unconscious of the person knows that his (or her) father is dead, quantum state $|I0\rangle$ (or $|U0\rangle$), while his (or her) consciousness does not know it, quantum state $|C1\rangle$. This situation is, for example, the one in which seeing his father's death is such a trauma for the son that his consciousness represses this death. On the other hand in such a situation the son's unconscious knows that his father is dead. The father's death is forced into the unconscious. As far as unconscious and consciousness are concerned it is the symmetrical situation of the one considered in the previous special case, noting that, as in special case I, it is pre-consciousness which interacts with consciousness. At time t the two-qubit system is represented by the state $|I, C\rangle_{(t)} = \mathcal{U}(t)|I0\rangle|C1\rangle$, i.e.:

$$|I,C\rangle_{(t)} = \mathcal{U}(t)|I0\rangle|C1\rangle = e^{+i\pi Jt/2}[\cos(\pi Jt)|I0\rangle|C1\rangle - i\sin(\pi Jt)|I1\rangle|C0\rangle]. \quad (44)$$

Like in the first special case, whereas initially the two-qubit system of qubits (28) and (29) is a separable system (there is factorisation of the two states $|I0\rangle$ and $|C1\rangle$), at time t there is quantum entanglement of states $|I\rangle$ et $|C\rangle$. This is indicated by the fact that there is no more factorisation of states $|I\rangle$ and $|C\rangle$ (except at time $t = k/(2J)$, k being an integer). So, generally speaking, at time t, the two-qubit system of qubits (28) and (29) is a non-separable system. As before this is a consequence of the interaction between pre-consciousness and consciousness.

Likewise in the first special case, formula (44) shows that the quantum entangled state $|I, C\rangle_{(t)}$ is subjected to Rabi oscillations between the states $|I0\rangle|C1\rangle$

[20] Let us recall that $\theta_I(0) = \theta_U/(0) = \pi$.

and $|I1\rangle|C0\rangle$. The frequency of those oscillations (Rabi frequency) is J. Let us notice that those Rabi oscillations are precisely the same as in the first special case, apart from the fact that they are shifted in time. After a time $t = 1/(2J)$ pre-consciousness is disentangled from consciousness:

$$\mathcal{U}(t = 1/(2J))|I0\rangle|C1\rangle = e^{-i\pi/4}|I1\rangle|C0\rangle. \quad (45)$$

We observe a swapping between the quantum state of pre-consciousness, which is initially the quantum state of the unconscious, and the quantum state of consciousness. With regard to the initial state, up to an overall (and thus irrelevant) phase, $|I0\rangle$ becomes $|I1\rangle$ and $|C1\rangle$ becomes $|C0\rangle$. We infer that at time $t = 1/(2J)$ consciousness is in the initial state of pre-consciousness, i.e. in the quantum state of the unconscious $|U0\rangle$. The information "$|0\rangle$", corresponding in mourning to the information "father is dead", reaches consciousness. So at this moment consciousness measures the unconscious and consequently faces reality: "father is dead".

After time $t = 1/J$ the quantum entangled state $\mathcal{U}(t)|I0\rangle|C1\rangle$ is again in the initial state $|I0\rangle|C1\rangle$ up to an overall irrelevant phase equal to $-\pi/2$.

To determine the influence of pre-consciousness (and therefore of the unconscious) on consciousness we will use the density operators such as they are described at the end of the previous Subsection. Thus we consider consciousness C as part of the quantum system $I + C$, i.e. pre-consciousness + consciousness. The quantum state of the system $I + C$ is the state (44) which exhibits quantum entanglement between pre-consciousness and consciousness. Consciousness C is not described by a pure quantum state but by the density operator ρ_C (39) in which $|\Psi\rangle_{IC}$ is given by (44). A calculation, thanks to definition (39), leads to:

$$\rho_C = Tr_I(|\Psi\rangle_{IC}\ {}_{IC}\langle\Psi|) = \cos^2(\pi Jt)|C1\rangle\langle C1| + \sin^2(\pi Jt)|C0\rangle\langle C0|. \quad (46)$$

This density operator corresponds to the density operator of a (statistical) mixing of pure quantum states (29) in which the $\theta_C(t)$ angle would be equal to $\pi - 2\pi Jt$.

The influence of pre-consciousness (and therefore of the unconscious) on consciousness is exactly the influence of consciousness on pre-consciousness such as it has been described in the first special case (Subsection 5.1.1). Consciousness acquires a component "father is dead" and thus is in a (statistical) mixing of quantum states "father is dead" and quantum states "father is still alive". The (statistical) weight of the component "father is dead" ($\sin^2(\pi Jt)$) depends on time t during which pre-consciousness and consciousness interact.

In this way, thanks to the interaction with pre-consciousness, the person's consciousness becomes gradually aware of his (or her) father's death. As a function of time the θ_C angle varies from π to $\pi - 2\pi Jt$, t being the time of interaction between consciousness and pre-consciousness.

Likewise if we want to describe pre-consciousness alone in the quantum entangled state (44) we calculate the density operator ρ_I:

$$\rho_I = Tr_C(|\Psi\rangle_{IC}\ {}_{IC}\langle\Psi|) = \cos^2(\pi Jt)|I0\rangle\langle I0| + \sin^2(\pi Jt)|I1\rangle\langle I1|. \quad (47)$$

This density operator corresponds to the density operator of a (statistical) mixing of pure quantum states (25) in which the $\theta_I(t)$ angle would be equal to $2\pi Jt$.[21]

The influence of consciousness on pre-consciousness is the same as the influence of the unconscious on consciousness such as it has been described in the first special case (Subsection 5.1.1). Pre-consciousness acquires a component "father is still alive" and thus is in a (statistical) mixing of quantum states "father is dead" and "father is still alive." The (statistical) weight of the component "father is still alive" ($\sin^2(\pi Jt)$) depends on time t during which pre-consciousness and consciousness interact. Therefore the influence of consciousness is to modify temporarily (during the time of interaction) in pre-consciousness the information "father is dead." As a function of time the θ_I angle varies from 0 to $2\pi Jt$, t being the time of interaction between consciousness and pre-consciousness.

In this second special case the entropy of entanglement $S_{IC}(t)$ between pre-consciousness and consciousness is given by the same formula as in the first special case (formula (43)).

5.2. General Case

We are going to consider the general case in which the initial states of qubits 1 and 2 are given by the general formula (1). Regarding qubits (28) and (29) their initial states are respectively given by:[22]

$$|I(0)\rangle = e^{-i\phi_U(0)/2}\cos(\theta_U(0)/2)|I0\rangle + e^{i\phi_U(0)/2}\sin(\theta_U(0)/2)|I1\rangle, \quad (48)$$

and

$$|C(0)\rangle = e^{-i\phi_C(0)/2}\cos(\theta_C(0)/2)|C0\rangle + e^{i\phi_C(0)/2}\sin(\theta_C(0)/2)|C1\rangle. \quad (49)$$

Initially, i.e. at time $t = 0$, the system made up of pre-consciousness and consciousness is represented by the factorised pure quantum state $|I(0)\rangle|C(0)\rangle$. Pre-

[21] Let us recall that in this case $\theta_I(0) = \theta_U(0) = 0$.

[22] Let us recall that initially, at time $t = 0$, thanks to swappings pre-consciousness is in the quantum state of the unconscious.

consciousness and consciousness form a separable system. We can write $|I(0)\rangle|C(0)\rangle$ in the form of:

$$|I(0)\rangle|C(0)\rangle = a_{00}(0)|I0\rangle|C0\rangle + a_{01}(0)|I0\rangle|C1\rangle + a_{10}(0)|I1\rangle|C0\rangle + a_{11}(0)|I1\rangle|C1\rangle, \quad (50)$$

with

$$a_{00}(0) = e^{-i[\phi_U(0)+\phi_C(0)]/2} \times \cos(\theta_U(0)/2)\cos(\theta_C(0)/2), \quad (51)$$

$$a_{01}(0) = e^{-i[\phi_U(0)-\phi_C(0)]/2} \times \cos(\theta_U(0)/2)\sin(\theta_C(0)/2), \quad (52)$$

$$a_{10}(0) = e^{+i[\phi_U(0)-\phi_C(0)]/2} \times \sin(\theta_U(0)/2)\cos(\theta_C(0)/2), \quad (53)$$

$$a_{11}(0) = e^{+i[\phi_U(0)+\phi_C(0)]/2} \times \sin(\theta_U(0)/2)\sin(\theta_C(0)/2). \quad (54)$$

Let us suppose that from time $t = 0$ pre-consciousness is in interaction with consciousness, with the interaction being described by Hamiltonian (12). At time t the pre-consciousness + consciousness system is represented by the quantum state $|I, C\rangle_{(t)} = \mathcal{U}(t)|I(0)\rangle|C(0)\rangle$, the operator $\mathcal{U}(t)$ being given by matrix (35). Then there is no more necessarily factorisation between pre-consciousness and consciousness. Pre-consciousness and consciousness are quantum entangled. They form a non-separable system. In a way similar to formula (50), which represents the decomposition of $|I(0)\rangle|C(0)\rangle$ on the base ($|I0, C0\rangle$, $|I0, C1\rangle$, $|I1, C0\rangle$, $|I1, C1\rangle$), we can decompose $|I, C\rangle_{(t)}$:

$$|I,C\rangle_{(t)} = a_{00}(t)|I0\rangle|C0\rangle + a_{01}(t)|I0\rangle|C1\rangle + a_{10}(t)|I1\rangle|C0\rangle + a_{11}(t)|I1\rangle|C1\rangle. \quad (55)$$

The action of the matrix operator (35) on the quantum state (50) leads to:

$$a_{00}(t) = e^{-i\pi Jt/2}a_{00}(0), \quad (56)$$

$$a_{01}(t) = e^{+i\pi Jt/2} \times [\cos(\pi Jt)a_{01}(0) - i\sin(\pi Jt)a_{10}(0)], \quad (57)$$

$$a_{10}(0) = e^{+i\pi Jt/2} \times [-i\sin(\pi Jt)a_{01}(0) + \cos(\pi Jt)a_{10}(t)], \quad (58)$$

$$a_{11}(t) = e^{-i\pi Jt/2}a_{11}(0). \quad (59)$$

Let us notice that the quantum entangled state $|I, C\rangle_{(t)}$ is the superposition of four quantum states:

—two states which do not vary as functions of time[23]: $|I0\rangle|C0\rangle$ and $|I1\rangle|C1\rangle$,

—and two states, (36) and (44), which, as we have seen before, are subjected (as functions of time) to Rabi oscillations of frequency J between the states $|I1\rangle|C0\rangle$ and $|I0\rangle|C1\rangle$.

[23]Except up to a phase equal to $-\pi Jt/2$.

The relative phase between the two first states and the two last ones is equal to $-\pi Jt$. Therefore it varies as a function of time.

All this can be directly seen on matrix (35), the Rabi oscillations being explicitly visible in the 2×2 matrix which is at the centre of the 4×4 matrix.

We will see further on in this Subsection that likewise in the two special cases, after a time $t = 1/(2J)$, pre-consciousness disentangles from consciousness, with a swapping between the quantum state of pre-consciousness, which is initially the quantum state of the unconscious, and the quantum state of consciousness.

The density operator of the pre-consciousness + consciousness system, $|I, C\rangle_{(t)}$, writes:

$$\rho_{IC}(t) = |I,C\rangle_{(t)\ (t)}\langle I,C|, \quad (60)$$

${}_{(t)}\langle I, C|$ being the hermitian conjugate vector of $|I, C\rangle_{(t)}$. The density operator (60) is the density operator of a pure quantum state, $|I, C\rangle_{(t)}$.

If we want to describe consciousness alone, it will be described by the density operator:

$$\rho_C(t) = Tr_I(|I,C\rangle_{(t)\ (t)}\langle I,C|). \quad (61)$$

The calculation of this trace leads to:

$$\rho_C(t) = b_{00}(t)|C0\rangle\langle C0| + b_{11}(t)|C1\rangle\langle C1| + b_{01}(t)|C0\rangle\langle C1| + b_{01}^*(t)|C1\rangle\langle C0|, \quad (62)$$

with $b_{00}(t) = |a_{00}(t)|^2 + |a_{10}(t)|^2$, $b_{11}(t) = |a_{01}(t)|^2 + |a_{11}(t)|^2$, $b_{01}(t) = a_{00}(t)a_{01}^*(t) + a_{10}(t)a_{11}^*(t)$, a^*'s and b^*'s being the complex conjugates of the corresponding a's and b's.

Unlike the density operator $\rho_{IC}(t)$, the density operator $\rho_C(t)$ is not in general the one of a pure quantum state, but is the one of a (statistical) mixing of pure quantum states (29) in which the $\theta_C(t)$ angle would be given by the relation:

$$\cos^2[\theta_C(t)/2] = Tr[\rho_C(t)|C0\rangle\langle C0|] = |a_{00}(t)|^2 + |a_{10}(t)|^2. \quad (63)$$

Making $a_{00}(t)$ and $a_{10}(t)$ explicit, thanks to formulae (56) and (58), a calculation leads to the relation:

$$\cos^2[\theta_C(t)/2] = \cos^2[\theta_C(0)/2]\cos^2(\pi Jt) + \cos^2[\theta_U(0)/2]\sin^2(\pi Jt) + D(t), \quad (64)$$

with

$$D(t) = (1/4)\sin(2\pi Jt)\sin\theta_U(0)\sin\theta_C(0) \times \sin[\phi_C(0) - \phi_U(0)]. \quad (65)$$

First of all let us notice that for the two special cases considered in the previous Subsections we find again the same results. The first special case corresponds to the initial conditions $\theta_U(0) = \pi$ and $\theta_C(0) = 0$ which, for relation (64), gives:

$$\cos^2[\theta_C(t)/2] = \cos^2(\pi Jt). \quad (66)$$

This relation does correspond to the $\theta_C(t)$ angle equals to $2\pi Jt$ as previously found.

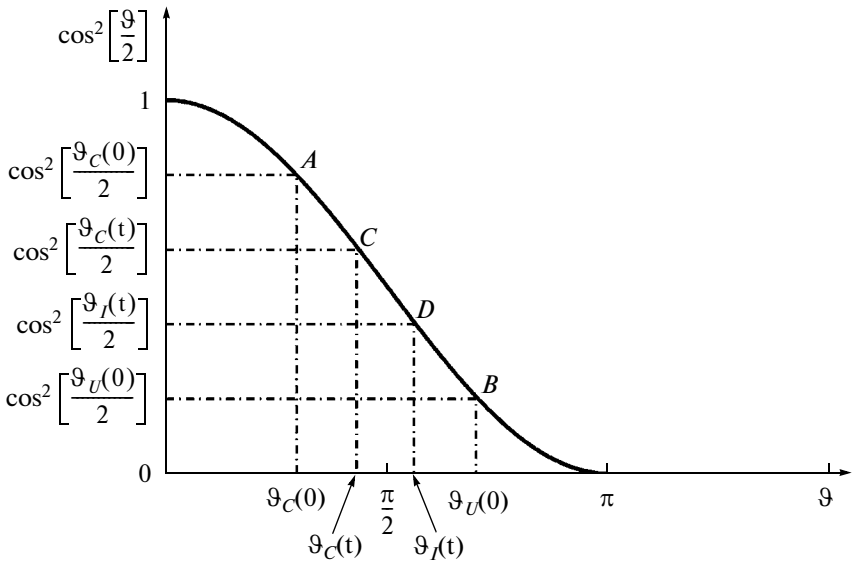

Fig. 5. Variations of $\vartheta_C(t)$ and $\vartheta_I(t)$ angles as functions of time in the general case (formulae (68) and (73)).

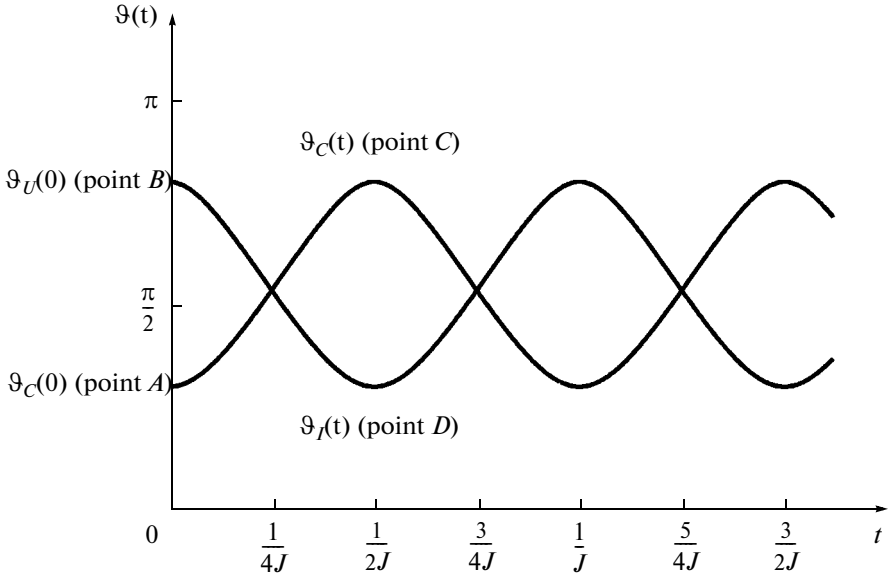

Fig. 6. Explicit variations of $\vartheta_C(t)$ and $\vartheta_I(t)$ angles showing oscillations as functions of time in the general case (formulae (68) and (73)).

In the second special case the initial conditions are $\theta_U(0) = 0$ and $\theta_C(0) = \pi$ which, for relation (64), gives:

$$\cos^2[\theta_C(t)/2] = \sin^2(\pi Jt). \tag{67}$$

This relation does correspond to the $\theta_I(t)$ angle equals to $\pi - 2\pi Jt$ as previously found.

To study the general case we will assume for simplicity that the initial conditions are such that $\phi_U(0) = \phi_C(0)$ which means that the initial qubits $|I(0)\rangle$ and $|C(0)\rangle$ are in the same plane going through the Oz axis. In this case $D(t)$ is equal to 0 and we have the simplified relation:

$$\begin{aligned}\cos^2[\theta_C(t)/2] = \cos^2[\theta_C(0)/2]\cos^2(\pi Jt)\\ + \cos^2[\theta_U(0)/2]\sin^2(\pi Jt).\end{aligned} \tag{68}$$

Thus when t varies, $\cos^2[\theta_C(t)/2]$ spans the interval $[\cos^2[\theta_C(0)/2], \cos^2[\theta_U(0)/2]]$ which means that the $\theta_C(t)$ angle spans the interval $[\theta_C(0), \theta_U(0)]$, the $\theta_C(0)$ and $\theta_U(0)$ angle values being between 0 and π (Figs. 5 and 6).

Likewise for consciousness, if we want to describe pre-consciousness alone, it will be described by the density operator:

$$\rho_I(t) = Tr_C(|I,C\rangle_{(t)\ \ (t)}\langle I,C|). \tag{69}$$

Calculation of this trace leads to:

$$\begin{aligned}\rho_I(t) = c_{00}(t)|I0\rangle\langle I0| + c_{11}(t)|I1\rangle\langle I1| \\ + c_{01}(t)|I0\rangle\langle I1| + c_{01}^*(t)|I1\rangle\langle I0|,\end{aligned} \tag{70}$$

with $c_{00}(t) = |a_{00}(t)|^2 + |a_{01}(t)|^2$, $c_{11}(t) = |a_{10}(t)|^2 + |a_{11}(t)|^2$, $c_{01}(t) = a_{00}(t)a_{10}^*(t) + a_{01}(t)a_{11}^*(t)$, a*'s and c*'s being the complex conjugates of the corresponding a's and c's.

Unlike the density operator $\rho_{IC}(t)$ the density operator $\rho_I(t)$ is not in general the one of a pure quantum state, but is the one of a (statistical) mixing of pure quantum states (25) in which the $\theta_I(t)$ angle would be given by the relation:

$$\begin{aligned}\cos^2[\theta_I(t)/2] = Tr[\rho_I(t)|I0\rangle\langle I0|] \\ = |a_{00}(t)|^2 + |a_{01}(t)|^2.\end{aligned} \tag{71}$$

Making $a_{00}(t)$ and $a_{01}(t)$ explicit, thanks to formulae (56) and (57), a calculation leads to the relation:

$$\begin{aligned}\cos^2[\theta_I(t)/2] = \cos^2[\theta_U(0)/2]\cos^2(\pi Jt) \\ + \cos^2[\theta_C(0)/2]\sin^2(\pi Jt) - D(t),\end{aligned} \tag{72}$$

with $D(t)$ given by formula (65).

Still standing in the case where the initial qubits $|I(0)\rangle$ and $|C(0)\rangle$ are in the same plane going through the Oz axis ($\phi_U(0) = \phi_C(0)$), $D(t)$ is equal to 0 and we have the simplified relation:

$$\begin{aligned}\cos^2[\theta_I(t)/2] = \cos^2[\theta_U(0)/2]\cos^2(\pi Jt) \\ + \cos^2[\theta_C(0)/2]\sin^2(\pi Jt).\end{aligned} \tag{73}$$

This relation shows that when time t varies, $\cos^2[\theta_I(t)/2]$ spans the interval $[\cos^2[\theta_U(0)/2], \cos^2[\theta_C(0)/2]]$ which means that the $\theta_I(t)$ angle spans the interval $[\theta_U(0), \theta_C(0)]$, the $\theta_U(0)$ and $\theta_C(0)$ angle values being between 0 and π (Figs. 5 and 6).

When t varies the $\theta_I(t)$ and $\theta_C(t)$ angles come closer together. On the curve of Fig. 5 this means that points C and D come closer together. When $t = 1/(4J)$ the two angles are equal, as shown by the fact that relations (68) and (73) are identical. On the curve of Fig. 5 points C and D are identical. In some way (because we are not dealing with pure quantum states but with mixings) we can say that pre-consciousness and consciousness are lined up.[24] Therefore when t varies from 0 to $1/(4J)$ there is some kind of attraction between pre-consciousness and consciousness.

Then when t varies from $1/(4J)$ to $1/(2J)$ the difference $|\theta_I(t) - \theta_C(t)|$ increases again from 0 to the initial value $|\theta_U(0) - \theta_C(0)|$. There is a kind of repulsion between pre-consciousness and consciousness. On the curve of Fig. 5, points C and D are now reversed with regard to what is shown on the Figure, point C getting closer to point B while point D gets closer to point A.

Let us notice that when $t = 1/(2J)$ the quantum state $|I, C\rangle_{(t)}$ is no more a quantum entangled state because we have the factorisation:

$$|I,C\rangle_{(t = 1/(2J))} = e^{-i\pi/4}|C(0)\rangle|I(0)\rangle, \tag{74}$$

i.e.

$$|I,C\rangle_{(t = 1/(2J))} = |I(t = 1/(2J))\rangle|C(t = 1/(2J))\rangle, \tag{75}$$

with, up to an overall (and thus irrelevant) phase equals to $-\pi/4$:

$|I(t = 1/(2J))\rangle = |C(0)\rangle$ and $|C(t = 1/(2J))\rangle = |I(0)\rangle$. Pre-consciousness and consciousness are quantum disentangled[25] as they were at the initial time $t = 0$. However there has been a swapping between pre-consciousness and consciousness. The quantum state of pre-consciousness at time $t = 1/(2J)$ is the quantum state of consciousness at time $t = 0$. On the curve of Fig. 5 this means that point D is identified with point A. As for the quantum state of consciousness, at time $t = 1/(2J)$ it is the quantum state of pre-consciousness at time $t = 0$, i.e. the quantum state of the unconscious at time $t = 0$. On the curve of Fig. 5 this means that point C is identified with point B. At time $t = 1/(2J)$ we can say that consciousness measures pre-consciousness as it was at time $t = 0$ and consequently it measures the unconscious (in a non destructive way; QND: Quantum Non-Demolition). Reciprocally, at the same time, pre-consciousness measures consciousness as it was at time $t = 0$.

If we let pre-consciousness and consciousness interact from time $t = 1/(2J)$ the difference $|\theta_I(t) - \theta_C(t)|$ decreases again until it cancels at time $t = 3/(4J)$. Points D and C come closer together again. We are again in the presence of a kind of attraction between pre-consciousness and consciousness. At time $t = 3/(4J)$ pre-consciousness and consciousness are again "lined up." Points D and C are again identical on the curve of Fig. 5.

Next, between time $t = 3/(4J)$ and $t = 1/J$, the difference $|\theta_I(t) - \theta_C(t)|$ increases again from 0 to the initial value $|\theta_U(0) - \theta_C(0)|$. There is again a kind of repulsion between pre-consciousness and consciousness. Point C comes closer to point A, while point D gets closer to point B. At time $t = 1/J$ we are back in the initial configuration. Point C is in A, whereas point D is in B. Pre-consciousness and consciousness are again quantum disentangled with, up to an overall (and thus irrelevant) phase equals to $-\pi/2$: $|I(t = 1/J)\rangle = |I(0)\rangle$ and $|C(t = 1/J)\rangle = |C(0)\rangle$.

[24] It is not an alignment of Bloch's sphere vectors because qubits $|I(t)\rangle$ and $|C(t)\rangle$ are not defined. It is an alignment for which $\theta_I(t = 1/(4J)) = \theta_C(t = 1/(4J))$. It is an alignment with regard to mourning.

[25] Let us notice that the factorisation property (74) or (75) is valid whatever the values of $\phi_U(0)$ and $\phi_C(0)$ may be. When $t = 1/(2J)$ pre-consciousness and consciousness are again identified by vectors on the Bloch's sphere and we have $\phi_I(t = 1/(2J)) = \phi_C(0)$ and $\phi_C(t = 1/(2J)) = \phi_I(0) = \phi_U(0)$.

It is important to emphasize that if we let pre-consciousness and consciousness interact with a Hamiltonian such as (12) during a time less or equal to $t_M = 1/(4J)$, pre-consciousness and consciousness will have an influence upon each other by getting closer, until they "line up" at time $t_M = 1/(4J)$. On the other hand if we let them interact during longer time the interaction leads to cyclic phenomena such as Rabi oscillations.

For example let us suppose that the initial conditions are such that we have $\theta_U(0) > \theta_C(0)$, i.e. mourning is more advanced in consciousness than in the unconscious and consequently in pre-consciousness. If pre-consciousness and consciousness interact during a time $t < t_M = 1/(4J)$ mourning will make progress at the level of pre-consciousness whereas it will decline at the level of consciousness.

6. INFLUENCE OF CONSCIOUSNESS ON UNCONSCIOUS. INTERACTION BETWEEN PRE-CONSCIOUSNESS AND UNCONSCIOUS

In the previous Section, thanks to a basic interaction between two "nearby" qubits, the interaction given by Hamiltonian (12), and thanks to a sequence of swappings allowing "to bring two qubits closer together", e.g. a qubit of the unconscious closer to a qubit of consciousness, we were able to determine, within the framework of quantum mechanics, the influence of the unconscious on consciousness (as well as the influence of consciousness on pre-consciousness). Likewise we can suppose the existence of a sequence of swappings allowing "to bring" a qubit of consciousness "closer" to a qubit deeply burried in the unconscious. The number of swappings N' of such a sequence, which allows the transfer of information contained in consciousness to "the pre-consciousness closest to this deep unconscious", can be large (see Subsection 4.2).

Although this sequence of swappings makes the conscious qubit "enter" deeply in the unconscious, still we will name it a sequence of "pre-consciousness qubits" which "brings" the conscious qubit "closer" to an unconscious one. It is only a matter of terminology.

Thus we start from an initial situation similar to the one of formulae (28) and (29):

$$|I\rangle = e^{-i\phi_C/2}\cos(\theta_C/2)|I0\rangle + e^{i\phi_C/2}\sin(\theta_C/2)|I1\rangle, \quad (76)$$

which is nothing else but the qubit representing the initial quantum state of consciousness related to mourning.

On the other hand, generally speaking, the unconscious qubit related to mourning is represented by:

$$|U\rangle = e^{-i\phi_U/2}\cos(\theta_U/2)|U0\rangle + e^{i\phi_U/2}\sin(\theta_U/2)|U1\rangle. \quad (77)$$

Then we study the interaction between the two qubits (76) and (77) as it is given by the Hamiltonian (12).

The situation is exactly symmetrical to the one of Section 5. We just have to exchange the words consciousness and unconscious to determine, in this framework, the influence of consciousness on the unconscious, this in both special cases studied in Section 5, as well as in the general case.

7. INTERACTION BETWEEN TWO UNCONSCIOUS

We now consider the interaction between two unconscious, e.g. Alice's unconscious and Bob's unconscious, this interaction being given by an Hamiltonian such as (12) in which the *coupling strength* will be measured not by J but by J'. Let us recall that for unconscious we consider binary situations, like for example the case of mourning, and that in such situations unconscious are described by qubits.

Formalism and results are exactly the same as in the case of interaction between the pre-consciousness and consciousness of a given individual, this in both special cases considered above as well as in the general case.

To describe the interaction between Alice's unconscious and Bob's unconscious, we directly consider the general case. The initial qubits, i.e. at time $t = 0$, representing respectively Alice's and Bob's unconscious (related to mourning) are:

$$|UA(0)\rangle = e^{-i\phi_{UA}(0)/2}\cos(\theta_{UA}(0)/2)|UA0\rangle + e^{i\phi_{UA}(0)/2}\sin(\theta_{UA}(0)/2)|UA1\rangle, \quad (78)$$

and

$$|UB(0)\rangle = e^{-i\phi_{UB}(0)/2}\cos(\theta_{UB}(0)/2)|UB0\rangle + e^{i\phi_{UB}(0)/2}\sin(\theta_{UB}(0)/2)|UB1\rangle. \quad (79)$$

The quantum states $|UA0\rangle$ and $|UA1\rangle$ are the states of Alice's unconscious for which mourning is respectively completely achieved and non achieved. It is the same for the quantum states of Bob's unconscious $|UB0\rangle$ and $|UB1\rangle$.

Initially the system made of Alice and Bob's unconscious is represented by the factorized pure quantum state $|UA(0)\rangle|UB(0)\rangle$. The two unconscious form a separable system. If, from time $t = 0$, the two unconscious are in interaction, the Hamiltonian of interaction being given by formula (12) (with J' instead of J), at time t the Alice's unconscious + Bob's unconscious system is represented by the quantum state $|UA, UB\rangle_{(t)} = \mathcal{U}(t)|UA(0)\rangle|UB(0)\rangle$, the operator $\mathcal{U}(t)$ being given by matrix (35) (with J' instead of J). Then there is no more necessarily factorisation between the two unconscious. The two unconscious are quantum entangled. They form a non-separable system.

Likewise $|I, C\rangle_{(t)}$ (formulae (55–59)) the quantum entangled state $|UA, UB\rangle_{(t)}$ is the superposition of four quantum states:

—two states which do not vary as functions of time[26]: $|UA0\rangle|UB0\rangle$ and $|UA1\rangle|UB1\rangle$,

—and two states which, like states (36) and (44), are subjected (as functions of time) to Rabi oscillations of frequency J' between the states $|UA1\rangle|UB0\rangle$ and $|UA0\rangle|UB1\rangle$.

The relative phase between the two first states and the two last ones is equal to $-\pi J't$. Therefore it varies as a function of time.

In a similar way as we have seen in Section 5, at time $t = 1/(2J')$, Alice's unconscious is quantum disentangled from Bob's unconscious with a swapping between the quantum states of the two unconscious. Thus at this moment Alice's unconscious measures Bob's unconscious as it was at time $t = 0$ and vice versa (this is done in a non destructive way; QND).

The density operator of Alice's unconscious + Bob's unconscious system, $|UA, UB\rangle_{(t)}$, writes:

$$\rho_{UA,UB}(t) = |UA, UB\rangle_{(t)\ (t)}\langle UA, UB|, \tag{80}$$

${}_{(t)}\langle U\,A, UB|$ being the hermitian conjugate vector of $|UA, UB\rangle_{(t)}$. The density operator (80) is the density operator of a pure quantum state $|UA, UB\rangle_{(t)}$. If we want to describe Alice's unconscious alone it will be described by the density operator:

$$\rho_{UA}(t) = Tr_{UB}(|UA, UB\rangle_{(t)\ (t)}\langle UA, UB|). \tag{81}$$

Unlike the density operator $\rho_{UA,\,UB}(t)$ the density operator. $\rho_{UA}(t)$ is not in general the one of a pure quantum state, but the one of a (statistical) mixing of pure quantum states:

$$\begin{aligned}|UA\rangle_{(t)} &= e^{-i\phi_{UA}(t)/2}\cos(\theta_{UA}(t)/2)|UA0\rangle \\ &+ e^{i\phi_{UA}(t)/2}\sin(\theta_{UA}(t)/2)|UA1\rangle,\end{aligned} \tag{82}$$

in which the $\theta_{UA}(t)$ angle would be given by the relation:

$$\cos^2[\theta_{UA}(t)/2] = Tr[\rho_{UA}(t)|UA0\rangle\langle UA0|]. \tag{83}$$

Assuming for simplicity that the initial conditions are such that $\phi_{UA}(0) = \phi_{UB}(0)$ which means that the initial $|UA(0)\rangle$ and $|UB(0)\rangle$ are in the same plane going through the Oz axis we obtain the relation:

$$\begin{aligned}\cos^2[\theta_{UA}(t)/2] &= \cos^2[\theta_{UA}(0)/2]\cos^2(\pi J't) \\ &+ \cos^2[\theta_{UB}(0)/2]\sin^2(\pi J't).\end{aligned} \tag{84}$$

In the same way if we want to describe Bob's unconscious alone it will be described by the density operator:

$$\rho_{UB}(t) = Tr_{UA}(|UA, UB\rangle_{(t)\ (t)}\langle UA, UB|). \tag{85}$$

Unlike the density operator $\rho_{UA,\,UB}(t)$ the density operator $\rho_{UB}(t)$ is not in general the one of a pure quantum state, but the one of a (statistical) mixing of pure quantum states:

$$\begin{aligned}|UB\rangle_{(t)} &= e^{-i\phi_{UB}(t)/2}\cos(\theta_{UB}(t)/2)|UB0\rangle \\ &+ e^{i\phi_{UB}(t)/2}\sin(\theta_{UB}(t)/2)|UB1\rangle,\end{aligned} \tag{86}$$

in which the $\theta_{UB}(t)$ angle is given by the relation:

$$\cos^2[\theta_{UB}(t)/2] = Tr[\rho_{UB}(t)|UB0\rangle\langle UB0|]. \tag{87}$$

Standing in the same simplified initial conditions than previously ($\phi_{UA}(0) = \phi_{UB}(0)$) we obtain the relation:

$$\begin{aligned}\cos^2[\theta_{UB}(t)/2] &= \cos^2[\theta_{UB}(0)/2]\cos^2(\pi J't) \\ &+ \cos^2[\theta_{UA}(0)/2]\sin^2(\pi J't).\end{aligned} \tag{88}$$

To describe the variations of $\theta_{UA}(t)$ and $\theta_{UB}(t)$ angles as functions of time we can reproduce verbatim the discussion of Subsection 5.2 about the variations of $\theta_I(t)$ and $\theta_C(t)$ angles as functions of time.

As an example let us suppose that Alice is a psychoanalyst who helps Bob to achieve his mourning. For Alice the initial angle $\theta_{UA}(0)$ is close to 0. Indeed, since she is not necessarily affected by Bob's mourning, Alice can easily achieve this mourning. On the other hand, if Bob finds it difficult to achieve his mourning, the initial $\theta_{UB}(0)$ angle can be close to π. The discussion of Subsection 5.2 indicates that, as a function of time, the $\theta_{UA}(t)$ angle increases whereas the $\theta_{UB}(t)$ angle decreases. There is an attraction between the two unconscious, Alice's unconscious helping Bob's unconscious toward the achievement of his mourning. This occurs until the time $t = 1/(4J')$ for which the $\theta_{UA}(t)$ and $\theta_{UB}(t)$ angles are equal. At this moment Alice's and Bob's unconscious related to mourning are "lined up." The two unconscious, the psychoanalyst's and her patient's, are "brought into alignment."

8. DISCUSSION

8.1. Nuclear Magnetic Resonance and Mental Qubits

In analogy with quantum information and control of qubits, as it is done, for instance, in Nuclear Magnetic Resonance (NMR), we have considered the control of mental qubits (belonging to the unconscious, pre-consciousness or consciousness, with as examples mental qubits describing mourning states).

Thus, thanks to a combination of psyche field pulses and of a spin-spin interaction (14) between two qubits, we have been able to implement a controlled-NOT (CNOT) quantum gate. The passage through this CNOT gate of a control qubit (e.g. belonging to the unconscious) and of a target qubit in a given state (e.g. from consciousness and in the state $|C0\rangle$) allows the target qubit to become entangled with the control qubit so that a measurement is performed upon the control qubit by the target qubit. In this way we have a measurement of the unconscious (or of pre-consciousness) by consciousness. In the same way, the passage through this CNOT gate of a control qubit

[26] Except up to a phase equal to $-\pi J't/2$.

from consciousness and of a target qubit belonging to the unconscious (or to pre-consciousness) in a given state (e.g. in the state $|U0\rangle$) allows the "measurement" of consciousness by the unconscious (or by pre-consciousness).

The implementation of this controlled-NOT quantum gate requires a time of interaction between the two qubits equals to $1/(2J)$ (see formula (18) and (19)). In Nuclear Magnetic Resonance (NMR) [28], when the magnetic interaction between two nuclear spins "is mediated by the electrons shared in the chemical bonds between the atoms", J is called "*the through-bond coupling strength*". "J depends on the respective nuclear species and decreases with the number of chemical bonds separating the nuclei. Typical values for J are up to a few hundred Hertz for *one-bound couplings* and down to only a few Hertz for *three- or four-bonds couplings*". As far as time $t = 1/(2J)$ is concerned, this corresponds, in the former case, to a time t of the order of a millisecond, and in the latter to a time t of the order of a tenth of a second.

Regarding the coupling strength J between pre-consciousness and consciousness, its estimation seems more difficult. Nevertheless, we can say that, as in the case of NMR, J must vary as a function of the "bonds" and must decrease as a function of the number of these "bonds". These "bonds" could be all that prevents the "reading" of pre-consciousness by consciousness, or more generally all that hinders pre-consciousness and consciousness to interact. These "bounds" could be of personal nature: introspection and reflection skill, inability to organize one's own memories into a hierarchy ..., or they can belong to the environment: social connections, different kinds of relationships, group situations, ... As we have seen in Section 4, J is also related to the respective intensities of the psyche fields generated by pre-consciousness and consciousness. *The more intense the respective psyche fields generated by pre-consciousness and consciousness are, the larger the coupling constant J will be.* In this case, the "bonds" could shield the interaction between the two psyche fields. Again, the larger the number of these "bonds" is, the smaller the constant J will be, and therefore the more difficult it will be for the two psyche fields to interact. In summary, the coupling constant J depends both on the intensity of each of the two interacting psyche fields and on the number of "bonds" that shield the interaction of these two psyche fields. These considerations are similar to what happens in renormalisation theory where the coupling constant between two particles (an electron and a proton for the electromagnetic field, or a proton and a neutron for the strong nuclear interaction field) depends on the number of virtual pairs of particles that shield the two interacting particles [9]. All that has been said above on the coupling strength J between pre-consciousness and consciousness is of course also valid for the coupling strength between pre-consciousness and the unconscious.

As far as the interaction between pre-consciousness and consciousness is concerned, for the time $t = 1/(2J)$, an order of magnitude can be estimated from the results of the experiments on the brain performed by Libet [51]. These experiments show that the decision to carry out a muscular action is taken half-a-second before the consciousness of the decision is acquired. If we assume that this half-a-second interval is the interaction time between pre-consciousness and consciousness, this will be of the same order of magnitude of the time $t = 1/(2J)$ used in analogy with NMR when there are several chemical bonds between two nuclei.

We have seen (Subsection 3.3) that is possible to modify the θ_U angle that measures mourning in the unconscious, or the θ_C angle measuring mourning in consciousness, by Rabi pulses of a psyche field "located in the (Ox, Oy) plane", that is in the plane perpendicular to the direction defined by the pointer-states ($|U0\rangle$, $|U1\rangle$ for the unconscious, or $|C0\rangle$, $|C1\rangle$ for consciousness).[27] These pulses of a psyche field can be emitted either by consciousness (as consequence of volition or Liberum Arbitrium), or by the unconscious (individual, group or collective). In NMR the Rabi pulses that are responsible for an appreciable modification of the θ angle (for instance by $\pi/2$) have a duration t_p of the order of 10^{-5} seconds [28]. Conversely, as far as the Rabi pulses of a psyche field are concerned, the order of magnitude of t_p seems more difficult to estimate. This duration depends on the Rabi frequency $\omega_1/2\pi$. For a $\pi/2$ rotation of the θ angle, the time t_p is equal to $\pi/(2\omega_1)$. If we associate this time lapse t_p with the interaction time $t = 1/(2J)$ between pre-consciousness and consciousness, we are led to assess t_p of the order of half-a-second.[28]

Let us recall that at the beginning of Section 3 we have underlined the fact that the time scales used in NMR (and in the experiences of polarisation of nuclear targets) depend on several factors: choice of the "target", intensity of the magnetic fields and so on. Moreover, the tuning of the radio-frequency magnetic fields has to be extremely precise. It is therefore difficult to compare time scales that, in NMR, and in the nuclear target polarisation experiments, span several orders of magnitude (from some tens of seconds to several days for the time of energy relaxation [41], or from 10^{-5} second to 10^{-1} second for the time to reach thermal equilibrium in spin systems [44]) with the time scales specific to mental processes and to the modifications of the mental states.

[27] On this subject, see Footnote 9.

[28] In fact, in the Sections where we discuss the interaction between pre-consciousness and consciousness, we have seen that the interaction under study leads to Rabi oscillations of frequency J. Consequently the duration of a Rabi pulse, $t_p = \pi/(2\omega_1)$, is associated with an interaction time $t = 1/(4J)$ between pre-consciousness and consciousness.

Let us notice that the clinical and psychoanalytical situations show that we were led to suppose that there is an orientation of the swappings going from the unconscious to the pre-consciousness closest to consciousness[29] (or vice versa from consciousness to "pre-consciousness" closest to the deep unconscious) so that these two entities can interact. In the present state of the establishment of a model we are unable to formalise this orientation. Which process creates a sequence of swappings allowing the deep unconscious to interact which consciousness remains an unsolved question. We still have to work on it.

8.2. Mental Rabi Oscillations

Then we have supposed (Section 5) an interaction between pre-consciousness and consciousness described by the Hamiltonian (12). This interaction leads to a quantum entanglement of pre-consciousness with consciousness. We have seen that the time evolution of this entanglement is such that it gives rise to Rabi oscillations of the system pre-consciousness + consciousness. The Rabi frequency of these oscillations is J. At time $t = 1/(4J)$ pre-consciousness and consciousness are "lined up". At time $t = 1/(2J)$ pre-consciousness and consciousness are swapped. Finally, at time $t = 1/J$ pre-consciousness and consciousness are back to their respective initial states.

We note that J, which measures the coupling between pre-consciousness and consciousness, can be different for one individual from the other. Indeed, at the level of the brain, there is evidence of an alternating activity of the two hemispheres. This oscillation expresses itself in the phenomenon of binocular rivalry [31]. When two images are presented to each of the two eyes of a subject, they enter in "competition" so that one image is visible while the other is not. The same happens when the subject is presented with two superposed images[30], a nice metaphor to represent the superposition of two quantum states. Measurements have been made on the alternating activity of the two hemispheres. In a normal subject, the alternation period is between one and two seconds. In a subject with bipolar troubles, the alternation period goes from ten to twenty seconds, a period one order of magnitude larger than in a normal subject [32]. *Thus the alternation of the hemispheric activity can be seen as an oscillatory effect. Experimentation shows that the Rabi oscillations between mental states may have their counterpart in the brain, and therefore neuronal, activity.* If we associate the alternation of the hemispheric activity with Rabi oscillations between mental states, the observed difference in the oscillation period between normal subjects and subjects suffering from bipolar disorders shows that J, which measures at the same time the period of the oscillations and the coupling between pre-consciousness and consciousness, effectively varies according to the subject considered.

Two important questions arise in what concerns the mental Rabi oscillations. How long these oscillations last and what is their effect?

Let us for instance consider the Rabi oscillations between pre-consciousness and consciousness, such as those that have been studied in Section 5, that is between the states $|I1\rangle|C0\rangle$ and $|I0\rangle|C1\rangle$. As far as the first question is concerned, when consciousness is awake, its interaction with the environment perturbs the interaction between pre-consciousness and consciousness and therefore interferes with the oscillations that, as a consequence, cannot last very long. We have seen before that they cannot last more than a maximum of half a second, the time for the awaken consciousness to receive an external stimulus. The situation is different for consciousness when it is asleep (e.g. consciousness during the paradoxical sleep (REM), when we dream), because in this case the perturbations coming from the environment are weak. In these conditions, the Rabi oscillations may extend over a time that can be long, probably of the order of several minutes (or more?).

As far as the second question is concerned, ("what is the effect of these oscillations?"), considering again the example of the Rabi oscillations between pre-consciousness and consciousness, we can say, as we already did in Section 5, that, in the case of awaken consciousness, if the interaction (or oscillation) time is less than $t = 1/(4J)$, pre-consciousness (or the unconscious) will alter the consciousness state, and, reciprocally, consciousness will modify the pre-consciousness state. This is notable in the case of the mourning process.

On the contrary, in the case of the sleeping consciousness, the situation is more complex, because the system pre-consciousness + consciousness (or at least part of this system) constantly oscillates between the states $|I1\rangle|C0\rangle$ and $|I0\rangle|C1\rangle$. However a pendulum alone cannot measure time. For this we need a system that keeps the memory of the number of the oscillations of the pendulum. This is what does a clock, which does measure time. In a clock the oscillations of the pendulum have a cumulative effect that allows to keep the memory of the number of oscillations. In the case of the Rabi oscillations of the system pre-consciousness + consciousness, we have to imagine a system, correlated to the first one, that is subject to cumulative effects and that allows to memorize the mental Rabi oscillations.[31] In this case, it is only thanks to the storage of the mental Rabi oscillations that consciousness or pre-consciousness can be modified. At the level of the brain this memorization can be actuated by the

[29] See footnote 15.

[30] For instance the well known image where we see either a young girl or an old woman, but not the two at the same time.

[31] Alain Connes, private communication.

limbic system, and in particular by the hippocampus. Concerning quantum information, the quantum pumps could possibly play the role of these systems, allowing the storage of the mental Rabi oscillations [52, 53].

In reference [9] Belal Baaquie and one of the authors of the present paper (F.M.) have considered (Subsection 10.3) the quantum entanglement between awake states and sleep states, the latter being possibly dream states. The quantum entanglement between consciousness and pre-consciousness considered in the present work is very similar to this one. Equation (27) of reference [9] shows the quantum entanglement between contradictory awake and sleep states (e.g. "failed exam" in sleep state coupled with "passed exam" in awake state and vice versa).[32] These couplings correspond exactly to the couplings $|I0\rangle|C1\rangle$ and $|I1\rangle|C0\rangle$ of this article. Equation (27) of reference [9] is therefore analogous to our formulae (36) and (44), except the fact that equation (27) is static (it does not depend on time), while equations (36) and (44) explicitly show Rabi oscillations. Therefore we will highlight the (possible) importance of Rabi oscillations in sleep states.

As we have seen in Section 4, the interaction Hamiltonian (12) can be interpreted as the Hamiltonian that describes the behaviour of consciousness in the field of pre-consciousness, and also as the Hamiltonian that describes the behaviour of pre-consciousness in the field of consciousness (Section 5). At the same time, it can be read as the Hamiltonian that describes the behaviour of the unconscious in the field of pre-consciousness, and also as the Hamiltonian that describes the behaviour of pre-consciousness in the field of the unconscious (Section 6). As this Hamiltonian leads to Rabi oscillations, we can conclude that it allows to model the Rabi pulses of the psyche field emitted either by the unconscious, preconsciousness or consciousness.

Finally we have considered an interaction between two unconscious (or rather between two qubits, each one belonging to one of two different unconscious, e.g. Alice's one and Bob's one) described by the Hamiltonian (12) (with a coupling constant J' instead of J). This interaction generates a quantum entanglement between the qubits of the two unconscious. As in the case of the system preconsciousness + consciousness, the time evolution of this quantum entanglement generates Rabi oscillations of the Alice's unconscious + Bob's unconscious system, between the states $|UA0\rangle|UB1\rangle$ and $|UA1\rangle|UB0\rangle$. The Rabi frequency of these oscillations is J'. These oscillations describe how each of the two unconscious qubits acts on the other.

As for the coupling constant J, J' may depend upon the number of "bonds" that each of the two unconscious qubits has with other parts of its own unconscious (or even of its own conscious). Thus, as seen before, the larger the number of "bonds", the smaller the Rabi frequency J' will be. In other words, J' expresses the "resistance" of each of the two qubits "to oscillate" with the other.

Nevertheless we have to note two points. First of all, contrary to what happens with the interaction between the unconscious (or pre-consciousness) and consciousness of the same person, for which we have seen (Subsection 4.2) that a relatively large number of swappings, N', could be necessary to "bring close" the unconscious and consciousness, increasing by a factor N' the time needed by the unconscious to operate a modification of consciousness, in the case of an interaction between two unconscious these swappings are not necessary. The interaction between the unconscious of two different people is therefore more direct than the interaction between the unconscious and the conscious of the same person. Therefore the interaction time necessary for the modification of the unconscious should be smaller than in the case of the interaction unconscious-conscious. In a similar way "the specific time-scale for the onset of internal equilibrium in a spin-spin system is much shorter (10^{-5}) than in the case of a Zeeman subsystem, thanks to the "flip-flop" mutual transitions amongst neighbouring spins that do not change the energy of the system" [44].

Moreover, the number of "bonds" shielding the two unconscious can be smaller than the number of "bonds" shielding the unconscious (or pre-consciousness) from the conscious of the same person. In this case the coupling constant J' is bound to be larger than the coupling constant J. Therefore the time necessary to modify Bob's unconscious will be shorter in the case of an interaction with Alice's unconscious than in the case of an interaction with his own consciousness. This would justify the presence of a therapist to help Bob complete his mourning.

In conclusion, we do note that, as in the case of the interaction between pre-consciousness and consciousness, the coupling constant J' between two unconscious is proportional to the respective intensities of the psyche fields associated to each unconscious. *Thus, the more intense the psyche field associated with one of the two unconscious is, the larger the coupling constant J' is, and the shorter the time needed for the modification of the other unconscious is.*

In summary, three factors favour the improvement of Bob's mourning process in presence of the psychoanalyst Alice:

• the lack of need of swappings for Alice's unconscious to interact with Bob's one,

• the small number of "bonds" shielding the two unconscious,

• and the possible large intensity of the psyche field generated by Alice's unconscious.

[32] Dreams causing awakening are often in deep conflict with reality of awake states (Chantal Camus, private communication).

Let us note that these three points are effectively correlated.

In this work we have begun to outline a hypothesis describing the direct interaction between the unconscious of the therapist (Alice) and the unconscious of the patient (Bob), where, via two possible mechanisms (the reduction of the "bonds" and the strength of the psyche field), the time necessary for the mourning process to be achieved could be shortened.

In the psychoanalytical, as well as in the cognitive-behavioural approach, part of the therapist's work is to identify repressions and to overcome resistances. Resistances cause an excessively heuristic and too automatic approach to internal and external reality and consequently to too large distortions in the appreciation of problems as well as a notable impasse in their solution. In our model the problem to solve is typically the death of the father, but we could say that this is just an example.

In a very evocative manner, the presence of resistances is comparable to the presence of "bonds" in our model. On the other hand, the presence of an interaction between the therapist's unconscious and the patient's one, acting in both ways, is what is defined in the psychoanalytical field as the interplay of transfer and counter-transfer: in our model we speak of field of interaction (or rather of interaction amongst the different psyche fields).

We have to admit that there is often a certain reticence to accept the most unsettling and the least therapeutic side of this phenomenon: the possible influence not only of the therapist on the patient, but also of the patient on the therapist.

Different meta-analyses, both rather old and very recent ones, have studied [54, 55] and compared different therapeutic approaches [56–64] and they have shown that in fact it is not only the therapeutic technique that matters in the therapy, but it is as well the therapist's personality (or simply his unconscious?), a fact which could be in excellent agreement with the model outlined here.

Jung, who was particularly interested by the archetypes of the collective unconscious [65, 66], spoke about this reciprocal influence between the therapist and the patient in several occasions, one of which in 1931, related by Cahen in 1953.

In the transcript of this intervention, it is said that "to have influence is synonym of being affected. It is vain for the doctor to dodge the influence of the patient and to surround himself of a smoky cloud of professional authority ..." [67].

If the interaction between therapist and patient is clinically palpable, it remains however very difficult to measure. On the other hand, in group, or group-therapy situations, this interaction could be amplified and become more easily quantifiable. This amplification could even be useful to study the effects of the interaction of the unconscious in group situations.

9. CONCLUSIONS AND PERSPECTIVES

Taking example from Quantum Information Theory, we have considered the human unconscious, pre-consciousness and consciousness as ensembles of quantum bits (qubits). We have supposed how information is exchanged between these different sets of qubits. In particular we have used an analogy with the Nuclear Magnetic Resonance effect. We have then provided an explicit model of how a qubit of the unconscious, pre-consciousness or consciousness can be manipulated via a psyche field.

Starting from an elementary interaction between two qubits, we have seen how information could pass from one qubit to the other, thanks to the implementation of a two-qubit logical quantum gate, the so-called controlled-NOT gate. Thus the passage of two qubits through such a gate creates a quantum entanglement that allows one of the two qubits (the target qubit) to measure the other qubit (the control qubit). In this way we have created a (quantum) process allowing consciousness to read the unconscious and vice versa.

We have also described a swapping process between two qubits. For instance, we can exchange a qubit of the unconscious with a qubit of pre-consciousness, and the quantum information will be entirely transferred from the unconscious to pre-consciousness and vice versa.

The elementary interaction between a qubit of pre-consciousness and a qubit of consciousness has allowed us to predict the time evolution of the combined system pre-consciousness + consciousness. *This evolution generates Rabi oscillations that we call mental Rabi oscillations.* This evolution shows how, after one (or several) swapping(s) with pre-consciousness, the unconscious can influence consciousness. In a similar way, studying the time evolution of the system preconsciousness + unconscious, we have shown how, after one (or several) swapping(s) with pre-consciousness, consciousness could influence the unconscious. In the case of the mourning process, the influence of the unconscious on consciousness, as well as the influence of consciousness on the unconscious are in agreement with what is observed in psychiatry.

We have seen that the mental Rabi oscillations could be put in relation with oscillations occurring in the brain, such as the alternating hemispheric activity and binocular rivalry. This analogy needs further developments. Moreover it would also be important to reach a deeper understanding of which mechanisms capable of producing cumulative effects would allow these Rabi oscillations to have effects on the unconscious and consciousness, and this in the three domains of Quantum Information Theory, Neurosciences and the Psyche.

The same elementary interaction between a qubit of Alice's unconscious and a qubit of Bob's one has allowed us to predict the time evolution of the system

Alice's unconscious + Bob's unconscious, *evolution that also produces Rabi (mental) oscillations*. In the same way, this evolution shows how Alice's unconscious can influence Bob's one and vice versa. In a mourning process, these interactions between the two unconscious are in agreement with what is observed in the psychiatric and psychoanalytical practice. However we still have to further develop the description of the elementary interaction between the unconscious qubits of two individuals, because the problems posed by the interactions of unconscious are subtle and far from being thoroughly understood, notably in the psychoanalytical domain.

When we consider a set of qubits belonging to the unconscious of one or more person, there exists the possibility of a Bose-Einstein condensation of this set of qubits. This condensation may lead to global effects. Also here there seems to be still a lot of ground to cover in order to understand the Bose-Einstein condensation of a set of interacting qubits both from the point of view of Quantum Information Theory and of the Psyche.

10. ACKNOWLEDGMENTS

François Martin wishes to thank Patrick Aurenche, Alain Connes et Benoît Douçot for fruitful discussions, as well as Yves Prêgnac for having pointed out to him the phenomenon of binocular rivalry.

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