Study of group phenomena as unconscious amplification in a quantum model

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Etude des phénomènes groupaux en tant qu'amplification de l'inconscient selon un modèle quantique

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-...Ma parole, vous décrochez le pompon ! Et maintenant si on allait manger un morceau !- (Christie 2006a, p 64)

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-...Un individu ne commet que très rarement un acte qui n'est pas dans son caractère. C'est même monotone, à la fin. (Christie 2006b, p 197)

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Ce monde tout neuf était le même que l'ancien. Les maisons n'avaient pas du même style...mais les êtres humains étaient semblables à ce qu'ils avaient toujours été. (Christie 2004, p 20)

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- ... Mais je persiste à souhaiter d'en apprendre d'avantage sur les enfants. (Christie 2004, p 132)

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- ... J'en fais mon suspect numéro un. (Christie 2004, p 133)

Résumé

Les phénomènes de groupe ont été utilisés depuis l'antiquité dans différents domaines comme la thérapie, le social, l'économie et la politique. Selon Bion, les interactions entre les membres d'un groupe génèrent un « inconscient groupal » et son comportement est gouverné et orienté pas les « Hypothèse de base » de Bion. Ce travail a été mené pendant une formation d'analyse de groupe à la Fondation Basque pour les Investigations en Santé Mentale (OMIE) à Bilbao, sur onze sessions. Les participants ont rempli un « questionnaire absurde » avec 50 paires d'images, dont il fallait en choisir une de chaque paire. Les résultats ont été élaborés dans le but de chercher, à travers l'amplification de l'inconscient, une possible influence de la dynamique groupale sur les choix des images des questionnaires. Nos analyses ont trouvé une évidence significative en faveur d'un effet de la dynamique groupale sur les choix initiaux des images, mais aussi sur l'évolution du nombre des changements (swaps) des images choisies au long des onze sessions. Nous avons aussi trouvé des relations entre les orientations des réponses dans les différents groupes, en tant que résultats d'Analyse en Composantes Multiples et du calcul de l'Entropie de la distribution de Bernoulli. Nous interprétons ces corrélations comme des effets groupaux à la lumière de la théorie groupale de Bion, qui postule une orientation inconsciente immédiate du groupe et son évolution successive tout au long des activités groupales.

Mots clés : Dynamique de Groupe, Amplification de l'Inconscient, Model Quantique, Entropie

Abstract

Group phenomena have been used since antiquity in therapeutic, social, economic and political domains. According to Bion, the interactions between group members generate a "group unconscious" and its behaviour is governed and oriented by Bion's "basic assumptions." The present work has been conducted during group analysis training at the Basque Foundation for the Investigation of Mental Health (OMIE) at Bilbao, consisting of eleven sessions. The participants are presented with an "absurd questionnaire" proposing 50 pairs of images, in each of which one image has to be chosen. The results are used to search through an unconscious amplification for evidence in favour of the influence of group dynamics on individual choices of the images proposed in the questionnaire. Our analysis finds some significant evidence for an effect of group dynamics both on the initial choice of the pictures and on the evolution of the number of changes (swaps) of picture choices across the eleven sessions. We find also some relations between the orientation of the answers in the groups as results of Multiple Variable Analysis and calculation of the distribution of Bernoulli's Entropy. We interpret these correlations as group effects in the light of Bion's view of group dynamics, which postulates an immediate onset of a group unconscious and its evolution during the group activity.

Keywords: Group Dynamics, Unconscious Amplification, Quantic Model, Entropy

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Introduction

Background theories

As Jung said in his conference at a symposium in London in 1919 (Jung, 1970): "The archetypes are being engraved on the human mind". This Jung's sentence correlates the experience into our psychic constitution as form without content: "There are as many archetypes as there are typical situations in life. Endless repetition has engraved these experiences into our psychic constitution, not in the form of images filled with content, but at first only as form without content, representing merely the possibility of a certain type of perception and action" (Jung, 1959).

Following Hogenson (Hogenson 2001), Jung was interested in the evolutionary history of the mind with no implied commitment to any particular theory of evolution. Although Darwin (1809-1882) (see for instance Brown, 2002, p. 283) disliked the association between his theory and the theory of Lamarck (1744-1829) (Lamarck, 1809), we have to remember that the work done by Gregor Mendel in 1866 (Mendel, 1866) was rediscovered only in 1900.

To say that the appearance and evolution of archetypes is explained by the evolution theory does not mean that we know where archetypes are "stored" – In the brain? Are they coded by the DNA? Will we find a "gene of the archetype"? Like the gene of the controversial scotophobine, supposed to transmit fear of the dark (Desiderio, Ungar & White 1971). Moreover one should also explain how the archetypes constitute an "evolutionary advantage" that has been selected and preserved. Even advocating evolutionary theory, we still find a fundamental difference between archetypes and, for instance, language. Human languages have diverged over the course of centuries, while archetypes have remained substantially invariant across time and space. Could we say that they belong to the realm of Platonic ideas? The problem in Platonic ideas is the separation between ideas and matter, or in another way to express this, mind and matter.

In 1925, Carl G. Jung expressed a kind of geological survey of the psyche (Jung, 1925). Jung's description of the geology of the psyche is shown on Figure 1. At the basis of the psyche there is what Jung called the central fire (H). Then there is the layer corresponding to general animal ancestors (G), the layer corresponding to primitive ancestors (F), the layer corresponding to large groups, such as Europeans (E), the layers corresponding to nations (D), to clans (C), to families (B) and to finish an individual psyche appears.

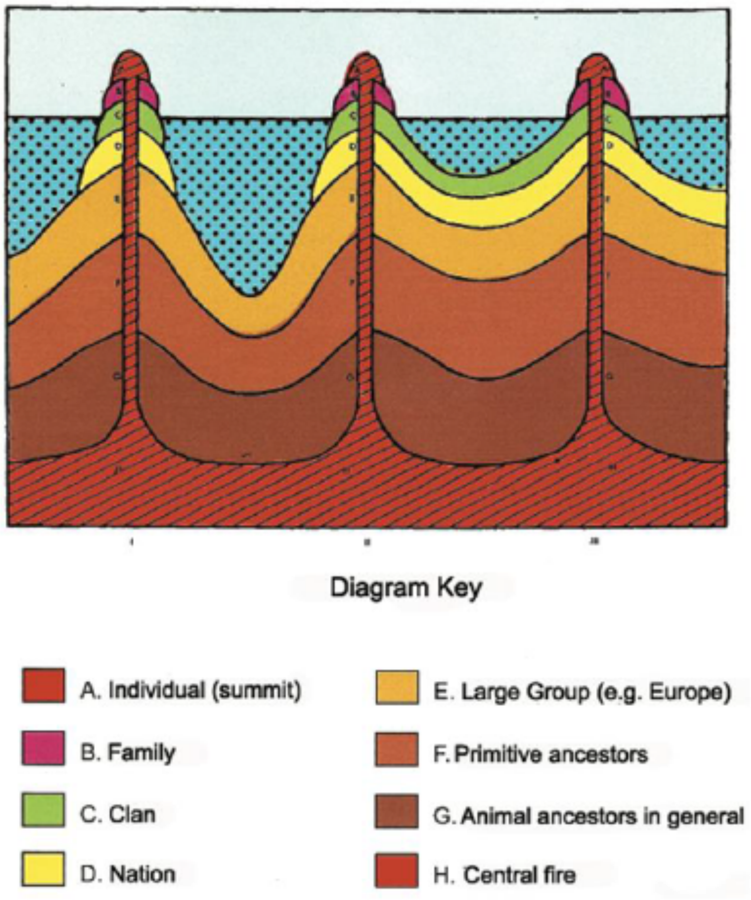

Figure 1: Jung's volcanoes diagram.

In Jung's sketch of the psyche, ego, or consciousness of an individual, appears as a peak. The personal unconscious underlies it. Next, the Collective Unconscious (Jung, 1961; 1991), starting from the family's unconscious until the animal ancestors (or even until the beginning of life), underlies the personal unconscious. At the bottom of all things, or at the beginning of all things, there is the central fire (or quantum vacuum).

An original property of Jung's vision of the human psyche is that the central fire is directly connected to the individual's unconscious. The central fire permeates every layers of the Collective Unconscious and comes right up to the personal unconscious if we let it do it. The vacuum or the central fire contains all the seeds of all archetypes, this means that we can have direct access to archetypes. This direct access of an individual's unconscious to the vacuum, or the central fire, can explain some kind of dreams, especially archetypal dreams (such as Pauli's dreams). It may also explain some a-causal events such as synchronicity effects. We can assert that an individual unconscious "knows everything", in the sense that any individual unconscious has access to any information in the Universe. This does not mean that this information will necessarily reach the consciousness of each individual.

In 2003, Baaquie and Martin (2005) rediscovered this Jung's geological survey model of the psyche in the framework of quantum field theory. In particle physics we postulate the existence of quantum fields associated to each elementary particle. Those fields are operators defined in all space-time and acting on states, vectors of a Hilbert space, corresponding to the wave function of a set of particles. A quantum field associated to a particle is the sum of a creation operator of the particle together with an annihilation operator of the particle. Thus the creation operator acting on the quantum vacuum creates a state of the particle. The quantum vacuum contains all the quantum fields in a virtual state, i.e., none of the normal modes of the fields are excited in the vacuum, although they are virtually present.

Baaquie and Martin postulated that, like matter, mental states and human consciousness (and unconscious) would be of quantum nature. Thus they assume that the human psyche would be a particular excitation of an underlying universal mental (unconscious and consciousness) quantum field. The human psyche is postulated to have a representation similar to a quantum system, with virtual and physical states corresponding to the potentiality and actuality of the human mind. To describe the human psyche they suppose the existence of two kinds of quantum fields, namely one that refers to the specific individuality of the person, and which should be more or less localized with the person's specific existence and excludes at least partially other person's individual quantum field.

The other quantum field represents the universality of the human psyche, which can overlap and include other's consciousness. In their model Baaquie and Martin represent the individualized state of the human psyche by a fermion field $\psi\ (t,x)$ and the universal character of human consciousness by a boson field $\varphi\ (t,x)$ where *t, x* are time and space coordinates.

As physicists try to unify all quantum fields of matter in a unique quantum field, we can try to unify the consciousness fields $\psi\ (t,x)$ and $\varphi\ (t,x)$ described above with this (possible) unique quantum field of matter and obtain a unique quantum field describing both matter and mind. In this way we will approach the holistic reality, the *Unus Mundus*, the "one world" of the 16th century alchemist Gerhard Dorn (Dorn, 1602). Jung and Pauli advocated this *Unus Mundus* as the underlying reality in which mind and matter are undivided. We can suppose that the "consciousness field" was separated from the unique quantum field of matter at the beginning of the Universe, but both fields remained quantumly entangled.

This possibly happened when space-time was generated, i.e., at time $t= 10^{-43}$ second, which is Planck's time, after the Big Bang. Of course, at that time, the individual centred consciousness field was zero together with all the boson field $\varphi\ (t,x)$ associated with each layers of Jung's volcanoes diagram (from B to G; see Figure 1). But all the seeds of those quantum fields, together with the seeds of archetypes, were present in the vacuum or the central fire (Figure 1). In their paper of 2005 Baaquie and Martin (Baaquie and Martin 2005) propose a simplified model for the ground state of the human species. This ground state $G(T)$ represents the total sum (or rather the total product) of all the excitations on the vacuum state of the "consciousness field" that has been affected by human subjectivity over the entire period of human evolution. It is on this ground state that the present day psyche of human beings is standing, and the entire theoretical structure that we are born into is encoded in the ground state $G(T) = G$, where *T* stands for our contemporary time. Let us notice that this ground state $G(T) = G$ is an unconscious state, and that it has a structure close to what C. G. Jung called the Collective Unconscious. Then, starting from this ground state of the human species, and taking account of the contributions of the mother, the father, and all the siblings, the grandparents and uncles and aunts and first cousins and so on, in other words the primary group around the individual, Baaquie and Martin built a family effective ground states, implicating that order, mind and matter are unseparated (non-separable) entities and considering that the existence of a universal quantum field of "consciousness" could represent not only the Collective Unconscious, but also a universal consciousness or awareness. The metaphor would be the one of a universal ocean of consciousness in which an individual consciousness would be like a wave that comes out of the ocean and eventually returns to the ocean: nullo ad nullum.

However there are some problems with this hypothesis. First, how did space-time emerge from this *Unus Mundus*, which could be the quantum vacuum or the central fire of Jung? Second, for Jung, the psyche is timeless and spaceless, i.e., it has its roots beyond space-time. But we already know that even in relativistic quantum field of matter there are some problems with space-time, especially in quantum gravity. Moreover we know that quantum entanglement transcends our notions of space and time (Caponigro, 2009). Atmanspacher et collaborators in their work on weak quantum theory introduced the concepts of complementarity as a formally generalized, weak version of quantum theory, more general than ordinary quantum theory of physical systems. Even if the world of physics and psyche are apparently different, the introduction of a different approach for psyche could reintroduce a dualism that is not completely coherent with the *Unus Mundus* approach (Altmanspacher, Roemer and Walach, 2001).

Time is a timeless trick in which the intuitive, sensitive, cognitive (et cetera) are like facets of a cut gem that constitute its beauty. In a drawing, Klee described time as a *visual sensation*. This is reported in a study of Demongeot (Demongeot 2009) where we can observe the difference between the mental image of time in a normal subject and in hemiplegic ones (see Figure 2).

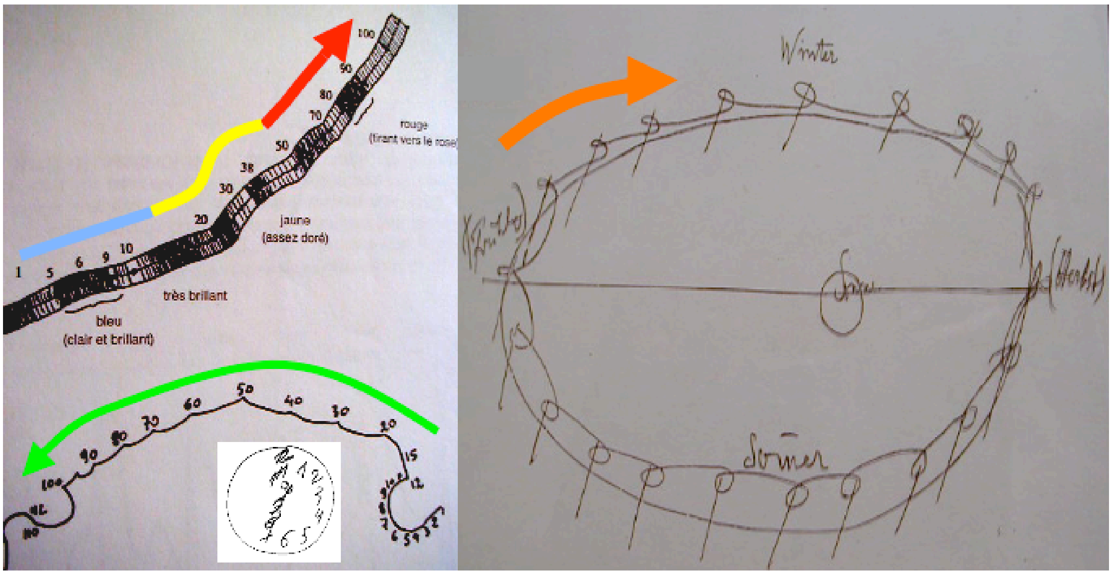

Figure 2: time of the patient and the subjective representation of Käiros in good health and illness: mental image of normal chronological time (top left), time for a left and right hemiplegic (bottom left and medallion) and representation of the year according to P.Klee. (Demongeot 2009)

The problem of measurement in quantum physics is still a topical subject. In 1932, von Neumann (von Neumann, 1932a) 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 (Zurek, 1991, Zurek, 1998) 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 (Everett 1957, Wheeler 1957) and the quantum information theory of N. Cerf and C. Adami (Cerf & Adami, 1997, 1998) 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 (von Neumann 1932b and see also Halmos 1958) and Wigner (Wigner & Margenau 1967). Particularly, for von Neumann, setting 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 (Stapp 1993) sets the interface between the observed system and the observing system in the observer's brain. This allows him to explain some behaviours of consciousness within quantum theory. In 1967 Ricciardi and Umezawa (Ricciardi & Umezawa, 1967) suggested the use of the formalism of quantum field theory for the states of the brain, especially for memory states. In 2005 Baaquie and Martin (Baaquie & Martin 2005) also proposed a quantum field theory of consciousness. But this theory applies firstly to mental states before it applies to brain states.

The observation of correlations at a distance between several minds, just as the observation of synchronicity phenomena, leads us to postulate a non-localization of mental unconscious. Concerning this subject we shall read with interest the article of Atmanspacher in the Stanford Encyclopaedia of Philosophy (Atmanspacher, 2006) reviewing the situation on present quantum theories of consciousness.

As far as matter and psyche are concerned, prior to any measurement, quantum correlations due to quantum entanglement are relevant to what David Bohm calls the *implicate* (or *enfolded*) order, which is beyond space-time, unlike the *explicate* (or *unfolded*) order which describes the phenomena that are manifest to our senses (consciousness) and to our instruments (Bohm, 1980). The implicate (or enfolded) order is in an undivided (or *unfragmented*) form, while the explicate (or unfolded) is in a *fragmented* form. In the implicate order, mind and matter are unseparated (non-separable) entities. For a lot (but not all, see for example Eccles, 1994; Beck & Eccles, 1998) of neuroscientists, consciousness, pre and un-consciousness are simply processes measuring dynamical complexity in the neural systems underlying consciousness: e.g., neural complexity, information integration and causal density (see Seth et al., 2006), or the consequences of complexity in large interacting systems, i.e., the emergent properties of simplexity in the dynamics of the mind (Berthoz 2009, Demongeot et al. 2014a).

At the beginning of his article, "*Synchronicity, Mind and Matter*" (Duch, 2003), W. Duch quotes, as a motto, a sentence of Pauli: "It would be most satisfactory if physics and psyche could be seen as complementary aspects of the same reality" (Jung & Pauli, 1952). Complementarity is the fact that two properties of a system are contradictory but nevertheless coexist in the system and appear depending on the kind of experiment we perform on the system. The best example is the wave aspect and the corpuscular aspect of matter.

Galli Carminati and Martin (Martin & Galli Carminati 2007; Martin, 2009) studied the individual unconscious and consciousness as quantum systems, i.e., as vectors of a Hilbert space. In such a frame they studied the phenomenon of consciousness and especially the awareness of unconscious components. Indicating the state of the unconscious as U and the state of consciousness as C , they introduced another state of the unconscious I which is the insight or pre-consciousness[8]. By building a model of quantum entanglement between those three states they apply it to the awareness of unconscious components.

In 2009, they proposed the theory of quantum information as a model for the psyche (Martin, Carminati & Galli Carminati, 2009; 2010). They considered the individual human unconscious, pre-consciousness and consciousness as sets of quantum bits (qubits). They described the communication between these various qubit sets. In doing this they were inspired by the theory of nuclear magnetic resonance (NMR). In this way they built a model where the state of a mental qubit is changed with the help of pulses of a mental field. Starting with an elementary interaction between two qubits they built two qubit quantum logic gates that allow information to be transferred from one qubit to the other. In this manner they describe a quantum process that allows consciousness to "read" the unconscious and vice versa. The elementary interaction, e.g., between a pre-consciousness qubit and a consciousness one, allows them to predict the time evolution of the combined pre-consciousness - consciousness system in which pre-consciousness and consciousness are quantum entangled. This time evolution shows how, for example, the unconscious can influence consciousness. In a process like mourning the influence of the unconscious on consciousness, as the influence of consciousness on the unconscious, are in agreement with what is observed in psychotherapy when the emotive and the cognitive investments are often contradictory.

It was also interesting, above all relation with therapeutic situations such as psychoanalysis, to build an explicit model of the interaction between the unconscious of two different subjects (e.g., Alice and Bob) which, as suggested in papers (Galli Carminati & Martin 2008 and Martin, Carminati & Galli Carminati 2009, 2010), leads to the quantum entanglement of the two unconscious. This quantum entanglement of the two unconscious could explain the long distance correlations that appears between several individual minds. But it could also explain how an unconscious can interact with another unconscious, for example during a session of psychoanalysis. We also tried to construct a quantum model of the correlations at a distance appearing between several minds, as in a group of people (group correlations).

In his book Tom Keve (Keve, 2000) describes the visit of Sigmund Freud, Carl Gustav Jung and Sandor Ferenczi in 1909 at the Clark University in New York. We are at the beginning of Quantum Mechanics and at the beginning of the psychoanalysis. The interaction of these three persons, and other outstanding persons could be proposed as a group dynamics creating a new vision of world as psychoanalysis was. In Keve's book, there are several examples in which physicists and psychoanalysts seem to think together about possible explications of the physic and psychic world, in a non dualistic perspective. Pierre Sabourin provides an original comment on the relationship between Freud et Ferenczi (Sabourin, 1992), when he says: "to speak about heritage is to evoke a very ambiguous notions ... disillusion with filiation for some, phantasm for others ... it is matter of one of the several child-illness of psychoanalysis". We can think that this filiation is another aspect, not completely formalised, of group dynamics with, as exposed by Sabourin, its known consequences such as ruptures, conflicts, exclusions between different generations of analysts.

The hypothesis of a universal "soul" which encompasses all living beings is a very ancient one. We can cite as example the Veda writings[1] that represent the most ancient texts of Sanskrit literature. More recently, in the 19th century R.V. Emerson, founder of the transcendentalist movement, introduced the concept of over-soul (Emerson 1836, Emerson 1837). Schopenhauer in his best known philosophical work, "The world as will and representation" (Schopenhauer 1818) introduced the concept of a world driven by a continuously unsatisfied will permeating all acts of the living. Many philosophers have treated the concept of universal consciousness. Nietzsche (Nietzsche 1885) takes the concept of over-soul as the crucible of the super-man. We could say that Adler (Adler 1964) rethinks the Nietzschean concept of will of power in his personality theory about the will to power and by Freud in the psychoanalysis as the will to pleasure. A detailed discussion of this subject would however go beyond the scope of this work.

The concept of universal consciousness (and unconscious) in a physical-mathematical language can be described in the terms of an immaterial quantum field. There are various views about consciousness. One, which is assumed by most neuroscientists, is the *materialist* view (Seth et al. 2006). This view postulates that consciousness is an emergent property of the brain reducible to its neural complexity.

In his book *L'Homme Quantique (The Quantum Man, Simon 2014),* Alain Simon underlines the exchanges between the real and the symbolic in which the principle of uncertainty is present in our field of consciousness as well as in quantum mechanics.

In his work on Predictive Metaphysics, Dolan (Dolan 2012) underlines that "ontology and the study of consciousness, long thought by physicists to be

[1] '"That particle which is the Soul of all this is Truth; it is the Universal Soul. O Swetaketu, thou art that." "Will it please, my Lord, to explain it again unto me?" "Be it so, my child" replied he', The Chándogya Upanishad of the Sama Veda With extracts from the Commentary of Sánkara Ácharya, translated from the original Sanskrita by Rájendralála Mitra, Printed by C.B. Lewis, Baptist Mission Press, Calcutta, 1862.

unapproachable metaphysical subjects, can indeed be studied as physics, leading to testable predictions about the physical universe" and present a model of the physical universe that is based on a nonphysical independent reality: consciousness identified with existence, and the relation between existence and the self is explored using concepts of quantum mechanics. This hypothesis is interesting and useful with the caveat that consciousness, even if it can be "clear and distinct" emerges from neural matter and unconscious and cannot exist separated from them.

In the paper "Mathematical Foundations of Consciousness" (Miranker & Zuckerman 2009), the authors describe the functioning of the brain as based on so-called consciousness logical operators belonging to an axiomatic system that characterizes experience and consciousness as primitives. Among these operators, the Russell operator R plays a central role as a distinguisher between the so-called normal and abnormal pure sets, which takes into account the self-referential character of consciousness (consciousness being itself a result of a consciousness operator being applied to experience), based on the 3 following definitions: Definition 1: A set is a pure set if its elements are sets, the elements of its elements are sets and so on. Definition 2: A pure set x is normal if $x \notin x$. It is abnormal if $x \in x$. Definition 3: Let A be a pure set. Then, $RA = \{x \in A \mid x \notin x\}$. The emergence of consciousness from a neural structure is probably a necessary step in the appearance of consciousness.

We would like to underline that the complexity of a system is a condition that is probably necessary but not necessarily sufficient for the appearance of emergent behaviours. Some authors (Mensky 2000, Mensky 2005a, Mensky 2005b, Mensky 2007a, Mensky 2007b), introduced the Extended Everett's Concept (EEC) as an extension of Everett's studies (Everett 1957) and assume the concept of post-correction proposing that "evolution of living matter is [...] determined not only by causes but also by the goals, first of all by the goals of survival and improvement of quality of life". Supposing that the concept of post-correction is similar to a concept of project, we can consider the need of an *immaterial universal quantum field* as the warp on which individual consciousness develops itself as the weft, or as some authors consider, the consciousness could be a particular excitation of this underlying universal mental quantum field (Baaquie & Martin 2005; Eccles 1994; Beck & Eccles 1998). In this view, consciousness, through the neural complexity of brain, is correlated to it, probably via quantum entanglement. The states of unconsciousness are defined by some authors as quantum states and the states of consciousness as attractor of the corresponding dynamical system, a classical system (Khrennikov 2002, Martin, Carminati & Galli Carminati 2009, Orlov 1982). However, there is a third view, which takes its roots in the fact that quantum entanglement is "controlled" from *outside space-time*[2]. This view assumes that consciousness is an entity which acts from *outside space-time*: "It is well known that quantum physics supports *experimental metaphysics*: Nothing speaks against considering mind and consciousness quantum-mechanical states of the brain. Actually, *self-organization* is another way of saying that random neural dynamics is controlled from *outside space-time* by unobservable principles like free will[3] and consciousness: *Self-organization* of the brain is synonymous to *organization by the Self*". (Suarez, 2008).

Present theories of quantum measurement presuppose quantum entanglement of the observed quantum system with a measuring apparatus also considered as a quantum system. In previous studies (Martin & Galli Carminati, 2007; Galli Carminati & Martin, 2008), we have assumed that the quantum entanglement can be achieved through several *ancillae*. Eventually the generated system quantum entangles itself with the environment and with the observer. The *ancillae,* constituted, in this case, by the *insight* or by quantum states of preconsciousness, the quantum entanglement of this system with the environment, or with other parts of the unconscious, leads consciousness to have access not to a pure quantum state, but to a (statistical) mix.

Indeed, a great number of information, to which consciousness has no access, gets lost in the environment or in the unconscious. However that may be, among "classically" possible quantum states that can reach consciousness, i.e.,

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[2] "In the quantum world, correlations have their own causes, non-reducible to those of events, and they are insensitive to space and time". (Gisin et al., 2001)

[3] According to Anton Zeilinger (Zeilinger, 2006) there exist **two freedoms**: "first the freedom of the experimenter in choosing the measuring equipment - that depends on my freedom of will; and then the freedom of nature in giving me the answer it pleases. The one freedom conditions the other, so to speak. This is a very fine property. It's too bad the philosophers don't spend more time thinking about it".

pointer states, only one reaches the consciousness of one human being at a given time. Presently the uniqueness of this state remains a mystery. Does consciousness make a choice? Is it a spontaneous symmetry breakdown that leads to this uniqueness of a conscious state? As postulated by Michael B. Mensky, awakened consciousness, by definition, is the separation between the various quantum states that are "classically" possible, the separation between the various "pointer states" (Mensky 2005a, 2007a, 2007b, 2007c). Let us emphasize that in the works of Everett (Everett 1957), Zurek (Zurek 2007) and Mensky (Mensky op. cit.), the observer's consciousness is considered as a quantum state and not as a classical one. In these works classicality, and consequently the collapse of the wave function, are considered as illusions. The uniqueness could also be due to the physiological nature of the evocation process, which could be related to a synchronization of multiple networks, dynamic memory support, prohibiting another concomitant synchronization related to cellular energy and transient exhaustion of ionic pools charge of the neuronal membrane potential (Abeles 1991; Tonnelier et al. 1999; Ben Amor, Glade & Demongeot 2010).

According to Jung "the amplification is the extension and the deepening of a dream-like image by means of associations centred on the dream theme and parallels based upon social studies and history of symbols (mythology, mystique, folklore, religion, ethnology, art, etc.). Thanks to this the dream becomes accessible to interpretation" (Jung, 1973).

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

In quantum physics, during a measurement, there is an amplification of a microscopic process that results in a macroscopic physical phenomenon. This is so for example for the track of a particle going through a bubble chamber. It is thanks to amplification that we can interpret a microscopic quantum process. It is only after an irreversible act of amplification that a microscopic quantum process can be called a physical phenomenon. In fact the trajectory of a particle which goes through a bubble chamber, is realised by a sequence of quantum entanglements which, when their number is big enough (of the order of Avogadro's number: 10^{23}), appears as a macroscopic phenomenon. It is the quantum entanglement with the environment, a part of the amplification process, which leads to decoherence (or desynchronization) and as a result to "the reduction (or collapse) of the wave function". Let us notice that the amplification process does not necessarily imply the collapse of the wave function. This process also occurs in the framework of Everett's "Relative State" or "many-worlds" theory (Everett, 1957; Zurek, 2007) in which the "other part of the measurement" comes back in a parallel universe.

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

This argues in favour of the fact that the unconscious could be a quantum system.

In the present study, the hypothesis is to apply the observation of Jung about the dream to group situation in which the group dynamics could amplify the individual, inaccessible unconscious.

In quantum optics, using (approximate) quantum cloning, it is possible to amplify a quantum state in an optimal way. By analogy, we speculate that it is an approximate process of quantum cloning which amplifies the information contained in the unconscious. The *nocloning theorem*, due to Wootters and Zurek (Wootters & Zurek, 1982) prevents to duplicate perfectly an arbitrary quantum state. However it is possible to make an approximate quantum cloning which could be optimal.

The *quantum no-cloning theorem* could explain why, for example, the information contained in a dream is transformed during the process of amplification before reaching consciousness. This is quite important since "dreams are the royal road which leads to the unconscious" (Freud, 1920). If we consider the group phenomena as amplification of unconscious we have to consider, too, the impossible perfect duplication of the individual unconscious trough the group amplification.

Group based theories

Group phenomena have been used since antiquity for different purposes in therapeutic, social, economic and political domains (Anzieu & Martin 1997). Studies dealing with the group psychology that we can define as modern go back to the XIX century, even before the appearance of psychoanalytical methods (le Bon 1895). W.R. Bion (Bion 1961) and S.H. Foulkes (Foulkes 1964), two psychoanalysts disciples of M. Klein for the former, and of S. Freud for the latter, were the first to elaborate a psychoanalytic framework for the interpretation of group phenomena and their evolution (group dynamics).

Although we realise that "There are many reeditions of Bion's formulation about groups but none can replicate the richness of the original [...]." (Lawrence, Bain & Gould 1996), for the purposes of this work we will venture to give yet another account of his working hypotheses. Bion's model is that, when any set of people gathers for an activity or a task, there is an immediate creation of a group and that the ensuing group dynamics consists actually in two kinds of groups, or rather in two configurations of mental activity, which are simultaneously present. At the surface there is the more or less sophisticated work group, referred to as the W group, which is directed at the accomplishment of the purpose for which the group has originally been formed (the organisation of a party, the management of a multinational company, planning of a war, deciding a strike and so on…). However underlying the W group is the other group, governed by universal principles that Bion calls “basic assumptions”. This is what Bion calls the BA group. The W group is, in Bion’s words, “constantly perturbed by influences that come from other group mental phenomena”. (Bion 1961, p.129).

To explain this, Bion (Bion 1961) postulates that a group situation leads to the formation of a group psyche generated by the interaction of the group members and that behaves according to the “basic assumptions”. The group requires to be protected by a leader, on whom it feels to depend for its survival. The refusal or inability of the leader to protect the group leads to conflicts, and ultimately to a “fight-flight” attitude where the group either gathers to fight against the dangers outside or it tries to run from them. This stressful situation may lead to the formation of sub-groups or couples. Coupling or sub-groups, despite they represent a danger for the group integrity, promote the messianic expectation, i.e. the hope for a new, better, perfect and powerful leader. This behavioural pattern is repeated during the life of the group.

Therefore, according to Bion the evolution of the group is governed both by these universal “basic assumptions” and by the conflicts that are rooted in the contingent reality of each specific group (Bion 1961; Vergopoulo 1983; Foulkes 1964).

Since the discovery of Quantum Mechanics, a tantalising similarity has been remarked between the quantum description of the world and the functioning of our psyche. Several authors have elaborated on this, developing physico-mathematical models of our psyche (Baaquie & Martin 2005; Beck & Eccles 1992; Hameroff & Penrose 1996; Penrose 1989; Penrose 1994; Pitkanen 1998; Jung & Pauli 1952; Vitiello 2003; Conte et al. 2003; Pauli & Jung 2001; Zurek 1981). Some researchers (Baaquie & Martin 2005) have even postulated the existence of a universal psychic field of quantum nature. In a recent series of works, Galli Carminati and colleagues (Galli Carminati & Carminati 2006; Galli Carminati & Martin 2008; Martin, Carminati & Galli Carminati 2010; Martin, Carminati & Galli Carminati 2013) extended this description to the group unconscious, proposing that this too could be described with a model similar to those used in quantum physics. This analogy relies on the observation that, as any individual, the group reacts to losses with a mourning process. In other words, mediated by the "basic assumptions", group dynamics is similar to individual dynamics, in particular if one considers the loss of the ideal group leader.

The correlations that appear between the groups and members of a group during group analysis sessions seem comparable in nature to the remote correlations that appear between two related quantum systems (Einstein, Podolsky & Rosen 1935; Schrödinger & Born 1935; Schrödinger & Dirac 1936; Bell 1964; Bell 1966; Aspect, Grangier & Roger 1982). This phenomenon is called quantum entanglement: two entangled quantum particles can be separated by thousands of kilometres and nevertheless form a single (whole) non-separable system, as long as no measurements are performed on one of the two particles. It is by analogy with this well-known phenomenon of quantum physics that we decided to investigate the similar entanglements between two individuals, and tried to generalize these correlations to individuals belonging to a group.

The correlations we tried to observe are between unconscious. In the model of G. Carminati and F. Martin (Galli Carminati & Martin 2008; Martin, Carminati & Galli Carminati 2010; Martin, Carminati & Galli Carminati 2013), the mechanism that brings parts of the unconscious of two individuals to form a single entangled (non-separable) quantum system is the so called Bose-Einstein condensation (Pitaevskij & Stringari 2004), in which distinct particles can form a single quantum system, where they lose their individuality in favour of a single collective behaviour.

Such a "condensation" could well appear between some parts of individual unconscious and as a result, causes the formation of the group unconscious. Bose-Einstein condensation and quantum entanglement, if applied to psyche, may explain the remote correlations that exist between group members and consequently group phenomena (Marshall, 1989). According to this model, a group situation would facilitate group members to orient their individual unconscious in a common direction (Galli Carminati & Martin 2008; Grinberg-Zylberbaum et al. 1994; Martin & Galli Carminati 2007), hence promoting the group quantum state to emerge.

The goal of the current study is to provide experimental evidence in support of the model proposed above (Galli Carminati & Martin 2008; Martin, Carminati & Galli Carminati 2010). Consequently, our first objective is to verify if the behaviour of individuals belonging to a group is influenced by the presence and the activity of the group.

Materials and methods

Because unconscious cannot be so far investigated using conventional measurements or direct observations (Cerf & Adami 1997; Cerf & Adami 1998; Atmanspacher 2006), we propose an indirect measure of the group orientation based on a questionnaire. The objective is to investigate whether group analysis situations can lead the unconscious of the participants to adopt a common orientation in the choice of pictures. In other words, we would like to test whether the presence of an orientation of the group unconscious has a measurable effect on the real world.

We could say that, at the philosophical level, this work aims at detecting an effect of mind on reality, and therefore to verify if, in spite of the dualism between them, there can be an influence of the former on the latter. This is certainly not a new problem in philosophy and approaches to describe mind and matter as manifestations of one underlying reality in which they are unseparated, go back to the holistic reality, *unus mundus*, the "one world" of the 16th century alchemist Gerhard Dorn (Atmanspacher & Fach 2013; Dorn 1602).

Doing this using a group setting leverages Bion's idea of "valency", by which Bion describes the immediacy of the onset of the basic assumptions, more analogous to tropisms than to purposive behavior. This tropism, and its effects on reality, is enhanced in the group setting by an amplification process whereby groups "amplify emotional reactions, resulting in a combustible process of emotional contagion" (Bion 1961, p. 54).

To try minimising biases that can be introduced by common cultural background such as news, politics, arts, and so forth, we designed an "absurdum" questionnaire so that answers would rely as little as possible on logical thinking and acquired knowledge, using pictures as unrelated as possible with each other.

Table 1: Demographic, socio-economical and group composition of the participant sample expressed in numbers and percentage for Staff, Trainees and for all participants. Quantities reported are: the number of participants in each age class, the median age with the interquartile range (Q1 and Q3: 25th and 75th percentiles

respectively), the sex distribution expressed as numbers and percentages of female subjects, the number of participants in each socio-economic subcategory, the number of participants in each enrolment year and in each of the sub-groups of the training. Groups from A to D were the four "small groups". Group E were the conductors of the "large group" and group F were the organising staff.

	Subcategories	Staff (n = 14)		Trainees (n = 31)		All (n = 45)	
Age (years)	20-30	1	7.1%	21	67.7%	22	48.9%
	31-40	5	35.7%	8	25.8%	13	28.9%
	41-50	4	28.6%	2	6.5%	6	13.3%
	>50	4	28.6%	0		4	8.9%
	Median (Q1-Q3)	42.5	(33-50.5)	29	(27-32.5)	31	(28-38)
Sex	Female	7	50.0%	24	77.4%	31	68.9%
Marital status	Married	4	28.6%	29	93.5%	33	73.3%
	Divorced/widowed	3	21.4%	0		3	6.7%
	Single	7	50.0%	2	6.5%	9	20.0%
Professional status	Psychologist	13	92.9%	17	54.8%	30	66.7%
	Psychiatrist	1	7.1%	4	12.9%	5	11.1%
	Social worker	0		4	12.9%	4	8.9%
	Nurse	0		3	9.7%	3	6.7%
	MD	0		2	6.5%	2	4.4%
	Public servant	0		1	3.2%	1	2.2%
Enrolment year	1	0		10	32.2%	10	22.2%
	2	0		14	45.2%	14	31.1%
	3	0		7	22.6%	7	15.6%
	4	8	57.1%	0		8	1.8%
	5	6	42.9%	0		6	13.3%
Sub-groups	A	2	14.3%	8	25.8%	10	22.2%
	B	2	14.3%	9	29.0%	11	24.4%
	C	2	14.3%	6	19.4%	8	17.8%
	D	2	14.3%	8	25.8%	10	22.2%
	E	2	14.3%	0		2	4.4%
	F	4	28.6%	0		4	8.9%

Participants

For this study we used forty-five adult participants (31 women and 14 men) involved in the group analysis training given by the Basque Foundation for the Investigation of Mental Health (OMIE Foundation**, Osasun Mentalaren Ikerketarako Ezarkundea, Bilbao).** This group was composed by 31 people attending the training, 10 members of the training staff and 4 members of the organizing staff. Two participants were excluded from the study because they did not complete the training.

The training consisted of 10 sessions, and at the beginning of the first session and the end of each session the participants were asked to fill the questionnaire. Demographic data and socio-economic characteristics of participants are presented in Table 1.

The Ethics Committee of Geneva University Hospitals approved the experimental protocol, in adherence to the Helsinki Declaration for research with human subjects, and approval was also granted by the OMIE Foundation. All participants gave written informed consent after receiving oral and written information about the experiment. All participant data were coded so that they were completely anonymous, including for the researchers analysing the data.

Questionnaire

To evaluate to what extent participants could act according to a common group unconscious, we used an “absurdum questionnaire” of 50 pairs of pictures. For each of the fifty pairs, participants were asked to choose one of the two pictures. A typical page with hypothetical answers can be seen in Figure 3.

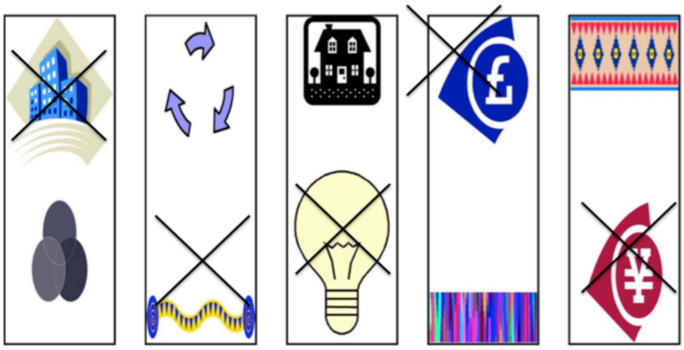

Figure 3: A page from the questionnaire with "fake" answers.

The questionnaire had to be filled within 3 minutes and no correction was allowed. The pictures were colour or black and white drawings and photographs selected from the Web, so that the choice could have minimal correlation with a common cultural background, logical thinking or common knowledge. This method aims at avoiding multiplier effects that a classical word questionnaire

(Zanello et al. 2004) can introduce, because the latter requires conscious reflection peculiar to one's own unconscious.

The one hundred images chosen for the questionnaire were randomized to form 50 pairs presented on 10 A4 format landscape oriented sheets with 5 pairs per page. Each pair occupied about 4 cm (horizontal) by 11.5 cm (vertical). For the 11 testing sessions, the pairs were randomly ordered on the 10 sheets to avoid mnemonic or learning effects.

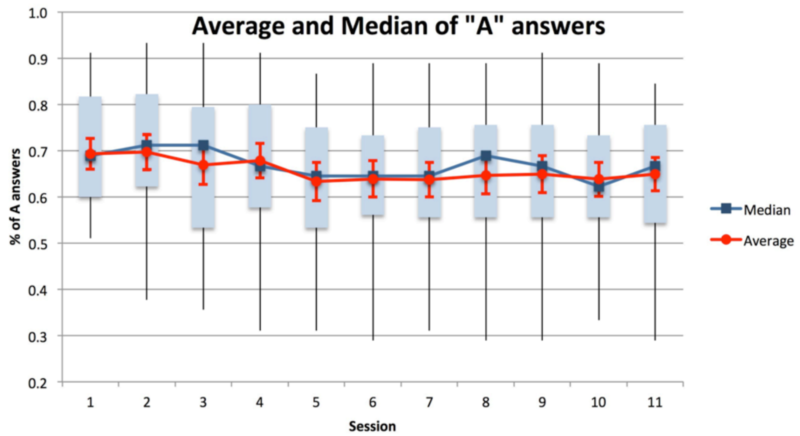

Figure 4: Evolution of the average proportion of the picture initially most selected (picture A). The proportions of participants (± 95% confidence interval shown on average points, red line) who have chosen the initially preferred picture (A) are averaged over the 50 questions for each of the 11 sessions (abscissa). The figure also shows the median and interquartile evolution.

Procedure

OMIE teaching is a 5-year program to train group therapists in group analysis. Trainees follow courses on group analysis theory, methods and applications, and they also participate to analytical groups to gain practical experience with group dynamics. Practical training is based on 10 modules per year, each one lasting one day and half: Friday from 9h00 to 21h00 and Saturday from 9h00 to 13h50. Participants of different years are divided in groups of 8 to 10 people including a conductor (group leader) and an observer (who does not speak) who are members of the staff. In the case under study there were four such groups (A to D, see Table 1). These groups met 3 times for 1h30 in the course of a module. At the end of each day, all four groups meet for 1h30 in a "large group" that includes also the "large group" leaders (who form group E in our table). Finally, group F is composed by the members of the directing committee, which includes the other staff and meets during the course of the module.

During the first test session, participants filled the socio-demographic form indexed with a code to render data anonymous. The same code was used to mark the "absurdum questionnaires". The overall experiment includes 11 tests, in which participants had to select one picture for each of the 50 pairs of the questionnaire. The first test was taken the first day before the training actually started. The remaining 10 tests were passed at the end of the second day (Saturday) of each module. For administrative reason, the staff did not pass the second test at the end of the first module.

Data Analysis

For the purpose of the data analysis, the most frequently chosen picture in each pair during the first test will be indicated as picture A (A_i, i=1,50), while the other picture will be designed as B (B_i, i=1,50). Frequency tables were computed for each pair of pictures and each one of the 11 sessions. Because the present work is devoted to evaluate the influence of the group unconscious on the measured effects, in this case the answers to the questionnaire, all statistics were carried out on the proportion of the number of participants choosing picture A or B for each of the 50 questions and 11 tests, irrespectively of how the individual participant's choice evolved.

a) First of all, potential biases in selecting A pictures for each of the 50 questions were tested. (1) A one-sample binomial test was used to test the hypothesis that selecting pictures A and B had equal probabilities (i.e., null hypothesis p(A) = p(B) = 0.5). (2) A chi-squared test was used to test the hypothesis that the probability to select picture A remained constant over time (i.e., null hypothesis p(A at follow-up tests) = p(A at first test)). (see Equation 1).

(i) $p(A_i) = \frac{A_i}{n}$ = nb of A choices for session i / n

(ii) $P(A) = \sum_{i=1}^{11} p(A_i)/11$

(iii) $\sigma_i^2 = n\, p(A_i)\,(1 - p(A_i))$

(iv) $$\chi^2 = \sum_{i=1}^{11} \frac{(\mu_j - x_{ij})^2}{nP(A)(1-P(A))}$$

Equation 1: $p(A_i)$: observed A frequency for a given question and for the session i; P(A): average (over all sessions) probability to get A; x_{ij}: number of A choices for a given session i during test j; n: total number of participants; σ_i: standard deviation of the binomial distribution; χ^2: chi-square value; μ_j: average (over all sessions) number of A choices for test j. Results will be assumed to be significant for $p<0.025$ for the one-tailed test, which corresponds to a two-tailed test alpha significance threshold of 0.05.

b) To evaluate whether the selection of the preferred pictures evolved randomly or as an effect of group sessions, two analyses were carried out. (1) A Friedman test was performed to compare the proportion of participants who choose picture A (initially preferred) for each of the 50 questions at each session. Planned post-hoc statistics between consecutive sessions were carried out with Wilcoxon signed rank tests with Bonferroni's adjustment ($n_s = 10$, i.e. the number of transition between sessions). (2) The absolute amount of changes is the result of the difference in the changes of choice from A to B and from B to A. These two quantities are, in principle, not directly related, apart from the obvious boundary conditions that there cannot be more swaps from A to B than A's in the first place, and the same holds for B's. This measure gives an idea of the group activity, independently from the net result of this activity. Using a Friedman test, we analysed the number of changes from picture A to picture B, and conversely from picture B to picture A. For each time interval, Wilcoxon signed rank tests with Bonferroni's adjustment ($n_s = 10$) were run on the numbers of changes from A to B and from B to A occurring for the 50 questions across the 11 sessions, to estimate whether there was an evolution in the frequency of swaps between A and B choices.

c) Random or group dynamics driven swaps of pictures across time were investigated using Friedman tests on the total number of changes from picture A to picture B and from picture B to A, occurring between consecutive sessions (10 intervals) for each of the 50 pairs of questions, as well as on each type of swaps (A to B and B to A) independently. Planned post-hoc statistics between consecutive time intervals were conducted with Wilcoxon signed rank tests with Bonferroni's adjustment ($n_i = 9$ tests between consecutive time intervals).

d) To assess whether changes occurred just by chance or as a consequence of group member common orientation, we compared the mean similarity for each studied group across sessions of test. To do so, we computed a measure of pairwise similarities based on the proportion of concordant (pictures) for each pair of participants within a studied group (Zubin 1938). Subsequently, the mean similarity for each participant with the other participants within the same studied group was calculated for each test's session. To compare mean similarities across test sessions, we used a permutation's test based on the raw data matrix that accounts for the non-independence of observations (i.e., 45 participant x 50 pairs) (Hepworth, Gordon & Mccullough 2007). For each permutation of the rows of the raw data matrix, a similarity matrix was computed. The mean similarities were calculated for each session and the corresponding Kruskall-Wallis statistic was computed. For each comparison, 100'000 permutations were performed and the p-value was determined based on the proportion of values lower than the observed statistic value. Two-sided p-values less than 0.05 were considered as statistically significant.

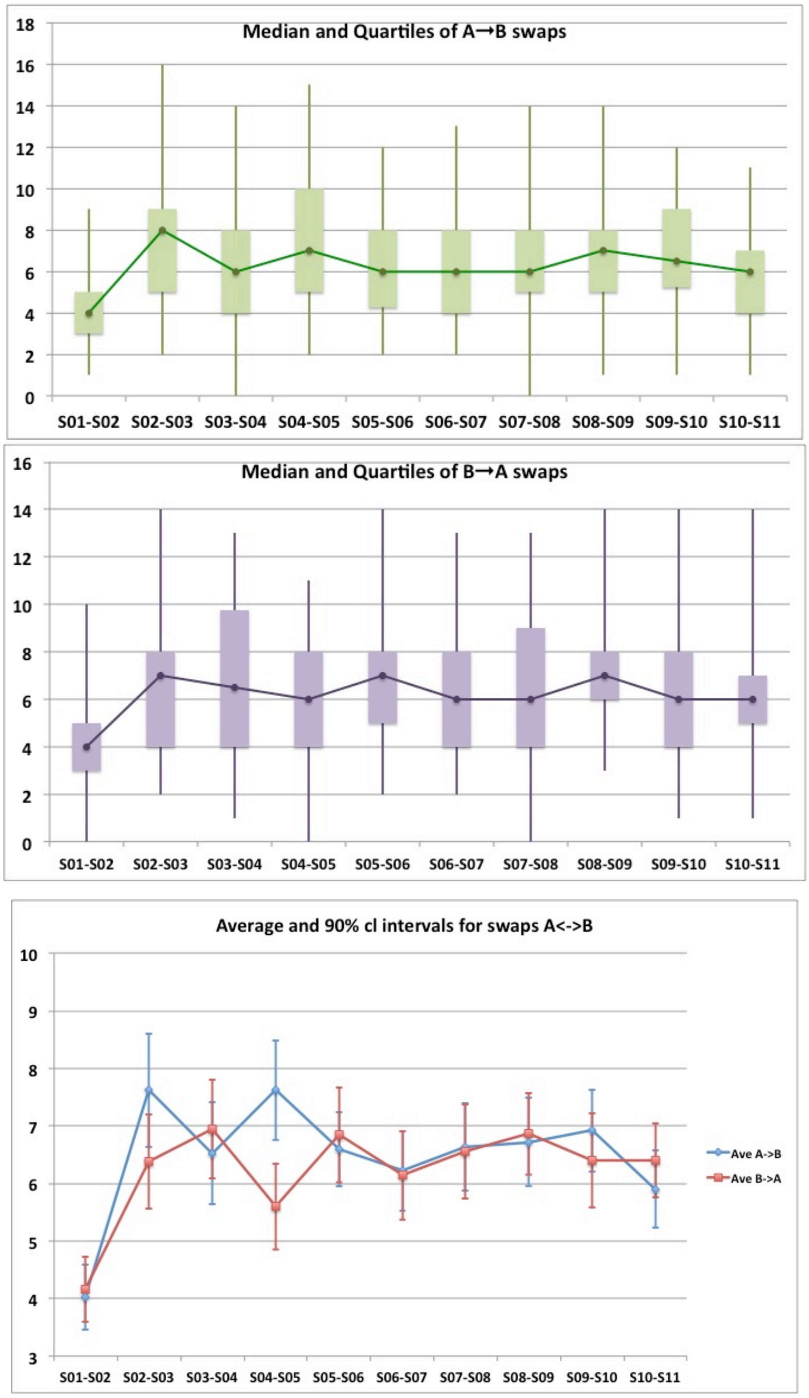

Figure 5: Median and inter-quartile number of changes (ordinate) observed between consecutive sessions (abscissa) is plotted for the swaps from pictures A to B (picture above) and for the swaps from pictures B to A (picture in the middle). We report also average number of swaps with 90% confidence intervals (picture below).

e) For each of the 11 time-points, we performed separate exploratory multiple correspondence analysis to describe participant attitude toward the 50 pairs of pictures. Multiple correspondence analysis is a generalization of principal component analysis where the variables to be analyzed are categorical. To explore the relationships within the 50 pairs of pictures among participants at a time-point, we analyzed an indicator matrix, with columns corresponding to all pairs of pictures and rows to participants. A value of one indicated that the corresponding picture was selected by the participant while a value of zero indicated it was not. Then, we derived the Burt matrix, which was a cross-tabulation of all pairs of pictures among participants, and performed correspondence analysis in order to display the decomposition of total inertia in orthogonal dimensions, analogous to the decomposition of variance in principal component analysis. We estimated the total inertia explained by the first six dimensions and the coordinates for each pair of pictures on these first six dimensions. To investigate changes in attitude toward pictures, we compared graphically picture projection plots of column coordinates after principal normalization across time-points.

f) We consider the evolution of entropy in group, studying the possible orientation of answers and the corresponding trend of the entropy. In the mid of the 19^{th} century Rudolf Clausius (Clausius 1850) introduced the concept of entropy, which was reinterpreted in terms of statistical mechanics by Ludwig Boltzmann (Boltzmann 1886) toward the end of the century. Entropy has often been loosely associated with the concepts of order, disorder and chaos. One of the more powerful (and confusing) aspects of the concept of entropy is that it provides a powerful abstract link between thermodynamics, statistical mechanism, information theory and quantum mechanics (Balian 2004). Although the concept of entropy was originally a thermodynamic construct, it has been adapted in other fields of study, including information theory, psychodynamics, thermo- and ecological economics, demography, evolution and genetics (Brooks & Wiley 1988; Avery 2003; Yockey 2005; Demongeot & Demetrius 1989 ; Demongeot et al. 2014b).

In this work, we are mainly interested in the interpretation of entropy as measure of information and, implicitly, as measure of order and disorder.

In this sense we can think of entropy as the amount of information needed to fully define the microscopic state of the system, which is otherwise left unspecified by the macroscopic description. The first to notice the connection between entropy and information was Claude Shannon (Shannon & Weaver 1949).

In information theory, entropy is the measure of the amount of information in a transmitted message and is sometimes referred to as Shannon entropy. In this context, the definition of entropy is expressed as the sum of terms depending on a set of discrete probabilities:

$$H(X) = -\sum_{i=1}^{n} p(x_i) \log p(x_i)$$

Where $p(x_i)$ is the probability that a particular message x_i is actually transmitted. We note here that the question of the relation between information and thermodynamic entropy has been, and still is, subject to controversy (Brillouin 1956; Georgescu-Roegen 1971; Tribus & McIrvine 1971; Balian 2004; Chen 2005; Frigg & Werndl 2010).

In case all probabilities are equal, the formula for the information entropy reduces to:

$$H = -k \log(p)$$

where k is the unit of entropy. It is interesting to note that, in this case, the Shannon entropy (in bits) is the number of yes/no questions needed to determine the content of the message. It is also instructive to note that this expression of the entropy is identical to the Boltzmann formula based on statistical mechanical considerations. Indeed, the equivalence of Shannon and Boltzmann entropy can be demonstrated in several ways, however some authors argue that the use of entropy for the former is arbitrary and should be dropped in favour of *uncertainty*.

In our case, the choice of one of the two pictures can be described as binary process whose outcome can be either 1 (upper picture) or 0 (lower picture). This kind of process is also called a Bernoulli process. In a Bernoulli process there can be only two outcomes, mutually exclusive and exhaustive, success with a probability of p and failure with a probability of (1-p). If X denotes a random variable, we have:

$$\Pr(X = 1) = 1 - \Pr(X = 0) = 1 - q = p.$$

A classical Bernoulli process is a single toss of a coin, and is defined fair if p=1/2. The Bernoulli distribution is a special case of a binomial distribution with n=*1,* hence we have:

$$f(k;p) = p^k(1-p)^k \text{ for } k \in \{0,1\}.$$

$$E(X) = p \text{ and } Var(X) = p(1-p)$$

In information theory, the entropy of a Bernoulli process is called Bernoulli entropy and is defined as

$$H(X) = H_b(p) = -p\log(p) - (1-p)\log(1-p)$$

When p=1/2, the binary entropy function attains its maximum value. This is the case of the unbiased bit, the most common unit of information entropy.

g) At the end we studied the comparison between the trend of the average of projections (average of p1, p2, p3, p4, p5, p6) and the trend of Entropy.

Results

2,143 missing data out of 24,750 data points were found in the overall data set, which were filled in as follows. For the first session, the missing response was replaced by the selection of the picture at the same spatial location in the preceding answer (top or bottom), and for the following sessions (2-11) the answer to the same question but in the preceding session was used instead (last observation carried forward approach or LOCF, Hamer & Simpson, 2009). We recall that the staff (14 members) did not complete the second questionnaire, which represents a total of 700 (i.e., 50 x 14) missing data.

Table 2: Binomial analysis of the choices. p-values are given for each question, i.e., each pair of pictures, at the 1st session (p_1), and for the overall sessions (p_o). Significant differences from a binomial distribution is assumed for $p<0.025$, and are indicated in italic and by stars. p-values for the 11 distributions have been calculated with the χ^2 tables for 10 degrees of freedom and in the table we have reported the values $\chi^2/10$ for easier inspection. A_1 is the number of A selected per question at the first session[4].

	1st session		All sessions			1st session		All sessions	
Question	$A_1/45$	p_1	χ^2(10 df)/10	p_o	Question	$A_1/45$	P_1	χ^2(10 df)/10	p_o
1	0.87	<0.001**	10.62	0.39	26	0.56	0.28	15.29	0.12
2	0.53	0.38	17.66	0.06	27	0.56	0.28	7.58	0.67
3	0.87	<0.001**	13.71	0.19	28	0.67	0.018*	9.11	0.52
4	0.64	0.036	6.22	0.8	29	0.76	<0.001**	12.07	0.28
5	0.51	0.5	16.56	0.08	30	0.56	0.28	8.02	0.63
6	0.84	<0.001**	15.69	0.11	31	0.51	0.5	15.67	0.11
7	0.64	0.036	11.21	0.34	32	0.73	0.0012**	16.59	0.08
8	0.78	<0.001**	5.74	0.84	33	0.62	0.068	12.17	0.27
9	0.67	0.018*	7.91	0.64	34	0.53	0.38	9.2	0.51
10	0.82	<0.001**	2.7	0.99	35	0.69	0.008**	13.48	0.2
11	0.89	<0.001**	29.23	<0.005**	36	0.73	0.0012**	11.67	0.31
12	0.78	<0.001**	12.6	0.25	37	0.73	0.0012**	17.09	0.07
13	0.69	0.008**	28.72	<0.005**	38	0.82	<0.001**	5.35	0.87
14	0.76	<0.001**	4.24	0.94	39	0.67	0.018*	9.87	0.45
15	0.67	0.018**	5.29	0.87	40	0.82	<0.001**	24.24	0.01*
16	0.67	0.018**	10.28	0.42	41	0.69	0.008**	4.72	0.91
17	0.56	0.28	7.83	0.65	42	0.60	0.12	17.91	0.06

[4] We warn the reader against the possible confusion between the *p* used in this table, which are the significance levels and the symbol *p* used in Equation 1 that corresponds to the frequency of A answers used as estimator of the probability of A answer.

18	0.51	0.5	7.38	0.69	43	0.67	*0.018**	4.25	0.94
19	0.53	0.38	14.57	0.15	44	0.62	0.068	4.6	0.92
20	0.62	0.068	5.28	0.87	45	0.82	*<0.001***	12.42	0.26
21	0.69	*0.008***	6.88	0.74	46	0.51	0.5	8.13	0.62
22	0.60	0.12	6.28	0.79	47	0.84	*<0.001***	13.11	0.22
23	0.80	*<0.001***	9.34	0.5	48	0.84	*<0.001***	9.47	0.49
24	0.53	0.38	22.41	*0.01**	49	0.87	*<0.001***	4.78	0.91
25	0.87	*<0.001***	23.21	*0.01**	50	0.91	*<0.001***	11.06	0.35

a. Cognitive versus group biases in choosing a picture of a pair

(a.1) The probability in selecting randomly A or B pictures at the first session was tested against a binomial distribution with a probability of 0.5. A significant result would indicate some kind(s) of cognitive bias(es) for a picture of a given pair (that we indicate with A) or a very rapid onset of the group unconscious, which would be consistent with Bion's theory of the group psychic apparatus. Significant preferences for pictures A were found in 31 out of 50 pairs, for which initial choices do not seem to have been made randomly (Table 2). We are not in the position to determine whether this was due to cognitive biases or to group dynamics, but we can definitely say that, globally, the initial choice of pictures was not made with a 50% probability.

Table 3: Wilcoxon signed rank tests between sessions on the proportion of participants. Z and p-values given by the Wilcoxon signed rank tests are provided for the comparisons between consecutive sessions (S(k)-S(k+1), k=1 to 10) of the proportions of participants who chose picture A at each question. A statistical significance (*) is assumed for p-values < 0.005 (i.e., α = 0.05/10 comparisons).

Sessions	S1-S2	S2-S3	S3-S4	S4-S5	S5-S6
Z	-0.487	-1.694	-0.908	-2.859	-0.224
P	0.626	0.090	0.364	0.004*	0.823
Sessions	**S6-S7**	**S7-S8**	**S8-S9**	**S9-S10**	**S10-S11**
Z	-0.543	-0.935	-0.045	-0.880	-1.081
P	0.587	0.350	0.964	0.379	0.280

b. Picture choice evolution

(b.1) The evolution of the probabilities to select the preferred pictures was examined over the 11 sessions, to assess whether the initial rational in selecting a picture of a pair would be maintained across time. The null hypothesis was that the variations of the choices are consistent with the fluctuations of a binomial distribution and therefore that chance drives the evolution of the picture choice and not the group dynamics. Evolution in choices appeared significant for 5 out of the 50 questions (Table 2) according to a classical χ^2 test with 10 degrees of freedom. These 5 questions have all a frequency $p(A_i) > 0.8$ significantly (p=0.05) more frequent (60%) than the whole set of 50 questions (27%). In the table, we report the χ^2(10 df)/10 for easier reading.

Table 4: Wilcoxon signed rank tests' statistics. Z and p-values given by the Wilcoxon signed rank tests are provided for the comparisons performed between changes from pictures A to B (AB) and B to A (BA) at each time interval (e.g., S1S2BA = B chosen at test 1 and A chosen at test 2). A statistical significance (*) is assumed for p-values < 0.005.

Time Intervals	S1S2BA S1S2AB	S2S3BA S2S3AB	S3S4BA S3S4AB	S4S5BA S4S5AB	S5S6BA S5S6AB
Z	-0.671	-1.742	-0.829	-2.893	-0.304
P	0.502	0.081	0.407	0.004*	0.761
Time Intervals	**S6S7BA S6S7AB**	**S7S8BA S7S8AB**	**S8S9BA S8S9AB**	**S9S10BA S94S10AB**	**S10S11BA S10S11AB**
Z	-0.510	-0.055	-0.199	-0.902	-1.043
P	0.610	0.956	0.842	0.367	0.297

(b.2) Figure 4 represents the evolution across sessions of the choices for the most selected (A) pictures determined in session 1, i.e., before the start of the group training. During the 4 first modules (i.e., sessions 2 to 4), the selection of picture A decreases slightly and progressively shifting toward picture B, without however inverting the preference. From session 5, the preference for pictures A remains steady to the end of the training (session 11). The Friedman's test conducted on the proportion of participants who chose picture A during the 11 sessions, revealed a significant evolution effect, i.e. the choice of pictures changed with time during the training ($\chi^2 = 34.092$, $N = 50$, $df = 10$, $p < 0.0001$*). The Wilcoxon signed rank tests carried out between consecutive sessions determined that there is a significant change in the choices between the 4th and the 5th tests ($p < 0.005$, Table 3) with a change of the median proportion of A from 66.6% to 63.3%.

(b.3) To evaluate whether swaps from pictures A to B or from pictures B to A evolved, Wilcoxon signed rank tests were performed on the swaps A→B and B→A for each session. As for the previous tests, this revealed that a significant change in the selection of picture A (initially preferred) between the 4th and 5th tests ($p < 0.005$, Figure 5, Table 4) with a difference between the average number of swaps A→B and B→A of peaking at 2.02 (see Figure 5). This is consistent with the previous Wilcoxon test and it tells us that a statistically significant change in the balance between A→B versus B→A swaps between sessions 4 and 5 determines a significant change in the number of A (and B) choices between these two sessions.

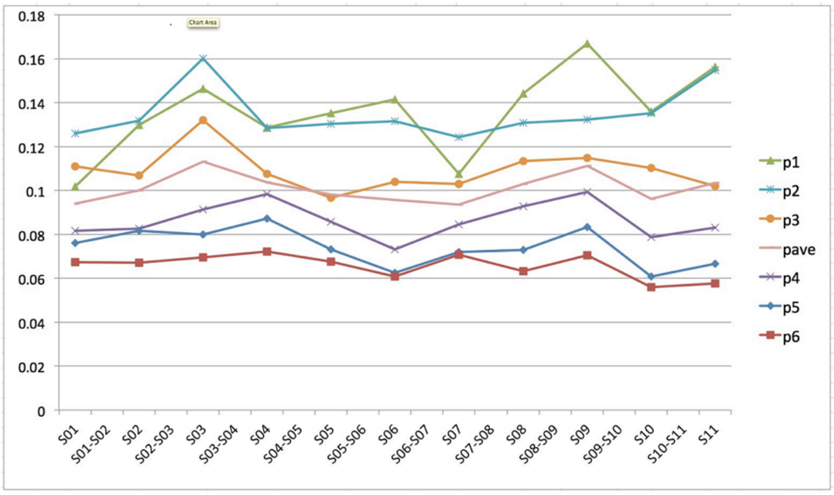

Figure 6: Evolution of the projections of the multiple correspondence analysis (p_1, p_2, p_3, p_4, p_5, p_6) and of their average (*pave*) during the 11 tests.

c. Group dynamics driven swaps of pictures

If we now turn to consider the frequency of swaps A→B, B→A and A→B+B→A across the 11 sessions, Friedman analysis tells us that their evolution is statistically relevant (A→B + B→A: $X^2 = 93.7$, N = 50, df = 9, $p < 0.0001$*; A→B: $X^2 = 61.3$, N = 50, df = 9, $p < 0.0001$*; B→A: $X^2 = 45.4$, N = 50, df = 9, $p < 0.0001$*) (Figure 5). If we then analyse which of these changes is relevant with a Wilcoxon signed rank test, we discover that the frequency of swaps increases significantly only between the first (i.e., from session 1 to session 2) and the second (i.e., from session 2 to session 3) interval, for all three frequency considered, e.g., the total number of swaps (Table 5 - a), the swaps A→B (Table 5 - b) and the swaps B→A (Table 5 - c) ($p < 0.0056$). In other word, swaps A↔B increased after the second training session (after a total of 4 days spent together), and remained almost constant until the end of the training. However it is interesting to highlight that independent analyses on A to B and B to A swaps showed both a marginal significance between time intervals 3-4 and 4-5 ($p = 0.019$ and $p = 0.010$ respectively), reflecting the significant decrease in choosing picture A between the 4th and the 5th testing sessions as revealed in the previous analyses (see § b2 and Figure 4).

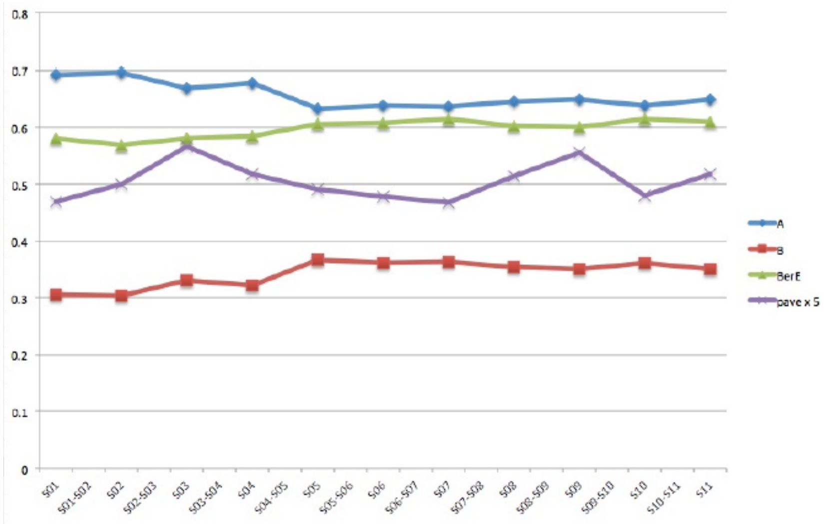

Figure 7: Evolution of the Bernoulli entropy during the 11 sessions (BerE). We have also reported the trend of the A and B responses during the sessions (see text for the explanation) and the average projection (pave), multiplied by five to facilitate the visual comparison.

d. Mean similarity measures

The computed similarity measures were devoted to assess whether pictures' selection, i.e., answers to the questionnaire, occurred just by chance or conversely, if they were driven from group members' common orientation.

Consequently Kruskall-Wallis tests were carried out for each group (A, B, C, D and F, see Table 6) and for the overall groups, which met together once per training day with group E (large group conductors). Statistics indicate that taken together, groups seemed to adopt a common orientation in their choice of pictures ($p = 0.003$*, statistical significance). However, at the level of the individual groups, the effect is more ambivalent. If groups D and F still displayed similar behaviour ($p = 0.02$* and 0.007* respectively), statistics were only marginally significant for group B ($p = 0.05$), and not at all for groups A and C ($p = 0.97$ and 0.79 respectively), indicating a choice by chance.

e. Orientation of choices

Table 5: Wilcoxon signed rank tests on the number of swaps between time intervals. Z and p-values given by the Wilcoxon signed rank tests are provided for the comparisons between consecutive time intervals (S_iS_{i+1} $S_{i+1}S_{i+2}$) of the total number of swaps from pictures A to B and B to A (a), swaps from A to B (b) and swaps from B to A (c). A statistical significance (*) is assumed for p-values < 0.0056 (i.e., $\alpha = 0.05/9$ comparisons).

Time Intervals		S1S2 S2S3	S2S3 S3S4	S3S4 S4S5	S4S5 S5S6	S5S6 S6S7	S6S7 S7S8	S7S8 S7S8	S8S9 S9S10	S9S10 S10S11
		A to B + B to A swaps								
A	Z	-6.014	-0.968	-0.279	-0.208	-1.986	-1.023	-0.566	-0.687	-1.973
	P	<0.0001*	0.333	0.780	0.835	0.047	0.306	0.572	0.492	0.048
		A to B swaps								
B	Z	-5.252	-1.581	-2.336	-1.576	-0.770	-0.750	-0.092	-0.523	-1.678
	P	<0.0001*	0.114	0.019	0.115	0.441	0.453	0.927	0.601	0.093
		B to A swaps								
C	Z	-3.964	-0.920	-2.563	-1.869	-1.548	-0.959	-0.669	-0.873	-0.217

	P	<0.0001*	0.357	0.010	0.062	0.122	0.338	0.503	0.383	0.828

We remember that, to explore the relationships within the 50 pairs of pictures among participants at a time-point, we performed separate exploratory multiple correspondence analyses to describe participant attitude toward the 50 pairs of pictures. In this method a value of one indicated that the corresponding picture was selected by the participant while a value of zero indicated it was not. The values are reported in Figure 6. The changes in attitude toward pictures show differences during the training with a first larger orientation in p1, p2 and p3 in the 4th test administration (3rd week of training). This first larger orientation appears in 5th test administration (4th week of training) for p4, p5 and p6. The average of projection (pave) shows the first larger orientation at the 4th test administration (3rd week of training). We observe a second stronger orientation for the projections p1, p4, p5, p6 and the average pave in the 9th test administration (8th week of training). The p1 shows also an important loss of orientation at the 7th test administration (6th week of training).

Table 6: Temporal variations in mean similarity measures within studied groups. Mean similarity measures are given for the 11 sessions of each group and for the overall group. P-values of the Kruskall-Wallis tests are also given. Significance (*) is assumed for p < 0.05.

Studied Groups	Sessions											P
	1 (Baseline)	2	3	4	5	6	7	8	9	10	11	
	Mean similarity measures											
A	.57	.56	.60	.60	.59	.59	.58	.59	.59	.60	.58	0.97
B	.58	.62	.57	.58	.53	.54	.54	.53	.53	.55	.55	0.05
C	.63	.59	.63	.60	.61	.61	.63	.60	.60	.59	.59	0.79
D	.60	.61	.59	.56	.54	.52	.53	.56	.57	.53	.53	0.02*
F	.63	.63	.59	.57	.56	.56	.50	.53	.49	.49	.54	0.007*
All	.59	.60	.59	.59	.57	.57	.56	.57	.58	.56	.57	0.003*

f. Entropy of the choices

The entropy (reported in Figure 7) shows an augmentation from the beginning to the end of experience, as in a closed environment, with a slight decrease at the 2nd test administration (1st week of training) and at the 9th test administration (8th week of training).

The diminution in the 1st week is not coincident with the trend of pave, as we expected, under the hypothesis of an inverse relationship between the orientation of the choices and the value of entropy. On the contrary, the diminution of the entropy at the 8th week of training is coincident with the second larger orientation of pave in the same week of training.

g. The monotony signature

Theoretical background

In order to continue our analysis of the answers to the "absurd questionnaire", we turn now our attention to the monotony of the data, following an idea originally introduced by Demongeot (Aracena et al. 2003). To define what we mean by monotony, let us consider the graphs of the real functions of time, X(t) and Y(t), recorded at the same observation times (see Figure 8). We call monotony signature of X (resp. Y) the sequence of the signs "+" and "–" of their successive monotony intervals: $sign_i X = +$ (resp. -) corresponds to the increase or constancy (resp. decrease) of the function X on its ith monotony interval, and the monotony signature of X (resp. Y) for the nine successive intervals of monotony is equal to:

$$sign_i\, X\ (i = 1{,}9) = \{-,-,+,+,+,-,+,+,-\}$$

$$sign_i\, Y\ (i = 1{,}9) = \{+,-,+,+,-,-,+,+,-\}$$

Confronting the temporal evolutions of different samples, we can test whether the signature of monotony of a sample profile significantly differs from the one of a reference profile.

We can, for example compare the signatures of two experimental samples: X (observed) and Y (reference) and test the similarity of their signatures due to a link between X and Y (hypothesis H_1) against a random choice of signs (hypothesis H_0), using the probability P_ to decrease from x to y (see Figure 9).

The probability P_ can be expressed by the following formula:

$$P_{-}=P(\{X>Y\})=P(\cup_{x\in support(f)}(\{X=x\}\cap\{Y<x\}))=\int_{support(f)}f(x)F(x)dx$$

Equation 2: General expression of the probability to decrease from x to y.

where *f* is the density function and *F* the cumulative distribution function of the errors, and *support(f)* represents the support in $\mathbb{R}$ of the functions f and F. If we denote by $P_{\_i}$ the probability of decrease of *X* on its i^th^ monotony interval, then the sequence *{P_i}, i=1,..,k* is called the weighted signature of monotony of X.

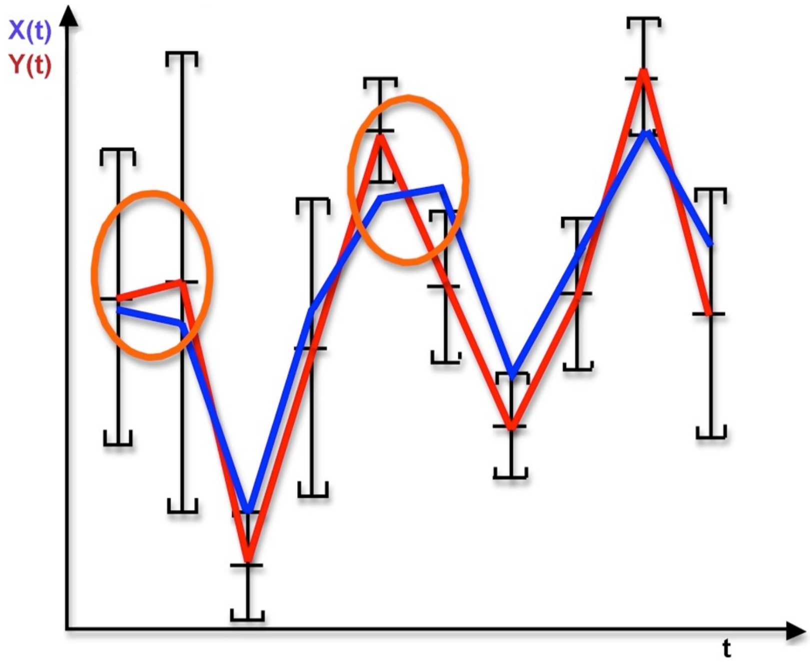

Figure 8: Temporal profiles of signals X and Y (red and blue) over time t, indicating monotony segments between successive averages, each average being the centre of an empirical 95% confidence interval. If the error on X is supposed to be uniform on each confidence interval, the weighted signature of monotony of X is equal to (0.4,1,0,0,1,1,0,0,1). The intervals of monotony circled in orange correspond to discrepancies between variations of X and a reference signal Y.

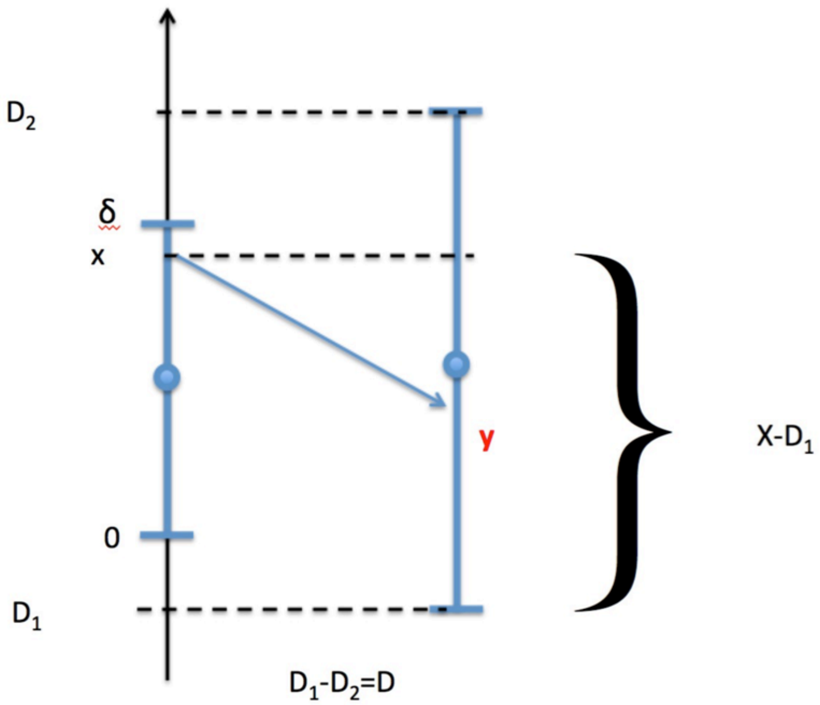

Figure 9: Calculation of the probability P_ of negative monotony.

If we want now to calculate the probability, following Equation 2, we have to formulate a hypothesis on the errors affecting our data. In case of systematic errors the probability function is uniform over the error interval and zero outside. We have therefore to distinguish six different cases (see Figure 10).

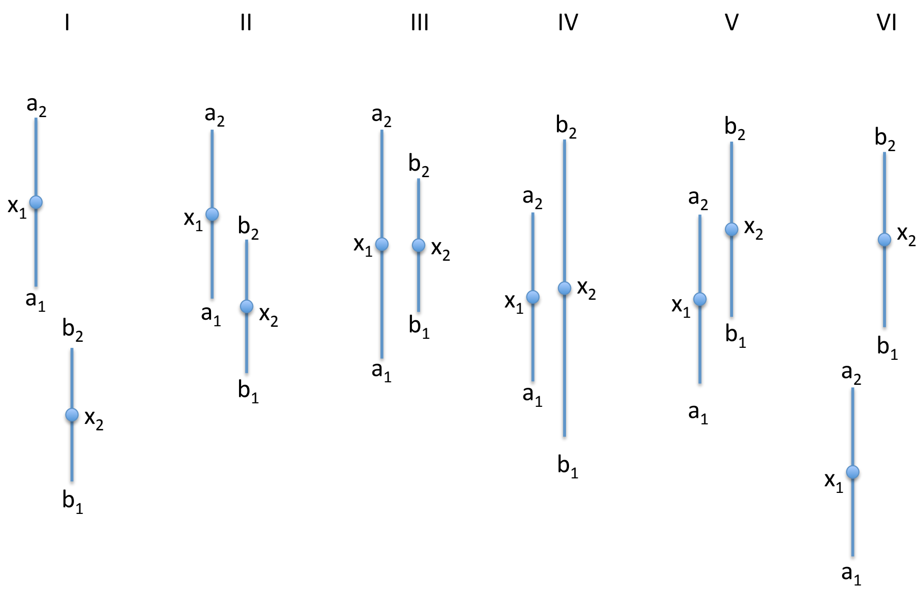

Figure 10: Six different configurations of X and Y values in case of "square" errors.

Calculation according to Equation 2 gives us the following expression:

$$P = \begin{cases} I \rightarrow 1 \\ II \rightarrow 1 - \dfrac{(b_2 - a_1)^2}{2(a_2 - a_1)(b_2 - b_1)} \\ III \rightarrow \dfrac{a_2 - x_2}{a_2 - a_1} \\ IV \rightarrow \dfrac{x_1 - b_1}{b_2 - b_1} \\ V \rightarrow \dfrac{(a_2 - b_1)^2}{2(a_2 - a_1)(b_2 - b_1)} \\ VI \rightarrow 0 \end{cases}$$

Equation 3: Probability of "decrease" in case of box probability distributions for the errors.

To verify "experimentally" the above formula we have we have sampled uniformly 10'000 sets of values (x_i, Δx_i, y_i, Δy_i), in ([-10,10], [0,10])^2, i=1,...,10'000. For each sampled set we have then calculated the probability of decrease P_i. We have then sampled 1'000'000 couples of values (x_{ik}, y_{ik}), k=1,...,1'000'000 uniformly in [x_i-Δx_i, x_i+Δx_i], [y_i-Δy_i, y_i+Δy_i] and we have measured the empirical frequency of decrease P*_i. We have then plotted the quantity $f\Delta_i^* = (P_{-i} - P_{-i}^*)/\sqrt{P_{-i}^*(1 - P_{-i}^*)/1'000'000}$ and the result can be seen in Figure 11.

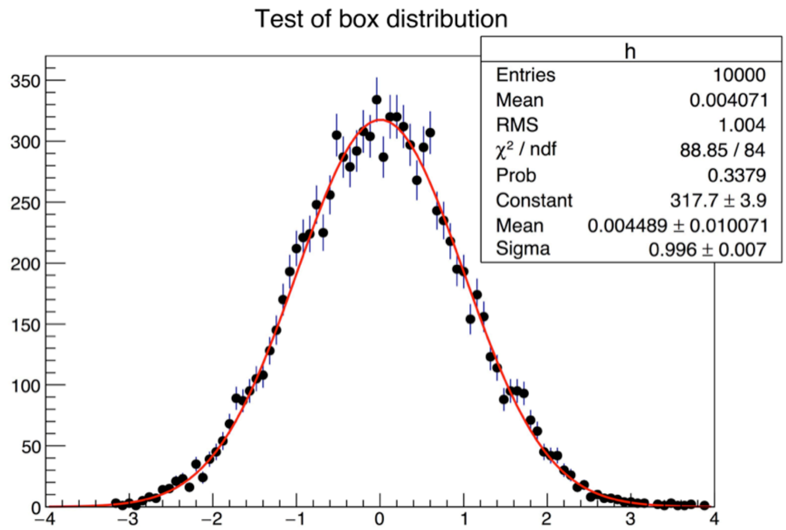

Figure 11: Distribution of the normalised difference between the calculated and the sampled probability of decrease in case of box errors. The red curve is a Gaussian fit.

In case the errors are not uniform but Gaussian, i.e. statistical errors, the integration of Equation 2 gives the following result:

$$P = \frac{1}{\sqrt{2\pi}\sigma_1}\frac{1}{\sqrt{2\pi}\sigma_2}\int_{-\infty}^{+\infty} e^{-\frac{(y-\bar{y}_1)^2}{2\sigma_1^2}} dy \int_{-\infty}^{y} e^{-\frac{(z-\bar{y}_2)^2}{2\sigma_2^2}} dz$$
$$= \frac{1}{\pi}\int_{-\infty}^{+\infty} e^{-t^2} dt \int_{-\infty}^{\alpha t+\beta} e^{-s^2} ds$$

with:

$$\alpha = \frac{\sigma_1}{\sigma_2} \qquad et \qquad \beta = \frac{\bar{y}_1 - \bar{y}_2}{\sigma_2}$$

This is a convolution integral of the form:

$$I = \int_{-\infty}^{+\infty} f'(x)\, f(\alpha x + \beta) dx$$

that has to be solved via numerical integration[5]. Again, to verify the correctness of this formula, we have run a Montecarlo, but this time we have generated statistical Gaussian errors. We have sampled uniformly 10'000 sets of values (x_i, σx_i, y_i, σy_i), in $([-10,10], [0,10])^2$, i=1,...,10'000. For each sampled set we have then calculated the probability of decrease P_i. We have then sampled 1'000'000 couples of values (x_{ik}, y_{ik}), k=1,...,1'000'000 using Gaussian distributions N(x_i, σx_i), N(y_i, σy_i) and we have measured the empirical frequency of decrease P*_i. We have then again plotted the quantity $f\Delta_i^* = (P_{-i} - P^*_{-i})/\sqrt{P^*_{-i}(1-P^*_{-i})/1'000'000}$ and the result can be seen in Figure 12.

[5] We have submitted the integral to the algebraic manipulation systems Mathematica (http://www.wolfram.com/mathematica) and Maxima (http://maxima.sourceforge.net) but apparently there is no analytical solution. J.Demongeot et al. (Demongeot, 2015) have found the following expression for $P_- = \int_0^1 exp[(-(g(z)-b)^2 + a^2 g(z)^2)/2a^2]/a\, dz$ where $g = f^{-1}$, which however still requires numerical integration.

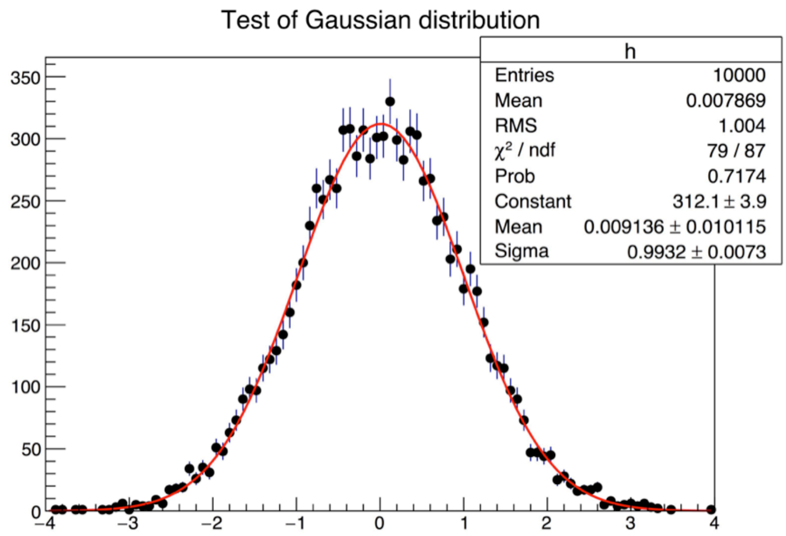

Figure 12: Distribution of the normalised difference between the calculated and the sampled probability of decrease in case of Gaussian errors. The red curve is a Gaussian fit.

As expected, these two tests show that the empirical distribution $f\Delta_i^*$ of the random variables is asymptotically (in sample size) Gaussian (cf. the red curve showing the Gaussian fit in the two pictures).

It is interesting to note that the two distributions are in fact not very different when confronted. Just as an example we have taken $y_1= \sigma_1= \sigma_2=5$ and we have varied y_2 from -25 to 35 (see Figure 13). As it can be seen the distribution for box errors (green points) is of course steeper.

Let's now turn to the application of this formula to a real case and then to our data. Let's suppose we have a distribution that we measure from the data $(x_i^0, y_i^0), i = 1, \dots n$ and that we can determine for each point an error, either experimental or systematic. Let's now suppose that we draw a second sample $(x_i^1, y_i^1), i = 1, \dots n$ (e.g. at a different time) and that we want to verify whether the two are statistically compatible one with the other.

The decrease probability is essentially a Bernoulli process with only two possible outcomes, either the next point decreases or it does not. If all probabilities of decrease are equal, say p_d, the probability to have k decreases in $(x_i^1, y_i^1), i = 1, \dots n$ can be calculated via the binomial distribution:

$$P(k) = \binom{n}{k} p_d^k (1 - p_d)^{n-k}$$

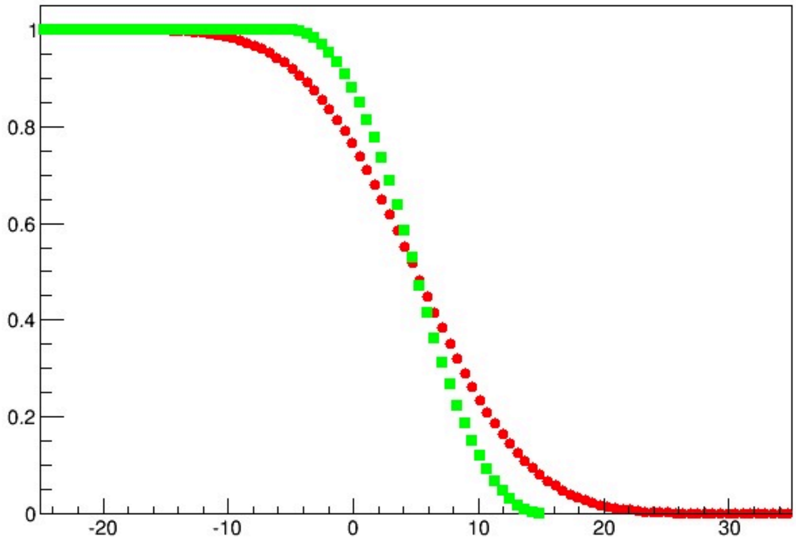

Figure 13: Comparison of the decrease probability between box errors (green points) and Gaussian errors (red points)

In our case, however, the probability of each decrease is different, and therefore we have to use the full combinatory expression

$$P(k) = \sum_{k_j} \prod_{l \in k_j} p_{d,l} \prod_{m \sim \in k_j} (1 - p_{d,m})$$

where k_j are all the subsets of k numbers that can be extracted from a set of n numbers without repetition and $p_{d,i}$ is the probability of decrease at the i^{th} interval. If all the probabilities are equal the expression reduces to the binomial probability:

$$P(k) = \sum_{k_j} \prod_{l \in k_j} p_{d,l} \prod_{m \sim \in k_j} (1 - p_{d,m})$$

$$= \sum_{k_j} p_d^k (1 - p_d)^{(n-k)} = \binom{n}{k} p_d^k (1 - p_d)^{(n-k)}$$

Unfortunately this formula cannot be used as such between pairs of adjacent points of a function repeatedly sampled as the decrease of one couple of points is dependent on the decrease of the preceding one. As a proof of this we have generated a simple function and we have calculated the probability of decrease (see Figure 14).

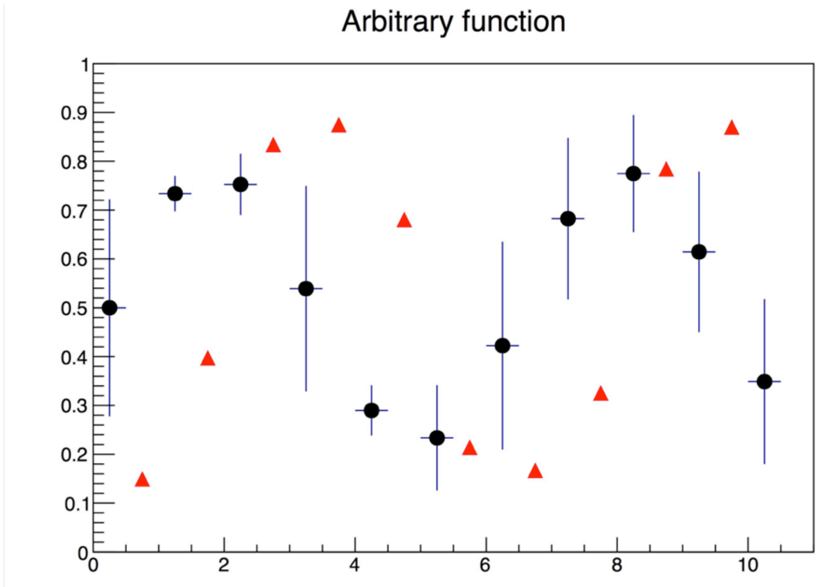

Figure 14: Probability of decrease for Gaussian errors (red points) for an arbitrary function (black points).

We have then sampled several sets of 11 points with the same average and error and we have compared the measured number of decreases with the calculated one. The result can be seen in Figure 15 and, as expected, the dependence of the different decreases alters the shape of the function.

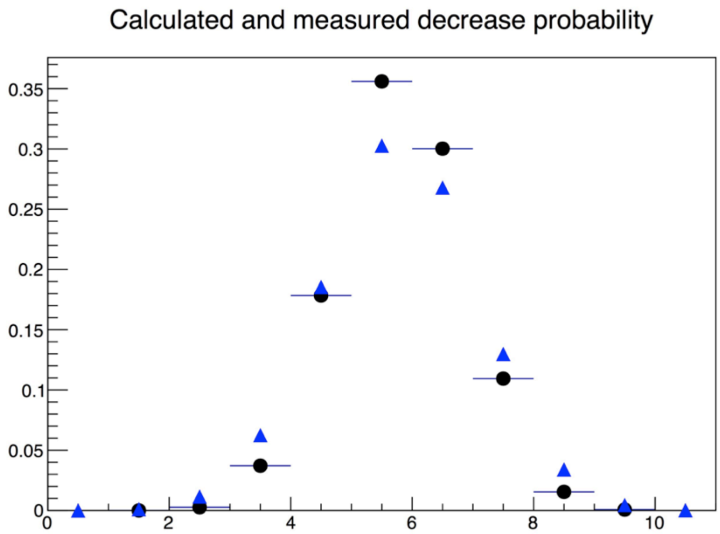

Figure 15: Calculated (blue triangles) and measured (black dots) probability of observing n decreases in the function of **Figure 14**. The calculated result has been obtained generating 1'000'000 functions. Vertical error bars are included in the symbols.

If we consider not each pair, but each other pair of points, we break the dependence and our formula becomes applicable. In other words, if we consider the decrease between odd-even points 1-2, 3-4, 5-6, 7-8, 9-10, and between even-odd points 2-3, 4-5, 6-7, 8-9, 10-11, these are independent and we can apply our formula. This is shown in Figure 16. The observed number of transition is reproduced quite precisely by the formula calculated above. Obviously the limitation of this is that we cannot utilise both distributions for a statistical test since these are themselves correlated.

A viable alternative would be to calculate the integral distribution using a MonteCarlo method and then compare it to the measured number of decreases.

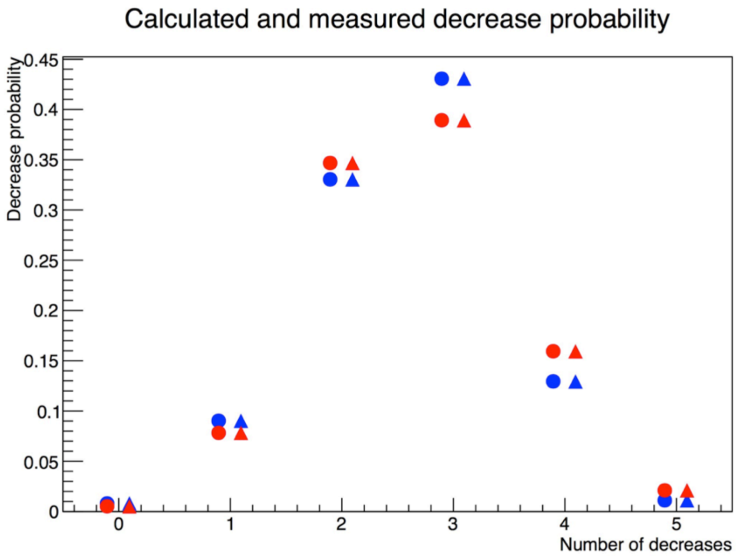

Figure 16: Separate measured (triangles) and calculated (circles) decrease probabilities for the odd-even (1-2, 3-4, 5-6, 7-8, 9-10, blue points) and even-odd (2-3, 4-5, 6-7, 8-9, 10-11, red points) couples. The calculated result has been obtained generating 1’000’000 functions. Vertical error bars are included in the symbols.

Application to our data

We decided to apply the above calculations to assess the randomness of the distributions of A’s answers and of the distribution of transitions from A to B for the 50 questions. Here is our null hypotheses are the following ones:

a. Number of A’s: the observed numbers of decreases in the number of A’s of one question and the next one in the 10 tests are compatible with statistical fluctuations of the first test;
b. Number of transitions A->B: the number of decreases observed in number of transitions between A and B for one question and the next

one in the 9 transitions between one text and the next are compatible with statistical fluctuations of the first transition.

Let's start with the number of A's. For each question we have calculated the frequency of the A answers and the corresponding error Poissonian error:

$$N_A \pm \sqrt{N_A \frac{N_A}{45}\left(1 - \frac{N_A}{45}\right)}$$

where N_A is the number of A answer for each question from 1 to 50 and 45 is the total number of participants.

We have then calculated the decrease probability for the number of A's from one question to the next for the first session and this can be seen in Figure 17.

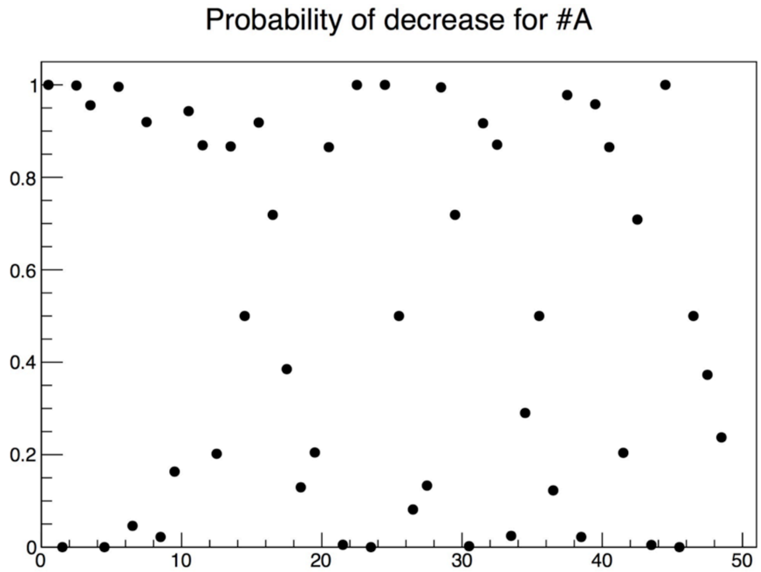

Figure 17: probability of decrease in the number of A's answers from one answer to the next for the first session.

Next step was to calculate the cumulative decrease probability distribution in function of the number of decreases observed for the two series: odd-even (1-2, 3-4, … , 47-48, 49-50), for which we have 25 points and for the even-odd (2-3, 4-5, … , 46-47, 48-49) for which we have 24 points. The result can be seen in Figure 18. As we have shown before, the transitions in each series are independent, however the two series are coupled. If we analyse the result for the probability of the number of decrease in the number of A's in the transitions actually observed during the 11 sessions we obtain Table 7.

As we can see there are several sessions that show a statistically significant number of transition. It is important to note here that the probabilities in the two series are strongly anti-correlated, the non-diagonal element of the correlation matrix being -0.66. This is due to the fact that if the number of A's for one question is particularly low, this increase the number of decreases in this series, but reduced the probability to have a decrease in the alternate series. It is also interesting to note how there seems to be a high degree of "polarisation" in the observed number of decreases, such that probability is either close to 0 or is close to 1.

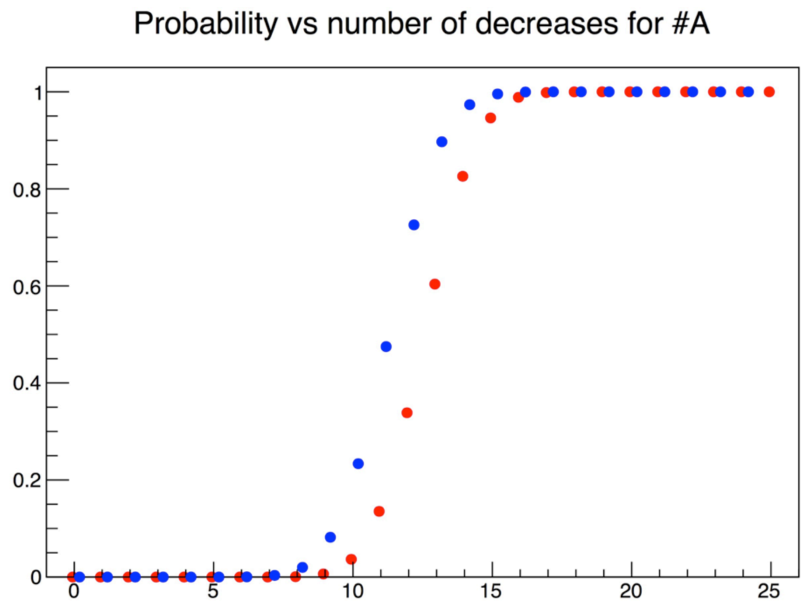

Figure 18: Cumulative probability as a function of the number of decreases in the number of A answers for the two series: odd-even (1-2, 3-4, … , 47-48, 49-50, red points), for which we have 25 points and for the even-odd (2-3, 4-5, … , 46-47, 48-49, blue points) for which we have 24 points. The points have been slightly displaced for visibility.

Before discussing the results, we report here the probability distribution of the number of decreases for the number of transitions between A->B observed for each question during the 11 sessions. In this case we have 10 transitions, and, as we will consider the distribution of first transition (between session 1 and 2) as the reference one, we will have 9 series of transitions for which we will count the number of decreases between adjacent questions.

The probability of decrease calculated from the distribution of the number of transitions A->B between the first and the second session is reported in Figure 19. It is interesting to note that the probability distribution is more "extreme" than the previous one, in the sense that probabilities of decrease are very close either to 0 or to 1.

Table 7: Calculated probability for the observed number of decreases in the distribution of the number of A's across the 11 sessions. Statistically significant numbers of decreases are marked in red.

Session	First series			Second series		
	# decr	p1	1-p1	# decr	p1	1-p1
2	13	0.604	0.396	10	0.234	0.766
3	12	0.339	0.661	14	0.973	0.027
4	9	0.006	0.994	14	0.973	0.027
5	10	0.037	0.963	12	0.726	0.274
6	9	0.006	0.994	14	0.973	0.027
7	13	0.604	0.396	11	0.475	0.525
8	10	0.037	0.963	12	0.726	0.274
9	12	0.339	0.661	13	0.897	0.103
10	12	0.339	0.661	10	0.234	0.766
11	11	0.135	0.865	14	0.973	0.027

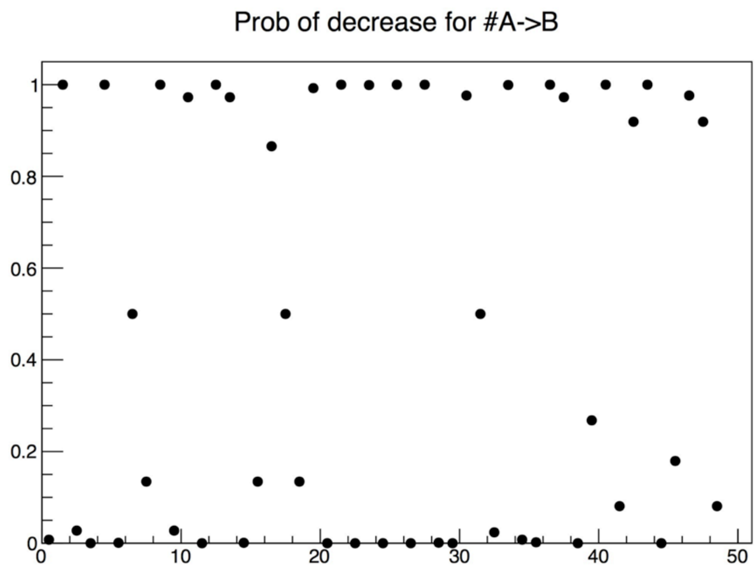

Figure 19: probability of decrease in the number of transition from A answer to B answer between the first and the second session from one answer to the next.

As before we have calculated the cumulative probability distribution as a function of the number of observed transitions A->B using the probabilities derived from the transitions between the first and the second session shown in Figure 19. As before we consider the odd-even series (1-2, 3-4, … , 47-48, 49-50) and the even-odd series (2-3, 4-5, … , 46-47, 48-49) separately. The result can be seen in .

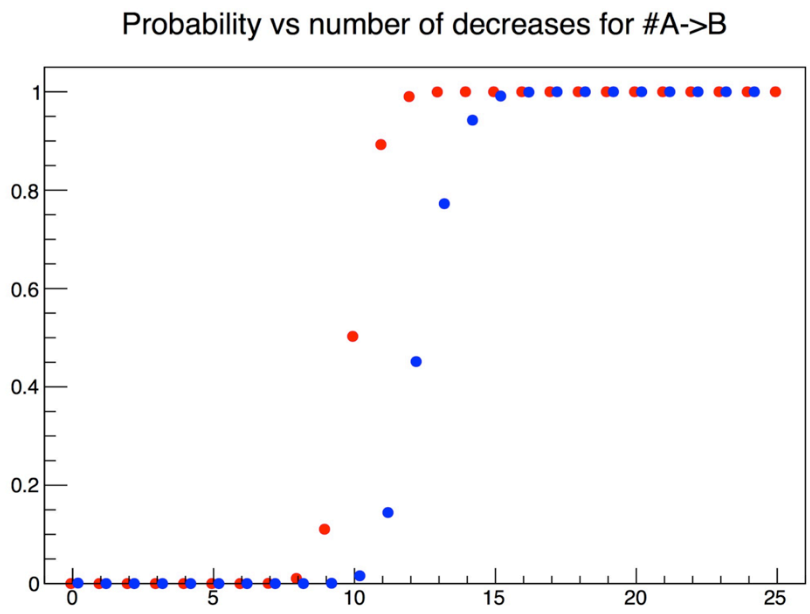

Figure 20: Cumulative probability as a function of the number of decreases of the number of transitions from A->B for the two series: odd-even (1-2, 3-4, … , 47-48, 49-50, red points), for which we have 25 points and for the even-odd (2-3, 4-5, … , 46-47, 48-49, blue points) for which we have 24 points. The points have been slightly displaced for visibility.

The result of the analysis of the number of transitions A->B can be seen in Table 8. The two series are strongly anti-correlated (-0.59), but less than in the preceding case.

Each transition presents in at least one of the two series a significant difference with the first transition (session 1-2). We recall that we have qualitatively observed that the global number of transitions between the first and the second series is lower than the transitions between the other sessions. The present result is consistent with this observation. The second remark is that only the last transition is anti-correlated in a statistically significant manner, while all the other transitions are either positively correlated or very little correlation.

If we compare the two tests, we can say that in the first case (number of A's) there is a statistically significant change in the fluctuations, but essentially no change in the shape of the distribution, as far as the number of decreases is concerned. This is also reflected by the strong anti-correlation.

Table 8: Calculated probability for the observed number of decreases in the distribution of the number of transitions A->B across the 11 sessions. Statistically significant numbers of decreases are marked in red.

Transition	First series			Second series		
	# decr	p1	1-p1	# decr	p1	1-p1
2-3	14	1.000	0.000	11	0.144	0.856
3-4	14	1.000	0.000	12	0.451	0.549
4-5	17	1.000	0.000	9	0.001	0.999
5-6	12	0.990	0.010	13	0.772	0.228
6-7	13	1.000	0.000	14	0.942	0.058
7-8	9	0.111	0.889	17	1.000	0.000
8-9	12	0.990	0.010	13	0.772	0.228
9-10	9	0.111	0.889	16	0.999	0.001
10-11	15	1.000	0.000	7	0.000	1.000

In the second case we have instead a global change "form" of distribution with a statistical significant increase of the number of transitions between A and B.

The second distribution is, somehow, a derivative of the first. The picture choices do not change at the group level, but the individual choices fluctuate more intensely.

Discussion

Cognitive versus group dynamics biases

The first outcome of our study is that the initial answer to the test is not a 50%-50% random choice between the two pictures of each pair, despite the fact that the pairs of pictures were chosen trying to not induce social or cultural bias. This initial bias could be the reflection of our shortcoming in avoiding these effects, but it could also have another explanation. According to Bion, group effects should be seen as soon as people are actually put together. They do not even need to interact actively, and the mere assembling of individuals should be enough to connect unconscious and to provoke group phenomena. So this orientation could be indeed a group effect. Unfortunately our protocol does not allow discriminating between these two explanations.

A future version of such a protocol should include a provision to determine bias that could be attributed to common social and / or cognitive preferences for one picture of the pairs, driven for instance by visual attributes (e.g., colour, spatial frequency contents, etc.) or meaning contents. One possible alternative would be to use some types of fractal pictures. Another approach would be to ask future participants to fill the questionnaire before they actually meet for the first time. Alternatively the questionnaire could be composed of pairs of questions previously tested on different samples not directly related to the Bilbao esperiment participants for perfect randomization. Whatever the origin of the initial orientation, it does not affect the statistical significance of group effects that occur in the following sessions and therefore the results obtained in this experiment.

In what follows we will analyse our data under two different angles. First of all we will consider what is the distribution of the choice of the different figures and its evolution during the experiment. The second quantity we will consider is the number of changes from one choice to another made by the participants in the different sessions (swaps). The rather strong initial orientation could be due to the influence of group dynamics following Bion's idea that the group is immediately created, or it could be the effect of social and cognitive phenomena, or a combination of the two effects. However, the evolution of the choices and frequency of swaps of A and B choices during the experiment can be attributed to group dynamics rooted in the "basic assumptions" described by Bion (Bion 1961).

Group unconscious common orientation during the training was investigated at two levels. First, its impact on similarity of choices was explored and second, its influence on the environment was examined by measuring choices and the frequency of their active changes at the level of the questionnaire.

Similarity of participant choices

Similarities of participant choices were examined at the level of individual small group (8-10 people), which is supposed to represent the "family", and at the large group level, which symbolizes the "society". We could have expected a greater coherence in choices at the "family" rather than at the "society" level. However this was not the case. The large group as a whole showed a common orientation across session, i.e., participants were collectively more likely to select the same response to questions. This orientation was less identifiable in the individual small groups. It seems that "society" is the driving force, which directs group unconscious to adopt similar behaviour, rather than smaller communities. This explanation tends to be in favour of the postulate of a universal psychic field proposed by Baaquie et Martin (Baaquie & Martin 2005).

Group unconscious

The evolution of the answers to the questionnaire was analysed to provide two kinds of information about group phenomena, dedicated to check whether group unconscious actually adopts a common orientation measurable on the environment, i.e., the answers to the questionnaire.

Evolution of group dynamics choices

It was postulated that group dynamics orientation should result in the evolution of picture preference. In other words, if the group has an effect at some stages of the training, picture choices evolution should not be random across testing sessions. The analysis showed that the evolution of the selection of the A picture is compatible with random fluctuations between the 1st and the 4th and between the 5th and 11th tests. Between the 4th and the 5th test (corresponding to the transition between the 3rd and the 4th sessions, as there were two tests in the first session) there was a “defocusing” in the choice of the preferred picture that is non-random with a high significance. This effect can clearly be seen also in the comparison of the A→B and B→A swaps between sessions. The A→B and B→A swaps for the same interval between two sessions are compatible with each other except for the transition from the 3rd to the 4th session, where they are clearly different, revealing significantly more A→B swaps in favour of the least selected picture and less B→A swaps in the direction of the favourite one. Both analyses show that the choice staid constant (without statistically significant variation) from the 1st to the 3rd and from the 4th to the 10th sessions, after the number of A’s has decreased.

This behaviour is very suggestive of group dynamics. During the first three sessions there is a “honeymoon” period where the group forms and enjoys the so-called “group illusion”. After that the group faces disillusion toward the leader and sees the end of the training approaching, so the cohesion is reduced, but remains constant to the end of the training. Although this simple measure cannot be said to catch the complexity and richness of group dynamics, it seems however that its behaviour is consistent with what we know and observe as group analysts.

It is also very interesting to note that this effect is very visible at the level of the global group and less at the level of the individual group, while group illusion and disillusion and mourning are effects that are also strongly felt at the level of the “small groups”. It seems that even if the evolution is individually felt stronger at the level of the small community (“family”), it is an effect that involves the whole society. So while there are individual variations in the way the small groups move across time, the global (“social”) picture maintains a high degree of coherency.

Evolution of swaps and group dynamics.

The swaps we measured across sessions could be interpreted as a manifestation of a group dynamics similar to that postulated by Bion (Bion 1961) with the “basic assumptions”. For instance, “honey moon” (dependence from the leader) and the successive “fight-flight” (reaction against the dependence from the leader) attitude could be represented by greater number of group dynamics swaps (further away from pure randomness). It seems intuitive that an increase of the swaps could be linked to an increased group activity or a group dynamics event.

Statistics carried out on the total number of swaps or individually on A→B or B→A changes evidenced a significant increase of those swaps between the 1st (S1S2) and the 2nd (S2S3) time intervals, i.e., between the 2nd and the 3rd testing sessions, incompatible with a random fluctuation. In other word the change of choice increased significantly between the 1st and the end of the 2nd training module, and then remained essentially constant until the end of the training, while the frequency of choices for the initially preferred picture changed significantly only between the 3rd and the 4th training sessions. Between these two sessions there is no sign of change in the evolution of the sum A→B+B→A, while the number of A→B and B→A swaps showed a fluctuation close to significance. This is consistent with the "defocusing" in the choice of A observed.

Again the pattern emerging is very suggestive. Even if the onset of the group is immediate (with a distribution of answer far from 50%-50% at the very beginning of the training) the group activity needs the group to meet and exchange for some time before setting in motion. Group dynamics really starts after a few days spent together (here 3-4 days training, i.e., about 9-12 hours), and remains essentially constant as long as the group exists, whatever the group evolution.

At this point we could propose two possible interpretations of the data. In the first one we postulate that, according to Bion's theory, the group exists from its earliest stage, and the modification of picture selection observed at mid-training, which corresponds to an evolution towards a more random or "less focused" choice, is coherent with a decreased group coherence, possibly caused by the group disillusion with the leaders or the perspective of the end of the training (the death of the group).

Alternatively, the initial choices are due to a cognitive or social bias and the group forms according to the basic assumption with a timescale compatible with the increase of the swap frequency, i.e., during the first training session. In this case, the decrease in the choice of the A pictures is rather the manifestation of a new equilibrium introduced by group dynamics, where initial cognitive choices are modified by an increase of group unconscious activity aimed at fulfilling the group desires or needs.

It is difficult to be more specific with this first questionnaire and a single evaluation at the end of each module.

Orientation of Choices and Entropy

We observe some changes in the trend of the orientation of choices at the 3rd and 9th test administrations, i.e., during the 2nd and 8th week end of training, corresponding respectively to the phase of groupal idealisation at the beginning and groupal disillusion before the morning of the group.

For instance, "honey moon" (dependence from the leader) and the successive "fight-flight" (reaction against the dependence from the leader) attitudes could be represented by an increase in the orientation of the choices.

The Entropy increases along the experience as in a closed system, with a slight diminution at the 2nd test administration (1st week of training), in fact very soon in the training (before the "honey moon") and at the 9th test administration (8th week of training) The trend of average projection and Entropy seem reciprocally inversed starting from the 4th test administration, We can suppose that the "honey moon" and the successive "fight-flight" attitudes influence the orientation of choices and the Entropy but that the only "fight-flight" attitude influence Entropy.

Conclusions

Our study aimed at detecting measurable effects of the psychical dynamics that takes place during a group training session. For this we used the answers given to a questionnaire aimed at minimising or at least reducing cognitive and social bias. Although our results are subject to interpretation, we believe that this study presents strong indications for evidence in favour of an influence of group dynamics on the answers to the questionnaire.

In particular we believe that there is evidence in favour of the building of a group unconscious according to Bion's "basic assumptions", as it is shown by the evolution in the frequency of swaps in the choices of images across sessions. The present study brings additional insight into the mechanisms at work in group dynamics, and indicates support for Bion's theory of both an immediate and a more progressive group dynamics effect.

Concerning the Entropy, globally speaking we find the behaviour of a close system. It is interesting to note that the orientation of choice is not similar to the trend of the Entropy in the 3 first test administrations. The orientation of the choices seems to change the trend of the Entropy only in the second part of the experience, during the "fight-flight" (reaction against the dependence from the leader) attitudes.

If we consider that entropy links the concepts of order and information, we could consider that it is an expression of a more fundamental archetype, which otherwise has been expressed as Chaos and Cosmos, Eros and Thanatos and so on. In this interpretation entropy, as all archetypes, has two faces, the creative order (how much order is there) and the destructive disorder (how much disorder is there), but also the destructive order (there is no more information to obtain) and the creative disorder (there is still information to obtain).

We could then propose the following interpretation. When entropy increases in groups, both creative and destructive, this is due to the "work group". According to Bion this is the aspect of the group that does "keep the group anchored to a sophisticated and rational level of behaviour" (Bion 1961). The activity of the work group increases order but reduces the amount of information that can be extracted. At the same time the disorder, both creative and destructive decreases, and this is a sign of a reduction of the effect of the basic assumptions. The action of the basic assumptions is to increase the disorder, but also to increase the amount of information that can be extracted from the group.

In this sense the observed evolution of entropy indicates that the work group progressively, but not monotonically, supersedes the action of the basic assumptions, once the information available is extracted and made explicit, and order is brought into the group, while creativity and disorder are reduced. This again is in accordance with Bion's view of the group dynamics, as he maintains that the action of the "work group" tends to eventually prevail.

Because of the precocious groupal orientation of the unconscious it would be important in following study to test the group of participants with an absurd test before personal interaction in group experience.

We are beginning a new study very similar to this described in this thesis in OMIE, starting from September 2014 following a year of training. In this new protocol an absurd questionnaire will be proposed to participants before any group situation at the moment of the inscription to the training.

Another study is now in work in the university of Gangneung in Korea, following an year of courses in the Biology faculty of the University of Gangneung, in this study too an absurd questionnaire will be propose to participant before any group situation before the beginning of the courses.

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Annexes

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Quantum Mechanics and the Psyche[¶]

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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.

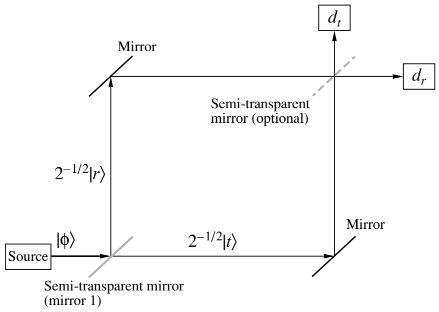
Finally, let us mention some works on quantum theories of consciousness related to physical states of the brain. In addition to those already quoted (by Ricciardi and Umezawa [7]), there are Beck and Eccles' work [13], those of Penrose [14], and those in which Penrose collaborated with Hameroff [15].

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 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.



The photon delayed-choice experiment.

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:

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

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:

$$p_n = |\langle\psi_n|\phi\rangle|^2. \quad (6)$$

"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

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

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:

$$\rho = |\psi_m\rangle\langle\psi_m|. \quad (8)$$

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)

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

The von Neumann entropy of this system is

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

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:

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

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

$$p_K = \sum_{n \in K} p_n, \quad (12)$$

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

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

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

$$S_J - p_K S_K, \quad (14)$$

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

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

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

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

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

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

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

which is a positive quantity, or increased by

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

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

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

"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":

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

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):

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

[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:

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

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):

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

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 *C*3, or even the collective unconscious $|G(t)\rangle$). We then obtain

$$\rho_{C1C2} = \sin^2\theta|C10\rangle\langle C10||C20\rangle\langle C20| + \cos^2\theta|C11\rangle\langle C11||C21\rangle\langle C21| \quad (29)$$

related to an increase in entropy

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

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 $|G_{\text{Individual}}(t)\rangle$ 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 $|G_{\text{Individual}}(t)\rangle$.

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

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

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 $H_{\text{Repressed}}$ 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:

$$|CR2\rangle = a|CR20\rangle + b|CR21\rangle. \quad (42)$$

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:

$$|CR2, C_{\text{Ego}}2\rangle = a'|CR20\rangle|C_{\text{Ego}}20\rangle + b'|CR21\rangle|C_{\text{Ego}}21\rangle. \quad (43)$$

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:

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

which we can rewrite by putting

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

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

and

$$|CD21\rangle = |CR21\rangle|C_{\text{Ego}}21\rangle|C_{\text{Id}}21\rangle|C_{\text{Super-ego}}21\rangle \times|C_{\text{OneSelf}}21\rangle\ldots, \quad (44)$$

$$|CD2\rangle = \sin\theta|CD20\rangle + \cos\theta e^{i\phi}|CD21\rangle,$$

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 π/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 π/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:

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

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

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

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:

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

that is,

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

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:

$$|CI0\rangle = |CI10\rangle|CI20\rangle \quad (49)$$

and

$$|CI1\rangle = |CI11\rangle|CI21\rangle. \quad (50)$$

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

$$|CD0\rangle = |CD10\rangle|CD20\rangle \quad (51)$$

and

$$|CD1\rangle = |CD11\rangle|CD21\rangle. \quad (52)$$

We can then rewrite formula 45 with group notation:

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

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

$$|CC0\rangle = |CC10\rangle|CC20\rangle \quad (54)$$

and

$$|CC1\rangle = |CC11\rangle|CC21\rangle, \quad (55)$$

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

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

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 Subsection 7.1, we can write the quantum state of the group related to the mourning (of the loss of the leader) as follows:

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

and we can reformulate this by defining

$$|CDgroupe\rangle = |CBob, CAlice, CPeter, CPaul, CMatthew, CJohn, CSandra, \ldots\rangle,$$
$$|CDgroupe\rangle = |CBob0, CAlice0, CPeter0, CPaul0, CMatthew0, CJohn0, CSandra0, \ldots\rangle,$$

and

$$|CDgroupe1\rangle = |CBob1, CAlice1, CPeter1, CPaul1, CMatthew1, CJohn1, CSandra1, \ldots\rangle,$$
$$|CDgroupe\rangle = \sin\theta|CDgroupe0\rangle + \cos\theta e^{i\phi}|CDgroupe1\rangle. \quad (57)$$

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:

$$|CDg, CIg, CCg\rangle = \sin\theta|CDg0\rangle|CIg0\rangle|CCg0\rangle + \cos\theta e^{i\phi}|CDg1\rangle|CIg1\rangle|CCg1\rangle. \quad (58)$$

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:

$$\rho_{CIg, CCg} = \sin^2\theta|CIg0\rangle\langle CIg0||CCg0\rangle\langle CCg0| + \cos^2\theta|CIg1\rangle\langle CIg1||CCg1\rangle\langle CCg1|. \quad (59)$$

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

$$S(CIgroupe, CCgroupe) = -(\sin^2\theta\ln(\sin^2\theta) + \cos^2\theta\ln(\cos^2\theta)). \quad (60)$$

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:

$$S(CDg|CIg, CCg) = -S(CIg, CCg) = \sin^2\theta\ln(\sin^2\theta) + \cos^2\theta\ln(\cos^2\theta). \quad (61)$$

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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Quantum Information, Oscillations and the Psyche[1]

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

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1. INTRODUCTION

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

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

[1] The article is published in the original.
[2] Concerning this subject we shall read with interest the review of H. Atmanspacher, *Quantum Approaches to Consciousness*, in the Stanford Encyclopedia of Philosophy [14]. This paper reviews the situation on present quantum theories of consciousness.
[3] Nevertheless one does not exclude the other.

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

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

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

In previous articles [15, 16] we tried to model the awareness of unconscious components from the present theories of quantum measurement, consciousness acting like a measuring device. We concluded that the model of quantum information of Cerf and Adami [19], in which there is no collapse of the wave function, seems to fit better to the phenomenon of awareness, because it does not alter so much the state of the unconscious. Let us notice that Everett's "Relative State" or "many-worlds" theory [20–22] can also serve the purpose.

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

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

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

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

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

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

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

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

Let us notice that, in all processes that we investigate (unconscious/unconscious, pre-consciousness/consciousness, ...), quantum information theory and the analogy with NMR lead to Rabi oscillations. Those oscillations can be of paramount importance for mental systems. Thus neuroscientists discovered "oscillations" as interhemispheric switchings in the brain in the case of binocular rivalry (see for example references [31, 32]).

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

2. ANALOGY BETWEEN UNCONSCIOUS PROCESSES BY JUNG AND QUANTUM MECHANICS

2.1. Amplification

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

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

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

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

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

2.2. Anima, Animus and Persona

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

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

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

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

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

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

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

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

2.3. Archetypes

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3. NUCLEAR MAGNETIC RESONANCE FORMALISM: APPLICATION TO THE UNCONSCIOUS

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

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

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

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

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

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

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

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

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

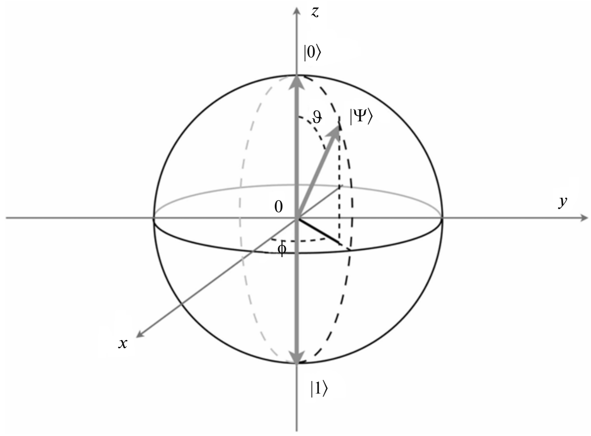

Fig. 1. Bloch's sphere which enables to represent the qubit $|\Psi\rangle$ by a vector of polar angles ϑ and ϕ.

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

3.1. Qubits

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

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

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

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

Pointer-states of mental qubits related to mourning

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

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

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

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

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

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

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

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

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

3.2. Rotations of a Qubit

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

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

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

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

with the usual Pauli matrix notations:

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

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

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

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

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

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

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

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

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

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

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

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

In such a coordinate system the complete Hamiltonian is:

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

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

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

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

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

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

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

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

3.3. Rotations of a Mental Qubit

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

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

4. INTERACTIONS BETWEEN TWO QUBITS

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

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

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

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

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

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

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

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

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

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

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

[8] See footnote 7.

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

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

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

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

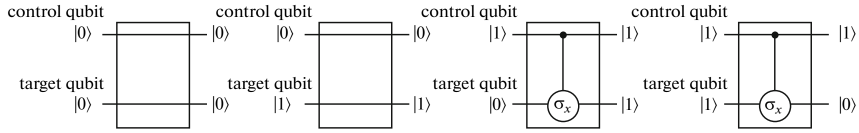

Fig. 2. Representation of the CNOT_{12} gate for base qubits (see formula (16)).

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

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

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

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

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

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

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

4.1. Implementation of Two-Qubit Logical Quantum Gates

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

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

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

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

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

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

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

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

in matrix notation:

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

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

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

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

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

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

4.2. CNOT Gate Properties

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

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

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

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

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

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

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

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

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

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

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

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

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

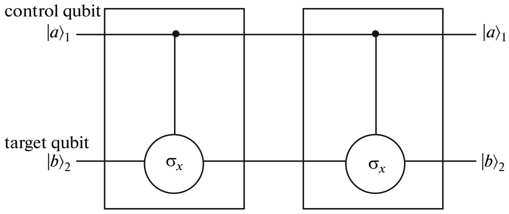

Fig. 3. Product of the $CNOT_{12}$ gate by itself giving identity.

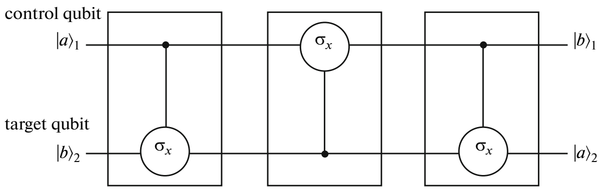

Fig. 4. Gate sequence $CNOT_{12}CNOT_{21}CNOT_{12}$ giving a swapping.

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

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

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

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

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

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

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

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

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

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

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

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

4.3. Awareness

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

which is the qubit representing the unconscious related to mourning.

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

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

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

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

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

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

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

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

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

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

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

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

and

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

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

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

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

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

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

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

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

5.1. Special Cases

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.2. General Case

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

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

and

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

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

[21] Let us recall that in this case $\theta_I(0) = \theta_U(0) = 0$.
[22] Let us recall that initially, at time $t = 0$, thanks to swappings pre-consciousness is in the quantum state of the unconscious.

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

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

with

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The calculation of this trace leads to:

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

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

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

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

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

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

with

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

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

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

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

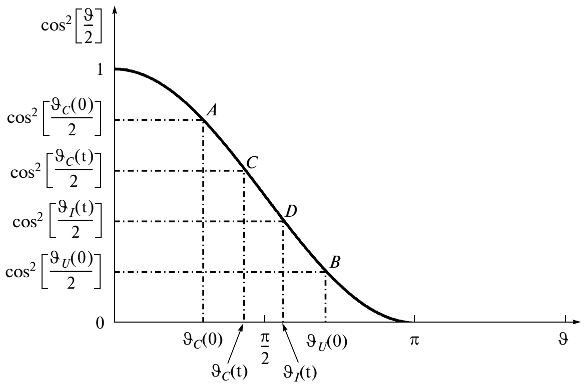

Fig. 5. Variations of $\vartheta_C(t)$ and $\vartheta_I(t)$ angles as functions of time in the general case (formulae (68) and (73)).

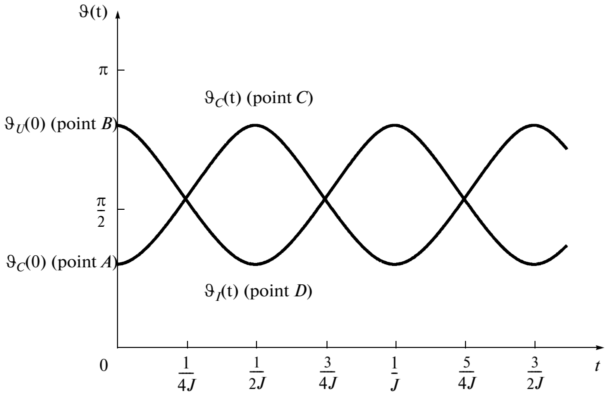

Fig. 6. Explicit variations of $\vartheta_C(t)$ and $\vartheta_I(t)$ angles showing oscillations as functions of time in the general case (formulae (68) and (73)).

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

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

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

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

$$\cos^2[\theta_C(t)/2] = \cos^2[\theta_C(0)/2]\cos^2(\pi Jt) + \cos^2[\theta_U(0)/2]\sin^2(\pi Jt). \quad (68)$$

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

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

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

Calculation of this trace leads to:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

i.e.

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

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

$|I(t = 1/(2J))\rangle = |C(0)\rangle$ and $|C(t = 1/(2J))\rangle = |I(0)\rangle$.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

7. INTERACTION BETWEEN TWO UNCONSCIOUS

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

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

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

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

and

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

8. DISCUSSION

8.1. Nuclear Magnetic Resonance and Mental Qubits

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

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

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

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

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

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

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

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

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

[27] On this subject, see Footnote 9.

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

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

8.2. Mental Rabi Oscillations

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

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

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

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

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

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

[29] See footnote 15.

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

[31] Alain Connes, private communication.

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

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

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

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

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

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

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

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

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

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

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

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

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

Let us note that these three points are effectively correlated.

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

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

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

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

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

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

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

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

9. CONCLUSIONS AND PERSPECTIVES

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

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

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

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

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

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

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

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

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Article

Quantum Information Theory Applied to Unconscious and Consciousness

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ABSTRACT

In this paper we make some comments about notions we already introduced in previous articles. First we further study the quantum field model of consciousness and unconscious built up together with Belal Baaquie and show that it is a quantum formulation of the layered model of the Collective Unconscious established by C. G. Jung in 1925. Then we further study quantum information and quantum cloning in order to apply them to amplification of unconscious components in such a way that they reach consciousness. After that, we study consciousness and its special feature when it consists in awareness of unconscious states. This leads us to examine if Archetypes could be quantum systems. In conclusion, we list various points of view about the essence of consciousness. The fact that quantum entanglement is "controlled" from *outside space-time* leads to the conclusion that consciousness would be an entity which acts from *outside space-time*.

Key Words: psychophysics, archetypes, consciousness, unconscious, quantum information

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1. Introduction

As Jung said in his conference at a symposium in London in 1919 (Jung, 1970): "The archetypes are being *engraved on the human mind*". Hogenson in his paper (Hogenson, 2001) argues that "This latter expression is taken by some commentators to be indicative of Lamarckian tendencies in Jung's thought" (Stevens, 1990; Stevens, 1998; Stevens and Price, 1996). This Jung's sentence correlates the experience into our psychic constitution as form without content: "There are as many archetypes as there are typical situations in life. Endless repetition has engraved these experiences into our psychic constitution, not in the form of images filled with content, but at first only as form without content, representing merely the possibility of a certain type of perception and action" (Jung, 1959). However, following Hogenson, Jung was interested in the evolutionary history of the mind with no implied commitment to any particular theory of evolution.

Although Darwin (1809-1882) disliked the association between his theory and the theory of Lamarck (1744-1829), we have to remember that the work of Gregor Mendel was rediscovered only in 1900.

To say that the appearance and evolution of archetypes is explained by the evolution theory does not mean that we know where archetypes are "stored" (In the brain? Are they coded by the DNA? Will we find a "gene of the archetype"?). Moreover one should also explain how the archetypes constitute an "evolutionary advantage" that has been selected and preserved. Moreover, even advocating evolutionary theory, we still find a fundamental difference between archetypes and, for instance, language. Human languages have diverged over the course of centuries, while archetypes have remained substantially invariant across time and space.

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Could we say that they belong to the realm of Platonic ideas?

In 1925, Carl G. Jung had the idea of a kind of geological survey of the psyche (Jung, 1925). Jung's description of the geology of the psyche is shown on Figure 1.

At the basis of the psyche there is what Jung called the central fire (H).[2] Then there is the layer corresponding to general animal ancestors (G), the layer corresponding to primitive ancestors (F), the layer corresponding to large groups, such as Europeans (E), the layers corresponding to nations (D), to clans (C), to families (B) and to finish an individual psyche appears. In Jung's sketch of the psyche, ego, or consciousness of an individual, appears as a peak. The personal unconscious underlies it. Next, the Collective Unconscious (Jung, 1961; 1991), starting from the family's unconscious until the animal ancestors (or even until the beginning of life), underlies the personal unconscious. At the bottom of all things, or at the beginning of all things, there is the central fire (or quantum vacuum).

An original property of Jung's vision of the human psyche is that the central fire is directly connected to the individual's unconscious. The central fire permeates every layers of the Collective Unconscious and comes right up to the personal unconscious if we let it do it. The vacuum or the central fire containing all the seeds of all archetypes, this means that we can have direct access to archetypes. This direct access of an individual's unconscious to the vacuum, or the central fire, can explain some kind of dreams, especially archetypal dreams (such as Pauli's dreams). It may also explain some a-causal events such as synchronicity effects. We can assert that an individual unconscious "knows everything", in the sense that any individual unconscious has access to any information in the Universe. This does not mean that this information will necessarily reach the consciousness of any individual.

In 2003, Baaquie and Martin (2005) rediscovered this Jung's geological survey model of the psyche in the framework of quantum field theory. In particle physics we postulate the existence of quantum fields associated to each elementary particle. Those fields are operators defined in all space-time and acting on states, vectors of a Hilbert space, corresponding to the wave function of a set of particles. A quantum field associated to a particle is the sum of a creation operator of the particle together with an annihilation operator of the particle. Thus the creation operator acting on the quantum vacuum $|\Omega\rangle$ creates a state of the particle. The quantum vacuum contains all the quantum fields in a virtual state, i.e., none of the normal modes of the fields are excited in the vacuum, although they are virtually present.

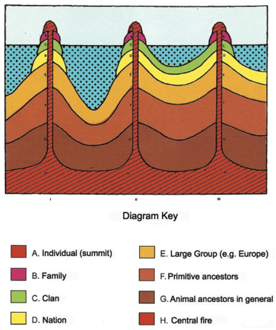

Figure 1. Jung's volcanoes diagram.

Baaquie and Martin postulated that, like matter, mental states and human consciousness (and unconscious) would be of quantum nature. Thus they assume that the human psyche would be a particular excitation of an underlying universal mental (unconscious and consciousness) quantum field[3]. The human psyche is postulated to have a representation similar to a quantum system, with virtual and physical states corresponding to the potentiality and actuality of the human mind.

To describe the human psyche they suppose the existence of two kinds of quantum fields, namely one that refers to the specific individuality of the person, and which should be more or less localized with the person's specific existence and excludes other person's individual quantum field. The other quantum field represents the universality of the human psyche, which can overlap and include other's consciousness. It is natural to represent the individualized state of the human psyche by a

[2] Later we will see that this central fire may be what physicists call the quantum vacuum.

[3] In the following when we will refer to a quantum field of consciousness it will necessarily include the unconscious.

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fermion field $\psi(t,x)$ and the universal character of human consciousness by a boson field $\varphi(t,x)$, where t, x are time and space coordinates.

As physicists try to unify all quantum fields of matter in a unique quantum field, we can try to unify the consciousness fields $\psi(t,x)$ and $\varphi(t,x)$ described above with this (possible) unique quantum field of matter and obtain a unique quantum field describing both matter and mind. In this way we will approach the holistic reality, the *Unus Mundus*, the "one world" of the 16th century alchemist Gerhard Dorn. This *Unus Mundus* was advocated by Jung and Pauli as the underlying reality in which mind and matter are unseparated. The "consciousness field" was separated from the unique quantum field of matter at the beginning of the Universe, but both fields remained quantum entangled. This happened when space-time was generated, i.e., at time $t = 10^{-43}$ second, which is Planck's time, after the Big Bang. Of course, at that time, the individual centred consciousness field was zero together with all the boson fields $\varphi_i(t,x)$ associated with each layers of Jung's volcanoes diagram (from B to G; see Figure 1). But all the seeds of those quantum fields, together with the seeds of archetypes, were present in the vacuum or the central fire (Figure 1).

However there are some problems. First, how did space-time emerge from this *Unus Mundus*, which could be the quantum vacuum or the central fire of Jung? Second, for Jung, the psyche is timeless and spaceless, i.e., it has its roots beyond space-time. But we already know that even in relativistic quantum field of matter there are some problems with space-time, especially in quantum gravity. Moreover we know that quantum entanglement transcends our notions of space and time (Caponigro, 2009). As far as matter and psyche are concerned, prior to any measurement, quantum correlations due to quantum entanglement are relevant to what David Bohm calls the *implicate* (or *enfolded*) order, which is beyond space-time, unlike the *explicate* (or *unfolded*) order which describes the phenomena that are manifest to our senses (consciousness) and to our instruments (Bohm, 1980). The implicate (or enfolded) order is in an undivided (or *unfragmented*) form, while the explicate (or unfolded) is in a *fragmented* form. In the implicate order, mind and matter are unseparated (non-separable) entities.

For a lot (but not all; see for example references Eccles, 1994; Beck and Eccles, 1998) of neuroscientists, consciousness, pre- and un-consciousness are simply processes measuring dynamical complexity in the neural systems underlying consciousness: e.g., neural complexity, information integration and causal density (see Seth, Izhikevich, Reeke and Edelman, 2006).

At the beginning of his article, "*Synchronicity, Mind and Matter*" (Duch, 2003), W. Duch quotes, as a motto, a sentence of Pauli: "It would be most satisfactory if physics and psyche could be seen as complementary aspects of the same reality" (Jung and Pauli, 1952). Complementarity is the fact that two properties of a system are contradictory but nevertheless coexist in the system and appear depending on the kind of experiment we perform on the system. The best example is the wave aspect and the corpuscular aspect of matter.

In their paper Baaquie and Martin (2005) propose a simplified model for the ground state of the human species. This ground state $|G(T)\rangle$ represents the total sum (or rather the total product) of all the excitations on the vacuum state $|\Omega\rangle$ of the "consciousness field" that has been effected by human subjectivity over the entire period of human evolution. It is on this ground state that the present day psyche of human beings is standing, and the entire theoretical structure that we are born into is encoded in the ground state $|G(T)\rangle = |G\rangle$, where T stands for our contemporary time. Let us notice that this ground state $|G(T)\rangle = |G\rangle$ is an unconscious state[4], and that it has a structure close to what the Swiss psychoanalyst C. G. Jung called the Collective Unconscious.

Then, starting from this ground state of the human species and taking account of the contributions of the mother, the father, and all the siblings, the grandparents and uncles and aunts and first cousins and so on, Baaquie and Martin built a family effective ground state[5]

[4] From which some components can come to consciousness
[5] Which is still an unconscious state, from which some components can come to consciousness.

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$|G_{Effectif}\rangle$ on which we can create an individual's ground state[6] together with the individual's mental states, which can be either unconscious or conscious.

In their paper they wrote: "What is our interpretation of the vacuum state $|\Omega\rangle$? It contains the seeds of all possible forms of subjectivity and consciousness that can exist in the Universe – be it human consciousness (and unconscious), or the consciousness of animals, or that of other alien species in some other planet. It is the state of possibility of all the psychic qualities and attributes of the Universe, all the laws and structure of the physical Universe." If we follow Jung the vacuum should also contain the seeds of all archetypes. Let us notice that we have a unique vacuum both for matter and for the psyche.

Baaquie and Martin's model is a layered model starting from the vacuum in which the various layers are generated by creation operators, i.e., mental fields. Thus there is a layer corresponding to life, another one corresponding to animals, then one corresponding to the human species, another one corresponding to a family until we reach the consciousness (and unconscious) of one individual belonging to that family.

How can we insert this direct connection between the vacuum and an individual's unconscious in a quantum field theory of the psyche? It could be similar to what happens in quantum field theory of matter in which vacuum permeates all space-time and all matter, leading to processes such as vacuum fluctuations which lead to observable, finite physical effects, e.g., in the Lamb shift.

To each layer of Jung's volcanoes diagram (from B to G) we can associate a boson field $\varphi_i(t,x)$ which is included in the Impersonal (general) "consciousness" field $\varphi(t,x)$ described above (which includes the unconscious) and which represents the Collective Unconscious. In conclusion, we can say that Baaquie and Martin (2005) have drawn up a quantum interpretation, in terms of quantum fields, of Jung's layered model of the Collective Unconscious. But they have done more than this, in the way that they have considered that the existence of a universal quantum field of "consciousness"[7] could represent not only the Collective Unconscious but also a universal consciousness or awareness. The metaphor would be the one of a universal ocean of consciousness in which an individual consciousness would be like a wave that comes out of the ocean and eventually returns to the ocean.

In 2007, Carminati and Martin (2008; Martin and Galli Carminati, 2009) studied the individual unconscious and consciousness as quantum systems, i.e., as vectors of a Hilbert space. In such a frame they studied the phenomenon of consciousness and especially the awareness of unconscious components. Writing down the state of the unconscious as $|U\rangle$ and the state of consciousness as $|C\rangle$, they introduced another state of the unconscious $|I\rangle$ which is the insight or pre-consciousness[8]. By building a model of quantum entanglement between those three states they apply it to the awareness of unconscious components.

In 2009 we took the theory of quantum information as a model for the psyche (Martin, Carminati, Galli Carminati, 2009; 2010). We considered the individual human unconscious, pre-consciousness and consciousness as sets of quantum bits (qubits). We viewed how there can be communication between these various qubit sets. In doing this we were inspired by the theory of nuclear magnetic resonance (NMR). In this way we built a model of handling a mental qubit with the help of pulses of a mental field. Starting with an elementary interaction between two qubits we built two-qubit quantum logic gates that allow information to be transferred from one qubit to the other. In this manner we built a quantum process that permits consciousness to "read" the unconscious and vice versa. The elementary interaction, e.g., between a pre-consciousness qubit and a consciousness one, allows us to predict the time evolution of the pre-consciousness + consciousness system in which pre-consciousness and consciousness are quantum entangled. *This time evolution exhibits Rabi oscillations that we named*

[6] Same as Footnote 5.

[7] See Footnote 3.

[8] In this article we will consider the insight states $|I\rangle$ and the pre-consciousness states $|P\rangle$ as different quantum states. Insight, which designates also perspicacity or intuition, is different from pre-consciousness which designates those quantum states which are "close" to consciousness. Latter in this article we will use insight as an ancilla or cloning machine M.

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mental Rabi oscillations. This time evolution shows how for example the unconscious can influence consciousness. In a process like mourning the influence of the unconscious on consciousness, as the influence of consciousness on the unconscious, are in agreement with what is observed in psychiatry.

In Section 2 of this article we remind one of our representation of mental qubits and of quantum psyche fields built by analogy with spin-qubits and magnetic fields in NMR. In Section 3, still by analogy with NMR, we remember how to rotate a mental qubit on the Bloch's sphere by a pulse of a quantum psyche field with could be the quantum field of consciousness (volition), or of the individual unconscious, or of Jung's Collective Unconscious (archetypes), or even a quantum field of someone else's unconscious (e.g., in the framework of psychoanalysis). In Section 4 we describe the three main types of contact interactions between two qubits, which are used in quantum information and could be applied to mental qubits. Then we remind one of the implementation of controlled-NOT (CNOT) two-qubit quantum gate which leads to *quantum entanglement* and to *non-separable* qubit systems. Due to a basic theorem of quantum computation which states that any unitary transformation on a two-qubit system can be factorized into a CNOT gate and rotations described in Section 3, we can build quantum circuits with any number of qubits. Therefore we can build *non-separable* qubit systems with any number of qubits. In Section 5 we consider quantum cloning. There is a *no-cloning theorem*, due to Wootters and Zurek (1982), which prevents to duplicate perfectly an arbitrary quantum state. However it is possible to make an approximate quantum cloning which could be optimal. In quantum optics, using (approximate) quantum cloning, it is possible to amplify a quantum state in an optimal way. By analogy, we speculate that it is an approximate process of quantum cloning which amplifies the information contained in the unconscious. The *quantum no-cloning theorem* could explain why, for example, the information contained in a dream is transformed during the process of amplification before reaching consciousness. This is quite important since "dreams are the royal road which leads to the unconscious" (Freud, 1920).

In Section 6 we consider consciousness and its various forms. First we study perceptive consciousness (subsection 6.a). In a normal state of awake consciousness, our sensor senses comprehend a "*classical*" external world, i.e., a world without superposition of states. But, as far as our internal world (mental states) is concerned (subsection 6.b), we show that our consciousness can comprehend a quantum world, with "pointer-states" (i.e., *classical* states, Zurek, 2007) together with interferences between them (i.e., superposition of mental states). In the same line of thought, we point out another difference between physical and mental states: If, in order to become *classical, quantum* physical states may be subjected to collapse of the wave function (or reduction of the wave packet),- a fact which is far to have unanimous support from physicists -, there is no such process for quantum mental states. A mental state can become conscious without any collapse of the wave function, i.e. without destroying the superposition of mental states, a phenomenon which fits with Everett's "Relative State" or "many-worlds" theory (Everett, 1957; Wheeler 1957). In continuation of those ideas, we study awareness of unconscious states (subsection 6.c). We put the emphasis on the fact that if, for physical states, decoherence (interaction with the environment) is of paramount importance in the transition from *quantum* to *classical*, there is no such process like decoherence in the realization of unconscious states (subsection 6.d).

In Section 7 we consider Archetypes which are, according to C. G. Jung (1971: page 167), basic entities of the deep Collective Unconscious. We tell apart Archetypes (with a big A) and archetypes (with a small a). We call them Archetypes, with a big A, when they are "*empty of form*", i.e., empty of any representation. In this instance they are quantum systems which simply contain quantum information. They could be quanta of the Universal Unconscious Quantum Field. The interaction of those Archetypes with an individual unconscious (especially with memory states) and also with some parts of the Collective Unconscious (especially the collective memory states of the human species) will make appear archetypes (with a small a) which will be representations of the Archetypes. Those archetypes can be considered as "pointer-states" of the unconscious, but of a very special kind. Contrarily to what occurs in quantum physics,

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these archetypal "pointer-states" of the unconscious coexist in the same representation, in the same archetype. In this way archetypes are conjunctions of opposites. They cannot be considered as *classical*, they remain *quantum*. We give some examples of archetypes: "young and old woman" (Figure 6), Rebis (Figure 7), representation of Shiva (Figure 8).

Then we make some comments about mathematics considered as Archetypes (subsection 7.1). Finally our conclusions are given in Section 8.

2. Quantum information theory: qubits

In his paper "World as system self-synthesized by quantum networking" J. A. Wheeler (1988) sees the world as a "self-synthesizing system of existences, built on observer-participancy via a network of elementary quantum phenomena. The elementary quantum phenomena in the sense of Bohr, the elementary act of observer-participancy, develops definiteness out of indeterminism, secures a communicable reply in response to a well-defined question." To such a well-defined question there is a yes or no answer. For example the no answer will be represented by the state $|0\rangle$ and the yes answer by the state $|1\rangle$. The elementary quantum state will be a qubit (quantum bit) which is a superposition of the states $|0\rangle$ and $|1\rangle$:

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

This qubit is represented by a vector on the Bloch's sphere (Figure 2).

In references (Galli Carminati and Martin, 2008; Martin and Galli Carminati, 2007; Martin, Carminati and Galli Carminati 2009; 2010) we have represented the unconscious of a person in a mourning process by the qubit:

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

where $|U0\rangle$ is the state corresponding to a mourning that is accomplished and $|U1\rangle$ the state corresponding to a mourning that is not achieved. Let us notice that the qubit $|U\rangle$ has to be multiplied by a function $f_U(\vec{x},t)$ which is the probability amplitude of finding the qubit $|U\rangle$ at the space-time point $(\vec{x},t)$. For an individual unconscious qubit this probability amplitude is more or less located in the body of the individual, especially in his brain.

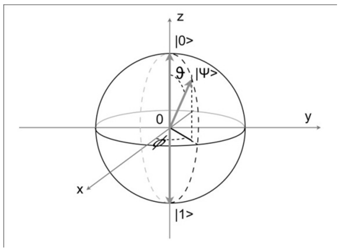

Figure 2. Bloch's sphere which enables to represent the qubit $|\Psi\rangle$ by a vector of polar angles θ and φ.

By analogy with the theory of nuclear magnetic resonance (NMR) we assume that there is a psyche mental field $\vec{B}_{U0}$ which points toward the direction of the qubit $|0\rangle$, i.e., toward the direction of the *Oz* axis on the Bloch's sphere. This psyche mental field $\vec{B}_{U0}$ is the analogue of the magnetic field $\vec{B}_0$ in NMR (Martin, Carminati and Galli Carminati, 2010; Vandersypen and Chuang, 2004). It has a space-time dependence, i.e., it depends on the space-time point$(\vec{x},t)$, and it can be a quantum field which means that since it points along the *Oz* axis it is a quantum field of which creation operator of a field quantum is proportional to the Pauli matrix σ_z.

Let us notice that the axes *Ox, Oy* and *Oz* of the Bloch's sphere are not space axes, since the Bloch's sphere is not a sphere in space but in the Hilbert space of the qubit. *Oz* axis direction is nothing else but the pointer-state directions $|U0\rangle$ (*e.g.,* father is dead) and $|U1\rangle$ (*e.g.,* father is alive). So the psyche field $\vec{B}_{U0}$ that "selects" this direction is a field related to the external reality and consequently to the environment. It is a quantum psyche field which has its roots in the external reality, in the environment. It measures the relation of the individual unconscious and consciousness with external reality.

Let us also notice that this psyche field $\vec{B}_{U0}$ that "selects" the pointer- states direction could also be a field related to the Collective Unconscious and more specifically to archetypes. As an example the archetype of

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"Eternity" will select the pointer-state $|U1\rangle$ (father is alive and never dies) in the unconscious. If the father is really dead, this unconscious state $|U1\rangle$ will be in contradiction with the state of consciousness $|Co\rangle$ (father is dead).[9]

3. Rotation of a qubit

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

$$R_{\vec{n}}(\theta_1) = \exp[-i\theta_1\vec{n}\cdot\vec{\sigma}/2] \qquad (3)$$

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

In reference (Martin, Carminati and Galli Carminati, 2010), still by analogy with NMR, we showed that any rotation (3) of a qubit on the Bloch's sphere can be implemented by a pulse of a psyche field $\vec{B}_{U0}$ "along the *Oz* axis", together with a radio-frequency pulse (RF pulse) in the (*Ox, Oy*) plane. Such a radio-frequency pulse is the pulse of a psyche field $\vec{B}_{U1}(t)$ (analogue to an electromagnetic field) which rotates in the (*Ox, Oy*) plane with frequency $\omega_{rf}/2\pi$, this frequency being equal or close to the Larmor frequency $\omega_0/2\pi$.[10,11] When the rotating frequency $\omega_{rf} = \omega_0$ (resonance), such a RF pulse is called a Rabi pulse.

For a mental qubit representing mourning (formula (2)), or for any binary mental state, a pulse of a psyche field "along the *Oz* axis", $\vec{B}_{U0}$, modifies the ϕ angle without modifying the θ angle, a fact which is not very interesting concerning the evolution of mourning, this one being "measured" by the variation of the θ angle.

By contrast a psyche field pulse "rotating in the (*Ox, Oy*) plane", $\vec{B}_{U1}(t)$, will modify the θ angle and therefore will make mourning evolve. For simplicity let us assume that the ϕ angle is equal to 0. Therefore in such a case a psyche field pulse pointing along the *Oy* axis will modify the θ angle by a quantity proportional to the duration t_p of the pulse. Effectively, in order for mourning to evolve in the "good" way, i.e., that the θ angle tends toward 0, it is necessary for the psyche field to point along the direction −*Oy*.

We have seen that the quantum psyche field, $\vec{B}_{U0}$, has its roots either in the external reality, in the environment, - it measures the relation of the individual unconscious and consciousness with external reality - , or in the Collective Unconscious (archetypes). What about the rotating quantum psyche field, $\vec{B}_{U1}(t)$? It could be a quantum field of consciousness (the will) or of the individual unconscious, e.g., of Freud's Id, Repressed, Ego and Super-ego, or of Jung's Persona, Shadow and Oneself. It could also be a quantum field of the Collective Unconscious (archetypes) or a quantum field of someone else's unconscious (e.g., in the framework of psychoanalysis).

4. Interaction between two qubits

In reference (Martin, Carminati and Galli Carminati, 2010) we have studied the effect of a contact interaction between two qubits of which the Hamiltonian is:

$$H_J = hJ\vec{I}^1 \otimes \vec{I}^2 \qquad (4)$$

where $\vec{I}^1 = \vec{I}^1_x\vec{e}_x + \vec{I}^1_y\vec{e}_y + \vec{I}^1_z\vec{e}_z = \vec{\sigma}^1/2$, $\vec{\sigma}^1$ being the Pauli matrix vector acting on qubit 1. The same is true for $\vec{I}^2 = \vec{\sigma}^2/2$, which concerns qubit 2. This is the Hamiltonian of an isotropic Heisenberg exchange interaction. It appears mainly in solid-state quantum information. The J constant is the coupling strength between the two qubits.[12]

[9] See Special case I (Subsection 5.1.1) in reference (Martin, Carminati and Galli Carminati, 2010)

[10] For a definition of the Larmor frequency $\omega_0/2\pi$, see reference (Martin, Carminati and Galli Carminati, 2010).

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

[12] The fact that Planck's constant *h* appears in a Hamiltonian supposed to describe a mental process looks meaningless, this constant being involved *a priori* only in microscopic matter processes. Moreover until proved otherwise we have not clearly define what is mental energy. However that may be, in Schrödinger's equation or in the time evolution operator *U(t)*, only the operator *H/h* takes place. Therefore Planck's constant does not appear in quantities that interest us, i.e. the time evolution operators. Let us notice that,

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

$$\vec{I}^1 \otimes \vec{I}^2 = \left(\sigma_x^1 \otimes \sigma_x^2 + \sigma_y^1 \otimes \sigma_y^2 + \sigma_z^1 \otimes \sigma_z^2\right)/4 \qquad (5)$$

In NMR, for nuclear spins in a static magnetic field $\vec{B}_0$ along the *Oz* axis, and under some conditions, the Hamiltonian (4) simplifies to:

$$H'_J = hJI_z^1 \otimes I_z^2 \qquad (6)$$

which is known as the Hamiltonian of a secular interaction.

In reference (Martin, Carminati and Galli Carminati, 2010), we have also assumed that in the presence of the quantum psyche field $\vec{B}_{U0}$, the interaction Hamiltonian (4) simplifies to the Hamiltonian (6). The interaction Hamiltonian (6) proves very useful to implement logical two-qubit gates.

There is a third Hamiltonian of a "contact type" interaction between two qubits, known as the flip-flop interaction:

$$\begin{aligned} H''_J &= hJ\left(\sigma_x^1 \otimes \sigma_x^2 + \sigma_y^1 \otimes \sigma_y^2\right)/4 \\ &= hJ\left(\sigma_+^1 \otimes \sigma_-^2 + \sigma_-^1 \otimes \sigma_+^2\right)/2 \end{aligned} \qquad (7)$$

This last interaction leads to Rabi oscillations of frequency J.

4.1 Implementation of two-qubit logical quantum gates

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

$$U_{CNOT} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix} \qquad (8)$$

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

$$|00\rangle = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad |01\rangle = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \quad |10\rangle = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \quad |11\rangle = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \qquad (9)$$

The U_{CNOT} transformation flips qubit 2 (target qubit) if and only if the quantum state of qubit 1 (control qubit) is $|1\rangle$ (Figure 3).

In the following we will represent the CNOT gates by the diagram of Figure 4. A basic theorem of quantum computation states that up to an irrelevant overall phase, any unitary transformation U acting on two qubits can be factorized into a U_{CNOT} gate and rotations $R_{\vec{n}}(\theta_1)$ acting on each of the two qubits (Nielsen and Chuang, 2000).

By analogy with NMR, in reference (Martin, Carminati and Galli Carminati, 2010) thanks to the interaction (6) acting between the two qubits during a given time $t = 1/2J$, and thanks to radio-frequency pulses acting on each of the two qubits also during a given time, we are able to implement a CNOT gate between two qubits and therefore to implement any unitary transformation on a two-qubit system.

Usually, if initially the system of the two qubits is in a factorized state $|\Psi_1\rangle|\Psi_2\rangle$, after going through the CNOT12 gate, the state of the two-qubit system will be *non-separable*. The two qubits will be quantum entangled.

In reference (Martin, Carminati and Galli Carminati, 2010), we saw that the product of the three CNOT gates: CNOT12 CNOT21 CNOT12 exchanges the states of qubits 1 and 2. It is a swapping of the states of qubits 1 and 2.

Knowing that any unitary transformation U acting on two qubits can be factorized into a U_{CNOT} gate and rotations $R_{\vec{n}}(\theta_1)$ acting on each of the two qubits we can build quantum circuits with any number of qubits. An example of such a circuit is given on Figure 5 (Haroche, 2010; Buzek and Hillery 1996; Scarani *et al.*, 2005).[13]

according to Lotka (1925; Vannini, 2008), Planck's constant could intervene in the phenomenon of emergence of (subjective) consciousness.

[13] This Figure is excerpted from Serge Haroche's Quantum Physics Lesson of February 1st 2010 (Haroche, 2010).

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Group Unconscious Common Orientation: Exploratory Study at the Basque Foundation for the Investigation of Mental Health Group Training for Therapists

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ABSTRACT

Group phenomena have been used since antiquity in therapeutic, social, economic and political domains. According to Bion, the interactions between group members generate a "group unconscious" and its behavior is governed and oriented by Bion's "basic assumptions." The present work has been conducted during group analysis training at the Basque Foundation for the Investigation of Mental Health (OMIE) at Bilbao, consisting of eleven sessions. The participants are presented with an "absurd questionnaire" proposing 50 pairs of images, in each of which one image has to be chosen. The results are used to search for evidence in favor of the influence of group dynamics on individual choices of the images proposed in the questionnaire. Our analysis finds some evidence for an effect of group dynamics both on the initial choice of the pictures and on the evolution of the number of changes (swaps) of picture choices across the eleven sessions. We interpret these effects in the light of Bion's view of group dynamics, which postulates an immediate onset of the unconscious and its evolution during the group activity.

Key Words: group dynamics, synchronicity, basic assumptions, group orientation
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1. Introduction

Group phenomena have been used since antiquity for different purposes in therapeutic, social, economic and political domains (Anzieu and Martin, 1997; pp.17-156). Studies dealing with the group psychology that we can define as modern go back to the XIX century, even before the appearance of psychoanalytical methods (le Bon 2006). W.R. Bion (1961) and S.H. Foulkes (1964), two psychoanalysts disciples of M. Klein for the former, and of S. Freud for the latter, were the first to elaborate a psychoanalytic framework for the interpretation of group phenomena and their evolution (group dynamics).

Although we realize that "There are many re-editions of Bion's formulation about groups but none can replicate the richness of the original [...]." (Lawrence *et al.*, 1996), for the purposes of this work we will venture to give yet another account of his working hypotheses. Bion's model is that, when any set of people gathers for an activity or a task, there is an immediate creation of a group and that the ensuing group dynamics consist actually in two kinds of groups, or rather in two configurations of mental activity, which are simultaneously present. At the surface there is the more or less sophisticated work group, referred to as the W group, which is directed at the accomplishment of the purpose for which the group has

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originally been formed (the organization of a party, the management of a multinational company, planning of a war, deciding a strike and so on…). However underlying the W group is the other group, governed by universal principles that Bion calls "basic assumptions". This is what Bion calls the BA group. The W group is, in Bion's words, "constantly perturbed by influences that come from other group mental phenomena" (Bion, 1961; p.129).

To explain this, Bion (1961) postulates that a group situation leads to the formation of a group psyche generated by the interaction of the group members and that behaves according to the "basic assumptions". The group requires the protection of a leader, on whom it feels dependent for its survival. The refusal or inability of the leader to protect the group leads to conflicts, and ultimately to a "fight-flight" attitude where the group either gathers to fight against the dangers outside or it tries to run from them. This stressful situation may lead to the formation of sub-groups or couples. Coupling or sub-groups, although they represent a danger for the group integrity, promote the messianic expectation, i.e. the hope for a new, better, perfect and powerful leader. This behavioral pattern is repeated during the life of the group.

Therefore, according to Bion the evolution of the group is governed both by these universal "basic assumptions" and by the conflicts that are rooted in the contingent reality of each specific group (Bion, 1961; Vergopoulo, 1983; Foulkes, 1964).

Since the discovery of quantum mechanics, a tantalizing similarity has been noted between the quantum description of the world and the functioning of our psyche. Several authors have elaborated on this, developing physico-mathematical models of our psyche (Baaquie and Martin, 2005; Beck and Eccles, 1992; Zurek, 1991; Hameroff and Penrose, 1996; Penrose, 1989; Penrose, 1994; Pitkanen, 1998; Jung and Pauli, 1955; Vitiello, 2003; Conte *et al.,* 2003; Pauli and Jung, 2001; Zurek, 1981). Some researchers (Baaquie and Martin, 2005) have even postulated the existence of a universal psychic field of quantum nature. In a recent series of works, Galli Carminati and colleagues (Galli Carminati and Carminati, 2006; Galli Carminati and Martin, 2008; Martin *et al.,* 2010; 2013) extended this description to the group unconscious, proposing that this too could be described with a model similar to those used in quantum physics. This analogy relies on the observation that, as for the individual, the group reacts to losses with a mourning process. In other words, mediated by the "basic assumptions", group dynamics are similar to individual dynamics, in particular if one considers the loss of the ideal group leader.

The correlations that appear between the groups and members of a group during group analysis sessions seem comparable in nature to the remote correlations that appear between two related quantum systems (Einstein *et al.,* 1935; Schrödinger and Born, 1935; Schrödinger and Dirac, 1936; Bell, 1964; 1966; Aspect *et al.,* 1982). This phenomenon is called quantum entanglement: two entangled quantum particles can be separated by thousands of kilometers and nevertheless form a single (whole) non-separable system, as long as no measurements are performed on one of the two particles. It is by analogy with this well-known phenomenon of quantum physics that we decided to investigate the similar entanglements between two individuals, and tried to generalize these correlations to individuals belonging to a group.

The correlations we tried to observe are between the unconscious of two individuals. In the model of Carminati and Martin (Galli Carminati and Martin, 2008; Martin *et al.,* 2010; 2013), the mechanism that brings parts of the unconscious of two individuals together to form a single entangled (non-separable) quantum system is the so called Bose-Einstein condensation (Pitaevskii and Stringari, 2004), in which distinct particles can form a single quantum system, where they lose their individuality in favor of a single collective behavior.

Such a "condensation" could well appear between some parts of the unconscious of individuals and as a result, cause the formation of the group unconscious. Bose-Einstein condensation and quantum entanglement, if applied to psyche, may explain the remote correlations that exist between group members and consequently group phenomena (Marshall 1989). According to this model, a group situation would influence group members to orient their individual unconscious in a common direction (Galli Carminati and Martin, 2008; Grinberg-Zylberbaum *et al.,* 1994; Martin and Galli Carminati, 2007) hence promoting the emergence of a group quantum state.

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The goal of the current study is to provide experimental evidence in support of the model proposed above (Galli Carminati and Martin, 2008; Martin *et al.,* 2010). Consequently, our first objective is to observe the behavior of individuals belonging to a group.

Table 1. Demographic, socio-economic and group composition of the participant sample expressed in numbers and percentage for Staff, Trainees and for all participants. Quantities reported are: the number of participants in each age class, the median age with the interquartile range (Q1 and Q3: 25th and 75th percentiles respectively), the sex distribution expressed as numbers and percentages of female subjects, the number of participants in each socio-economic subcategory, the number of participants in each enrolment year and in each of the sub-groups of the training. Groups from A to D were the four "small groups". Group E were the conductors of the "large group" and group F were the organizing staff.

	Subcategories	Staff		Trainees		All	
		(n = 14)		(n = 31)		(n = 45)	
Age (years)	20-30	1	7.1%	21	67.7%	22	48.9%
	31-40	5	35.7%	8	25.8%	13	28.9%
	41-50	4	28.6%	2	6.5%	6	13.3%
	>50	4	28.6%	0		4	8.9%
	Median (Q1-Q3)	42.5	(33-50.5)	29	(27-32.5)	31	(28-38)
Sex	Female	7	50.0%	24	77.4%	31	68.9%
Marital status	Married	4	28.6%	29	93.5%	33	73.3%
	Divorced/widowed	3	21.4%	0		3	6.7%
	Single	7	50.0%	2	6.5%	9	20.0%
Professional status	Psychologist	13	92.9%	17	54.8%	30	66.7%
	Psychiatrist	1	7.1%	4	12.9%	5	11.1%
	Social worker	0		4	12.9%	4	8.9%
	Nurse	0		3	9.7%	3	6.7%
	MD	0		2	6.5%	2	4.4%
	Public servant	0		1	3.2%	1	2.2%
Enrolment year	1	0		10	32.2%	10	22.2%
	2	0		14	45.2%	14	31.1%
	3	0		7	22.6%	7	15.6%
	4	8	57.1%	0		8	1.8%
	5	6	42.9%	0		6	13.3%
Sub-groups	A	2	14.3%	8	25.8%	10	22.2%
	B	2	14.3%	9	29.0%	11	24.4%
	C	2	14.3%	6	19.4%	8	17.8%
	D	2	14.3%	8	25.8%	10	22.2%
	E	2	14.3%	0		2	4.4%
	F	4	28.6%	0		4	8.9%

Because unconscious phenomena cannot so far be investigated using conventional measurements or direct observations (Cerf and Adami, 1997; 1998; Atmanspacher, 2006) we propose an indirect measure of the group orientation based on a questionnaire. The objective is to investigate whether group analysis situations can lead the unconscious of the participants to adopt a common orientation in the choice of pictures. In other words, we would like to test whether the presence of an orientation of the group unconscious has a measurable effect on the real world.

We could say that, at the philosophical level, this work aims at detecting an effect of mind on reality, and therefore to verify if, in spite of the dualism between them, there can be an influence of the former on the latter. This is certainly not a new problem in philosophy, and approaches that describe mind and matter as manifestations of one underlying reality in which they are reunited, go back to a holistic reality, *unus mundus*, the "one world" of the 16th century alchemist Gerhard Dorn (Atmanspacher and Fach, 2013; Dorn, 1602).

Doing this in a group setting gives leverage to Bion's idea of "valence", by which Bion describes the immediacy of the onset of the basic assumptions, more analogous to tropisms than to purposive behavior. This tropism, and its effects on reality, is enhanced in the group setting by an amplification process whereby groups "amplify emotional reactions, resulting in a combustible process of emotional contagion" (Bion, 1961; p.54).

To try to minimize biases that can be introduced by common cultural background such as news, politics, arts, and so forth, we designed an "absurdum" questionnaire so that answers would rely as little as possible on logical thinking and acquired knowledge, using pictures as unrelated as possible with each other.

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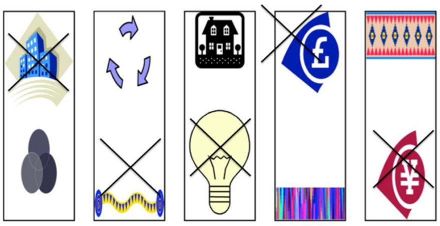

Figure 1. A page from the questionnaire with "fake" answers.

2 Materials and methods

2.1 Participants

For this study we used forty-five adult participants (31 women and 14 men) involved in the group analysis training given by the Basque Foundation for the Investigation of Mental Health (OMIE). This group was composed of 31 people attending the training, 10 members of the training staff and 4 members of the organizing staff. Two participants in this training were excluded from the study because they did not complete the experiment. The training consisted of 10 sessions, and at the beginning of the first session and the end of each session the participants were asked to fill in the questionnaire. Demographic data and socio-economic characteristics of participants are presented in Table 1.

The Ethics Committee of Geneva University Hospitals approved the experimental protocol, in adherence to the Helsinki Declaration for research with human subjects, and approval was also granted by the OMIE foundation. All participants gave written informed consent after receiving oral and written information about the experiment. All participant data were coded so that they were completely anonymous, including for the researchers analyzing the data.

2.1 Questionnaire

To evaluate to what extent participants could act according to a common group unconscious, we used an “absurdum questionnaire” of 50 pairs of pictures. For each of the fifty pairs, participants were asked to choose one of the two pictures. A typical page with hypothetical answers can be seen in Figure 1. The questionnaire had to be filled within 3 minutes and no correction was allowed. The pictures were color or black and white drawings and photographs selected from the Web, so that the choice could have minimal correlation with a common cultural background, logical thinking or common knowledge. This method aims at avoiding multiplier effects that a classical word questionnaire (Zanello *et al.,* 2004) can introduce, because the latter requires conscious reflection peculiar to one’s own unconscious.

The one hundred images chosen for the questionnaire were randomized to form 50 pairs presented on 10 A4 format landscape oriented sheets with 5 pairs per page. Each pair occupied about 4 cm (horizontal) by 11.5 cm (vertical). For the 11 testing sessions, the pairs were randomly ordered on the 10 sheets to avoid mnemonic or learning effects.

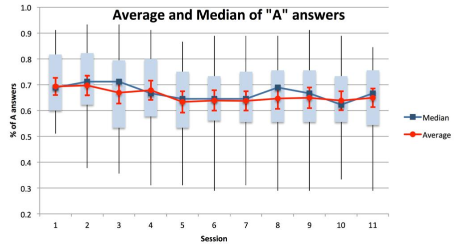

Figure 2. Evolution of the average proportion of the picture initially most selected (picture A). The proportions of participants (± 95% confidence interval shown on average points, red line) who have chosen the initially preferred picture (A) are averaged over the 50 questions for each of the 11 sessions (abscissa). The figure also shows the median and interquartile evolution.

Procedure

OMIE teaching is a 5-year program to train group therapists in group analysis. Trainees follow courses on group analysis theory, methods and applications, and they also participate in analytical groups to gain practical experience with group dynamics. Practical training is based on 10 modules per year, each one lasting one day and half: Friday from 9h00 to 21h00 and Saturday from 9h00 to 13h50. Participants of different years are divided in groups of 8 to 10 people including a conductor (group leader) and an observer who are members of staff. In the case under study there were four such groups (A to D, see Table 1). These groups met 3 times for 1h30 in the course of a module. At the end of each day, all four groups meet for 1h30 in a “large group” that includes also the “large group” leaders (who form group E in our table). Finally, group F is composed of the members of the directing committee, who include the other staff and

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meets during the course of the module. During the first test session, participants filled in the socio-demographic form indexed with a code to render data anonymous. The same code was used to mark the “absurdum questionnaires”. The overall experiment includes 11 tests, in which participants had to select one picture for each of the 50 pairs of the questionnaire. The first test was taken the first day before the training actually started. The remaining 10 tests were taken at the end of the second day (Saturday) of each module. For administrative reasons, the staff did not take the second test at the end of the first module.

2.2 Data Analysis

For the purpose of the data analysis, the most frequently chosen picture in each pair during the first test will be indicated as picture A (A_i, i=1,50), while the other picture will be designed as B (B_i, i=1,50). Frequency tables were computed for each pair of pictures and each one of the 11 sessions. Because the present work is devoted to evaluating the influence of the group unconscious on the measured effects, in this case the answers to the questionnaire, all statistics were carried out on the proportion of the number of participants choosing picture A or B for each of the 50 questions and 11 tests, irrespectively of how the individual participant’s choice evolved.

a) First of all, potential biases in selecting A pictures for each of the 50 questions were tested. (1) A one-sample binomial test was used to test the hypothesis that selecting pictures A and B had equal probabilities (i.e. null hypothesis p(A) = p(B) = 0.5). (2) A chi-squared test was used to test the hypothesis that the probability to select picture A remained constant over time (i.e. null hypothesis p(A at follow-up tests) = p(A at first test)). (see Equation 1):.

$$(i) p(A_i) = \frac{A_i}{n} = \text{nb of A choices for pair } i \text{ / n}$$

$$(ii) P(A) = \sum_{i=1}^{11} p(A_i)/11$$

$$(iii) \sigma_i^2 = n\, p(A_i)\, (1 - p(A_i))$$

$$(iv) \chi 2 = \sum_{j=1}^{11} \frac{(\mu_i - x_{ij})^2}{nP(A)(1-P(A))}$$

Equation 1: p (A_i): observed A frequency for a given question and for the session i; P(A): average (over all sessions) probability to get A; x_{ij}: number of A choices for a given session i during test j; n: total number of participants; σ_i: standard deviation of the binomial distribution; χ^2: chi-square value; μ: average (over all sessions) number of A choices. Results will be assumed to be significant for $p<0.025$ for the one-tailed test, which corresponds to a two-tailed test alpha value of 0.05.

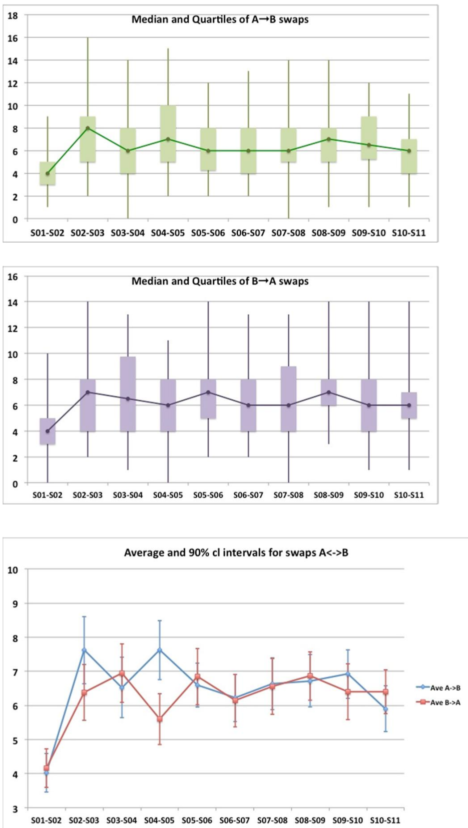

Figure 3. Median and inter-quartile number of changes (ordinate) observed between consecutive sessions (abscissa) is plotted for the swaps from pictures A to B (picture above) and for the swaps from pictures B to A (picture in the middle). We report also average number of swaps with 90% cl intervals (picture below).

b) To evaluate whether the selection of the preferred pictures evolved randomly or as an effect of group sessions, two analyses were carried out. (1) A Friedman test was performed to compare the proportion of participants who

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choose picture A (initially preferred) for each of the 50 questions at each session. Planned post-hoc statistics between consecutive sessions were carried out with Wilcoxon signed rank tests with Bonferroni's adjustment (n_s = 10, i.e. the number of transition between sessions). (2) The absolute amount of changes is the result of the difference in the changes of choice from A to B and from B to A. These two quantities are, in principle, not directly related, apart from the obvious boundary conditions that there cannot be more swaps from A to B than A's in the first place, and the same holds for B's. This measure gives an idea of the group activity, independently from the net result of this activity. Using a Friedman test, we analyzed the number of changes from picture A to picture B, and conversely from picture B to picture A. For each time interval, Wilcoxon signed rank tests with Bonferroni's adjustment (n_s = 10) were run on the numbers of changes from A to B and from B to A occurring for the 50 questions across the 11 sessions, to estimate whether there was an evolution in the frequency of swaps between A and B choices.

c) Random or group dynamics driven swaps of pictures across time were investigated using Friedman tests on the total number of changes from picture A to picture B and from picture B to A, occurring between consecutive sessions (10 intervals) for each of the 50 pairs of questions, as well as on each type of swaps (A to B and B to A) independently. Planned post-hoc statistics between consecutive time intervals were conducted with Wilcoxon signed rank tests with Bonferroni's adjustment (n_i = 9 tests between consecutive time intervals).

d) To assess whether changes occurred just by chance or as a consequence of group member common orientation, we compared the mean similarity for each studied group across test sessions. To do so, we computed a measure of pairwise similarities based on the proportion of concordant pictures for each pair of participants within a studied group (Zubin, 1938). Subsequently, the mean similarity for each participant with the other participants within the same studied group was calculated for each test's session. To compare mean similarities across test sessions, we used a permutation test based on the raw data matrix that accounts for the non-independence of observations (i.e., 45 participant x 50 pairs) (Hepworth, 2007). For each permutation of the rows of the raw data matrix, a similarity matrix was computed. The mean similarities were calculated for each session and the corresponding Kruskall-Wallis statistic was computed. For each comparison, 100'000 permutations were performed and the *p*-value was determined based on the proportion of values lower than the observed statistic value. Two-sided *p*-values less than 0.05 were considered as statistically significant.

3 Results

2,143 missing data out of 24,750 data points were found in the overall data set, which was filled in as follows. For the first session, the missing response was replaced by the selection of the picture at the same spatial location in the preceding answer (top or bottom), and for the following sessions (2-11) the answer to the same question but in the preceding session was used instead (last observation carried forward approach or LOCF). We repeat that the staff (14 members) did not complete the second questionnaire, which represents a total of 700 (i.e., 50 x 14) missing data.

Cognitive versus group biases in choosing a picture of a pair

The probability in selecting randomly A or B pictures at the first session was tested against a binomial distribution with a probability of 0.5. A significant result would indicate some kinds of cognitive biases for a picture of a given pair (that we indicate with A) or a very rapid onset of the group unconscious, which would be consistent with Bion's theory of the group psychic apparatus. Significant preferences for pictures A were found in 31 out of 50 pairs, for which initial choices do not seem to have been made randomly (Table 2). We are not in a position to determine whether this was due to cognitive biases or to group dynamics, but we can definitely say that, globally, the initial choice of pictures was not made with a 50-50% probability.

Picture choice evolution

The evolution of the probability of selecting the preferred pictures was examined over the 11 sessions, to assess whether the initial rationale in selecting a picture of a pair would be maintained across time.

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Table 2. Binomial analysis of the choices. P-values are given for each question, i.e., each pair of pictures, at the 1st session (p_1), and for the overall sessions (p_o). Significant differences from a binomial distribution is assumed for p<0.025, and are indicated in italic and by stars. p-values for the 11 distributions have been calculated with the χ^2 tables for 10 degrees of freedom and in the table we have reported the values $\chi^2/10$ for easier inspection. A_1 is the number of A selected per question at the first session.[2]

	1st session		All sessions			1st session		All sessions	
Question	A1/45	p1	χ2(10 df)/10	po	Question	A1/45	p1	χ2(10 df)/10	po
1	0.87	<0.001**	10.62	0.39	26	0.56	0.28	15.29	0.12
2	0.53	0.38	17.66	0.06	27	0.56	0.28	7.58	0.67
3	0.87	<0.001**	13.71	0.19	28	0.67	0.018*	9.11	0.52
4	0.64	0.036	6.22	0.8	29	0.76	<0.001**	12.07	0.28
5	0.51	0.5	16.56	0.08	30	0.56	0.28	8.02	0.63
6	0.84	<0.001**	15.69	0.11	31	0.51	0.5	15.67	0.11
7	0.64	0.036	11.21	0.34	32	0.73	0.0012**	16.59	0.08
8	0.78	<0.001**	5.74	0.84	33	0.62	0.068	12.17	0.27
9	0.67	0.018*	7.91	0.64	34	0.53	0.38	9.2	0.51
10	0.82	<0.001**	2.7	0.99	35	0.69	0.008**	13.48	0.2
11	0.89	<0.001**	29.23	<0.005**	36	0.73	0.0012**	11.67	0.31
12	0.78	<0.001**	12.6	0.25	37	0.73	0.0012**	17.09	0.07
13	0.69	0.008**	28.72	<0.005**	38	0.82	<0.001**	5.35	0.87
14	0.76	<0.001**	4.24	0.94	39	0.67	0.018*	9.87	0.45
15	0.67	0.018**	5.29	0.87	40	0.82	<0.001**	24.24	0.01*
16	0.67	0.018**	10.28	0.42	41	0.69	0.008**	4.72	0.91
17	0.56	0.28	7.83	0.65	42	0.60	0.12	17.91	0.06
18	0.51	0.5	7.38	0.69	43	0.67	0.018*	4.25	0.94
19	0.53	0.38	14.57	0.15	44	0.62	0.068	4.6	0.92
20	0.62	0.068	5.28	0.87	45	0.82	<0.001**	12.42	0.26
21	0.69	0.008**	6.88	0.74	46	0.51	0.5	8.13	0.62
22	0.60	0.12	6.28	0.79	47	0.84	<0.001**	13.11	0.22
23	0.80	<0.001**	9.34	0.5	48	0.84	<0.001**	9.47	0.49
24	0.53	0.38	22.41	0.01*	49	0.87	<0.001**	4.78	0.91
25	0.87	<0.001**	23.21	0.01*	50	0.91	<0.001**	11.06	0.35

Table 3. Wilcoxon signed rank tests between sessions on the proportion of participants. Z and p-values given by the Wilcoxon signed rank tests are provided for the comparisons between consecutive sessions (S k-S (k+1), k=1 to 10) of the proportions of participants who chose picture A at each question. A statistical significance (*) is assumed for p-values < 0.005 (i.e., α = 0.05/10 comparisons).

Sessions	S1-S2	S2-S3	S3-S4	S4-S5	S5-S6
Z	-0.487	-1.694	-0.908	-2.859	-0.224
P	0.626	0.090	0.364	0.004*	0.823
Sessions	S6-S7	S7-S8	S8-S9	S9-S10	S10-S11
Z	-0.543	-0.935	-0.045	-0.880	-1.081
P	0.587	0.350	0.964	0.379	0.280

Table 4. Wilcoxon signed rank tests' statistics. Z and p values given by the Wilcoxon signed rank tests are provided for the comparisons performed between changes from pictures A to B (AB) and B to A (BA) at each time interval (e.g., S1S2BA = B chosen at test 1 and A chosen at test 2). A statistical significance (*) is assumed for p values < 0.005.

Time	S1S2BA	S2S3BA	S3S4BA	S4S5BA	S5S6BA
Intervals	S1S2AB	S2S3AB	S3S4AB	S4S5AB	S5S6AB
Z	-0.671	-1.742	-0.829	-2.893	-0.304
P	0.502	0.081	0.407	0.004*	0.761
Time	S6S7BA	S7S8BA	S8S9BA	S9S10BA	S10S11BA
Intervals	S6S7AB	S7S8AB	S8S9AB	S94S10AB	S10S11AB
Z	-0.510	-0.055	-0.199	-0.902	-1.043
P	0.610	0.956	0.842	0.367	0.297

[2] We warn the reader against the possible confusion between the *p* used in this table, which are the significance levels and the symbol *p* used in Equation 1 that are the frequencies of A answers used as estimators of the probability.

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The null hypothesis was that the variations of the choices are consistent with the fluctuations of a binomial distribution and therefore that chance drives the evolution of the picture choice and not the group dynamics. Evolution in choices appeared significant for 5 out of the 50 questions (Table 2) according to a classical $\chi2$ test with 10 degrees of freedom. These 5 questions all have a frequency p(Ai) > 0.8 significantly (p=0.05) more frequent (60%) than the whole set of 50 questions (27%). In the table we report the $\chi2(10\ df)/10$ for easier reading.

Figure 2 represents the evolution across sessions of the choices for the most selected (A) pictures determined in session 1, i.e., before the start of the group training. During the first 4 modules (i.e., sessions 2 to 4), the selection of picture A decreases slightly and progressively shifts toward picture B, without however inverting the preference. From session 5, the preference for pictures A remains steady to the end of the training (session 11). The Friedman test conducted on the proportion of participants who chose picture A during the 11 sessions, revealed a significant evolution effect, i.e. the choice of pictures changed with time during the training ($\chi2 = 34.092$, N = 50, df = 10, $p < 0.0001$*). The Wilcoxon signed rank tests carried out between consecutive sessions determined that there is a significant change in the choices between the 4th and the 5th tests ($p < 0.005$, Table 3) with a change of the median proportion of A from 66.6% to 63.3%.

To evaluate whether swaps from pictures A to B or from pictures B to A evolved, Wilcoxon signed rank tests were performed on the swaps A→B and B→A for each session. As for the previous tests, this revealed a significant change in the selection of picture A (initially preferred) between the 4th and 5th tests ($p < 0.005$, Figure 3, Table 4) with a difference between the average number of swaps A→B and B→A of peaking at 2.02 (see Figure 3). This is consistent with the previous Wilcoxon test and it tells us that a statistically significant change in the balance between A→B versus B→A swaps between sessions 4 and 5 determines a significant change in the number of A (and B) choices between these two sessions.

Group dynamics driven swaps of pictures

If we now turn to consider the frequency of swaps A→B, B→A and A→B+B→A across the 11 sessions, Friedman analysis tells us that their evolution is statistically relevant (A→B + B→A: $X^2 = 93.7$, N = 50, df = 9, $p < 0.0001$*; A→B: $X^2 = 61.3$, N = 50, df = 9, $p < 0.0001$*; B→A: $X^2 = 45.4$, N = 50, df = 9, $p < 0.0001$*) (Figure 3). If we then analyze which of these changes is relevant with a Wilcoxon signed rank test, we discover that the frequency of swaps increases significantly only between the first (i.e., from session 1 to session 2) and the second (i.e., from session 2 to session 3) interval, for all three swaps considered, e.g. the total number of swaps (Table-5a), the swaps A→B (Table-5b) and the swaps B→A (Table-5c) ($p < 0.0056$). In other word, swaps A↔B increased after the second training session (after a total of 4 days spent together), and remained almost constant until the end of the training. However it is interesting to highlight that independent analyses on A to B and B to A swaps both showed a marginal significance between time intervals 3-4 and 4-5 ($p = 0.019$ and $p = 0.010$ respectively), reflecting the significant decrease in choosing picture A between the 4th and the 5th testing sessions as revealed in the previous analyses (see § b2 and Figure 2).

Mean similarity measures

The computed similarity measures were devoted to assessing whether a picture's selection, i.e., answers to the questionnaire, occurred just by chance or conversely, if they were driven from group members' common orientation.

Consequently Kruskall-Wallis tests were carried out for each group (A, B, C, D and F, see Table 6) and for the overall groups, which met together once per training day with group E (large group conductors). Statistics indicate that taken together, groups seemed to adopt a common orientation in their choice of pictures ($p = 0.003$). However, at the level of the individual groups, the effect is more ambivalent. If groups D and F still displayed similar behavior ($p = 0.02$ and 0.007), statistics were only marginally significant for group B ($p = 0.05$), and not at all for groups A and C ($p = 0.97$ and 0.79 respectively), indicating a choice by chance.

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4 Discussion

4.1 Cognitive versus group dynamics biases

The first outcome of our study is that the initial answer to the test is not a 50%-50% random choice between the two pictures of each pair, despite the fact that the pairs of pictures were chosen with an attempt to avoid inducing social or cultural bias. This initial bias could be the reflection of our shortcoming in avoiding these effects, but it could also have another explanation. According to Bion, group effects should be seen as soon as people are actually put together. They do not even need to interact actively, and the mere assembling of individuals should be enough to promote an unconscious connection and to provoke group phenomena. So this orientation could indeed be the result of a group effect. Unfortunately our protocol does not allow discrimination between these two explanations.

A future version of such a protocol should include a provision to determine bias that could be attributed to common social and / or cognitive preferences for one picture of the pairs, driven for instance by visual attributes (e.g., color, spatial frequency contents, etc.) or meaning contents. One possible alternative would be to use some type of fractal pictures. Another approach would be to ask future participants to fill in the questionnaire before they actually meet for the first time. Alternatively the questionnaire could be composed of pairs of questions previously tested for perfect randomization. Whatever the origin of the initial orientation, it does not affect the statistical significance of group effects that occur in the following sessions and therefore the results obtained in this experiment.

In what follows we will analyze our data under two different angles. First of all we will consider the distribution of the choice of the different figures and its evolution during the experiment. The second quantity we will consider is the number of changes from one choice to another made by the participants in the different sessions (swaps). The rather strong initial orientation could be due to the influence of group dynamics following Bion's idea that the group is immediately created, or it could be the effect of social and cognitive phenomena, or a combination of the two effects. However, the evolution of the choices and frequency of swaps of A and B choices during the experiment can be attributed to group dynamics rooted in the "basic assumptions" described by Bion (1961).

Table 5. Wilcoxon signed rank tests on the number of swaps between time intervals. Z and p-values given by the Wilcoxon signed rank tests are provided for the comparisons between consecutive time intervals (S_iS_{i+1} $S_{i+1}S_{i+2}$) of the total number of swaps from pictures A to B and B to A (a), swaps from A to B (b) and swaps from B to A (c). A statistical significance (*) is assumed for p-values < 0.0056 (i.e., α = 0.05/9 comparisons).

Time Intervals		S1S2 S2S3	S2S3 S3S4	S3S4 S4S5	S4S5 S5S6	S5S6 S6S7	S6S7 S7S8	S7S8 S7S8	S8S9 S9S10	S9S10 S10S11
a	A to B + B to A swaps									
	Z	-6.014	-0.968	-0.279	-0.208	-1.986	-1.023	-0.566	-0.687	-1.973
	p	<0.0001*	0.333	0.780	0.835	0.047	0.306	0.572	0.492	0.048
b	A to B swaps									
	Z	-5.252	-1.581	-2.336	-1.576	-0.770	-0.750	-0.092	-0.523	-1.678
	p	<0.0001*	0.114	0.019	0.115	0.441	0.453	0.927	0.601	0.093
c	B to A swaps									
	Z	-3.964	-0.920	-2.563	-1.869	-1.548	-0.959	-0.669	-0.873	-0.217
	p	<0.0001*	0.357	0.010	0.062	0.122	0.338	0.503	0.383	0.828

We recall that, as explained at the beginning, the evolution of the group psyche according to the basic assumptions can largely be seen as a reaction to the inability of the supposedly almighty leader to assume his mythical role of protecting the group.

Group unconscious common orientation during the training was investigated at two levels. First its impact on similarity of choices was explored and second, its influence on the environment was examined by measuring choices and the frequency of their active changes at the level of the questionnaire.

4.2 Similarity of participant choices

Similarities of participant choices were examined at the level of the individual small group (8-10 people), which is supposed to represent the "family", and at the large group level, which symbolizes the "society". We could

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have expected a greater coherence in choices at the "family" rather than at the "society" level. However this was not the case. The large group as a whole showed a common orientation across sessions, i.e., participants were collectively more likely to select the same response to questions. This orientation was less identifiable in the individual small groups. It seems that "society" is the driving force that directs the group unconscious to adopt similar behavior, rather than smaller communities. This explanation tends to be in favor of the postulate of a universal psychic field proposed by Baaquie and Martin (2005).

4.3 Group unconscious

The evolution of the answers to the questionnaire was analyzed to provide two kinds of information about group phenomena, designed to check whether the group unconscious actually adopts a common orientation measurable on the environment, i.e., the answers to the questionnaire.

4.3.1 Evolution of group dynamics choices

It was postulated that group dynamics orientation should result in the evolution of picture preference. In other words, if the group has an effect at some stages of the training, the evolution of picture choices should not be random across testing sessions. The analysis showed that the evolution of the selection of the A picture is compatible with random fluctuations between the 1st and the 4th and between the 5th and 11th tests. Between the 4th and the 5th test (corresponding to the transition between the 3rd and the 4th sessions, as there were two tests in the first session) there was a "defocusing" in the choice of the preferred picture that is non-random with a high significance. This effect can clearly be seen also in the comparison of the A→B and B→A swaps between sessions. The A→B and B→A swaps for the same interval between two sessions are compatible with each other except for the transition from the 3rd to the 4th session, where they are clearly different, revealing significantly more A→B swaps in favor of the least selected picture and fewer B→A swaps in the direction of the favorite one. Both analyses show that the choice stayed constant (without statistically significant variation) from the 1st to the 3rd and from the 4th to the 10th sessions, after the number of A's had decreased.

Table 6. Temporal variations in mean similarity measures within studied groups. Mean similarity measures are given for the 11 sessions of each group and for the overall group. P-values of the Kruskall-Wallis tests are also given. Significance (*) is assumed for p < 0.05.

	Sessions											
Studied	1 (Baseline)	2	3	4	5	6	7	8	9	10	11	*p*
groups	Mean similarity measures											
A	.57	.56	.60	.60	.59	.59	.58	.59	.59	.60	.58	0.97
B	.58	.62	.57	.58	.53	.54	.54	.53	.53	.55	.55	0.05
C	.63	.59	.63	.60	.61	.61	.63	.60	.60	.59	.59	0.79
D	.60	.61	.59	.56	.54	.52	.53	.56	.57	.53	.53	0.02*
F	.63	.63	.59	.57	.56	.56	.50	.53	.49	.49	.54	0.007*
All	.59	.60	.59	.59	.57	.57	.56	.57	.58	.56	.57	0.003*

This behavior is very suggestive of group dynamics. During the first three sessions there is a "honeymoon" period where the group forms and enjoys the so-called "group illusion". After that the group faces disillusion toward the leader and sees the end of the training approaching, so the cohesion is reduced, but remains constant to the end of the training. Although this simple measure cannot be said to catch the complexity and richness of group dynamics, it seems however that its behavior is consistent with what we know and observe as group analysts.

It is also very interesting to note that this effect is very visible at the level of the global group and less at the level of the individual group, while group illusion and disillusion and mourning are effects that are also strongly felt at the level of the "small groups". It seems that even if the evolution is individually felt more powerfully at the level of the small community ("family"), it is an effect that involves the whole society. So while there are individual variations in the way the small groups move across time, the global ("social") picture maintains a high degree of coherency.

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4.3.2 Evolution of swaps and group dynamics

The swaps we measured across sessions could be interpreted as a manifestation of group dynamics similar to that postulated by Bion (1961) with the "basic assumptions". For instance, "honeymoon" (dependence on the leader) and the successive "fight-flight" (reaction against the dependence on the leader) attitude could be represented by a greater number of group dynamics swaps (further away from pure randomness). It seems intuitive that an increase in the swaps could be linked to increased group activity or to a group dynamics event.

Statistics carried out on the total number of swaps or individually on A→B or B→A changes evidenced a significant increase in those swaps between the 1st (S1S2) and the 2nd (S2S3) time intervals, i.e., between the 2nd and the 3rd testing sessions, incompatible with a random fluctuation. In other words the change of choice increased significantly between the 1st and the end of the 2nd training module, and then remained essentially constant to the end of the training, while the frequency of choices for the initially preferred picture changed significantly only between the 3rd and the 4th training sessions. Between these two sessions there is no sign of change in the evolution of the sum A→B+B→A, while the number of A→B and B→A swaps showed a fluctuation close to significance. This is consistent with the "defocusing" in the choice of A observed.

Again the pattern emerging is very suggestive. Even if the onset of the group is immediate (with a distribution of answers far from 50%-50% at the very beginning of the training) the group activity needs the group to meet and exchange for some time before being set in motion. Group dynamics really start after a few days spent together (here 3-4 days training, i.e., about 9-12 hours), and remain essentially constant as long as the group exists, whatever the group evolution.

At this point we could propose two possible interpretations of the data. In the first one we postulate that, according to Bion's theory, the group exists from its earliest stage, and the modification of picture selection observed at mid-training, which corresponds to an evolution towards a more random or "less focused" choice, is coherent with a decreased group coherence, possibly caused by the group disillusion with the leaders or the prospect of the end of the training (the death of the group).

Alternatively, the initial choices are due to a cognitive or social bias and the group forms according to the basic assumption with a timescale compatible with the increase of the swap frequency, i.e. during the first training session. In this case the decrease in the choice of the A pictures is rather the manifestation of a new equilibrium introduced by group dynamics, where initial cognitive choices are modified by increased group unconscious activity aimed at fulfilling the group desires or needs.

It is difficult to be more specific with this first questionnaire and a single evaluation at the end of each module.

5. Conclusions

Our study aimed at detecting measurable effects of the psychical dynamics that take place during a group training session. For this we used the answers given to a questionnaire designed to minimize or at least reduce cognitive and social bias. Although our results are subject to interpretation, we believe that this study presents strong indications in favor of an influence of group dynamics on the answers to the questionnaire.

In particular we believe that there is evidence in favor of the building of a group unconscious according to Bion's "basic assumptions", as is shown by the evolution in the frequency of swaps in the choices of images across sessions. The present study brings additional insight into the mechanisms at work in group dynamics, and indicates support for Bion's theory of both an immediate and a more progressive group dynamics effect.

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ARTICLE – REVIEW ARTICLE – INVITED ARTICLE

Addendum on Entropy to the Exploratory Study on Group Unconscious at the Basque Foundation for the Investigation of Mental Health Group Training for Therapists

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ABSTRACT-

The present paper is an addendum to a previous study on the work that has been conducted during the eleven sessions of a group analysis training at the Basque Foundation for the Investigation of Mental Health (OMIE[1]) at Bilbao. The participants were presented with an "absurd questionnaire" proposing 50 pairs of images, in each of which one image had to be chosen. The results of the previous study were in favour of the influence of group dynamics on individual choices of the images proposed in the questionnaire. Our present analyses complements the previous work with the exploration of the relations between the orientation of the answers in the groups as results of Multiple Variable Analysis and the distribution of Bernoulli's Entropy. Consistently with the conclusions of the previous paper, we interpret these correlations as group effects in the light of Bion's view of group dynamics, which postulates an immediate onset of a group unconscious and its evolution during the group activity.

Key Words: Group dynamics, Entropy, basic assumptions, group orientation.

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1 Introduction

"I thought of calling it *information*, but the word was overly used, so I decided to call it uncertainty. [...] Von Neumann told me, 'You should call it entropy, for two reasons. In the first place your uncertainty function has been used in statistical mechanics under that name, so it already has a name. In the second place, and more important, nobody knows what entropy really is, so in a debate you will always have the advantage.'" Excerpt from a conversation between Claude Shannon and John von Neumann regarding what name to give to the attenuation in phone-line signals (Tribus & McIrvine 1971; Sommaruga 2009).

The present papers extends a previous work (Trojaola-Zapirain et al. 2014) on Group unconscious common orientation based on an exploratory study at the Basque Foundation for the Investigation of Mental Health group training for therapists. In this work we presented evidence of the effects of the group situation on the behaviour of the group members in terms of their choices when confronted with a questionnaire proposing the choice of pictures in pairs.

The correlations that appear between the groups and members of a group during group analysis sessions seem comparable in nature to the remote correlations that appear between two related quantum systems (Einstein, Podolsky & Rosen 1935; Schrödinger & Born 1935; Schrödinger &

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Dirac 1936; Bell 1964; Bell 1966; Aspect, Grangier & Roger 1982). This phenomenon is called quantum entanglement: two entangled quantum particles can be separated by thousands of kilometres and nevertheless form a single (whole) non-separable system, as long as no measurements are performed on one of the two particles. Since the discovery of Quantum Mechanics, similarities have been observed between the quantum description of the world and the functioning of our psyche. In this perspective we decided to investigate the similar entanglements between individuals, and tried to generalize these correlations to individuals belonging to a group.

According to Bion, the evolution of the group is governed both by universal principles he calls "basic assumptions" and by the conflicts that are rooted in the contingent reality of each specific group (Bion 1961; Vergopoulo 1983; Foulkes 1964). Mediated by the "basic assumptions", group dynamics is similar to individual dynamics, in particular if one considers the loss of the ideal group leader.

Table 1: Demographic, socio-economical and group composition of the participant sample expressed in numbers and percentages for Staff, Trainees, and for the overall participants. Quantities reported are: the number of participants in each age class, the median age with the interquartile range (Q1 and Q3: 25th and 75th percentiles respectively), the sex distribution expressed as numbers and percentages of female subjects, the number of participants in each socio-economic subcategory, the number of participants in each enrolment year and in each of the sub-groups of the training. Groups from A to D were the four "small groups". Group E was the conductors of the "large group" and group F was the organising staff.

	Subcategories	Staff		Trainees		All	
		(n = 14)		(n = 31)		(n = 45)	
Age (years)	20-30	1	7.1%	21	67.7%	22	48.9%
	31-40	5	35.7%	8	25.8%	13	28.9%
	41-50	4	28.6%	2	6.5%	6	13.3%
	>50	4	28.6%	0		4	8.9%
	Median (Q1-Q3)	42.5	(33-50.5)	29	(27-32.5)	31	(28-38)
Sex	Female	7	50.0%	24	77.4%	31	68.9%
Marital status	Married	4	28.6%	29	93.5%	33	73.3%
	Divorced/widowed	3	21.4%	0		3	6.7%
	Single	7	50.0%	2	6.5%	9	20.0%
Professional status	Psychologist	13	92.9%	17	54.8%	30	66.7%
	Psychiatrist	1	7.1%	4	12.9%	5	11.1%
	Social worker	0		4	12.9%	4	8.9%
	Nurse	0		3	9.7%	3	6.7%
	MD	0		2	6.5%	2	4.4%
	Public servant	0		1	3.2%	1	2.2%
Enrolment year	1	0		10	32.2%	10	22.2%
	2	0		14	45.2%	14	31.1%
	3	0		7	22.6%	7	15.6%
	4	8	57.1%	0		8	1.8%
	5	6	42.9%	0		6	13.3%
Sub-groups	A	2	14.3%	8	25.8%	10	22.2%
	B	2	14.3%	9	29.0%	11	24.4%
	C	2	14.3%	6	19.4%	8	17.8%
	D	2	14.3%	8	25.8%	10	22.2%
	E	2	14.3%	0		2	4.4%
	F	4	28.6%	0		4	8.9%

As explained in the previous paper, our assumption is that the correlations between individual unconscious form a single entangled (non-separable) quantum system where they lose their individuality in favour of a single collective behaviour.

The objective of the present work is to investigate further evidence that group analysis situations can lead the unconscious of the participants to adopt a common orientation in the choice of pictures. In other words, we would like to test whether the presence of an orientation of the group unconscious has a measurable effect on the real world.

As described in the our previous paper (Trojaola-Zapirain et al. 2014) we try minimising biases that can be introduced by common cultural background such as news, politics, arts, and so forth, we designed an "absurdum" questionnaire so that answers would rely as little as possible on logical thinking and acquired knowledge, using pictures as unrelated as possible to each other (see Figure 1).

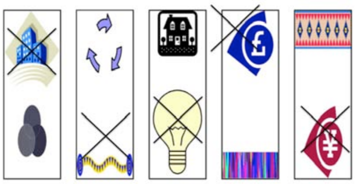

Figure 1: A page from the questionnaire with "fake" answers.

The goal of the current study is to consider here the evolution of entropy in groups, studying the possible orientation of answers and the corresponding trend of the entropy. In the mid of the 19th century, Rudolf Clausius (Clausius 1850) introduced the concept of entropy, which was reinterpreted in terms of statistical mechanics by Ludwig Boltzman (Boltzman 1886) toward the end of the century. Entropy has often been loosely associated with the concepts of order, disorder and chaos. One of the more powerful (and confusing) aspects of the concept of entropy is that it provides a powerful abstract link between thermodynamics, statistical mechanisms, information theory and quantum mechanics (Balian 2004). Although the concept of entropy was originally a thermodynamic construct, it has been adapted in other fields of study, including information theory, psychodynamics, thermo- and ecological economics, and evolution (Brooks & Wiley 1988; Avery 2003; Yockey 2005).

In this work, we are mainly interested in the interpretation of entropy as measure of information and, implicitly, a measure of order and disorder.

In this context we can think of entropy as the amount of information needed to fully define the microscopic state of the system, which is otherwise left unspecified by the macroscopic description. The first to notice the connection between entropy and information was Claude Shannon (Shannon & Weaver 1949). In information theory, entropy is the measure of the amount of information in a transmitted message and is sometimes referred to as Shannon entropy. In this context, the definition of entropy is expressed as the sum of terms depending on a set of discrete probabilities:

$$H(X) = -\sum_{i=1}^{n} p(x_i) \log p(x_i)$$

where $p(x_i)$ is the probability that a particular message x_i is actually transmitted. We note here that the question of the relation between information and thermodynamic entropy has been, and still is, subject to controversy (Brillouin 1956; Georgescu-Roegen 1971; Tribus & McIrvine 1971; Balian 2004; Chen 2005; Frigg & Werndl 2010).

In case all probabilities are equal, the formula for the information entropy reduces to:

$$H = -k \log(p)$$

where k is the unit of entropy. It is interesting to note that, in these cases, the Shannon entropy (in bits) is the number of yes/no questions needed to determine the content of the message. It is also instructive to note that this expression of the entropy is identical to the Boltzmann (Boltzmann 1896) formula based on statistical mechanical considerations. Although the equivalence between Shannon and Boltzmann entropy can be demonstrated in several ways, some authors argue that the use of the name entropy for the former is arbitrary and should be dropped in favour of *uncertainty*.

In our case, the choice of one of the two pictures can be described as a binary process whose outcome can be either 1 (upper picture) or 0 (lower picture). This kind of process is also called a Bernoulli process. In a Bernoulli process there can be only two outcomes (1 or 0), mutually exclusive and exhaustive: success with a probability of p and failure with a probability of (1-p). If X denotes a random variable, we have:

$$\Pr(X = 1) = 1 - \Pr(X = 0) = 1 - q = p.$$

with Pr being the probability of the outcome. A classical Bernoulli process is a single toss of a coin, and is defined fair if p=1/2. The Bernoulli distribution is a special case of a binomial distribution with $n=1$, hence we have:

$$f(k; p) = p^k(1 - p)^k \text{ for } k \in \{0,1\}.$$

$$E(X) = p \text{ and } Var(X) = p(1 - p)$$

In information theory, the entropy of a Bernoulli process is called Bernoulli entropy (H_b) and is defined as

$$H(X) = H_b(p) = -p\log(p) - (1 - p)\log(1 - p)$$

When p=1/2, the binary entropy function attains its maximum value. This is the case of the unbiased bit, the most common unit of information entropy.

2 Materials and methods

2.1 Participants

For this study we used forty-five adult participants (31 women and 14 men) involved in the group analysis training given by the Basque Foundation for the Investigation of Mental Health (OMIE[1]). This group was composed by 31 people attending the training, 10 members of the training staff and 4 members of the organizing staff. Two participants of this training were excluded from the study because they did not complete the experiment. The training consisted of 10 sessions. At the beginning of the first session and at the end of each session, the participants were asked to fill the questionnaire. Demographic data and socio-economic characteristics of participants have been reported in the previous study and are presented here in Table 1 for completeness.

The Ethics Committee of Geneva University Hospitals approved the experimental protocol, in adherence to the Helsinki Declaration for research with human subjects, and approval was also granted by the OMIE foundation. All participants gave written informed consent after receiving oral and written information about the experiment. All participant data were coded so that they were completely anonymous, including for the researchers analysing the data.

2.2 Questionnaire

To evaluate to what extent participants could act according to a common group unconscious, we used an “absurdum questionnaire” of 50 pairs of pictures (Trojaola-Zapirain et al. 2014). For each of the fifty pairs, participants were asked to choose one of the two pictures. A typical page with hypothetical answers can be seen in Figure 1. The questionnaire had to be filled within 3 minutes and no correction was allowed. The pictures were colour or black and white drawings and photographs selected from the Web, so that the choice could have minimal correlation either with common cultural background or knowledge or else logical thinking. This method aims at avoiding multiplier effects that a classical word questionnaire (Zanello et al. 2004) can introduce, because the latter requires conscious reflection peculiar to one’s own unconscious.

The one hundred images chosen for the questionnaire were randomized to form 50 pairs presented on 10 A4 format landscape oriented sheets with 5 pairs per page. Each pair occupied about 4 cm (horizontal) by 11.5 cm (vertical). For the 11 testing sessions, the pairs were randomly ordered on the 10 sheets to avoid mnemonic or learning effects.

2.3 Procedure

OMIE’s teaching is a 5-year program to train group therapists for group analysis. Trainees follow courses on group analysis theory, methods and applications, and they also participate in analytical groups to gain practical experience with group dynamics. Practical training is based on 10 modules per year, each one lasting one day and a half. Participants of different years are divided into groups of 8 to 10 people including a conductor (group leader) and an observer, who are members of staff. In the case under study there were four such groups (A to D, Table 1). These groups meet 3 times for 1h30 in the course of a module. At the end of each day, the four groups gather for 1h30 in a “large group” that also includes the “large group” leaders (group E in our table).

Finally, group F is composed by the members of the directing committee, which includes the remaining staff and meets during the course of the module.

During the first test session, participants filled the socio-demographic form indexed with a code to render data anonymous. The same code was used to mark the "absurdum questionnaires". The overall experiment includes 11 tests, in which participants had to select one picture for each of the 50 pairs of the questionnaire. The first test was taken the first day before the training actually started. The remaining 10 tests were given at the end of the second day (Saturday) of each module. For administrative reason, the staff did not pass the second test at the end of the first module.

2.4 Data Analysis

To analyse the data, the most frequently selected picture of each pair during the first test will be indicated as picture A (A_i, i=1, 50), while the other picture will be designed as B (B_i, i=1, 50). Frequency tables were computed for each pair of pictures and each one of the 11 sessions (see Figure 2) and a detailed analysis has been reported in the previous work.

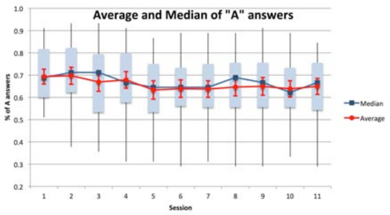

Figure 2: Evolution of the average proportions of the pictures the most selected initially (picture A). The proportions of participants (± 95% confidence interval shown on average points, red vertical lines), who chose the initially preferred pictures (A), are averaged over the 50 questions for each of the 11 sessions (abscissa). The figure also shows the median (blue line) and interquartile (blue boxes and black lines) evolutions.

a) For each of the 11 time-points, we performed separate exploratory multiple correspondence analyses (Le Roux & Rouanet 2004; Greenacre & Blasius 2006) to describe participant behaviour toward the 50 pairs of pictures. Multiple correspondence analysis is a generalization of principal component analysis, where the variables to be analysed are categorical (Jolliffe 2002). To explore the relationships among participants within the 50 pairs of pictures at a time-point, we analysed an indicator matrix, with columns corresponding to the pairs of pictures and rows to participants. A value of one indicates that the participant selected the A picture of the corresponding pair, while a value of zero indicates they selected B. Then, we derived the Burt matrix (Greenacre 2007), which is a cross-tabulation of all pairs of pictures among participants, and performed correspondence analysis in order to obtain the decomposition of total inertia in orthogonal dimensions, in a way analogous to the decomposition of variance in principal component analysis. We estimated the total inertia explained by the first six dimensions, and the coordinates for each pair of pictures on these first six dimensions. To investigate changes in behaviour toward pictures, we compared graphically picture projection plots of column coordinates after principal normalization across time-points.

   We calculated the average for each of the six projections (p_1, p_2, p_3, p_4, p_5, p_6), and the global average of these averages (p_{ave}).

b) We calculated the Bernoulli entropy as the sum of the entropy of the answers to the 50 questions for each of the session:

$$H_j = \sum_{i=1}^{50} -p_{ij}\log(p_{ij}) - (1-p_{ij})\log(1-p_{ij})$$

   where p_{ij} is the observed probability (frequency) of obtaining answer A for the i^{th} question ($i \in [1, 50]$) at the j^{th} session ($j \in [1, 11]$). We compared the trends of multiple components analysis and the one of Bernoulli entropy over the 11 sessions. The objective was to observe the coherence between the

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evolution of the choices expressed by the multiple components method (the average for each of the six projections (p_1, p_2, p_3, p_4, p_5, p_6) and the global average of these averages (p_{ave}) with the evolution of entropy. We underline that this comparison is only qualitative.

3 Results

In the overall data set we found 2,143 missing data points out of 24,750, which were filled in using the last observation carried forward approach (LOCF) as detailed in the previous study. We recall that the staff (14 members) did not complete the second questionnaire, which represents a total of 700 (i.e., 50 x 14) missing data.

a. Orientation of the choices

To explore the relationships within the 50 pairs of pictures among participants at each time-point, we performed separate exploratory multiple correspondence. The results are reported in Figure 3. The change in choices is signalled by a sudden variation of the values of the projections and their average. An increase in the value of the projections is associated with a greater coherence in the answers (orientation of the group), while a decrease is associated with a loss of coherence in the answers of the group. We observe a first large increase of p_1, p_2 and p_3 at the 4th test administration (3rd week of training). The first visible change for p_4, p_5 and p_6 appears instead at the 5th test administration (4th week of training). The projection average (p_{ave}) shows a first positive fluctuation at the 4th test administration (3rd week of training). We observe a second large increase for the projections p_1, p_4, p_5, p_6 and p_{ave} at the 9th test administration (8th week of training). p_1 shows an important decrease the 7th test administration (6th week of training), accompanied by a less marked decrease of p_2 and p_3.

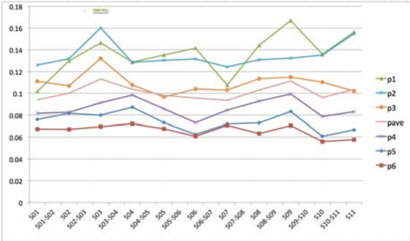

Figure 3: Evolution of the projections of the multiple correspondence analysis (p_1, p_2, p_3, p_4, p_5, p_6) and of their average (p_{ave}) during the 11 tests.

b. Entropy of the choices

The entropy (reported in Figure 4, green line) shows an increase from the beginning to the end of the experience, which is the expected behaviour in an isolated system, with a slight decrease at the 2nd test administration (1st week of training) and at the 9th test administration (8th week of training). The diminution at the 1st week is not coincident with the trend of p_{ave}, as we could expect, under the hypothesis of an inverse relationship between the orientation of the choices and the value of entropy. By contrast, the diminution of the entropy at the 8th week of training is coincident with the second larger change of p_{ave}, which happens at the same week of training.

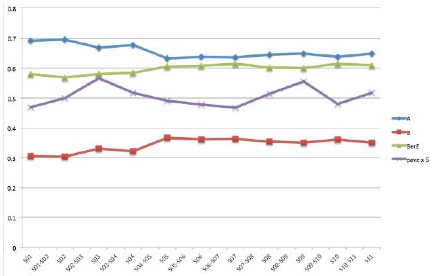

Figure 4: Evolution of the Bernoulli entropy during the 11 sessions (BerE, green line). We have also reported the trend of the A and B responses during the sessions (blue and red lines, see text for explanation) and the average projection (p_{ave}, purple line),

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multiplied by five to facilitate visual comparison.

4 Discussion

As reported in the previous study, the initial answers to the test are not a 50%-50% random choice between the two pictures of each pair, despite the fact that the pairs of pictures were chosen trying not to induce social or cultural biases. As discussed, this initial bias could be, at least in part, the reflection of some shortcoming of our protocol or a genuine group effect.

Indeed, according to Bion, group effects could be seen as soon as people are actually put together. They do not even need to interact actively, and the mere assembly of individuals should be enough to connect unconscious and to provoke group phenomena.

A future version of such a protocol will include the demand for prospect participants to fill the questionnaire before they actually meet for the first session. In practice it is not easy to obtain a questionnaire filled before the beginning of the training above all because during the first evaluation meeting the candidate is not yet chosen for the training. In other hand, sending the questionnaire after the selection exposes the study to the danger of copies with possible memorisation of the images. To propose a second meeting for the purpose of the research is very demanding in organisation and expensive.

4.1 Orientation and Entropy of Choices

We observe some changes in the trend of the orientation of choices at the 3rd and 9th test administrations, i.e., during the 2nd and 8th weekends of training, corresponding respectively to the phases of group idealisation at the beginning, and of group disillusion that occurs before the mourning of the group.

"Honey moon" (dependence from the leader), and the successive "fight-flight" attitudes (reaction against the dependence from the leader) could be represented by an increase in the joint orientation of the choices.

The Entropy increases during the experience as in a closed system, with a slight diminution at the 2nd test administration (1st week of training), i.e. very early in the training (before the "honey moon"), and at the 9th test administration (8th week of training). The trend of average projection and Entropy seem reciprocally inversed starting from the 4th test administration. We can postulate that the "honey moon" and the successive "fight-flight" attitudes influence the orientation of choices and the Entropy, but that only "fight-flight" attitudes influence Entropy.

5 Conclusions

The present work has been conducted during a group analysis training at the Basque Foundation for the Investigation of Mental Health (OMIE) at Bilbao. The objective is to look for evidence in favour of the influence of group dynamics on individual choices of images in a questionnaire aimed at minimising, or at least reducing, cognitive and social bias.

Globally the Entropy shows the typical behaviour of a closed system. It is interesting to notice that the orientation of choices as described by the exploratory multiple correspondence analysis is not similar to the trend of the Entropy in the three first test administrations. Subsequently the trend of choices and the trend of the Entropy become inversely correlated from the 4th test administration. The orientation of choices seems to change the trend of the Entropy only in the second part of the experience, during the "fight-flight" (reaction against the dependence from the leader) attitudes

If we consider that entropy links the concepts of order and information, we could consider that it is an expression of a more fundamental archetype, which otherwise has been expressed as Chaos and Cosmos, Eros and Thanatos and so on. In this interpretation entropy, as all archetypes, has two faces, the creative order (how much order is there) and the destructive disorder (how much disorder is there), but also the destructive order (there is no more information to obtain) and the creative disorder (there is still information to obtain).

We could then propose the following interpretation. When entropy increases in groups, both creative and destructive, this is due to the “work group”. According to Bion this is the aspect of the group that does “keep the group anchored to a sophisticated and rational level of behaviour” (Bion 1961). The activity of the work group increases order but reduces the amount of information that can be extracted. At the same time the disorder, both creative and destructive decreases, and this is a sign of a reduction of the effect of the basic assumptions. The action of the basic assumptions is to increase the disorder, but also to increase the amount of information that can be extracted from the group.

In this sense the observed evolution of entropy indicates that the work group progressively, but not monotonically, supersedes the action of the basic assumptions, once the information available is extracted and made explicit. Consequently order is brought into the group, while creativity and disorder are reduced. This again is in accordance with Bion’s view of the group dynamics, as he maintains that the action of the “work group” tends to eventually prevail.

Because of the postulated early group orientation of the unconscious it will be important in following studies to test the group of participants with an absurd test before personal interactions in group experience take place.

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In 2005 she founded ASTRAG (ASsociation pour le TRAvail Groupal thérapeutique et social) and Simposietto, a reflection group on the relations between physics and human mind. She is member of the Institut International de Psychanalyse et Psychothérapie Baudouin (IIPPB) at Geneva.

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Biological modelling / Biomodélisation

Stochastic monotony signature and biomedical applications

Signature de monotonie aléatoire et applications biomédicales

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ABSTRACT

We introduce a new concept, the stochastic monotony signature of a function, made of the sequence of the signs that indicate if the function is increasing or constant (sign +), or decreasing (sign −). If the function results from the averaging of successive observations with errors, the monotony sign is a random binary variable, whose density is studied under two hypotheses for the distribution of errors: uniform and Gaussian. Then, we describe a simple statistical test allowing the comparison between the monotony signatures of two functions (e.g., one observed and the other as reference) and we apply the test to four biomedical examples, coming from genetics, psychology, gerontology, and morphogenesis.

RÉSUMÉ

Nous introduisons un nouveau concept, la signature de monotonie aléatoire d'une fonction, constituée de la séquence des signes indiquant si une fonction est croissante ou constante (signe +), ou bien décroissante (signe −). Si la fonction résulte de la moyennisation d'observations successives entachées d'erreurs, le signe de monotonie est une variable aléatoire binaire, dont nous étudions la loi de probabilité sous deux hypothèses de distribution des erreurs : uniforme et gaussienne. Nous décrivons ensuite un test statistique simple permettant de comparer les signatures de monotonie de deux fonctions (par exemple, l'une observée et l'autre servant de référence) et nous l'appliquons à quatre exemples de fonctions, issues de la génétique, de la psychologie, de la gérontologie et de la morphogenèse.

1. Introduction

In many biomedical applications, semi-quantitative or qualitative variables are observed, which are valued on a small number of levels (typically the integers from 0 to 10), but are comparable through a strategy of monotony testing. If only the succession of intervals of monotony of the function, between the times of observation (either discrete or continuous), is important for comparing these variables, we only consider the sequence of signs of these intervals ("+1", if the function is increasing or constant, and "−1" if the function is decreasing) called the stochastic monotony signature, and then we calculate the probability that a sequence of signs is similar or not to another

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reference sequence. We will restrict the present study to the case where one cannot observe the same biological object at different times or locations on a one-dimensional scale, because it is experimentally destroyed, censored or individually hidden by a double blind procedure. Hence, it is observed a series of empirical distributions and the monotony intervals, bounded by observation times. The support of the empirical distributions is an interval in the uniform case and an estimate of the 95%-confidence interval in the Gaussian case.

A test will be built under the assumption of independence of the components and increments of the observed variables at the observation times which constitute the frontiers of the monotony intervals and we will present typical examples in four application domains: one will focus on the comparison of intervals of monotony of histograms corresponding to the observation of physiological events (crossing-overs), observed for men and women and compared on a single human chromosome. The second example concerns the answers of a group of individuals during double blinded exercises of choice of an image among a pair of images, along a succession of image pairs presented successively. The third example is related to the evolution during the nychthemeron (day/night 24 h interval) of the number of entrances in a given room, observed for different rooms and successive 25 days. The final example concerns microscopic data about segregation and transport of colloidal particles during microtubule morphogenesis, phenomena compared with and without gravity.

The former biomedical methodologies concerning monotony comparison are essentially coming from the LD50 toxicological bioassays, in which there is no individual horizontal sampling because the animals tested are not reused (because death or pathologic—even minor—reaction) after each dose administration. These bioassays produce data susceptible to benefit from a monotony signature testing, notably in their sequential version, in which the experimental procedure consists in choosing increasing toxic doses $d_1,\ldots,d_n$, giving lethal effects $X_1,\ldots,X_n$ (measured by the percentage of death) based on former experiments done on a known reference drug of the same chemical family giving lethal effects $Y_1,\ldots,Y_n$, procedure called prediction and based on reference chemicals testing [1]. $X_1,\ldots,X_n$ and $Y_1,\ldots,Y_n$ are considered as random variables observed at the same times.

The first attempt to compare the monotony intervals has been to use the rank statistics correlation test [2,3]. More precisely, if $r(X)$ denotes the decreasing rank statistics of X, we have for the sign of the ith monotony interval of X, denoted $\mathrm{sgn}X_i$:

$$\forall I = 1,\ldots,n-1,\ \mathrm{sgn}X_i = 1\mathrm{I}_{\{r(X)_i < r(X)_i+1\}} - 1\mathrm{I}_{\{r(X)_i > r(X)_i+1\}}.$$

Hence, we have:

$$\{\mathrm{sgn}X = \sigma\} = \cap_{i=1,\ldots,n-1}\{X_{i-(\sigma_i-1)/2} < X_{i+(\sigma_i+1)/2}\}$$
$$\text{and } P(\{\mathrm{sgn}X = \sigma\}) = P\left(\cap_{i=1,\ldots,n-1}\{X_{i-(\sigma_i-1)/2} < X_{i+(\sigma_i+1)/2}\}\right) = \int\cdots\int_{A(\sigma)} f(\xi)\mathrm{d}\xi \quad (1)$$

where f is the joint distribution function of X and $A(\sigma) = \cap_{i=1,\ldots n-1}\{\xi, \xi_{i-(\sigma_i-1)/2} < \xi_{i+(\sigma_i+1)/2}\}$

Let us suppose that X is a random vector with independent components and increments; then (1) becomes (2):

$$P(\{\mathrm{sgn}X = \sigma\}) = \prod_{i=1,\ldots,n-1} P(\{X_{i-(\sigma_i-1)/2} < X_{i+((\sigma_i+1)/2)}\}) = \int\cdots\int_{A(\sigma)} \prod_{i=1,\ldots,n-1} f_{i+(\sigma_i+1)/2}(\xi_i)$$
$$F_{i-(\sigma_i-1)/2}(\xi_i) = \prod_{i=1,\ldots,n-1} \int_{S(f_i)} f_i(\xi_i) [(1+\mathrm{sgn}X_i)/2 - \mathrm{sgn}X_i F_{i+1}(\xi_i)]\mathrm{d}\xi_i \quad (2)$$

where f_i (resp. F_i) is the distribution (resp. Cumulative distribution) function of X_i, and $S(f_i)$ denotes its support.

For example, if $\mathrm{sgn}X = (-1,\ldots,-1)$, then we have: $P(\{\mathrm{sgn}X = (-1,\ldots,-1)\}) = P(\cap_{i=1,\ldots,n-1}\{X_{i+1} - X_i < 0\}) = \prod_{i=1,\ldots,n-1} P(\{X_{i+1} < X_i\}) = \prod_{i=1,\ldots,n-1} P(\cup_{\xi i \in S(fi)} (\{X_i = \xi_i\} \cap \{X_{i+1} < \xi_i\})) = \prod_{i=1,\ldots,n-1} \int_{S(fi)} f_i(\xi_i) F_{i+1}(\xi_i)\, \mathrm{d}\xi_i$.

The formulas above show that the knowledge about the rank statistics $r(X)$ gives the monotony signature $\mathrm{sgn}X$, but that the converse is false. Then, an identity test between $\mathrm{sgn}X$ and $\mathrm{sgn}Y$ is possible when the monotony intervals are observed, even if the rank statistics remain unknown. We will build such a test in the following.

2. Stochastic monotony signature: definition and study of the distribution

2.1. Definitions

Let us consider the graphs of real functions of time, $X(t)$ and $Y(t)$, recorded at the same observation instants belonging to the discrete time set $\{t_1,\ldots t_n\} \subset \mathbb{R}$ given in Fig. 1. We suppose that the studied phenomenon involves in

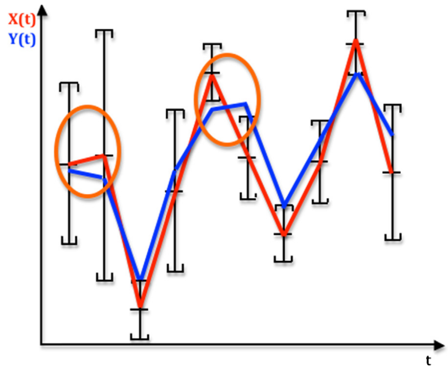

Fig. 1. (Color online.) Temporal profiles of an observed signal X (red) and a reference signal Y (blue) over time t, indicating monotony segments between the successive averages of X, each average being the centre of the empirical 95% confidence interval of a distribution of errors on X supposed to be symmetrical. If it is supposed to be uniform, the weighted monotony signature of X is equal to (0.4,1,0,0,1,1,0,0,1). Monotony intervals circled in orange correspond to the difference between X and Y monotonies.

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general the censoring of the observed system (individual, cell, chromosome...) by loss, death, destruction... Hence, we only get from the experiments the empirical distribution of the data recorded on a sample of individuals different at each time (like in the LD50 experiments). We call monotony signature of X (resp. Y) the sequence of the values "+1" and "−1" corresponding to their successive monotony intervals: $\text{sgn}X_i = +1$ (resp. -1) corresponds to the increase or constancy (resp. decrease) of the function X on its ith monotony interval, and the monotony signature of X (resp. Y) for nine successive intervals of monotony in Fig. 1 equals:
$\{\text{sgn}X_i\}_{i=1,9} = (+1,-1,+1,+1,-1,-1,+1,+1,-1)$ (resp. $\{\text{sgn}Y_i\}_{i=1,9} = (-1,-1,+1,+1,+1,-1,+1,+1,-1)$.

We can decide that the monotony signature of the observed X profile is significantly different from the Y reference profile (Fig. 1), after testing the similarity of these signatures due to a common causality between X and Y (hypothesis H1) against a random choice of the values of the successive $\text{sgn}X_i$'s (hypothesis H0), by using, when $\text{sgn}_iY = -1$, the probability P_{-i} decreasing from a value taken on the support in $\mathbb{R}$ (denoted above $S(f_i)$) of the distribution f_i of X_i to a value of X_{i+1} on $S(f_{i+1})$ (cf. Fig. 2 for $i = 1$):

$$P_{-i} = P(\{X_{i+1} < X_i\}) = P\Big(\cup_{\xi \in S(f_i)}(\{X_i = \xi\} \cap \{X_{i+1} < \xi\})\Big) = \int_{S(f_i)} f_i(\xi) F_{i+1}(\xi) \mathrm{d}\xi \quad (3)$$

where F_{i+1} is the cumulative distribution function of X_{i+1}.

The sequence of the probabilities $\{P_{-i}\}_{i=1,\ldots,n-1}$ of decay of X on its ith monotony interval is called the weighted monotony signature of X.

2.2. Gaussian errors

Proposition 1 In the Gaussian case, where the distribution of X_i is $N(x_i,\sigma_i)$, we have:

$$P_{-i} = \int_0^1 \exp\left[\left(-(g_i(z)-b)^2 + a^2 g(z)^2\right)/2a^2\right]/a\,\mathrm{d}z \quad (4)$$

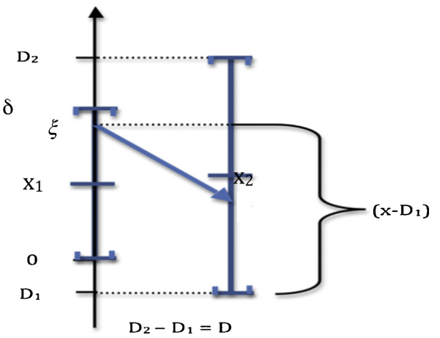

Fig. 2. (Color online.) Calculation of the probability $P\_$ of negative monotony, where $[0,\delta]$ (resp. $[D_1,D_2]$) and x_1 (resp. X_2) denote the interval and the mean of the uniform law of X_1 (resp. X_2).

where $a = \sigma_i/\sigma_{i+1}$, $b = (x_i - x_{i+1})/\sigma_{i+1}$ and $g_i = F_i^{-1}$.

Proof 1 If the density distribution of errors is Gaussian, the formula (3) becomes (by neglecting the index i):

$P\_ = \int_{\mathrm{IR}} f(\xi)\, F(a\xi + b)\, \mathrm{d}\xi$,

where f (resp. F) is the distribution (resp. cumulative distribution) function of the standard Gaussian law $N(0,1)$, $a = \sigma_1/\sigma_2$ and $b = (\mu_1 - \mu_2)/\sigma_2$. By changing the integration variable ξ in $z = F(ax + b)$, we have:

$\mathrm{d}z = af(a\xi + b)\,\mathrm{d}\xi$ and $\xi = (g(z) - b)/a$,

where $g = F^{-1}$. Then we can write $P\_$ under the following formula:

$$P\_ = \int_0^1 [f((g(z)-b)/a)/af(g(z))]\mathrm{d}z$$
$$= \int_0^1 \exp\left[\left(-(g(z)-b)^2 + a^2 g(z)^2\right)/2a^2\right]/a\,\mathrm{d}z$$
$$= \int_0^1 \exp((b(2g(z)-b))/2)\mathrm{d}z \quad \text{if} \quad a = 1$$

Because the cumulative distribution functions of the uniform law on $[-2\sigma, 2\sigma]$ and of the Gaussian law $N(0,\sigma)$ are very close (cf. Fig. 3, right), the results concerning the calculations of $P\_$ are similar. Then, in any case of errors, we have chosen uniformly 100 couples of values $(x_i,x_{i+1})_{i=1,\ldots,100}$ in $[0,10]^2$. Then, we simulated 100 samples of 100 couples of values $(\xi_{ik},\xi_{(i+1)k})_{k=1,\ldots,100}$ by using 100 couples of Gaussian distributions $\{N(x_i,1), N(x_{i+1},1)\}_{i=1,\ldots,100}$, and we calculated the difference Δ_i between the probability P_{-i} calculated from the integral formula (1) and the empirical frequency P_{-i}^* obtained from the observation of the events $\{\xi_{ik} > \xi_{(i+1)k}\}_{k=1,\ldots,100}$. The result is given in Fig. 3 (left), showing as expected that the empirical distribution f_Δ^* of the random variable $\Delta_i = P_{-i} - P_{-i}^*$ is asymptotically (in sample size) Gaussian $N(0,1)$.

2.3. Uniform errors

Proposition 2 In the uniform case, let denote by $[0,\delta]$ (resp. $[D_1,D_2]$) and x_1 (resp. x_2) the interval and the mean of the uniform law of X_1 (resp. X_2). Then, there are six different configurations (cf. Fig. 4):

1) $D_1 < 0 \le \delta \le D_2$, then $P\_ = [(\delta - D_1)^2 - D_1^2]/2\delta D = \delta/2D - D_1/D$ I

2) $D_1 < 0 \le D_2 < \delta$, then $P\_ = 1 - D_2^2/2\delta D$ II

3) $D_2 \ge \delta \ge D_1 \ge 0$, then $P\_ = (d\text{-}D_1)^2/2\delta D$ III (5)

4) $0 \le D_1 \le D_2 < \delta$, then $P\_ = 1\text{-}(D_2^2\text{-}D_1^2)/2\delta D = (2\delta\text{-}(D_2 + D_1))/2\delta$ IV

5) $D_1 > \delta$, then $P\_ = 0$ V

6) $D_2 < 0$, then $P\_ = 1$ VI

Proof 2 In the uniform case, the formula (3) becomes:

$$P\_ = \int_{\sup(0,D1)}^{\inf(\delta,D2)} f(\xi)F(\xi)\mathrm{d}\xi,$$

Hence, we have:

inf(δ,D2)

$$\text{If} \ D_2 \ge \delta, P\_ = \int_{\sup(0,D1)}^{\inf(\delta,D2)} (\xi - D_1)\mathrm{d}\xi/\delta D$$

inf(δ,D2)

$$\text{If} \ D_2 < \delta, P\_ = 1 - \int_{\sup(0,D1)}^{\inf(\delta,D2)} \mathrm{d}\xi/\delta D$$

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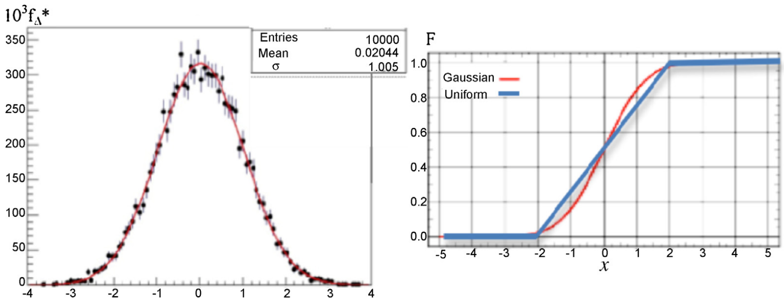

Fig. 3. (Color online.) Left: empirical distribution f_Δ* of the random variable $\Delta = P\_ - P\_$*, asymptotically (in sample size) Gaussian $N(0,1)$ (red curve). Right: theoretical cumulative function F of the uniform (blue) and Gaussian (red) distributions of errors.

Then, by considering all the possibilities of values of the extrema inf(δ,D_2) and sup(0,D_1), we get the six different formulas (5) (cf. Fig. 4) ■

3. A statistical test of monotony

We will suppose in the following that the distribution function of X_i is uniform on $[a_{i1},a_{i2}]$ and that X is a stochastic process with independent components and increments. In Fig. 1, the probability $P\_$ of decay of X is equal to 0.4 for the first interval of monotony and 1 for the fifth (both circled in orange). $P\_$ equals also 1 for the second, sixth and ninth intervals, and 0 for the third, fourth, seventh and eighth ones. Let us denote by $\boldsymbol{P}(\eta)$ the probability of having η differences between the signs of monotony of observed $X(t)$ and reference Y(t) signals. We call H0 the hypothesis saying that monotony signatures of X and Y are similar by chance with independency between X and Y, the probabilistic structure being defined by the empirical estimates of their distributions and the independency of the components and increments of X.

Then, if $\eta = 2$, the probability $\boldsymbol{P}(2)$ under the hypothesis H0 equals:

$$\boldsymbol{P}(2) = \Sigma_{i,j=1,9} P_{\neq i} P_{\neq j} P(\{\forall k \in \{i,j\}, \mathrm{sgn}X_k \neq \mathrm{sgn}Y_k;\ \forall k \notin \{i,j\}, \mathrm{sgn}X_k = \mathrm{sgn}Y_k\}) \quad (6)$$

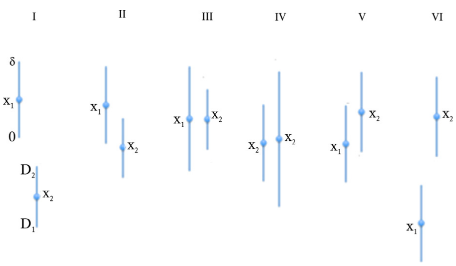

Fig. 4. (Color online.) The six different configurations of X_1 and X_2 supports in the case of the uniform distributions of errors.

where $P_{\neq i}$ is the probability that the monotonies of X and Y are different on the ith interval:

- in the case where sgn$Y$ is deterministic, $P_{\neq i} = P\_{}_i$ if sgn$Y_i = +1$ and $P_{\neq i} = 1 - P\_{}_i$ if sgn$Y_i = -1$;
- in the case where sgn$Y$ is random and independent of sgn$X$: $P_{\neq i} = P\_{}_i(X)(1 - P\_{}_i(Y)) + (1 - P\_{}_i(X))P\_{}_i(Y)$, where $P\_{}_i(X)$ denotes the probability that X decreases on its ith monotony interval.

In the case of Fig. 1, we have, by supposing the successive monotony signs of Y known with a certainty of 3/4:

$$\boldsymbol{P}(2) = (0.4 \times 0.75 + 0.6 \times 0.25)(1 \times 0.75 + 0)(0.75)^7 \approx 0.045 \quad (7)$$

We can therefore consider that the probability of rejecting falsely the hypothesis that monotony similarity, except for $\eta = 2$ intervals, is due to chance with independency between X and Y is less than 5%. This test is not as powerful as a correlation test, but it is interesting in the case of a low number of longitudinal observations in which signal amplitude is not pertinent compared to monotony, when the variance of the empirical correlation with a reference signal is important. Easy calculations above require that reference Y and observed signal X are known at the same instants of observation and random process X(t) has independent components and increments. The cause of rejecting the hypothesis of similarity with independency between X and Y is the presence of a link between successive values of the observed and reference signals.

4. Biomedical applications

We will give in the following simple illustrative examples where monotony signature is pertinent.

4.1. Genetic events localization

Fig. 5 below gives the localization X (resp. Y) of the physiologic crossing-overs along chromosome 3 for human females, with the blue curve in Fig. 5 (resp. males, with red bars) [4]. By comparing the two monotony signatures as given, we reject the hypothesis that female and male

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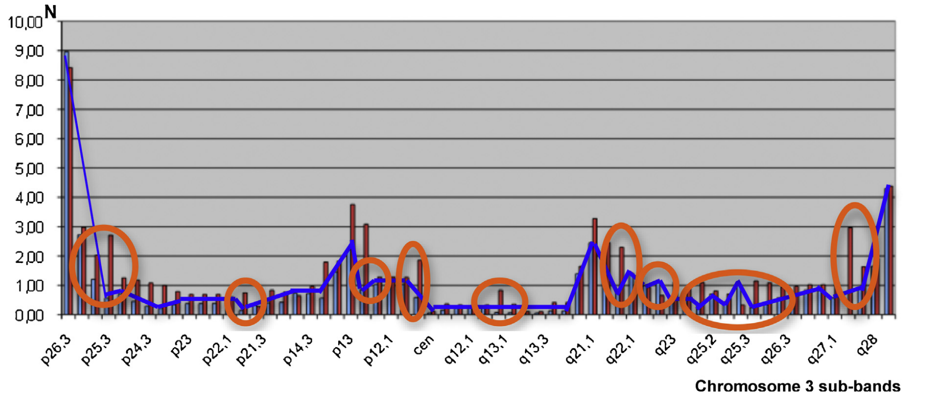

Fig. 5. (Color online.) Crossing-over numbers N (male red bars and female blue curve) along the human chromosome 3 (12/63 monotonic discrepancies encircled by orange ellipses).

crossing-overs have similar localization by chance with independency between X and Y ($P < 10^{-7}$), which is in favor of the existence of the same frailty domains along the male and female chromosome, explaining the frequency of crossing-over co-occurrences.

4.2. Individual choices and collective consciousness

During successive sessions of choice, participants belonging to a defined group are choosing one picture from an "absurd questionnaire" consisting of 50 pairs of pictures, in each of which one picture has to be chosen [5]. The results given in Fig. 6 are used to search for evidence in favor of the influence of group dynamics on individual choices of the pictures proposed in the questionnaire. The swaps between the two pictures of a pair, measured for each pair of pictures between the initial choice (called A choice) across sessions could be interpreted as a manifestation of group dynamics: for instance, the "honeymoon" (dependence on the leader) and the successive "fight-flight" (reaction against the dependence on the leader) attitudes could be represented by a greater number of group dynamics swaps (further away from pure randomness). It seems intuitive that an increase of simultaneous swaps could be linked to an increased group activity or group dynamics event. Statistics carried out on the totality of swaps A→B or B→A evidenced a significant increase in the swap numbers between S01/S02 and S02/S03 session transitions, and between S03/S04 and S04/S05 session transitions, incompatible with a random fluctuation. In other words, the number of changes in choices increased

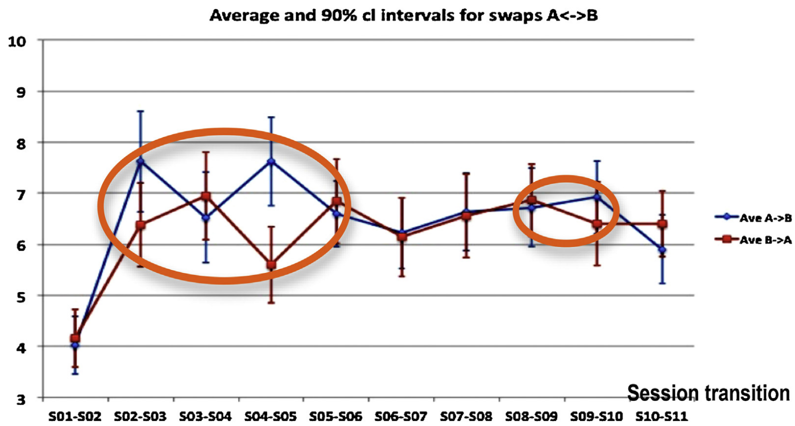

Fig. 6. (Color online.) Group dynamics-driven swaps from picture A to B and from picture B to A, occurring over time between 11 consecutive sessions for each of 50 pairs of pictures, for the two types of swaps (A to B and B to A). We see inside orange ellipses the localization of discrepancies between the monotony of the curves relative to A→B and B→A swap numbers.

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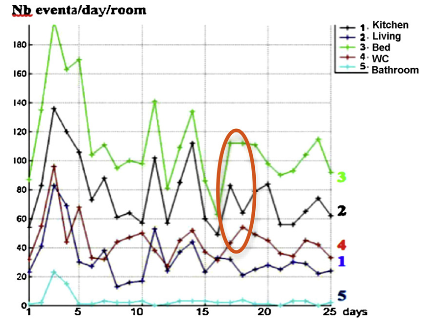

Fig. 7. (Color online.) Evolution during the nychthemeron (day/night 24-h interval) of the number of entrances in room, for different rooms, during 25 successive days. We see in orange the localization of the monotony dissimilarities between curves No. 3 (number of entrances in bedroom) and No. 4 (number of entrances in the toilets).

significantly between the 1st and the 3rd sessions, and then remained essentially constant until the end of the training, except between the 3rd and the 5th sessions. During session S04, the number X of A→B swaps and Y of B→A swaps showed similar fluctuations close to significance against similarity obtained by chance with independency between X and Y ($P = 0.6$), while there is no significant change in the evolution of the sum $X + Y$. This is consistent with the existence of a collective unconscious behavior.

4.3. Actimetry

After 25 days of observation of a person at home [6–8], we get the results given in Fig. 7 corresponding to his/her staying in the different rooms of a smart flat in which different sensors recorded his/her activity at home. They allow us to calculate different temporal profiles assigning the observed person in different clusters corresponding to a normal or a pathologic behavior. Alarms can be triggered when passing from a normal type of nychthemeral activity to a pathologic one. For example, in a degenerative neural pathology like Alzheimer's disease, we can observe an abnormal activity in the same room, called perseveration, which is a pathologic repetition of actions in general already successful ("errare humanum est, perseverare diabolicum") [9]. We model this phenomenon of persistence in a pathologic activity by setting atypical extended occupancy periods in a room or by performing repetitively a specific daily routine, in comparison to more standard scenarios encountered in everyday life.

A way to compare different temporal evolutions of room occupancies is to follow the evolution in time of the number of events of entrance in room, for different rooms and 25 successive days. The fluidity of the activity can be related to the number of entrances in connected rooms like the bedroom and the toilets, because a decorrelation between these numbers could sign a stereotyped activity by repeating for example pathological entrances in the toilets or non-entrances from the bedroom (e.g., in case of anuria, nocturia, or pollakiuria). The data in Fig. 7 show that only three discrepancies within a period of 25 days allow us to reject a similarity between entrance activities No. 3 and No. 4 by chance, with independency of these activities ($P = 2 \times 10^{-7}$), the same monotony signature for connected rooms being then the sign of a normal behavior.

4.4. Microtubule morphogenesis

In [9,10], the authors recall that weightlessness is known to affect cellular functions by as yet undetermined processes, but with a role of the cytoskeleton and

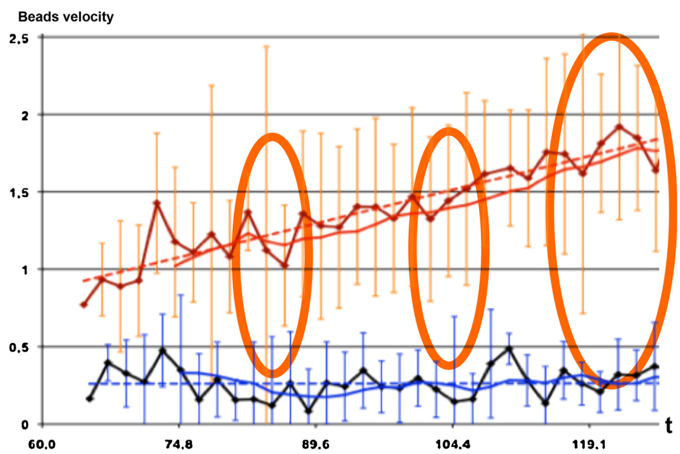

Fig. 8. (Color online.) Evolution during 60 s of the observed number of beads in the cell preparation, showing 4/30 discrepancies (orange ellipses) between the bead numbers observed under a gravity field (1G for the red curves) and in the absence of gravity (black and blue curves).

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microtubules, which behave as a complex system that self-organizes by a combination of reaction, diffusion, collective transport and self-organization of any present colloidal particles [9]. This self-organization does not occur when samples are exposed to a brief early period of weightlessness [10]. During both space-flight and ground-based (clino-rotation) experiments on the effect of weightlessness on the transport and segregation of colloidal particles, a significant difference between the velocity of colloidal particle beads has been observed (Fig. 8), as well as the rejection of the similarity by chance with independency between gravity and non-gravity monotony signatures during the evolution of the microtubule organization in embryonic cells ($P = 3 \times 10^{-5}$). This suggests, depending on factors such as cell and embryo shapes, that major biological functions associated with microtubule-driven particle transport and self-organization might be strongly perturbed in velocity amplitude, but not in sequencing, by weightlessness.

5. Conclusion

The stochastic signature of monotony and the associated statistical test of similarity of monotony allow us to manage situations in which two signals have to be compared, not in amplitude, but only through the succession of their monotony intervals. Numerous situations in which this approach can be used exist in biology, and we have selected four cases in biomedicine, in which the present tool seems to be pertinent.

If there exists an empirical correlation between two successive increments, then the test must be done with a reference signature provided with this correlation structure estimated from the empirical law. It is the case if the process is observed through a longitudinal sampling of individual histories, even if the process has independent components. More, if the components are not independent, but if it is possible to calculate the joint empirical distribution of the signs of monotony signature for each individual history, provided it makes sense at the observation level (time sampling allowing the estimation of the non-Markovian dependence of the increments), and if we know the distribution of the reference signature, then the test to be used is an identity test between reference and empirical distributions. This situation will be studied in a future article.

Disclosure of interest

The authors declare that they have no competing interest.

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