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Quantum Mechanics and the Psyche[¶]

G. Galli Carminati[a] and F. Martin[b]

[a] *Mental Development Psychiatry Unit—Adult Psychiatry Service, Department of Psychiatry, University Hospitals of Geneva, Switzerland*
[b] *Laboratoire de Physique Théorique et Hautes Energies, Universités Paris 6 et 7, Place Jussieu, 75252 Paris Cedex 05, France*
e-mail: Giuliana.GalliCarminati@hcuge.ch; martin@lpthe.jussieu.fr

Abstract—In this paper we apply the last developments of the theory of measurement in quantum mechanics to the phenomenon of consciousness and especially to the awareness of unconscious components. Various models of measurement in quantum mechanics can be distinguished by the fact that there is, or there is not, a collapse of the wave function. The passive aspect of consciousness seems to agree better with models in which there is no collapse of the wave function, whereas in the active aspect of consciousness—i.e., that which goes together with an act or a choice—there seems to be a collapse of the wave function. As an example of the second possibility we study in detail the photon delayed-choice experiment and its consequences for subjective or psychological time. We apply this as an attempt to explain synchronicity phenomena. As a model of application of the awareness of unconscious components we study the mourning process. We apply also the quantum paradigm to the phenomenon of correlation at a distance between minds, as well as to group correlations that appear during group therapies or group training. Quantum entanglement leads to the formation of group unconscious or collective unconscious. Finally we propose to test the existence of such correlations during sessions of group training.

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1. INTRODUCTION

The problem of measurement in quantum physics is still a topical subject. In 1932, von Neumann [1] proposed to split the evolution of the wave function, as a function of time, during a measurement into two processes. The first process is the unitary and deterministic evolution of this wave function. The second process is the collapse of this wave function into one of the eigenstates of the measured observable. If the first process is continuous and deterministic, the second one is discontinuous and non-deterministic (probabilistic).

The theory of quantum decoherence [2] allows to explain how, due to interaction with the environment, a quantum system composed of the observed object and the detector goes from a coherent superposition of quantum states to a statistical mixture of states referred to a given basis (reduced density operator).

Some theories (e.g., the "Relative State" theory of H. Everett [3] and the quantum information theory of N. Cerf and C. Adami [4]) try to escape the collapse of the wave function.

How does consciousness play a part in the quantum measurement process? Does there exist a quantum theory of consciousness? Works on the role of consciousness in the quantum measurement process go back to von Neumann [1] and Wigner [5]. Particularly, for von Neumann, to set the border dividing the observed system from the observing system (roughly dividing the quantum system from the classical one) gives exactly the same experimental results as if we set this border between the system composed of the observed object and the detector on one side and human consciousness on the other side.

Following von Neumann and Wigner in this way, Stapp [6] set the interface between the observed system and the observing system in the observer's brain. This allowed him to explain some behaviors of consciousness within quantum theory.

In 1967 Ricciardi and Umezawa [7] suggested the use of the formalism of quantum field theory for the states of the brain, especially for memory states.

In 2003 Baaquie and Martin [8] also proposed a quantum field theory of consciousness. But this theory applies firstly to mental states before it applies to brain states. This theory considers dual aspects of mind and matter. Such theories considered within the scope of quantum theory go back to Jung and Pauli [9–11][1].

It is in the framework of this dualistic aspect of mind and matter that our work takes place. The observation of correlations at a distance between several minds, just as the observation of synchronicity phenomena, lead us to postulate a non-localization of unconscious mental

[¶] The text was submitted by the authors in English.

[1] Concerning this subject we shall read with interest the review of H. Atmanspacher, *Quantum Approaches to Consciousness*, in the Stanford Encyclopedia of Philosophy [12]. This paper reviews the situation on present quantum theories of consciousness.

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 synchronicity phenomena, i.e., significant coincidences that appear between a mental state (subjective) and an event occurring in the external world (objective), they confirm that the border between the observed object and the human consciousness does not really exist. In this respect we are going further than Stapp [6].

In this paper we shall try to build up a quantum model of the correlations at a distance that show themselves between several minds, for example, between two people (e.g., Alice and Bob), or in a group of people (group correlations). We shall also try to model the awareness of unconscious components from the present theories of quantum measurement. We shall see that the model of Cerf and Adami [4], in which there is no collapse of the wave function, seems to fit to the phenomenon of awareness better, because it does not so greatly alter the state of the unconscious.

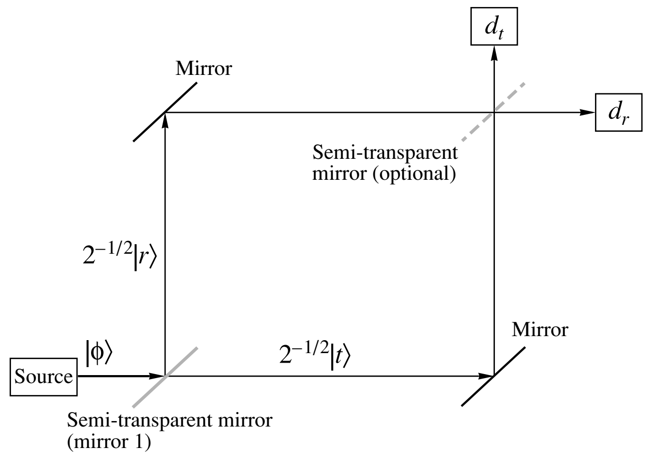
Finally, let us mention some works on quantum theories of consciousness related to physical states of the brain. In addition to those already quoted (by Ricciardi and Umezawa [7]), there are Beck and Eccles' work [13], those of Penrose [14], and those in which Penrose collaborated with Hameroff [15].

In our work we restrict our considerations to human consciousness, which not only has the property "to be aware of itself," but also to be aware of the surrounding environment. Other works have explored the concept of universal consciousness [8, 14] and therefore, to characterize the object of this work, we have chosen the term psyche instead of the more general one of consciousness, which could be interpreted as universal consciousness.

2. CHOICE OF THE PAST

It could be interesting to consider some psychological phenomena (correlations between minds at a distance, synchronicity effects) in light of some phenomena observed in quantum mechanics which pose problems with "classical" causality, such as the Einstein–Podolsky–Rosen "paradox" (EPR paradox) [16], Bell's inequalities [17] and Alain Aspect's experiments [18], or the photon delayed-choice experiment.

Let us consider this last experiment (figure). An electromagnetic wave (photon beam) is divided into two equal parts by a semi-transparent mirror (mirror 1, half-silvered mirror). Then, two reflectors deviate each of the two beams in such a way that they intersect again at some point. Next, two detectors are set on each path of the two beams, just after the crossing point. Half of the photons are recorded in one detector (d_t), while the other half are recorded in the other detector (d_r). Therefore, for each detected photon we can determine which



The photon delayed-choice experiment.

path has been followed. At the crossing point of the two beams we can put a second semi-transparent mirror that brings in a new phase difference between the different partial waves. The phase differences are such that all photons go into one of the detectors (d_r) and none into the other (d_t). We can choose to put, or not to put, the second semi-transparent mirror at the crossing point of the beams. Thus we can make a choice on the photon: either it follows one of the two paths when the second semi-transparent mirror is not set up, or "it follows the two paths simultaneously," in such a way that there is an interference phenomenon, when the second semi-transparent mirror is set up at the crossing point. We can make this choice at the last moment, just before the photon reaches the crossing point, after it has left the source, reached the first semi-transparent mirror and been deviated by the reflectors. We conclude that we have an effect on the past of the photon. We are able to choose the past of the photon after this past has gone by.

This experiment, conceived by John Archibald Wheeler [19], has been performed in laboratories [20]. According to Wheeler this experiment could be achieved with photons that have traveled through a galaxy and thus have been deviated in several different ways by the galaxy. Photons would have been emitted by their source millions, or even billions, of years before they reach the detectors. In such a case, the delayed-choice experiment ("the choice on the past of the photon") would be performed on millions, or billions, years and not simply on millionths of a second as they are performed in laboratories.

The quantum interpretation of the delayed-choice experiment is that we can say nothing about the photon as a particle between the moment it has been emitted by the source and the moment it has been detected, because at the last moment we can make the choice we like. As said by Niels Bohr, "No elementary quantum phenomenon is a phenomenon until it is a registered phenomenon—that is, indelibly recorded or brought to a close by an irreversible act of amplification." What happens between the time the photon is emitted by the source and the time it is detected has no localization in space–time as we conceive it usually. The delayed-choice experiment leads us to rethink the notion of past. There is indeterminacy in the past of the photon. This indeterminacy comes from the wave–particle duality[2]. The past of the photon is not fully determined either as a wave or as a particle. The delayed-choice experiment allows us to remove this indeterminacy, even if we act on "things" that have already happened. John Archibald Wheeler stresses upon the fact that "the past has no existence except as it is contained in the records, near and far, of the present."

A superposition of quantum states persists in the past. Unless a measure has been performed or a choice has been made, this coherent superposition of states still exists as indeterminacy of the past.

Quantum mechanics teaches us that there exist two levels of reality. First there is the quantum level of reality in which there exist superpositions of quantum states that evolve in time in a deterministic way. For example, in the experiment described above the wave function of the photon (or the quantum electromagnetic field) evolves in a deterministic way, this evolution being given by a unitary operator.

The second level of reality is what we call the level of classical reality. It is the level of the single reality that we observe with our consciousness. It is also the level that in physics is given by the (single) result of a measure. The crossing of the bridge between the quantum and the classical reality is accomplished through an operation that we call "the reduction of the wave packet" (or "the collapse of the wave function"). This crossing is done in an irreversible and non-deterministic (probabilistic) way. In the delayed choice experiment the wave function of the photon evolves in a deterministic way in space and time, up to the two detectors set up on each path of the photon. The collapse of the wave function happens in the two detectors. It is probabilistic and, hence, non-deterministic.

When, at the crossing point of the two beams, we decide to put or not to put the second semi-transparent mirror, the past of the photon as a quantum state is fully determined. On the other hand, as a classical system, and especially as a particle, the state of the photon is not fully determined. The act of putting or not putting the second semi-transparent mirror will not modify its quantum aspect before the photon reaches this mirror or the crossing point. However, it will modify the "classical" vision that we have of this photon. When the mirror will is not set up the photon will have followed one of the two paths when it is registered by one of the two detectors. When the mirror is set up the photon will have followed the two paths when it is registered.

[2] The photon is, in itself, neither a wave nor a particle; it is the smallest possible excitation, in terms of energy, of the electromagnetic field.

The choice to put or not to put the second semi-transparent mirror has no influence on the past of the photon as a quantum system before the photon reaches this mirror or the crossing point. This past has gone by and as a quantum system the photon has evolved in a deterministic way. On the other hand, due to the choice that we make about the second semi-transparent mirror, we have an influence on the past of the photon considered as a classical system before it reaches this mirror or the crossing point. We have an influence on the "classical" vision of the photon. This is what John Wheeler calls observer-participancy. When the second semi-transparent mirror is not set up, as a detected particle, the photon will have followed one of the two paths. When this mirror is set up we are led to say that the detected photon has behaved like a wave and therefore has followed the two paths simultaneously. It is on the classical reconstruction of the past of the photon that we have an influence. The "quantum past" of the photon is itself fully determined and therefore cannot be modified. On the other hand, we can make choices on the classical reconstruction of the past of the photon. As we said before, what happens between the moment the photon is emitted by the source and the moment it makes a click in one of the two detectors so far has no localization in space–time as we usually conceive it. The result is that any "classical" reconstruction of what happened is ambiguous.

In our consciousness the past appears as a succession of events that already happened and therefore cannot be modified. However, this is a restriction of our consciousness that is confined in the linear flow of time (the stream of consciousness). A particular event that reaches our consciousness (that is registered by our consciousness) is like a photon that is registered by a detector. In the photon delayed-choice experiment, if we don't put the second semi-transparent mirror at the crossing point of the two paths, the probability of the photon reaching one of the two detectors is 50 percent for one and 50 percent for the other one. It is a probabilistic prediction of quantum mechanics. On the other hand, if we set up the second semi-transparent mirror, the probability becomes 100 per cent for one of the detectors (d_r) and zero for the other one (d_t). The act of putting the second semi-transparent mirror modifies the probabilities. In this case it transforms a probability into a certainty.

We can make an analogy between physical states and mental states, and try to apply quantum mechanics to mental states as we do for physical states. In order to do that we will consider mental states as quantum states, i.e., as vectors of a Hilbert space, obeying, for example, the superposition principle, … (see [8]). Among the mental states we will distinguish the states of consciousness that correspond to the thoughts and ideas we are aware of. The states of consciousness will constitute a part of the whole Hilbert space of mental states. On the other hand there will be states of unconsciousness and pre-consciousness (insight) that will be the states of our mind we are not aware of. As psychoanalysts such as Freud and Jung did, we will suppose the existence of an unconscious for every human being. As for the states of consciousness, we will suppose that the states of this unconscious are also quantum states, i.e., are vectors of a Hilbert space. The states of consciousness together with the states of unconsciousness and pre-consciousness will form the whole set of mental states.

If we now make the analogy between quantum mechanics and the phenomena of meaningful coincidences (synchronicity effects), we can say that these coincidences are "ready for use" before they happen. They already belong to the Potentia but are not yet actualized. They exist in the past only as potentialities, such as quantum states, or such as unconscious states. They can be called phenomena only when "they are indelibly recorded by an irreversible act of amplification," i.e., by consciousness. The delayed choices that trigger off (or don't trigger off) a phenomenon of meaningful coincidence are our acts of our everyday life. The analogue of setting up or not setting up the second semi-transparent mirror at the crossing point of the two paths lies in our acts. Every act is a choice. The analogy with "the crossing point of the two paths" is really meaningful because we can imagine that for a significant coincidence to happen there should be a constructive interference between two paths: one path is in our mind, a subjective path, unconscious path, and the other path is in the external world, an "objective" path. These two paths cross at some point in space–time, they interfere and are actualized by a choice and an act of consciousness.

However, one difference with the photon delayed-choice experiment is that in this experiment the delayed choice is made by the physicist who knows exactly the phenomenon that will happen. In the case of meaningful coincidences the delayed choices are unconscious: unconscious of the phenomenon of coincidence that will happen and will be brought to our consciousness.

The quantum-entangled systems, non-separable systems, are not locally but globally defined in space–time. As said by Antoine Suarez [21], "In those systems there is a dependence between events, but this dependence does not correspond to a temporal order. The quantum world cannot be anymore defined in terms of 'before' and 'after.' Things happen, but time, itself, does not go by."

If in a quantum mechanics experiment the "classical" past of the photon remains indeterminate, what about the indeterminacies of our own past? As far as our mind is concerned, the analogue of a classical system is our consciousness, which acts as a detector. As for the analogue of a quantum system, it is our whole psyche, in which there is especially our unconscious. As we said above, we can imagine that as time flows our unconscious exists as a superposition of quantum states. Unless a "classical" measure has been done by our consciousness, unless a choice has been done, this coherent superposition of states of our unconscious still exists as indeterminacy of the past. In the photon delayed-choice experiment we can make a choice on the "classical" past of this photon, and therefore have an influence on this past, by choosing to put, or not to put, the second semi-transparent mirror. By analogy, to what extent can we have an influence on our own past and eventually modify it? At the quantum level, i.e., at the level of our unconscious, this "past" is determined. On the other hand, at the classical level, at the level of our consciousness, it is not necessarily fully determined. The "classical" reconstruction of our past has always to be done. In the photon delayed-choice experiment the influence on the "classical" past lies in the choice between the two possibilities of the second semi-transparent mirror. It would be the same for our psyche. According to the "mirror" that we "set up" in the present our "classical" past appears in one way or in another. The phenomena recorded by our unconscious persist as coherent superposition of quantum states. The way our consciousness sheds light on these superposition makes a choice among the different quantum states and therefore gives it its "classical" aspect.

Let us examine in detail the experimental device of the photon delayed-choice experiment (figure). Let us consider the case in which there is only one semi-transparent mirror (mirror 1). At the crossing of mirror 1 the wave function of the photon splits into two parts:

$$|\phi\rangle = 2^{-1/2}|r\rangle + 2^{-1/2}|t\rangle, \tag{1}$$

a reflected part $2^{-1/2}|r\rangle$ and a transmitted part $2^{-1/2}|t\rangle$. $|r\rangle$ will interact with detector d_r and $|t\rangle$ with detector d_t. The wave function of the system composed by the photon and the two detectors is thus:

$$|\psi\rangle = 2^{-1/2}|r\rangle|d_r\rangle + 2^{-1/2}|t\rangle|d_t\rangle. \tag{2}$$

The density operator of the system is the one of a pure state:

$$\rho = |\psi\rangle\langle\psi|. \tag{3}$$

However, the two detectors d_r and d_t interact with the environment. Let us suppose that environment is also a quantum system. The wave function of the overall system is

$$|\Psi\rangle = 2^{-1/2}|r\rangle|d_r\rangle|E_r\rangle + 2^{-1/2}|t\rangle|d_t\rangle|E_t\rangle. \tag{4}$$

The information transmitted to the environment being lost for the observer, the system is therefore described by a reduced density operator:

$$\begin{aligned}\rho_r = \mathrm{Tr}_E|\Psi\rangle\langle\Psi| &= 1/2|r\rangle\langle r||d_r\rangle\langle d_r| \\ &+ 1/2|t\rangle\langle t||d_t\rangle\langle d_t|.\end{aligned} \tag{5}$$

This density operator does not correspond anymore to a pure state but to a statistical mixture.

How is the choice made between the two detectors d_r and d_t, and consequently between the two states $|r\rangle$ and $|t\rangle$?

Let us notice that there is a symmetry between d_r and d_t in the reduced density operator (5).

We can imagine that it is a spontaneous breakdown of this symmetry which causes the choice between d_r and d_t (the photon is detected either in d_r or in d_t)[3]. Let us notice that as long as we consider the photon as a wave the symmetry is preserved. It is only when the photon is registered as a particle that the symmetry is broken.

The choice between d_r and d_t could be a spontaneous broken symmetry similar to the one of the bowls of salad set on both sides of each guest having dinner on a round table (left–right symmetry)[4]. In this example it is the choice of one of the guests that causes the spontaneous breakdown of symmetry. It could be also a spontaneous broken symmetry similar to the one that occurs in a ferromagnet below a critical temperature. In such a material the choice of a direction of alignment for all the magnetic moments happens globally.

Let us come back to "our" photon. If we make the classical reconstruction of the route of the photon between the moment it has been emitted by the source and the moment it has been recorded, for example in detector d_t, there is a collapse of the wave function of the photon between the moment the photon has crossed mirror 1 and the moment it has been registered by d_t. In fact there is a collapse of the wave function on all the temporal duration bounded by the moment the photon has been emitted by the source and the moment it has been detected. But the photon delayed choice experiment shows that this collapse happens at the right moment the photon is recorded. We conclude that there is a repercussion of the collapse of the wave function in the past. Let us emphasize again that this effect appears only when we consider the flow of time, the reconstruction of the "classical" past, the construction of "one" history. At the quantum level there is not only one classical history; there are many histories that are there as potentialities.

The reduction of the wave packet, or the collapse of the wave function, thus occurs in space but also in time (in the past). Then this reduction of the wave packet appears, on a classical level, as a process that is global and not local in space–time (the reduction of the wave packet of the photon registered by d_t does not occur only at the level of detector d_t but in all the space, including the source and the two detectors, and in all time, between the moment the photon has been emitted and the moment it has been recorded).

Let us notice that the setting of the experimental device is due to the human consciousness. Afterwards it is the recording of the photon by one of the two detectors that collapses the wave function in space and time (especially by going back in the past).

[3] Alain Connes' private communication.
[4] Example given by Alain Connes.

We can imagine that something similar happens for psychological processes. When our consciousness registers an event (like a detector registers the click made by a photon) there is also a collapse of the wave function corresponding to the potentiality of this event. This collapse occurs in all space but also in an interval of time that can go back far in the past. When the present event recorded by our consciousness is in significant coincidence with an event belonging to the past the collapse of the wave function occurs on all the temporal duration between this past event and the present.

When we perform an act for which, thanks to our free will, we have the choice to accomplish or not to accomplish and when immediately after we observe in the world that surrounds us symbolic events that are in significant coincidence with the act we have just accomplished, this means that the completion of our act causes the collapse of a wave function which affects the past. This collapse can even affect a remote past. This collapse is not a local one but a global one. This is the reason why synchronicity phenomena (significant coincidences) appear as non-causal (or acausal).

3. QUANTUM ENTANGLEMENT

The paper of Ray Streater, "Locality in the EPR experiment" [22], allows to make the following conclusions.

Suppose that Alice and Bob each own a part of a quantum-entangled system, for example, two photons or two electrons whose spins are correlated. If Alice does a measurement on the quantum object she possesses and reads the result of the measurement, in case Bob has not yet done the measurement on his own quantum object (or if he has done the measurement corresponding to the one done by Alice), Alice knows the quantum state of the object in Bob's possession.

However she does not know the "classical" state of this object, i.e., the state resulting from a measurement done by Bob. There is one exception to this assertion. It is when Bob does, has done, or will do the (classical) measurement corresponding to the (classical) measurement that Alice has done herself on her own object. In this case, and only in this case, does Alice know the "classical" state of the object in Bob's possession.

If we assume that minds can be entangled like quantum particle states, in the case of two quantum-entangled minds (e.g., Alice and Bob's), if (at a distance) Alice becomes aware of information which concerns Bob, Alice knows the quantum state of some part of Bob's psyche (the one that is quantum-entangled with her own psyche).

However, she does not know the "classical" state of Bob's psyche, i.e., what Bob becomes aware of. It could be that what Bob becomes aware of is related to that part of his psyche that is quantum-entangled with the one of Alice. In this situation there would be correlation between the two consciousnesses (the one of

Alice and the one of Bob). But it could be also be that what Bob becomes aware of does not concern at all that part of his psyche that is quantum-entangled with Alice's. In this situation the appearance of quantum entanglement (the correlation) of which Alice becomes aware remains unconscious for Bob.

When two twins buy simultaneously (at a distance) two identical ties without having consulted each other beforehand, the entanglement (the correlation) appears in the "classical" world only when a human consciousness (one of the two twins or a third party) becomes aware of the fact.

When C.G. feels bad she makes a phone call to her twin sister. This one, who is a psychotherapist, tells her that she is presently treating a difficult case. C.G. has the insight that her feeling of sickness is the result of her quantum entanglement with her twin sister. However, she needs to telephone her sister, that is to say, she needs the transmission of information by a "classical" channel, in order to confirm that her feeling of sickness is really the demonstration of her correlation with her twin sister. While she is treating the case of a difficult patient, her twin sister is probably not aware of the fact that it causes a feeling of sickness for her sister. However by experiencing this fact several times she can become aware of it. Nevertheless, she will never be sure, because her sister does not necessarily have a feeling of sickness every time she is treating a difficult case. There is still a difference between what is quantum-entangled at the unconscious level and what reaches insight and consciousness and appears in the "classical" world.

4. MEASUREMENT AND ENTROPY

In a slightly different way from von Neumann's splitting of the measurement process into two processes, we can consider that the first stage of a measurement process in quantum physics is the interaction of the quantum object (the observed object) with the measuring device (which can be considered as a classical object after interaction with the environment). The second stage is the reading of the result of the measurement by the observer (e.g., Alice). Let us suppose that the measurement concerns an observable X whose eigenstates are $|\psi_n\rangle$ (with no multiplicity), n running over a set of labels J. Let us suppose in addition that the initial state of the quantum system is a pure state $|\phi\rangle$ belonging to a Hilbert space H.

At the end of the first stage the state of the quantum system is a statistical mixture of all the eigenstates of X with weights given by the quantum transition probabilities:

$$p_n = |\langle\psi_n|\phi\rangle|^2. \tag{6}$$

"A good measuring device is a classical system in which the "pointer" of the device is 100% correlated with the eigenstate into which the quantum system is projected" [22]. When the statistical mixture is the result of the interaction of the measuring device—considered also as a quantum system—with the environment we use the term "pointer-state."

According to Ray Streater the details of the measuring device do not affect the reading of the measurement result by the observer: "Thus, a complete description of the measuring device is given by the label n, element of J." We can describe the "pointer-states" of the measuring device with the help of a family of operators χ_n which act on the Hilbert space $L^2(J)$:

$$\chi_n(m) = \delta_{nm} \text{ (Kronecker's symbol)} = 1$$

if $m = n$ and = 0 if m is different from n.

The result of the first stage of the measurement is described by the reduced density operator

$$\rho_{\text{red}} = \sum_{n \in J} p_n \chi_n \otimes |\psi_n\rangle\langle\psi_n| \tag{7}$$

acting on the tensor product of $L^2(J)$ and H. Let us suppose now that the quantum object has left the neighborhood of the measuring instrument, that Alice reads the result of the measurement, and that this result corresponds to the label m, element of J. After the measurement the quantum system is thus in the pure state $|\psi_m\rangle$. The density operator of the quantum system is therefore one of a pure state:

$$\rho = |\psi_m\rangle\langle\psi_m|. \tag{8}$$

The von Neumann entropy ($S = -\text{Tr}(\rho \ln \rho)$) of the quantum system is therefore equal to zero. Let us suppose now that Alice has done an incomplete reading of the measuring instrument, so that she only knows that the label n lies in some subset K of J. The density operator of the quantum system as it observed by Alice is (von Neumann)

$$\rho_K = \frac{\sum_{n \in K} p_n |\psi_n\rangle\langle\psi_n|}{\sum_{n \in K} p_n}. \tag{9}$$

The von Neumann entropy of this system is

$$S_K = -\frac{\sum_{n \in K} p_n \ln\left(\frac{p_n}{\sum_{m \in K} p_m}\right)}{\sum_{n \in K} p_n} = -\left(\frac{\sum_{n \in K} p_n \ln p_n}{\sum_{n \in K} p_n} - \ln\left(\sum_{n \in K} p_n\right)\right). \tag{10}$$

When the measurement done by Alice is complete (measure of an eigenstate $|\psi_m\rangle$ of the observable X) we find again an entropy equal to zero, and when the measurement done by Alice is totally incomplete, e.g., when she has not yet read the result of the measurement, we find again the usual entropy of a statistical mixture result of the interaction of the quantum system with the measuring device followed by the interaction of this device with the environment:

$$S_J = -\sum_{n \in J} p_n \ln(p_n). \tag{11}$$

We see in these examples that the entropy (of von Neumann) of the quantum system after the measurement is directly linked up to the knowledge, i.e., the information, that Alice has of the quantum system that has gone through the process of measurement.

If Alice has done a complete measurement of the observable X, her information has increased by the amount S_J given by equation 11, which corresponds to an increase of the entropy of the environment (including Alice's body) by a quantity at least equal to S_J. The fact that the information acquired by Alice on the quantum object has increased by the quantity S_J tells us that the von Neumann entropy of the system *quantum – object + Alice's consciousness* has decreased by this very same quantity balanced by a quantity at least equal to the increase of the entropy of the environment.

Let us come back now to the case where Alice has done an incomplete reading of the measurement of the observable X, and that she only knows that the eigenvalue of the observable X lies in the subset of eigenvalues labeled by the subset K of J. If we write

$$p_K = \sum_{n \in K} p_n, \tag{12}$$

which is nothing other than the probability of measuring the eigenvalue of X in the subset labeled by K, equation 10 can be rewritten:

$$S_K = -\sum_{n \in K} \frac{p_n}{p_K} \ln\left(\frac{p_n}{p_K}\right). \tag{13}$$

The quantity S_K measures the missing information of Alice regarding the observable X linked to the quantum object. We are faced with an entropy relative to the subset of labels K.

If the measuring device is macroscopic and if it has registered a specific eigenvalue of the observable X, the entropy of the environment has increased by the quantity S_J given by formula 11. If it is the reading made by Alice of the measuring device that is incomplete, then the von Neumann entropy of the system *quantum – object + Alice's consciousness* will have decreased by the quantity

$$S_J - p_K S_K, \tag{14}$$

balanced by an increase of a quantity at least equal to the entropy of the environment (for example, the heat emitted by Alice's body).

Let us suppose that we have a system O (which may be a quantum one) on which we want to obtain some information (e.g., on an observable quantity X of this system). The missing information, that is to say, the Shannon entropy (or the von Neumann entropy if this is a quantum system that interacts with the environment), is given by formula 11.

If we split the information that we can obtain on system O into two subsets, corresponding to two subsets of indexes J_1 and J_2 of J (such that $J_1 \cup J_2 = J$ and $J_1 \cap J_2 = \emptyset$), and if p_{J_1} and p_{J_2} indicate respectively the probabilities that the missing information is indexed in J_1 or in J_2, we can rewrite equation 11 as

$$S_J = p_{J_1} S_{J_1} + p_{J_2} S_{J_2} - (p_{J_1} \ln(p_{J_1}) + p_{J_2} \ln(p_{J_2})), \tag{15}$$

in which S_{J_1} and S_{J_2} are the relative entropies given by expressions similar to 13:

$$S_{J_1} = -\sum_{n \in J_1} \frac{p_n}{p_{J_1}} \ln\left(\frac{p_n}{p_{J_1}}\right), \tag{16}$$

$$S_{J_2} = -\sum_{n \in J_2} \frac{p_n}{p_{J_2}} \ln\left(\frac{p_n}{p_{J_2}}\right). \tag{17}$$

If Alice performs a measurement and she finds that the information she is looking for is in the subset indexed by J_1, her Shannon entropy (her missing information) will be decreased by

$$p_{J_2} S_{J_2} - (p_{J_1} \ln(p_{J_1}) + p_{J_2} \ln(p_{J_2})), \tag{18}$$

which is a positive quantity, or increased by

$$-p_{J_2} S_{J_2} + (p_{J_1} \ln(p_{J_1}) + p_{J_2} \ln(p_{J_2})), \tag{19}$$

which is a negative quantity.

The information which is still missing for Alice is then expressed by S_{J_1}.

At each level of information acquired by Alice, the entropy of the environment increases by a quantity at least equal to the quantity of information obtained.

We note that everything that has been said in this section, as well as what will be exposed in the following one, corresponds to classical information, expressed by the classical Shannon–Boltzmann–Gibbs entropy, given that, after interaction with the environment, the von Neumann entropy becomes such a classical entropy. Indeed, information on the phases between the various quantum states, phases that are characteristic of the coherent superposition of quantum states, is not accessible any longer for the kind of measurement under consideration.

5. LAYERED INFORMATION

The first step of the construction of the psyche of a given individual is the creation of the fundamental state of the human species $|G(t)\rangle$ (see formulas 13–16 in [8]) from the vacuum state $|\Omega\rangle$. The second step is the construction, starting from the state $|G(t)\rangle$, which describes the collective unconscious, of a family unconscious described by the state $|G_{\text{Effective}}(t)\rangle$ (formula 19 in [8]), and then the creation of an individual unconscious, described by the state $|G_{\text{Individual}}(t)\rangle$ (formula 19 in [8]). The state of the psyche of this individual is therefore described, at a given moment t, by the action of the creation operator specific to this individual $a^{\dagger}_{\text{Individual}}(t, x_{\text{Individual}}(t))$ on the state $|G_{\text{Individual}}(t)\rangle$ (his individual unconscious at time t):

$$|P(t, x(x))\rangle = a^{\dagger}_{\text{Individual}}(t, x_{\text{Individual}}(t))|G_{\text{Individual}}(t)\rangle. \quad (20)$$

We therefore have a kind of layered model for the human psyche that we can compare to the layered model of matter: molecules, atoms, nuclei, protons, neutrons, and finally, at our present level of knowledge, quarks and gluons. We note that the latter are confined inside nucleons (protons and neutrons). We could then compare this confinement of quarks and gluons to the deepest layers of our unconscious, in particular, its repressed parts.

Let us suppose that Alice (described by mental state $|C1\rangle$) wants to obtain some information about Bob's unconscious (mental state $|C2\rangle$). At first, when Alice and Bob meet, their unconscious states interact, and this generates a state of quantum entanglement of their unconscious states. Let us further suppose that at first Alice wants to obtain information on an observable X_1 with two eigenvalues and eigenstates (binary situation). The mental (unconscious) interaction of Alice with the environment (represented here by the collective unconscious $|G(t)\rangle$) generates two "pointer states" $|C11\rangle$ and $|C12\rangle$ in Alice's psyche, which are respectively correlated with the states $|C21\rangle$ and $|C22\rangle$ of Bob's psyche (eigenstates of the X observable about which Alice wants to obtain some information).

If p_1 and p_2 are the respective probabilities that the pointer states $|C11\rangle$ and $|C12\rangle$ come to Alice's consciousness, the information that she is still missing (Shannon or von Neumann entropy) is given by the formula

$$-(p_1\ln(p_1) + p_2\ln(p_2)). \quad (21)$$

When Alice acquires the information $|C11\rangle$ or $|C12\rangle$, that is, when this information comes to her consciousness, the entropy of the system *Bob's unconscious + Alice's consciousness* is decreased by the quantity

$$-(p_1\ln(p_1) + p_2\ln(p_2)), \quad (22)$$

while the entropy of the environment increases by the same quantity.

Let us suppose that the state which came to Alice's consciousness was $|C11\rangle$, showing that Bob's unconscious is in the state $|C21\rangle$. Let us further suppose that Alice wanted to refine her information on Bob's unconscious and that, starting from this state $|C21\rangle$ of Bob's unconscious, she wanted to get access to deeper layers of his unconscious.

To this end, she tries to gain access to the eigenvalues and eigenstates of a new observable X_2 of Bob's unconscious. Let us suppose, as in the preceding paragraph, that the eigenstates of X_2, $|C21n_1\rangle$, are labeled in a set J_1 ($n_1 \in J_1$). After the interaction with the environment, the corresponding pointer-states of Alice's psyche will be the states $|C11n_1\rangle$ (each state $|C11n_1\rangle$ of Alice's psyche being correlated to the state $|C21n_1\rangle$ of Bob's unconscious). Let p_{n_1} be the probability that Bob's psyche is in the state $|C21n_1\rangle$. The relative probability after the first measurement performed by Alice (observable X_1) is $\frac{p_{n_1}}{p_1}$, and Alice's missing information (Shannon or von Neumann entropy) is given by a formula similar to 16:

$$S_1 = -\sum_{n_1 \in J_1} \frac{p_{n_1}}{p_1}\ln\left(\frac{p_{n_1}}{p_1}\right). \quad (23)$$

Before Alice becomes aware of what concerns the observable X_2, the entropy of the system *Bob's unconscious + Alice's consciousness* is S_1. When Alice obtains the information, that is, when she comes to know the pointer-state $|C11n_1\rangle$, the entropy of this system decreases by S_1, compensated by an increase of the environment entropy of at least the same magnitude.

We can of course follow the same argument for new and deeper layers of Bob's unconscious.

6. IS THERE A COLLAPSE OF THE WAVE FUNCTION?

Nicolas J. Cerf and Chris Adami [4] have analyzed the measurement process in quantum mechanics from the point of view of information theory applied to quantum entanglement. In their interpretation, the measurement process is described by entropy-conserving unitary interactions. In this framework, during the measurement process, there is neither collapse of the wave function nor quantum jump. Cerf and Adami take into consideration a quantum object Q and a measurement device A, itself a quantum system. The measurement process begins with quantum entanglement between Q and A (the first step of von Neumann's measurement process), which corresponds to the creation of an EPR state "QA," that creates "*super-correlations*" between Q and A, rather than correlations.

"The system QA thus created is inherently quantum, and cannot reveal any classical information. To obtain the latter, we need to create classical correlations between *part* of the EPR-pair QA and *another* ancilla A'; i.e., we need to observe the quantum observer." An EPR triplet QAA' is then created via unitary process, and it is a pure state $|QAA'\rangle$ described by the density matrix

$$\rho_{QAA'} = |QAA'\rangle\langle QAA'|. \qquad (24)$$

"Experimentally, we are *only* interested in the correlations between A and A' and *not* in the correlations between A and Q (which are unobservable anyway)…. It is immediately obvious that when ignoring the quantum state Q *itself*, as paradoxically as it may appear at first sight, A and A' find themselves classically correlated and in a *mixed* state":

$$\rho_{AA'} = \mathrm{Tr}_Q(\rho_{QAA'}). \qquad (25)$$

The entropy of the AA' system is positive, but it is compensated by a conditional entropy of Q (the entropy of Q when the AA' system is known) that is negative, the total entropy of the QAA' system remaining null and QAA' staying as a pure state.

It is difficult to justify how the EPR triplet QAA' can remain a pure state described by $|QAA'\rangle$ after the measurement. Indeed, in all known models of quantum measurement, if the measurement of the classical correlation between A and A' reveals a given eigenvalue of the observable X, the quantum object Q is left in the corresponding eigenstate. A choice, namely, the choice of the measured eigenstate, has happened. We have had a quantum jump and a collapse of the wave function. This does not happen in the model of Cerf and Adami.

We would need to find an experimental test that could discriminate between the theories of quantum measurement that does not imply either the collapse of the wave function or a quantum jump (Everett's "Relative State" theory [3], negative entropy theory of Cerf and Adami [4]) and the more "ordinary" theories that suppose (or imply) a collapse of the wave function and quantum jumps (Copenhagen school theory, von Neumann's theory [1], quantum decoherence [2], etc.).

Nevertheless, the fact that there is no quantum jump and that an EPR system remains practically in the pure state in which it was before the measurement is very interesting as far as the unconscious is concerned.

Let us suppose that, with respect to a given piece of information (for example, mourning or not-mourning[5], Bob's unconscious (C2) is described by a superposition two states (representation similar to Bloch's sphere):

$$|C2\rangle = \sin\theta|C20\rangle + \cos\theta e^{i\phi}|C21\rangle. \qquad (26)$$

[5] See Section 7.

Such a superposition of two elementary states has been studied by Yuri Orlov [23] for doubt mental states.

Let us further suppose that, in the framework of this binary information, Alice's unconscious (C1) connects to Bob's one to form an EPR state:

$$|C1, C2\rangle = \sin\theta|C10\rangle|C20\rangle + \cos\theta e^{i\phi}|C11\rangle|C21\rangle. \qquad (27)$$

We can consider that, due to the interaction of Alice's psyche with the environment (a phenomenon akin to quantum decoherence for physical systems), Alice's consciousness cannot access the pure state $|C1, C2\rangle$ but rather a reduced density matrix similar to equation (25):

$$\rho_{C1C2} = \mathrm{Tr}_{C3}(\rho_{C1C2C3}), \qquad (28)$$

the trace being taken on an unknown degree of freedom that forms an EPR triplet with Alice's and Bob's unconscious (this can be the unconscious of a third person $C3$, or even the collective unconscious $|G(t)\rangle$). We then obtain

$$\begin{aligned}\rho_{C1C2} = {} & \sin^2\theta|C10\rangle\langle C10||C20\rangle\langle C20| \\ & + \cos^2\theta|C11\rangle\langle C11||C21\rangle\langle C21|\end{aligned} \qquad (29)$$

related to an increase in entropy

$$S = -(\sin^2\theta\ln(\sin^2\theta) + \cos^2\theta\ln(\cos^2\theta)). \qquad (30)$$

We will suppose that this realization (awareness) by Alice, linked to an entropy production, does not destroy the EPR state $|C1, C2\rangle$ (27); this realization can, nevertheless, introduce an unitary transformation of the $|C1, C2\rangle$ EPR state (27), specifically changing the θ and ϕ angles as functions of time.

We note that our development does not correspond to Cerf and Adami's one. In contrast to them, we did not take the trace on the quantum state of the measured object (Bob's unconscious), but on a third quantum state $|C3\rangle$ with which Bob and Alice are quantum-correlated. This method is closer to the one used in quantum decoherence, which implies the dispersion in the environment of some degrees of freedom.

Nevertheless, starting from the next paragraph, we will treat the measurement of the unconscious in a way very similar to the one elaborated by Cerf and Adami.

Let us come back for a moment to Cerf and Adami's theory of negative entropy. In their article "What Information Theory Can Tell Us About Quantum Reality" [24], they claim to solve the "Schrödinger's Cat" paradox summing on all quantum states of the radioactive substance causing (or not causing) the death of the cat. However, as they do not define at any moment pointer-states (which are usually defined by the interaction with the environment), it is always possible to make a change of basis before summing the states of the radioactive atom, and therefore we will obtain real states that are superpositions of the state "live cat" and the state "dead cat" (we note that the same problem exists in Everett's theory of "Relative State" [3]).

Moreover, they write, "Fundamentally, the reason why the observer does not register a cat mired in a quantum superposition of the living and non-living states is because the observer, having interacted with the cat, is entangled with, and thus part of, the *same* wave function. As the wave function is *indivisible*, an observer (or measurement device) would have to monitor *itself* in order to learn about the wave function. This is logically impossible."

This is opposed by D.G. Chakalov [25]: "I think self-monitoring is an essential introspective feature of human consciousness: we do know the quale of our brain's wave function—the human self?—being entangled with our brain, and thus part of the *same* wave function. Psychologically, this is manifested in our ability to think ABOUT that which we think (our brain), BY that with which we think (our brain). Hence the statement by C. Adami and N.J. Cerf is NOT valid for human consciousness."

In a similar way, Matti Pitkanen [26] writes

> Quantum jump/state function collapse can explain the active aspect of conscious (bodily actions, etc.). But can it explain the passive aspect of consciousness involving no conscious choice (sensory experience)?
>
> That standard quantum jump between eigenstates of observables is not enough to understand consciousness is suggested by several arguments, besides this self-monitoring aspect emphasized by Dimitri Chakalov.
>
> (a) Sensory experience does not involve experience of free will.
>
> (b) If contents of contents are defined by the initial and final states of quantum jumps which are different, then it would be impossible to have objective information about quantum states but only quantum state pairs.
>
> (c) It would be difficult to understand the apparent continuity of conscious experience, since same subsystem could not participate in subsequence quantum jumps.
>
> If one assumes also that quantum jumps changing only the phase associated with subsystems state function so that physical state remains as such, are possible then one can solve these problems. In Topological Geometrodynamics context the strong form of Negentropy Maximization Principle allows systems with *minimal* quantum entanglement to perform these quantum jumps. These passive quantum jumps could also correspond to the self-monitoring aspect of consciousness. They are also very close to classical measurements since they do not change the physical state, but of course, respect uncertainty principle. This leads to two strategies of being conscious: either minimize/maximize entanglement entropy in order to achieve knowledge about world/power to change it.

This comforts us in the idea that consciousness states are related to quantum jumps that are not associated with a collapse of the wave function of the unconscious. In particular, they do not destroy the states of quantum entanglement of the unconscious. This is very similar to Cerf and Adami's point of view. However, in our opinion, pointer-states, which are those states that come to be known to consciousness, are defined by the interaction of the psyche with the environment. This interaction with the environment brings to consciousness states that are *in harmony* with the environment and thus with the *classical* reality that surrounds us. This is why a state of superposition of a "dead cat" with a "live cat" does not become manifest to our consciousness. There can, however, be situations where consciousness acquires knowledge of *mystical* states that are not *in harmony* with the *classical* reality around us. In these rare occurrences, the conscious realization of a fundamentally quantum state is "protected" from the interaction with the environment.

7. QUANTUM MODEL OF MOURNING

We will study how Bob faces mourning, for example, the loss of his father[6]. We will consider the part of Bob's unconscious related to this mourning. We will designate it by $|CD2\rangle$, a vector of a Hilbert space.

As a consequence of interaction with the environment, we will suppose that there exist two pointer-states, i.e., two stable states as far as the mourning is concerned, of which Bob can become aware. Thus there would be, first, the state $|CD21\rangle$ that would correspond to a totally not carried through mourning (Bob would not have accepted at all his father's death). Then there would be the state $|CD20\rangle$ for which the mourning would be achieved (Bob would have accepted completely his father's death). It seems to us that these two states can represent realistic pointer-states insofar as each of them is associated to some reality. The first state is associated to the reality in which the father is still alive, while the second state is associated to the reality in which the father is deceased. Those two pointer-states also correspond each to the answers that Bob can make to the question "Is your father dead?", the reply being "No" in the first case and "Yes" in the second one. We will suppose that each of those two states is of minimal entropy as far as the interaction with the environment is concerned. We are thus dealing with a binary situation.

Therefore, the state of Bob's unconscious related to this mourning is a superposition of the two pointer-states $|CD21\rangle$ and $|CD20\rangle$, a superposition that we

[6] One of the two authors of this paper (GGC) has published a study of the mechanism of mourning within the framework of chaos theory [27].

parameterize with the angles θ and ϕ (through a representation which is close to Bloch's sphere):

$$|CD2\rangle = \sin\theta|CD20\rangle + \cos\theta e^{i\phi}|CD21\rangle. \quad (31)$$

The states of consciousness corresponding respectively to the two pointer-states will be designated by $|CC21\rangle$ and $|CC20\rangle$ ($|CC\rangle$ indicates in a general way the states of consciousness). To be more precise they are themselves the pointer-states.

If we follow the model of quantum measurement of Cerf and Adami we are led to suppose the existence of an intermediary quantum system between $|CD\rangle$ and $|CC\rangle$ which interacts with $|CD\rangle$ in such a way that it forms with it an EPR-doublet (a quantum-entangled state). Then this intermediary quantum system allows transition to a conscious state. Cerf and Adami call this intermediary quantum system an ancilla (A). In our situation we can suppose that this ancilla is the insight, which allows ideas to reach our consciousness. It is an unconscious quantum system (or preconscious; a part of the unconscious functioning of our brain) that we will designate by $|CI\rangle$, vector of a Hilbert space.

Let us sum up. In the case of Bob and his mourning problem, the part of his unconscious related to this mourning forms, in a first stage, an EPR-doublet with the insight

$$|CD2, CI2\rangle = \sin\theta|CD20\rangle|CI20\rangle + \cos\theta e^{i\phi}|CD21\rangle|CI21\rangle. \quad (32)$$

Then, in a second stage, this forms an EPR triplet with the states of consciousness $|CC\rangle$:

$$|CD2, CI2, CC2\rangle = \sin\theta|CD20\rangle|CI20\rangle|CC20\rangle + \cos\theta e^{i\phi}|CD21\rangle|CI21\rangle|CC21.\rangle \quad (33)$$

This EPR triplet is a pure state, written here in the basis of pointer-states $|CC20\rangle$ and $|CC21\rangle$. The density operator describing this pure state is

$$\rho_{CD2, CI2, CC2} = |CD2, CI2, CC2\rangle\langle CD2, CI2, CC2|. \quad (34)$$

Still following Cerf and Adami's method, we sum over the unconscious states $|CD\rangle$ to which we have no access and obtain the reduced density operator

$$\rho_{CI2, CC2} = \mathrm{Tr}_{CD2}(\rho_{CD2, CI2, CC2}), \quad (35)$$

that is to say,

$$\rho_{CI2, CC2} = \sin^2\theta|CI20\rangle\langle CI20||CC20\rangle\langle CC20| + \cos^2\theta|CI21\rangle\langle CI21||CC21\rangle\langle CC21|. \quad (36)$$

This exhibits a classical correlation between the insight and the states of consciousness. The von Neumann entropy of the system ($CI2$, $CC2$) is positive:

$$S(CI2, CC2) = -(\sin^2\theta\ln(\sin^2\theta) + \cos^2\theta\ln(\cos^2\theta)) \quad (37)$$

The von Neumann entropy of the EPR triplet ($CD2$, $CI2$, $CC2$) is equal to zero, this system being a pure state:

$$S(CD2, CI2, CC2) = 0. \quad (38)$$

But we have the formula

$$S(CD2, CI2, CC2) = S(CI2, CC2) + S(CD2|CI2, CC2), \quad (39)$$

in which $S(CD2|CI2, CC2)$ is the *conditional* quantum entropy which describes the entropy of Bob's unconscious (CD2) *knowing* the system composed by Bob's insight and consciousness: (CI2, CC2). This *conditional* entropy is negative:

$$S(CD2|CI2, CC2) = -S(CI2, CC2) = \sin^2\theta\ln(\sin^2\theta) + \cos^2\theta\ln(\cos^2\theta). \quad (40)$$

This is the result that we obtain by applying Cerf and Adami's method, assuming in addition that the pointer-states of consciousness are specified by the environment.

7.1. The Role of the Different Parts of the Unconscious in Mourning

According to Freud, the unconscious is composed of various parts: the Id, the Repressed, the Ego, and the Super-ego, to which we should add the Oneself defined by C.G. Jung (Selbst in German). From a quantum point of view those various parts form the fundamental state $|G_{\mathrm{Individual}}(t)\rangle$ on which is built an individual's psyche at time t (especially his states of consciousness) [8]. Moreover, we should not forget the fundamental state $|G(t)\rangle$, a kind of collective unconscious, upon which is built the individual fundamental state $|G_{\mathrm{Individual}}(t)\rangle$.

Each of these different parts of the unconscious will be formalized by a Hilbert space: e.g. H_{Id}, $H_{\mathrm{Repressed}}$, H_{Ego}, $H_{\mathrm{Super\text{-}ego}}$, H_{Oneself}, etc. The Hilbert space H representing the unconscious will be the tensor product of those various Hilbert spaces:

$$H = H_{\mathrm{Id}} \otimes H_{\mathrm{Repressed}} \otimes H_{\mathrm{Ego}} \otimes H_{\mathrm{Super-ego}} \otimes H_{\mathrm{Oneself}} \ldots. \quad (41)$$

Let us notice that according to Freud a part of the ego and a part of the super-ego are in the preconscious and in the conscious ("the tip of the iceberg").

Let us consider now how those different parts of the unconscious act during mourning.

Let us take the Repressed. The states of the Hilbert space $H_{\mathrm{Repressed}}$ related to Bob's unconscious will be denoted $|CR2\rangle$. Let us suppose that Bob has repressed the thought "I would like to kill my father." This repressed thought will make the mourning for his father impossible to achieve. Therefore we will suppose that in this situation, concerning the mourning, Bob's repressed unconscious will be in the state $|CR21\rangle$ (state making the mourning impossible). At the opposite extreme let us suppose that nothing in Bob's repressed unconscious will prevent the mourning from being achieved. In this case Bob's repressed unconscious will be in the state $|CR20\rangle$.

On a quantum point of view Bob's repressed unconscious can be written as a linear combination of those two states:

$$|CR2\rangle = a|CR20\rangle + b|CR21\rangle. \tag{42}$$

Let us consider now the Hilbert space tensor product $H_{\text{Repressed}} \otimes H_{\text{Ego}}$. Let us express a state of this space, $|CR2, C_{\text{Ego}}2\rangle$, related to the mourning, on the basis $(|CR20\rangle, |CR21\rangle)$. We will write the following:

$$\begin{aligned} |CR2, C_{\text{Ego}}2\rangle &= a'|CR20\rangle|C_{\text{Ego}}20\rangle \\ &\quad + b'|CR21\rangle|C_{\text{Ego}}21\rangle. \end{aligned} \tag{43}$$

Let us carry on with this reasoning by including all the parts of the unconscious that take part in the mourning. Then the state of the Hilbert space H related to the mourning can be written, using a representation which is close to Bloch's sphere:

$$\begin{aligned} &|CR2, C_{\text{Ego}}2, C_{\text{Id}}2, C_{\text{Super-ego}}2, C_{\text{OneSelf}}2, \ldots\rangle \\ &= \sin\theta|CR20\rangle|C_{\text{Ego}}20\rangle|C_{\text{Id}}20\rangle|C_{\text{Super-ego}}20\rangle \\ &\times|C_{\text{OneSelf}}20\rangle\ldots + \cos\theta e^{i\phi}|CR21\rangle|C_{\text{Ego}}21\rangle|C_{\text{Id}}21\rangle \\ &\times|C_{\text{Super-ego}}21\rangle|C_{\text{OneSelf}}21\rangle\ldots, \end{aligned}$$

which we can rewrite by putting

$$|CD2\rangle = |CR2, C_{\text{Ego}}2, C_{\text{Id}}2, C_{\text{Super-ego}}2, C_{\text{OneSelf}}2, \ldots\rangle,$$

$$\begin{aligned} |CD20\rangle &= |CR20\rangle|C_{\text{Ego}}20\rangle|C_{\text{Id}}20\rangle|C_{\text{Super-ego}}20\rangle \\ &\quad \times|C_{\text{OneSelf}}20\rangle\ldots, \end{aligned}$$

and

$$\begin{aligned} |CD21\rangle &= |CR21\rangle|C_{\text{Ego}}21\rangle|C_{\text{Id}}21\rangle|C_{\text{Super-ego}}21\rangle \\ &\quad \times|C_{\text{OneSelf}}21\rangle\ldots, \\ |CD2\rangle &= \sin\theta|CD20\rangle + \cos\theta e^{i\phi}|CD21\rangle, \end{aligned} \tag{44}$$

which is nothing but formula 31.

We have thus built up the part of Bob's unconscious related to the mourning from the influence on this mourning of each of the structures of this unconscious. Let us notice that the angles θ and ϕ (and especially the angle θ) are fixed by the influence of each part of the unconscious on the process of mourning.

In particular, if the Repressed is such that it makes the mourning impossible to achieve (e.g., because of the thought "I would like to kill my father") the angle θ will be nearly zero and the state $|CD2\rangle$ will be almost equal to $|CD21\rangle$ (up to a phase ϕ) (the mourning will not be achieved at all).

7.2. Realization of the Mourning States

Given that formula 44 is analogous to formula 31, we suppose that the process of realization by Bob of his father's mourning is the one described at the beginning of Section 7. In other words, Bob's consciousness (state $|CC2\rangle$) connects with the part of his unconscious concerning mourning ($|CD2\rangle$) through the mediation of the insight ($|CI2\rangle$), this pre-conscious element of psyche that effects the transition of an element from unconscious to consciousness.

We note that in Libet's experiences on the brain [28], the decision of executing a muscular action is taken half second before the actual consciousness of this decision. It seems therefore clear that at the neuronal level there is an unconscious process that precedes the conscious realization of an act (or a thought). It is this very process that we will associate to the insight.

As far as the Freudian subdivision of psyche is concerned, the conscious states, $|CC\rangle$, will be associated to the conscious self (Ego). We can then associate the insight states, $|CI\rangle$, to the pre-conscious self. We will neglect the possibility of having a conscious or pre-conscious Super-ego.

As we indicated at the beginning of Section 7, an EPR triplet $|CD, CI, CC\rangle$ is formed, as described by formula 33. Following Cerf and Adami, we sum on the unconscious states of mourning $|CD\rangle$, to which Bob has no access, to obtain a classical correlation between Bob's insight and his conscious states. The statistical mixture 36 is a mixture of the pointer-states corresponding to a given reality of the classical world as we perceive it: $|CC21\rangle$, the father is still alive, and $|CC20\rangle$, the father is accepted as dead.

When we are awake, we are continuously thinking. This means that insight is continuously bringing thoughts to our consciousness. In Bob's case, in this continuous stream of thoughts, some are related to his mourning, that is, to the death of his father. Some of these thoughts will be like: "the death of my father is too painful, I cannot accept his passing away" ($|CC21\rangle$). Others will be: "my father is dead, this is a fact, I am in peace with this idea" ($|CC20\rangle$). In the statistical ensemble of Bob's thoughts related to his father's mourning, the thoughts of the first kind will have statistical weight $\cos^2\theta$. On the other hand the thoughts of the second kind will have statistical weight $\sin^2\theta$.

According to Cerf and Adami's philosophy, who maintain that there is no wave-function collapse, and in agreement with Matti Pitkanen, who asserts that quantum jumps associated with conscious realizations do not imply the collapse of the unconscious wave function, Bob's realizations about his mourning will not modify substantially his unconscious quantum state $|CD2\rangle$ related to mourning. The latter will always be described by a formula similar to 31 or 44. This quantum state will evolve according to a unitary transformation as a function of time, an evolution that we can qualify as adiabatic (with no variation of entropy).

Thus the θ angle will be a function of Bob's psychological time, which is obviously linked to physical time. Soon after his father's death, the θ angle will be very close to zero (the mourning will not have started yet). However in some cases, when we know that our father is going to die, the mourning may have begun before his physical death. In any case, when the mourning has not yet started, the θ angle is equal to zero. Bob is then in a state of denial or refusal. If the mourning evolves positively, this angle will evolve, as a function of the psychological time, from zero to $\pi/2$, describing a consciously achieved mourning, that corresponds to a "normal" neurotic state. We note that the θ angle does not necessarily vary monotonously as a function of (psychological) time. We can have "backward" movements. In the case of pathological mourning the θ angle may remain frozen at a value close to zero. We can seek the help of a therapist to achieve the mourning process (see section 8). When the value of the θ angle is between zero and $\pi/2$ this corresponds in general to a state of depression.

8. CORRELATION BETWEEN BOB AND ALICE

8.1. Correlation via the Exchange of an Interaction Boson

The example that we are going to describe has really happened. During a concert given in Bob's honor, the Beethoven 32nd sonata is performed. Alice, who has not seen Bob in a long time, is absolutely unaware of the concert, but nevertheless she writes to him a long letter about Beethoven's 32nd sonata.

Beethoven's 32nd sonata is part of Bob's conscious states, as well as of the states of his unconscious. Without necessarily resorting to quantum entanglement, we can imagine that Bob's and Alice's unconscious interact via the exchange of virtual bosons (bosons that are the quanta of a psyche field). Thus virtual bosons carry the information "Beethoven's 32nd sonata" and they trigger Alice's unconscious. Consequently Alice writes to Bob a long letter on Beethoven's 32nd sonata.

This is a way to describe the long-range correlations that can happen between different psyches.

Let us now imagine these correlations as consequences of the quantum entanglement phenomenon.

8.2. Correlation via Quantum Entanglement

When Bob thinks about Beethoven's 32nd sonata, or when he has to deal with a problem concerning the interpretation of this sonata, his insight is in a given quantum state $|CI21\rangle$. This quantum state is a pre-conscious pure state that brings to the conscious level the information "Beethoven's 32nd sonata." When Alice decides to write to Bob a letter about Beethoven's 32nd sonata, her insight is in quantum state $|CI11\rangle$, which is the same as $|CI21\rangle$.

When two twins decide, without previous agreement, to buy practically simultaneously the same necktie, their respective insights are also in the same quantum state.

We can therefore imagine that in the situations that we have just illustrated there is a kind of Bose–Einstein condensation that happens at the unconscious level, as well as at the level of the insight[7].

A part of Alice's unconscious "condensates" with a part of Bob's unconscious to form a sort of group unconscious described by a single quantum state. In a similar way, a portion of Alice's insight "condensates" with a portion of Bob's insight to form a kind of group insight also described by a single quantum state. A kind of coalescence effect happens, akin to superfluidity or superconductivity, at the unconscious and insight levels.

Nevertheless, via the continuous transition of different thoughts from unconscious to conscious states, the insight continuously changes its state, as well as consciousness itself. Our insight is thus not always in a state of group insight. In fact, most of the time, it is in a state of individual insight. This is the reason why twins, or two partners of a couple, are not continuously having the same thoughts. This is also the reason why long-range correlations do not necessarily happen with exact simultaneity. Alice has not written her letter about Beethoven's 32nd sonata at the precise instant when Bob was thinking about this sonata. This does not prevent there being a quantum correlation between their two unconscious (formation of a group unconscious) or the formation of a group insight leading to a certain form of group consciousness.

The fact that there is the formation of a group insight without a total fusion of the two consciousness can be compared to a superconductor where a certain number of electrons bind themselves into Cooper pairs and then form the superfluid (or superconducting) part of the system, while there are still "individual" electrons not bound into Cooper pairs and forming the "normal" component of the system. The group insight is therefore associated with the "superfluid" component of the system, while the individual insight is associated with the "normal" component of the system.

8.3. Mourning and the Correlation between Alice and Bob

Let us come back to Bob's problem and to the mourning process he has to achieve (due to his father's

[7] Herbert Fröhlich [29] has proposed a model of Bose–Einstein condensation in biological systems. This model has been adopted by Ian Marshall [30], which has given it a major role in the brain activity, a role that allows the brain to have a global activity. In our case this is a different Bose–Einstein condensation that is situated at the level of the unconscious mental states as opposed to the level of the physical states of the brain.

death). To solve this problem, let us suppose that he sees a therapist, Alice.

The state of Bob's unconscious related to the mourning process he has to go through is given by formula 31 or 44. During a psychoanalysis session, Alice's unconscious interacts with the part of Bob's unconscious related to his mourning to form an EPR state described by a formula similar to formula 27:

$$|CD1, CD2\rangle = \sin\theta|CD10\rangle|CD20\rangle + \cos\theta e^{i\phi}|CD11\rangle|CD21\rangle. \tag{45}$$

This is a definition of the states $|CD10\rangle$ and $|CD11\rangle$, states of Alice's unconscious entangled with the unconscious mourning states of Bob. Thanks to this situation of quantum entanglement and to her insight, Alice can realize Bob's mourning states. So, as far as Alice and the quantum correlation of her unconscious with Bob's one are concerned, we have an EPR quadruplet, similar to the EPR quadruplet 33:

$$|CD2, CD1, CI1, CC1\rangle = \sin\theta|CD20\rangle|CD10\rangle \times|CI10\rangle|CC10\rangle + \cos\theta e^{i\phi}|CD21\rangle|CD11\rangle \times|CI11\rangle|CC11\rangle,$$

in which $|CI1\rangle$ and $|CC1\rangle$ are respectively the states of Alice's insight and consciousness. $|CI10\rangle$ and $|CC10\rangle$ are correlated to Bob's mourning state $|CD20\rangle$, and $|CI11\rangle$ and $|CC11\rangle$ are correlated to Bob's $|CD21\rangle$ mourning state.

The density operator representing the $|CD2, CD1, CI1, CC1\rangle$ pure state is

$$\rho_{CD2, CD1, CI1, CC1} = |CD2, CD1, CI1, CC1\rangle\langle CD2, CD1, CI1, CC1|. \tag{46}$$

As we have done for Bob, following Cerf and Adami's method, we sum on the unconscious states $|CD2, CD1\rangle$ to which Alice has no access and we obtain a reduced density operator:

$$\rho_{CI1, CC1} = \mathrm{Tr}_{CD2, CD1}(\rho_{CD2, CD1, CI1, CC1}); \tag{47}$$

that is,

$$\rho_{CI1, CC1} = \sin^2\theta|CI10\rangle\langle CI10||CC10\rangle\langle CC10| + \cos^2\theta|CI11\rangle\langle CI11||CC11\rangle\langle CC11|, \tag{48}$$

which is analogous to the reduced density operator 36.

As for Bob, this procedure therefore reveals a classical correlation between Alice's insight and her conscious states.

The existence of the EPR quadruplet $|CD2, CD1, CI1, CC1\rangle$ allows Alice to realize, at a given moment and in particular during the analysis session, the mourning states of Bob's unconscious. As is the case for Bob, formula 48 gives the statistical weights of the thoughts "Bob has realized his mourning" or "Bob has not realized his mourning." During the analysis session, according to the thoughts that come to her consciousness (or even unconsciously), Alice can, via spoken words, actualize some of them, and this could help Bob to achieve his mourning process, causing a positive evolution of the θ angle (from zero towards π/2).

The quantum state of Alice's insight, $|CI10\rangle$, which makes her realize her unconscious state $|CD10\rangle$, which is itself quantum correlated to the state $|CD20\rangle$ of Bob's unconscious, is the same quantum state of Bob's insight, $|CI20\rangle$, which makes him realize his unconscious state $|CD20\rangle$. In the same way, the quantum state of Alice's insight $|CI11\rangle$ is the same as the quantum state $|CI21\rangle$ of Bob's insight. We can therefore define the quantum states of the group insight of Bob and Alice:

$$|CI0\rangle = |CI10\rangle|CI20\rangle \tag{49}$$

and

$$|CI1\rangle = |CI11\rangle|CI21\rangle. \tag{50}$$

We can also define the quantum states of the group unconscious of Alice and Bob related to Bob's mourning:

$$|CD0\rangle = |CD10\rangle|CD20\rangle \tag{51}$$

and

$$|CD1\rangle = |CD11\rangle|CD21\rangle. \tag{52}$$

We can then rewrite formula 45 with group notation:

$$|CD\rangle = \sin\theta|CD0\rangle + \cos\theta e^{i\phi}|CD1\rangle. \tag{53}$$

In a similar way we can define the quantum states of Bob's and Alice's group consciousness:

$$|CC0\rangle = |CC10\rangle|CC20\rangle \tag{54}$$

and

$$|CC1\rangle = |CC11\rangle|CC21\rangle, \tag{55}$$

and write an group EPR triplet similar to EPR triplet 33:

$$|CD, CI, CC\rangle = \sin\theta|CD0\rangle|CI0\rangle|CC0\rangle + \cos\theta e^{i\phi}|CD1\rangle|CI1\rangle|CC1\rangle. \tag{56}$$

Following Cerf and Adami's method, all that has been written about Bob's and Alice's density operators can be rigorously written in the same way, but with group notation.

We insist once more on the fact that the thoughts that reach Bob's and Alice's consciousness are in most cases individual thoughts, and only from time to time are they group thoughts.

9. QUANTUM GROUP MODEL

9.1. Group Dynamics as Extension to the Group of the Mourning Dynamics

W.R. Bion and S.H. Foulkes, both psychoanalysts, the first a disciple of M. Klein and the second of Freud, have elaborated and formalized group dynamics.

According to W.R. Bion, *the group is moved by two fundamental principles*:

First principle: The conscious cooperation of the members of the group, necessary to the success of their undertakings, requires an unconscious emotional and phantasmatic communication between them.

Second principle: The individuals in a group combine instantaneously and involuntarily to act according to affective states called "basic assumptions." Starting from and in contrast to the "basic assumptions" the group's work, linked to reality, can develop. Here are, briefly described, these "basic assumptions":

9.1.1. Dependence: The group asks to be protected by the leader, on whom it feels dependent for its intellectual or spiritual food. It can exist without conflicts only if the leader accepts the role attributed to him, with all the implied prerogatives and duties. Dependence responds to an eternal aspiration of the groups: the dream of an intelligent, benevolent, and strong leader who can assume responsibility for them, the dream of an "almighty leader."

9.1.2. Fight or flight: The refusal of the assumption of dependence on the leader represents a danger for the group, which believes that its survival in danger. Confronted with this danger, the participants gather to fight or to flight. In this sense the fight or flight attitude is a sign of solidarity of the group.

9.1.3. Pairing: sometimes the fight or flight attitude results in the formation of subgroups or pairs. The pair represents a danger for the group, as it tends to form an independent subgroup.

9.1.4. Messianic hope: the pair, or sometimes the entire group, in its idealization, will give birth to a new leader, perfect, good, etc. This hope allows the group to project negative feelings (deception, desire, hate, rivalry, etc.) onto the leader who could not be almighty (these negative feelings are often diverted towards the other participants to spare the leader), in a positive feeling of hope in the savior who, being still unborn, is just a distant danger.

S.H. Foulkes said that [31]

> The group proceeds at its own rhythm governed by progressive and regressive forces, integrating and separating, continuously opposing change, and continuously changing, never the same. "You cannot step twice in the same river because fresh waters are ever flowing upon you," says Heraclitus. The same is true for a group, a group in evolution is never twice the same.

Both Bion and Foulkes have used the metaphor of the "matrix" applied to the group. They concentrate on the situation "here and now." They are guided by the analogy to transfer and counter-transfer in psychoanalysis. They highlight the conflicts that are inherent to the group and underline the impact of resistances against the change of the "status quo".

They both consider that the therapist is part of the group experience and they believe in the value of the therapy by the group. They both believe in the virtue of learning by experience. They both maintain that "it is absolutely impossible for the individual in the group to 'do nothing,' even while doing nothing" (extracts from reference [31]).

The assumptions we have mentioned before (dependence, fight or flight, pairing, and messianic hope) do not appear at the same time. One dominates and masks the others, which however remain potentially there. By removing its present weight to the dominant assumption, interpretation frees at the same time the others, and allows the group to function differently.

The gist of our parallel between the mourning process and the group dynamics is in the remark that, as all individuals, the group reacts to a loss. In other terms, via the basic assumptions, the group dynamics is similar to the dynamics of the individual mourning.

Dependence responds to the aspiration of all individuals to be protected by an intelligent, good, strong, and almighty leader. The refusal or the incapacity of the leader to assume this role, or the verification that this leader is not almighty, represent a loss for the group, which is comparable to the mourning experience for the individual.

The de-idealization of the leader corresponds to his (or her) symbolic death, the ultimate proof of his inability, his wickedness and weakness. The group, as well as the individual who believes he cannot survive, reacts either with the fight or with the escape, or it pairs or mates to generate another leader.

The dependence from an almighty leader is thus necessarily followed by the loss of this illusion of protection, and then by the temptation of repair via combat-escape, pairing, and, finally, messianic hope. This is the denial and anger phase face to a loss. Then comes the moment of sadness, the depressive phase, after which follows acceptance of the loss.

Analogously to what has been done in the two preceding sections, when we considered Bob at first, and then Alice and Bob, facing the mourning, we can, in a group situation, confront the group to a situation of choice comparable to mourning: "the leader is good/live" versus "the leader is bad/dead."

Moreover, in analogy with the previous definition of pointer-states $|CD21\rangle$ and $|CD20\rangle$, and as we did for Bob's unconscious (C2) and for Alice and Bob's one (C1, C2), let us consider the Hilbert space built as tensor product of the Hilbert spaces of the components of Bob's unconscious, of Alice's one, and also all those of the unconscious of the other participants in a group: Peter, Paul, Matthew, John, Sandra, etc.

In this Hilbert space, in a manner similar to Sub-section 7.1, we can write the quantum state of the group related to the mourning (of the loss of the leader) as follows:

$$\begin{aligned}&|CBob, CAlice, CPeter, CPaul, CMatthew, CJohn, CSandra, \ldots\rangle\\&= \sin\theta|CBob0, CAlice0, CPeter0, CPaul0, CMatthew0, CJohn0, CSandra0, \ldots\rangle\\&+ \cos\theta e^{i\phi}|CBob1, CAlice1, CPeter1, CPaul1, CMatthew1, CJohn1, CSandra1, \ldots\rangle,\end{aligned}$$

and we can reformulate this by defining

$$\begin{aligned}&|CDgroupe\rangle = |CBob, CAlice, CPeter, CPaul, CMatthew, CJohn, CSandra, \ldots\rangle,\\&|CDgroupe\rangle = |CBob0, CAlice0, CPeter0, CPaul0, CMatthew0, CJohn0, CSandra0, \ldots\rangle,\end{aligned}$$

and

$$\begin{aligned}&|CDgroupe1\rangle = |CBob1, CAlice1, CPeter1, CPaul1, CMatthew1, CJohn1, CSandra1, \ldots\rangle,\\&|CDgroupe\rangle = \sin\theta|CDgroupe0\rangle + \cos\theta e^{i\phi}|CDgroupe1\rangle.\end{aligned} \tag{57}$$

This expression is analogous to formulas 31 and 44.

We have thus built the part of the group unconscious related to the mourning of the leader starting from the influence of this loss on the unconscious of each member of the group.

$|CDgroupe\rangle$ is the quantum state that is created starting from the different individual unconscious of the group. This group state can be compared to a Bose–Einstein condensate, insofar as the group situation could cause a large majority of the unconscious of the group to be in the same quantum state, as we have seen in Section 8.2 in relation with Alice and Bob. This group quantum state is a low energy one, close to the fundamental state. We can also imagine a picture of the individual unconscious that tends to "orientate" in a homogeneous manner.

We now suppose the formation of an EPR triplet composed by $|CDgroupe\rangle$, $|CIgroupe\rangle$, and $|CCgroupe\rangle$. $|CIgroupe\rangle$ is the group insight. This is a pre-conscious entity. This group insight is analogous to Alice and Bob's group insight defined in 49 and 50. The insight focuses consciousness on those pointer-states that have minimal interaction entropy with the environment, e.g., "for or against a remark," "right or left," and "up or down." In such situations of dual choice, where two alternatives are submitted to consciousness, and therefore can be present at the same time, we arrive at a statistical sample composed by a set of results (a set of choices).

$|CCgroupe\rangle$ indicates the quantum state of group consciousness. This group consciousness is similar to Alice and Bob's group consciousness as we defined it in 54 and 55.

Given that formula 57 is analogous to formulas 31 and 44, we suppose here that the process of realization by the group that the leader is not almighty is similar to the mechanism of realization of the loss of his father by Bob, in order to achieve his mourning process.

As Bob's, the group consciousness (state $|CCgroupe\rangle$ or $|CCg\rangle$) couples to the part of group unconscious concerning mourning ($|CDgroupe\rangle$ or $|CDg\rangle$) via the mediation of the pre-conscious group "insight" ($|CIgroupe\rangle$ or $|CIg\rangle$) that operates the transition of an element from the unconscious to consciousness.

We therefore have the formation of an EPR triplet analogous to the EPR triplets 33 and 56:

$$\begin{aligned}|CDg, CIg, CCg\rangle &= \sin\theta|CDg0\rangle|CIg0\rangle|CCg0\rangle\\&+ \cos\theta e^{i\phi}|CDg1\rangle|CIg1\rangle|CCg1\rangle.\end{aligned} \tag{58}$$

Following once more Cerf and Adami, we sum on all the unconscious states of mourning, $|CDgroupe\rangle$ or $|CDg\rangle$, that the group cannot have access to, and this leads us to a classical correlation between the insight and the conscious states of the group. We thus obtain the following reduced density operator:

$$\begin{aligned}\rho_{CIg, CCg} &= \sin^2\theta|CIg0\rangle\langle CIg0||CCg0\rangle\langle CCg0|\\&+ \cos^2\theta|CIg1\rangle\langle CIg1||CCg1\rangle\langle CCg1|.\end{aligned} \tag{59}$$

The von Neumann entropy of the system (CIgroupe, CCgroupe) is positive:

$$\begin{aligned}&S(CIgroupe, CCgroupe)\\&= -(\sin^2\theta\ln(\sin^2\theta) + \cos^2\theta\ln(\cos^2\theta)).\end{aligned} \tag{60}$$

Using formulas 38 and 39 we can define $S(CDgroupe|CIgroupe, CCgroupe)$, the conditional entropy of the group unconscious, $|CDgroupe\rangle$ or $|CDg\rangle$, knowing the system composed by the group insight and consciousness: (CIgroupe, CCgroupe). This conditional entropy is negative:

$$\begin{aligned}S(CDg|CIg, CCg) &= -S(CIg, CCg)\\&= \sin^2\theta\ln(\sin^2\theta) + \cos^2\theta\ln(\cos^2\theta).\end{aligned} \tag{61}$$

When, following Cerf and Adami's model, we calculate the trace over the degrees of freedom of the group unconscious, we obtain a reduced density operator that describes the classical correlation between the measurement device (the group insight) and the observer (the group consciousness). This classical correlation, described by a statistical mixture, is supposed to describe the quantum object (the group unconscious) that is, and will remain, impossible to know directly. We note that in the model of quantum decoherence [2] we calculate the trace over the degrees of freedom of the environment that are quantum correlated to the measurement device and to the observed quantum object.

The statistical mixture, which is a mixture of pointer-states corresponding to a given reality of the classical world that the group can perceive, can allow us to estimate, even if, we say again, in an indirect manner, the functioning of the group facing, for instance, a given question asked. If this question is on the level of consciousness, that is, if this is a "classical" kind of question, the answer to which requires a conscious reflection, we will remain in the context of the individual consciousness, "multiplied" by the number of participants in the group, as happens in a vote at the parliament (where we agree to vote on the "purely rational" decisions of the representatives).

A possible method of perceiving the unconscious working of a group, although indirect, as we have indicated, via the correlation between group insight and group consciousness is to propose a set of "absurd" questions at different times during a group experience, taking care to choose a situation where exchanges with the environment are reduced as much as possible, and where the number of participants and the place are kept constant and the subject of the conversations amongst participants not arranged in advance, while adopting ethically correct procedures and paying attention to the well-being of the participants.

9.2. Outline of an Experiment to Measure the Orientation of the Group Unconscious

As we just said, it might be possible to study the orientation of the answers to a set of "absurd" questions (based on a choice of two possible answers to each question) during a group experience spread over a given number of days, where the participants work in small and large groups (ten participants in average for the small groups and approximately thirty for the large group). They will work organized in a number of theory and reflection groups, in a way similar to what is done, e.g., in the framework of training on group dynamics intended for mental health and social workers.

In the interest in the utilization of an "absurd" set of questions, they should be as detached as possible from rational stimuli, such as the media, cultural or political events, and even the theoretical lessons given during the training.

It would be ethically unacceptable, uncomfortable, and, above all, practically impossible, to completely isolate the participants during the experiment. Moreover, such an artificial situation would risk introducing important biases connected with the artificially constrained situation of the group.

The questionnaires could be proposed to the participants in the morning, before the meeting of the first group, and in the evening, after the meeting of the large group that closes the working day, and repeated every day during the whole duration of the training.

In a first instance, we could limit ourselves to a single training session, because the presence of several environmental stimuli between one session and the next could perturb too greatly the group matrix.

The "absurd" questionnaires, strictly anonymous, should present questions in a variable order to avoid biases due to memory or learning effects, and we could target a set of fifty questions to be answered in three minutes, without the possibility of correcting the answers. For ethical reasons, an explanation of the experiment and written consent by the participants, as well as the distribution of written information, will be necessary before the first experiment.

CONCLUSIONS

The photon delayed-choice experiment shows that an act done by a human being (in this experiment a physicist) in the present can cause a collapse of the wave function that can affect the past, even a remote past. This collapse is global and not local in space–time. The acts and choices that we make not only determine the vision that we have of the world in which we live, but by having consequences in the past (via the collapse of the wave function) they can explain synchronicity phenomena in which a mental state (subjective) is in a significant coincidence with an event happening in the external world (objective). This global collapse in time could explain the apparent classical acausality of these phenomena. Let us note that these effects belong to the active aspect of consciousness.

Choosing resolutely a dualistic view of mind and matter (but taking also into account the correlations between mental states and the physical states of the brain) we have studied the phenomenon of quantum entanglement between mental states considered as quantum states. We emphasized the quantum entanglement between different psyches of various human beings. This could explain the long-range correlations that reveal themselves between individuals such as twins, couples, friends, etc.

Taking into account various models of quantum measurement, it appeared to us that in the case of "passive" consciousness, e.g., awareness of quantum-entangled mental states, models such as Cerf and Adami's (model with negative conditional entropy), in which there is no collapse of the wave function, are extremely interesting because they protect the quantum-entangled mental states and perturb only slightly the unconscious.

We have applied these reflections to the psychological process of mourning. We have modeled the realization (awareness) of elements of the unconscious related to mourning in the case where a person alone proceed to a mourning, as well as in the case where he (or she) receives the help of a psychotherapist. In the latter case there is a quantum entanglement between the patient's unconscious and the therapist's one. Therefore there is formation of a group unconscious, as well as formation of a group insight (ancilla), and even formation of some group consciousness. We have investigated how the unconscious related to the mourning could evolve unitarily as a function of the psychological time, allowing the mourning to be achieved or not to be achieved in pathological cases.

Then we have inferred this to the group dynamics that takes place during group therapy and group training. As in the case of a pair of individuals there is formation of a group unconscious, as well as a group insight (ancilla), and even of some form of group consciousness. We have proposed experiments in order to test the existence of correlations between members of a group, or of various groups, as a result of a group unconscious and a group ancilla-insight.

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