Cognition and Consciousness as manifested in the quantum model of reality realized by using Clifford algebra.

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Abstract

The brief history of the development of quantum mechanics is elucidated and the important concepts of observability, quantization, wave function, measurement are elaborated. Cognition is described as a quantum interference phenomenon and Clifford algebra is employed to describe this processes of thoughts, intention, consciousness etc. It is indeed a highly technical paper employing mathematical equations significant with philosophical implications on Quantum consciousness expressing the long research experience and the physical and mathematical erudition of the writer.

Key words:
quantization (quantum action), observability, existence and wave function.

Development of Quantum Mechanics

Niels Bohr ., "On the Constitution of Atoms and Molecules", Philos. Mag. Ser. 6, 26; 1-25 (Part I), 476-502 (Part II), 857-875 (Part

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III); (1913). Quantum theory made its debut in the fall of 1900 when Max Planck, professor at the University of Berlin, succeeded in deriving a formula for the spectral distribution of thermal radiation that agreed precisely with experiment (Planck 1900).

The formula was based on the unconventional, and (at the time) unjustified assumption that electromagnetic radiation at any (visible or invisible) spectral colour can be absorbed or emitted only in tiny portions of energy, called "quanta." Planck's formula—later called "Planck's law"—resolved the long-standing puzzle of why all ("black") bodies at the same temperature have the same thermal colour. Fostered by advances in spectroscopy and thermodynamics, Gustav Kirchhoff, a previous professor at Berlin, had discovered a half-century earlier, this universal relation (Kirchhoff 1859). Kirchhoff's discovery was recognized as being of fundamental rather than technical importance—something akin to Newton's universal law of gravity. Accordingly, much experimental and theoretical effort was devoted to thermal-radiation spectroscopy. With Planck's successful resolution of a problem of universal scope, quantum theory, while still at the margins of physics, acquired a touch of foundational significance. More importantly, the theory's underlying concept of stepwise change introduced a new paradigm to the description of nature. The previous paradigm—continuous change—had gained universal credibility because of its basic role in the greatest triumph of mathematics: the calculus.

The second step in the advance of quantum theory occurred in 1905 when iconoclast Albert Einstein, still a patent clerk in Bern, used Planck's quantum concept to explain the obscure photoelectric effect (Einstein 1905). Einstein assumed that light consisted of "light quanta"—later called "photons"—that would hit electrons like bullets. Both Planck and Einstein assumed a universal ratio between photon energy and radiation frequency, $Q/f = h$, later called Planck's constant. They differed, though, in interpretation. Planck regarded merely the radiative emission and absorption process as quantized, but not, like Einstein, radiation per se. In contrast to Planck's resolution of a universal problem (thermal radiation), Einstein's contribution appeared less significant—an attempt to explain an experimental oddity. Einstein invoked Planck's quantum theory in two other cases. One was his theory of the specific heat of solids at low temperatures (Einstein 1907). In the other case, Einstein calculated energy fluctuations of radiation and found that they consisted of both wave and particle contributions (Einstein 1909).

With its next appearance, however, quantum theory moved from the margins of physics to centre stage when it addressed the most important question of the day: the structure of the atom. The notion of atoms had already appeared in some natural philosophy of ancient Greece—a speculation vindicated only two and a half millennia later. However, from the late 1700s on, the concept of atoms had attracted serious consideration as it provided a simple explanation for the discovery that pure chemicals react without remainders only in certain weight (or volume) proportions (Dalton 1842). Strong support for atoms came from the related discovery that all chemicals can be broken down into (less than 100) "elements," whose systematic relations were successfully displayed in the periodic table (Meyer 1864, Mendel´eev 1869). Other support for the concept of atoms came from the gas laws and their explanation with molecular kinetics (Maxwell 1859, Boltzmann 1868). Nevertheless, in the phenomenological spirit of thermodynamics, opposition to the existence of atoms was still raised at the turn of the century by extreme proponents (Mach 1896, Ostwald 1902) of the greatest discovery in physics in the 1800s—the unifying principle of conservation of energy (Mayer 1867).

The atomic adversaries ("energeticists") conceded that atoms were useful thought patterns but not reality. Their main argument was that mechanical laws, applied to atoms, could not account for irreversibility because of the independence of the equation of motion on the direction of time. [In response to such doubts, and following Boltzmann's footsteps, Einstein, in his doctoral thesis, put forth further arguments—molecular suspension—for the existence of atoms (Einstein 1906).] So it was in 1913, while on a post-doctoral fellowship in Manchester under the tutelage of Ernest Rutherford, that Niels Bohr of Copenhagen proposed a model of the atom that resolved the century-old mystery of spectral lines (Bohr 1913a). Elaborating Rutherford's recent planetary concept of the atom, Bohr combined Kepler's laws of celestial mechanics with the Planck-Einstein quantization of energy (or alternatively, of angular momentum).

The result was a frequency formula [conceived three decades earlier with numerological guesswork (Balmer 1885)] for the spectrum of the simplest atom—hydrogen—that agreed with experiment to high precision. The same method yielded a reasonable value for the ground-state energy of the next atom in the periodic table, helium, and promising results for some other atoms (Bohr 1913b). Extending the method to questions of the chemical bond, Bohr obtained reasonable values for the binding and spacing of the hydrogen molecule, H_2, but instability for the hydrogen molecule ion, H+ 2(Bohr 1913c).

Bohr's quantum theory found rapid acceptance not only because of its promise to explain atomic structure, spectroscopy, and chemical bonding, but also because of its mathematical simplicity—a back-of-the-envelope calculation with high-school algebra. This was in contrast to Planck's derivation of thermal radiation with demanding mathematics, applied to advanced thermodynamics and electrodynamics. In further contrast to Planck's abstract theory, the great conceptual appeal of the Bohr model lay in its visualization with electron orbits and quantum leaps.

The advantage was that with bold assumptions Bohr derived in a few, strikingly simple steps a frequency formula that historically breached the long-standing riddle of the spectral lines and provided a key to the structure of the atom. It was therefore reasonable to expect that more refined

assumptions would resolve its short-comings and lead to further progress.

Such refinement occurred soon. Inspired by the fact that Planck's constant h has the same dimension as the process quantity of action, $A = \int pdg$ with q being a generalized coordinate and p the conjugate momentum, Arnold Sommerfeld, professor at the University of Munich, had previously sought a connection of quantization with the process quantity A—the quantity that the backbone of the (least-) action-principle of mechanics. In this context he had coined for h the term "quantum of action" (Sommerfeld 1911). Instead of Bohr's ad hoc quantization of angular momentum, Sommerfeld subsequently proposed that atomic process action should be quantized for each degree of freedom (Sommerfeld 1916). [The same quantization conditions had been proposed independently, albeit without application to atomic structure (Wilson 1915, Ishiwara 1915).] Lifting Bohr's special assumption circular orbits, Arnold Sommerfeld, invoked the general case of Kepler motion: elliptical orbits. He quantized separately the action of the electron's radial and angular motion.

Werner Heisenberg enters the University of Munich in 1920 where leading the quantum theorist of Bohr, Sommerfeld , and their co-workers. Heisenberg set for himself the task of finding a new quantum mechanics upon returning to Gottingen from Copenhagen in 1925. Inspired by Bohr and his assistant H.A. Kramers in Copenaghen, Pauli in Hamburg, and Born in Gottingen, Heisenberg's intensive work is to achieve a well definite and detail goal. Since the electron orbits in atoms could not be observed, the Heisenberg's objective is to try to develop a quantum theory without them. He relied instead on what can be observed, namely the light emitted and absorbed by atoms. By July 1925 Heisenberg reached this objective by giving an answer. However, the employed mathematics was so unfamiliar that he was not sure to have hit the target. Heisenberg handed a paper on the derivation to Max Born. After puzzling over the derivation, Born finally recognized that the unfamiliar mathematics was related to the mathematics of arrays of numbers known as "matrices." Born sent Heisenberg's paper off for publication. It was the advent of quantum mechanics. The following was the abstract of the Heisenberg's first paper on quantum mechanics:

The present paper seeks to establish a basis for theoretical quantum mechanics founded exclusively upon relationships between quantities which in principle are observable

Together with his other assistant, Pascual Jordan, Born worked toward the further development of quantum mechanics based upon the abstract mathematics of matrices. After Heisenberg returned from his youth-movement travels, the Göttingen work resulted in a famous "three-man paper" setting forth the details of a new matrix-based quantum mechanics, the "matrix mechanics." With the introduction of additional concepts (electron "spin" and Pauli's "exclusion principle"), Heisenberg, Born, Jordan, Pauli, and others showed that the new quantum mechanics could account for many of the properties of atoms and atomic events.

Within few years some basic results have been reached:- The authors were convinced to have realized a theory of atoms. Really, they have undermined the conceptual foundations of physics introducing a completely new vision of our reality at the microscopic level. The objective is realized in a wild manner uprooting the foundations of our more traditional knowledge. Their new conceptual references are clear: quantization, quantum of action, physics founded exclusively upon relationships between quantities which in principle are observable namely, Heisenberg's indetermination principle and, finally, under the mathematical perspective, the use of abstract mathematics of the matrices.

Really, the situation in physics in those years, it is not excellent. The authors are not actually in front of a great achievement of the knowledge: finally, we have realized the atomic physics! Are we emerging in fact into the elements of a deep crisis at the conceptual level? The quantum of action discovery, underlying concept of stepwise change, does not introduce only a new paradigm to the description of nature. The previous paradigm, the continuous change, had gained universal credibility because of its basic role in the greatest triumph of mathematics and its relative calculus. But of course also continuous approach had given serious problems and discussion about basic paradoxes well known as Zeno's. Quantum of action arrives as a major upheaval that has remarkable implications both in science and philosophy. We have discussed in detail such feature in previous papers (see as example Neuroquantology, What is the reason to use Clifford algebra, Part I and II) and we have shown as the way to solve the old problem of continuous and discrete jumps is to admit existence of abstract entities, just the basic elements of the $A(S_i)$ -Clifford algebra , reconciling of course it and bit (matter and information) .

Concept of Observability

Heisenberg introduces the concept of observability. Note that he speaks of a quantum mechanics, founded exclusively upon relationships between quantities which in principle are observable. Note that he use terms as founded, in principle, observable. The physics of that time is based upon a very simple and clear assumption. We have the outside world, the matter, molecules, atoms, macroscopic structures as solid bodies, gas mixtures, all concrete entities existing independently from our observation and thus from our perception and cognition. About matter we, as human beings, may perform measurements, and matter operates by itself as well as on the other hand our mental abstract entities operate on the other independent hand. The physics of the time elaborates on a vision of naive realism that rejects the suspension of judgment and mostly does not admit an external reality in relationship with or depending from the observer. The Heisenberg proposal, which in addition is still connected to his uncertainty principle, sets out a new vision, shocking because it does not appear of immediate approach as Bridgman operativism, but a new prospect having profound not only epistemological but ontological implications. Physics founded in principle on obesrvability implies the advent of a measurement device, still of an automatic or human observation and each measurement or observation implies a semantic act. A semantic act implies cognition. The net distance between the two previously admitted worlds of matter from one side and mind entities from the other hand, for the first time it seems to be reduced and in some way to relate. A principle of existence was also introduced by Heisenberg. *I believe that the existence of the classical "path" can be pregnantly formulated as follows: The "path" comes into existence only when we observe it. (Heisenberg, in uncertainty principle paper, 192)*

Albert Einstein was the first to catch a profound and uncertain loss of previous conceptual foundations about the foundations of our reality and to guess that there could be implications not only at epistemological but also ontological level. Immediately, Einstein objected to Heisenberg approach about a theory based only on observable quantities. Einstein was right. In fact, note that according to the founding father of the theory we are now running about three basic keywords: quantization, observability, existence.

Observability implies a semantic act. Therefore, Heisenberg first introduced cognition and thus mental entities recalling the fundamental role of the observability. In my opinion this is the first basic indication that should not escape to our consideration. Heisenberg also spoke of existence, another concept that was foreign to classical physics. According to classical physics, matter is there by itself and it does not come to existing as consequence of observability. Some new important ontological features seemed to arise and the surprising feature is that all such so new "keywords" seemed to approach the basic scheme of our reality also if the initial purpose of the quantum theory seemed to be that one to realize a theory of atoms. There is another feature. The mathematics (supporting the theory) was considered complex and inadequate in those times. Matrix algebra was little used by physicists at that time as well as Clifford algebra that of course establishes a matrix isomorphism. Let us look at the illuminating words of P.M. Dirac:

> “I saw that non commutation was really the dominant characteristic of Heisenberg’s new theory. It was really more important than Heisenberg’s idea of building up the theory in terms of quantities closely connected with experimental results. So I was led to concentrate on the idea of non commutation. I was dealing with these new variables, the quantum variables, and they seemed to be some very mysterious physical quantities and I invented a new word to describe them. I called them q-numbers and the ordinary variables of mathematics I called c- numbers to distinguish them… Then I proceed to build up a theory of these q-numbers. Now, I did not know anything about the real nature of these q-numbers. Heisenberg’s matrices, I thought, were just an example of q- numbers, may be q-numbers were really something more general. All that I knew about q-numbers was that they obeyed an algebra satisfying the ordinary axioms except for the commutative axiom of multiplication. I did not bother at all about finding a precise mathematical nature of q-numbers”.

It seems to me that Dirac sees the need to use an appropriate mathematical structure which then subsequently I will identify in the algebra of Clifford. In conclusion, my opinion remains that, in front of a great advance of the knowledge that was retained to have been obtained about the physics of the atoms, a great conceptual upheaval took hold even without full awareness of the founding fathers of the new theory. In order to explain the physics of the atoms they arrived to nock some basic features of our reality suggesting a radical and shocking way of looking at it.

Consequently we had a time of great achievement of knowledge because finally we began to understand the physics of the atoms but at the same time, it brought immediately to a model of reality totally unrelated to the physics of the past and to the traditional model of classical physics to intend our reality and our ordinary experience, causing in this way what I have called previously a strong condition of crisis. Of course, it does not end here.

Just to complicate the situation, independently, and somewhat later, the Austrian physicist Erwin Schrödinger proposed another quantum mechanics, an alternative "wave mechanics" in 1926 introducing his celebrated equation. The wave mechanics appealed to many physicists because it seemed to do everything that matrix mechanics could do but much more easily and seemingly without giving up the visualization of orbits within the atom. Erwin Schrodinger developed an equation that revolutionized the known world of physics. It is an equation that describes how the quantum state of a physical system changes in time. Simply the equation uses the wave function of a particular system to predict how the system will change over time. Some important features of the equation are the quantized energies and the form of the wave function. These products can be used to calculate other properties of the same system. The Schrodinger Equation is the core of today's quantum mechanics.

Now the keywords have become four: quantization (quantum action), observability, existence and wave function.

Wave function is a further object obscure in its meaning. An observable? No. It cannot be observed. Has it objective or subjective meaning? This question will determine a so long debate. Certainly, it enters with bullying in the set of our four keywords. According to our results, given a quantum system, it enters as a "factor of knowledge" whose importance is basic in the architecture of our reality. Still according to our results, it is not an observable in the usual sense previously said by us in quantum theory, but, according to our results, it may be reconstructed. In the traditional sense it represents a probability amplitude that is to say an estimated mathematical entity whose square modulus gives a density probability. This was the interpretation that was connected to the wave function by Born and it runs correctly still to day.

The result of this long story is that complementarity, uncertainty, and the statistical interpretation of Schrödinger's wave function resulted finally to be all related. Together they formed a logical interpretation of the physical meaning of quantum mechanics known as the "Copenhagen interpretation." About Bohr's complementarity we will not discuss here for brevity. Of course it is a celebrated principle, well known also from ordinary textbooks of quantum mechanics. Only we will indicate a detail that may be less known. Introducing the complementarity principle, Bohr was long influenced by a thorough reading of William James, philosopher and psychologist. Still we have to outline the meaning of wave function intended as "factor of knowledge". Again the cognitive aspect is also called into question in this case as previously outlined also for the other keyword that we discussed.

Finally, there is the probabilistic interpretation given by Born to the wave function. Copenaghen interpretation introduces an irreducible indetermination and a probabilistic essential feature as basic features in investigation of our reality. By these new paradigms, the old classical physics results a distant memory now. Events in quantum mechanics are regulated by probability fields. This is to say that probability fields are abstract entities and at the same time they are causally responsible for the events that occur in our reality. We may conclude here. The basic keywords are: quantization (quantum action) , observability, existence, wave function, irreducible indetermination, quantum probability fields as abstract entities.

We outline several times the term abstract in abstract entities.
Let us summarize Copenaghen interpretation:

1. A system is completely described by a wave function Ψ , representing the state of the system, which evolves smoothly in time, except when a measurement is made, at which point it instantaneously collapses to an eigenstate of the observable that is measured.

2. The description of nature is essentially probabilistic, with the probability of a given outcome of a measurement given by the square of the modulus of the amplitude of the wave function. (TheBorn rule, after Max Born)

3. It is not possible to know the value of all the properties of the system at the same time; those properties that are not known exactly must be described by probabilities. (Heisenberg's uncertainty principle)

4. Matter exhibits a wave–particle duality. An experiment can show the particle-like properties of matter, or the wave-like properties; in some experiments both of these complementary viewpoints must be invoked to explain the results, according to the complementarity principle of Niels Bohr.
5. easuring devices are essentially classical devices, and measure only classical properties such as position and momentum.
6. The quantum mechanical description of large systems will closely approximate the classical description. (This is the correspondence principle of Bohr and Heisenberg.).

Collapse of the Wavefunction

Mathematically, quantum mechanics runs about states represented in an orthonormal basis in an Hilbert space. Observables are represented by linear, hermitean operators acting on. The most basic principle of quantum mechanics is the superposition principle. Mathematically, it refers to a property of solutions to the Schrödinger equation; since the Schrödinger equation is linear, any linear combination of solutions to a particular equation will also be a solution of it. Such solutions are often made to be orthogonal (i.e. the vectors are at right-angles to each other), such as the energy levels of an electron. In other words, the overlap of the states is nullified, and the expectation value of an operator is the expectation value of the operator in the individual states, multiplied by the fraction of the superposition state that is "in" that state (eigenstates). In brief quantum mechanics runs about possible alternative states for a system. They all exist at the same time for the given system. The principle of quantum superposition states that if a physical system may be in one of many configurations (alternatives, states) then the most general state is a combination of all of these possibilities (of all such alternatives simultaneously coexisting), where the amount in each configuration is specified by a complex number.

Let us assume, as example that there are two configurations (alternatives, 0 ,1; Yes , Not) , the superposition principle states that such two alternatives both coexist simultaneously . The wave function or the Hilbert state vector is expressed as

$$|\Psi\rangle = c_1[0) + c_2[1)$$

or

$$|\Psi\rangle = c_1[Yes) + c_2[Not)$$

where $|c_1|^2$ is the probability for state $|0\rangle$ (or $|Yes\rangle$) to arise as result of the measurement and where $|c_2|^2$ is the probability for state $|1\rangle$ (or $|Not\rangle$) to arise as result of the measurement .

The following features must be hold.

The superposition principle has an ontological and not an epistemological meaning. This is to say that reality, as described from quantum mechanics, runs maintaining simultaneously the different alternatives, as example $|0\rangle$ and $|1\rangle$ simultaneously, $|Yes\rangle$ and $|Not\rangle$) simultaneously.

Each alternative state has a probability of being and thus to be actualized during the measurement or during the collapse of the wave function as correctly such jump and unpredictable mechanism of transition is currently named. Thus we have an irreducible , intrinsic indetermination for reality described from quantum mechanics and regulated from a field of probability that is an abstract field and it is causal responsible of events. The most extraordinary property of quantum reality, so distant from our every day experience, is that by the superposition principle, alternatives simultaneously coexist.

The basic thesis is that, starting considering a quantum system, we focus our investigation toward a given physical quantity, the observable, to which a linear hermitean operator is connected. Operating in an Hilbert space we have the corresponding eigen vectors that represent the possible orthonormal states (alternatives) linked to such observable while eigenvalues are the corersponding values that this observable may assume as consequence of a measurement We have a wave function, an Hilbert state vector that results to be direct expression of the holding superposition principle . In absence of observation superposition principle and Schrodinger equaltion hold (this last relating time evolution of the given wave function) : all the possible alternatives simultaneously coexist. During the interaction of this system with a measurement device , the given wave function collapses. This is to say that we have transition from such given superposition to a final actualized state and we will measure the outcome of the measurement,(the numerical result of the observable) with a certain probability.

Let us consider as example the S_Z spin component admitting possible values $+\frac{\hbar}{2}$ and $-\frac{\hbar}{2}$.

Call $|0\rangle$ and $|1\rangle$ the orthonormal basis that spans the spin - $\frac{1}{2}$ space.

$+\frac{\hbar}{2}$ and $-\frac{\hbar}{2}$ represent the two possible eigenvalues corresponding to the two possible eigenstates $|0\rangle$ and $|1\rangle$ In this case we have only two possible alternatives.

In this manner, owing to the pressing validity of the superposition principle, the most general spin state (or we may call it wave function) is represented as

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

where $|\alpha|^2$ represents the probability that , when measuring, we will obtain the value $+\frac{\hbar}{2}$ while $|\beta|^2$ represents the probability that , when measuring, we will obtain the value $-\frac{\hbar}{2}$.

Note some important features:

before of the measurement both the alternative simultaneously coexist , in fact we have

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

- As consequence of the measurement we will have the collapse the Ψ and a corresponding process of actualization in the sense that between the two existing alternatives , only and only one value will be actualized with some defined probability (or $+\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$). and we, in the framework of our ordinary, everyday experience, will conclude that, as consequence of the measurement , the investigated physical quantity has assumed the value $+\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$

Some observations result necessary. What is really the meaning of the superposition principle in the context of our reality! Copenhagen interpretation frequently was not completely clear on this point. Several times it outlined that the wave function is only a mathematical instrument to evaluate probabilities, a representation of our knowledge status about the investigated system. We may acknowledge that, also if posed in such so approximate terms, the statement is of extraordinary importance since, still again, it recalls the role and the function of the knowledge, and thus of our cognition and of our mental entities. We need to involve us as human being and cognitive functions in order to represent quantum reality. In addition Heisenberg went a step on. He introduced the term of *potentia* in a manner that resulted very similar to that one used many centuries before by Aristotle.

Further advances achieved in the last eighty years have convinced us that the role of the superposition principle must be acknowledged very seriously and therefore the concept of *potentia*, initially invoked by Heisenberg, although not in the Aristotle sense, really represents a fundamental aspect of reality as described from quantum mechanics. In absence of our observation, quantum reality is no more represented as in our ordinary experience regulated from a stringent Boolean logic, yes-not, true –false. Quantum reality admits "and" and not "or". All the alternatives coexist in the framework of a new category that we must identify with the term of potentiality. Potentiality is ontological at this level of reality. And wave function is expression of such ontological, potential condition. When a measurement arises, a transition is realized in quantum reality from potentiality to actualization. This transition is the well known mechanism of wave function collapse. As a final point it is to be noted that the measurement cannot be intended as the poor act to look at a device. We must convince ourselves that every measurement is a semantic act. Consequently always cognition and mental entities are involved.

Therefore, concluding, we started considering that the quantum mechanics performed its advent to be the physics of the atoms. We have arrived to conclude that presently it has shown to be much more. It outlines a model of our reality and it is like a god of two faces Giano looking on one side to matter per se and, on the other face, looking to abstract entities, to mental entities, to the basic concept of existence and to cognitive functions. Another thing quantum reality has been revealed. It is marked from an irreducible, intrinsic indetermination. Let us now go on discussing our results. The lesson given us from quantum mechanics is very hard. Classical physics is limited not only because it is unable to enter in the domain of our microphysical reality but, fundamentally, because it is based on a vision of ingenuous realism that rejects the refuses the suspension of judgment that instead quantum mechanics evidences as basic feature of quantum reality and, in addition, it is structured on a classical scientific and philosophical vision according to which the external reality does not depend from the observer, a feature that instead quantum reality poses at the basis of its approach.

Clifford Algebra

Still another question is would the mathematics that finally was used to elaborate quantum mechanics was appropriate? My answer is negative. Still remember Dirac's words about c- and q-numbers. We really need a mathematics that is able to make out the reality delineated by quantum mechanics as a bare bone skeleton. Clifford algebra has such basic features. Let us sketch briefly what a Clifford $A(S_i)$ algebra is.

Let us admit that we introduce three abstract symbols, three elements that for our purpose we will indicate as basic unities, not to be confused with the basic unity 1 of the natural numbers.

Call them e_1, e_2, and e_3. I repeat. They are not numbers. They are symbols, abstract entities.

Let us admit now the first axiom. I assume that

$$e_1^2 = 1 \ , \ e_2^2 = 1 \ , \ e_3^2 = 1 \ ,$$

I am admitting that the square of such basic elements is 1.

Now let us introduce the second axiom.

When we consider natural numbers, we are accustomed to consider the commutativity respect to the multiplication. This is to say that

5x4=4x5 =20; 3x7=7x3=21 and so on.

In the cased of the Clifford we admit instead that commutativity no more holds and in detail we admit that

$$e_1 e_2 = -e_2 e_1 \; ; \; e_2 e_3 = -e_3 e_2 \; ; \; e_3 e_1 = -e_1 e_3 \; .$$

In conclusion, we have three abstract symbols, called basic elements, their square is 1 and they are not commutative.

A Clifford member of the $A(S_i)$ algebra may be realized easily using such basic elements and the unity of the natural number. As example, A Clifford member is

$$q = 1 + 7e_1 - 2e_2 + 3e_3$$

and I may execute all the standard arithmetic operations among Clifford members, as the sum, the difference and the multiplication.

As example I may perform the sum of the following two members:

$7 + 2e_1$ and $2 - 3e_3$

and I will obtain $9 + 2e_1 - 3e_3$.

I may perform multiplication, and I will obtain

$$(7+2e_1)\,(2-3e_3) = 14 - 21e_3 + 4e_1 - 6e_1e_3$$

Obviously the result will be different if I perform the following multiplication

$$(2-3e_3)\,(7+2e_1) = 14 - 21e_3 + 4e_1 - 6e_1e_3$$

Does it exist an algebraic structure having such mentioned properties?

The answer is positive. It was introduced by Clifford and looking at my publications the reader will verify that we have given direct mathematical proof. We started to use such kind of algebra starting with 1972 because we are convinced that such mentioned three symbols and the two added axioms represent the basis to describe a large scale of our reality.

Let us start discussing the first axiom. As mentioned we admit that

$$e_1^2 = 1 \; , \; e_2^2 = 1 \; , \; e_3^2 = 1$$

Remember that e_1, e_2, and e_3 are symbols not number . I never can write $e_1 = 1$ or $e_2 = -1$ or $e_3 = 1$

So doing I should go admitting that they no more are symbols but numbers and this procedure is prohibited from its starting. They never can assume numerical values.

Of course, instead

$$e_1^2 = 1 \ , \ e_2^2 = 1 \ , \ e_3^2 = 1$$

means that their square is the unity 1.

What is the conclusion! It is that I have three basic symbolic elements that cannot assume a numerical value but their square is 1. This is to say that they have the potentiality to be or $+1$ or -1, better $+1$ and -1 since the square of $+1$ or -1 is always 1.

Such basic elements, e_1 , e_2 , and e_3 ,have the ontological potential possibility to be +1 and -1 at the same time also if never a definite numerical value , +1 or -1 , may be attributed to them.

They have the potentiality but not the actualization to be a definite numerical value.

As you see we re-find verbatim the superposition principle of quantum mechanics. There both states have the ontological potentiality to exist, here each basic abstract element has the ontological potentiality to be $+1$ and -1 without never assuming one of such definite values. During mathematical elaboration they constantly transport such intrinsic property to be +1 and -1 .By Clifford algebra we have re-found one of the basic foundations of quantum mechanics: the superposition principle.

We see with our eyes as quantum reality runs. Admit that we are discussing a physical process that requires a complex number of Clifford members operations. During the mathematical development conducting to the final result, each basic element, e_1 , e_2 , and e_3 , travels with such marked property of being +1 and -1 at the same time. And this is exactly what it happens for quantum states until an actualization happens. Out of actualization the arising quantum model of reality is thus pure ontological potentiality where all the alternatives coexist.

Let us admit that we have a situation to which the basic element e_1 is connected. Still consider that $+1$ means as example that something is true or that something happens or that something exists. On the contrary -1 means that that it is false or that it does not happen or that it does not exist. Quantum reality, in absence of actualization, does not respond to a Boolean logic. This is true or it is false. This happens or it does not happen, it exists or it does not exist. Both the alternatives coexist and the level of this reality is of potentiality not of actualization. That is true and false at the same time; it happens and does not happen, it exists and does not exist at the same time.

What is the rule in these cases? It is that one of the probability. Such alternatives are given in this quantum reality from probabilities. True and false may coexist at the same time with 0.5 of probability but may be also that true is with probability 0.7 and false with probability 0.3 or the vice versa. The same reasoning hold for what it happens or what exists. We have the picture of a reality in which all the alternatives coexist and signed from a probability field, marked consequently from an irreducible indetermination and so distant from our ordinary experience since in our current every day experience a traffic light is red or green but never we are accustomed to use a traffic light being at the same time red and green with some probability. Instead this is the quantum reality that we re-find now by using Clifford algebra and in full agreement with standard quantum mechanics.

Why do we use Clifford algebra? The reason is so important. I adopt a structuralist position. Mathematical structuralism is the view that pure mathematics is about abstract structure or structures. This philosophical view is currently displayed in a variety of forms. I acknowledge that abstract structures exist, that pure objects of the mathematics are in some sense elements of, or places in, those structures, and that there is nothing more to the pure objects of mathematics than can be described by the basic relations of their corresponding structure. I view mathematical structures as abstract objects and analyze elements and relations of such structures. My background theory is based on an insight into the nature of abstract objects and predication, namely, that abstract objects are constituted by the properties through which we conceive or theoretically define them and therefore are connected to those properties in a way that is very different from the way ordinary bear their properties. I may say that mathematical objects encode these constitutive properties, though they may exemplify or even necessarily exemplify, other properties independently of their encoded properties. On the contrary, ordinary objects only exemplify their properties. As mentioned by Nodelman and Zalta, as example, ordinary triangular objects (as example , the faces of some physical pyramid , triangles , ..) exemplify properties like having sides with a particular length, having interior angles of particular magnitudes, being made of a particular substance, and so on. By contrast, the mathematical object, the Euclidean triangle, does not exemplify any of these properties indeed, it exemplifies their negations. Instead it encodes only the theoretical properties implied by being triangular, such as being trilateral, having interior angles summing to 180 degrees and still more. The Euclidean triangle encodes no other properties than those implied by being triangular. Therefore, although classical logic requires that exemplification mode of predication exclude objects that are incomplete, the encoding mode of predication allows us to assert the existence of abstract objects that are incomplete with respect the properties they encode. Thus, we might use the encoding mode of predication to assert the existence of abstract objects whose only encoded properties are those they are theoretically defined to have according to some mathematical theory.

This is the reason because, starting with 1972, linked to standard formulation of quantum mechanics, we started to use Clifford algebra to attempt to evidence the bare bone skeleton that is delineated from quantum reality. The first objective has been reached. Using an algebraic structure we have been able to delineate some basic features of quantum reality that are represented from the ontological potentiality, from the probability fields as abstract entities that are causally responsible of events and from an irreducible intrinsic indetermination. We are now in the condition to take a step on. We said previously that a given mechanism is given in quantum mechanics. It is the so called collapse of the wave function.

Given a quantum system, it has some potential alternatives that are represented by the wave function or state function of the system. When such system is interacting with a measurement device, the wave function collapses. This means that all the alternatives or potential states cease to exist and we measure only and only one result on our instrument with a certain probability. The wave function is reduced to represent only one of such possible alternatives. We have what we may call a transition from a condition of potentiality to a condition of actualization.

We may say that by the collapse of the wave function we re-enters in the picture of the world of our every day normal experience. No more a traffic light having simultaneously red and green but an appropriate empirical evaluation. We see, we measure that it is red or green. We transitate from the world of the *and* to that one of the *or* as actually happens at any instant for any object, thing or property that obeys to our direct perception and cognition. In the framework of a correct Boolean logic alternatives no more exist, *tertium non datur*, we have direct actualization of something, of some considered property.

We are thus in one of the greatest problems of quantum mechanics. The theory indicates that we have transitions from potentiality to actualization during observation. The problem is that the science is not accustomed to admit processes without direct explanation and verification. Starting with the Copenaghen interpretation the problem was first of all to convince physicists about such existing process indicating directly the mechanism as it happens. No one was ever able to find the mechanism of the collapse of the wave function. The only possible explanation was suggested that when entering the wave function in our brain, consciousness induces such collapse .Some observations are required at this point. Again we remember our initial position. Apparently quantum theory was introduced as atomic physics but in fact right from beginning it went to touch central and nodal points of our reality. In confirmation of this we find now that it invokes the intervention of consciousness bringing somehow to light the central problem of mind matter interaction

Quantum Measurement

Physicists accustomed to follow the basic foundations of classical physics, correctly evidenced profound reservation about the new address that physics was assuming since they were convinced that matter is there and that the explanation of processes relating matter does not require the advent of consciousness or of mind entities. In addition, we have to consider that the role of consciousness as responsible of the collapse of the wave function was introduced there without any clear formulation of scientific elaboration. The only valuable effort was that one of von Neumann in 1936 when he introduced some postulates that in fact have remained in the complete formulation of quantum mechanics as the von Neumann's postulates about quantum measurement. This led to a situation of crisis. Science does not admit theories that are not self-consistent. A scientific theory must explain processes with clear and complete elaborations eliminating further appendixes or postulates added ad hoc only to maintain the final coherence of the elaborated theoretical formulation.

The case of quantum mechanics was instead different. From one hand we arrived to have a theory, strange , aggressive, shocking in the presented model of reality : quantization, observability, irreducible indetermination, potentiality, role of mental entities , cognition and consciousness, probability no more intended as in the ordinary meaning in classical statistics but as basic abstract field responsible of events …. But of course it arrived to be self-consistent and well arranged about a sufficient mathematical apparatus. On the other side we had still strange processes as the collapse of the wave function , the transition from potentiality to actualization, role of consciousness and, in addition, suggested only as indication, without demonstration, finally, supported only from some von Neumann's postulates. From one side a theory and from the other side some postulates stuck from the outside of the body of the theory. In brief it arised a theory that for several years was accepted owing to its continuous excellent confirmations but on the other side a non self-consistent theory correctly recalling the profound reservations of a number of serious researchers.

Here I find the great importance of the structuralism that I outlined previously. Few years ago, again using Clifford algebra as mathematical structure to framework quantum mechanics, we have been able to give for the first time demonstration of von Neumann postulates. I think that the result is of valuable importance since for the first time we have given proof of von Neumann postulates, thus we have arrived to give for the first time mathematical explanation of the process of wave function collapse demonstrating that it happens by a transition from the starting Clifford algebra $A(S_i)$ that enables us to formulate all the standard quantum mechanics to the dihedral $N_{i,\pm 1}$ Clifford algebra.

Consequently, the most important objective to return and give self-consistency to the theory has been reached. For the first time we have reached also mathematical confirmation of the existence of wave function collapse. In addition, by using Clifford algebra we have been able to give a complete formulation of quantum mechanics, including basic questions as the quantization, the study of the hydrogen atom, the analysis of the harmonic oscillator, the Schrodinger and Dirac equation, quantum interference, arriving to give also very satisfactory explanations of the well known Einstein, Podolsky, and Rosen paradox of quantum mechanics and, finally, Bell's inequalities. We have covered all the standard as well as all the most advanced questions relating quantum mechanics.

The reader may convince him (her)-self that the structuralism pays and rewards. Starting with 2003 we have started also to consider the question that we advanced previously. My vision is that quantum mechanics is a god Two faces Giano looking from one side to matter and from the other side to mind entities. It was important for us to be able to give a scientific guise to this problem.

We had to give demonstration that quantum mechanics has definite role at the level of our mind entities. The problem is so complex here. Brain is the most complex system we have in nature more than our universe. It is a macroscopic structure. We expect correctly that it follows the rules of classical physics. Of course a lot of results that we do not mention here for brevity, evidence that this is the case. Therefore, looking at the brain, where quantum mechanics should be! Quantum mechanics runs about the basic superposition principle, alternatives coexist at a level of potentiality but actualization is immediately realized as soon an interaction with a macroscopic device is realized. How could potential quantum states survive in a macroscopic structure as the brain? The conclusion seems evident. There is no room for quantum mechanics in the brain. Of course, we have verified that from its starting, quantum mechanics went requiring abstract mind entities as cognition, consciousness, semantic acts, abstract probability fields that are causally responsible of events.

How can an *ab initio* theory that seems to invoke abstract entities of our minds then be unrelated to the brain which is ultimately the key hardware component of our sensory faculties, cognitive and emotional? It seems really difficult to accept reasoning of this type and in fact it is our reasoning approach that is not correct.

Cognition:- A Quantum Process

Brain is a macroscopic structure and, as confirmed from a lot of experimental and theoretical results, it seems to respond to the laws of classical physics. But of course, it is widely accepted that consciousness or, more generally, mental activity is in some way correlated to the behaviour of the material brain. Since quantum theory is the most fundamental theory of matter that is currently available, it is a legitimate question to ask whether quantum theory can help us to understand consciousness. What is the neural correlate of a mental representation? According to standard accounts, mental representations are correlated with the activity of neuronal assemblies, i.e., ensembles of several thousands of coupled neurons. The neural correlate of a mental representation can be characterized by the fact that the connectivities, or couplings, among those neurons form an assembly confined with respect to its environment, to which connectivities are weaker than within the assembly. The neural correlate of a mental representation is activated if the neurons forming the assembly operate more actively, e.g., produce higher firing rates, than in their default mode. The fact that neuronal assemblies are mostly described in terms of classical behaviour does not rule out that classically undescribable quantum effects may be significant if one focuses on individual constituents of assemblies, i.e., single neurons or interfaces between them. These interfaces, through which the signals between neurons propagate, are called synapses. There are electrical and chemical synapses, depending on whether they transmit a signal electrically or chemically.

At electrical synapses, the current generated by the action potential at the presynaptic neuron flows directly into the postsynaptic cell, which is physically connected to the presynaptic terminal by a so-called gap junction. At chemical synapses, there is a cleft between pre- and postsynaptic cell. In order to propagate a signal, a chemical transmitter (glutamate) is released at the presynaptic terminal. This release process is called exocytosis. The transmitter diffuses across the synaptic cleft and binds to receptors at the postsynaptic membrane, thus opening an ion channel.

Distinguished scientists as Eccles, Beck and Walker did an important observation. Also if the whole brain should be considered as a macroscopic classical structure, there is in it one and only one mechanisms that on the contrary and without of any doubt evidences intrinsic indetermination and uncertainty. This is matter of quantum mechanics. The idea suggested by Beck and Eccles in the 1990s was that quantum mechanical processes are relevant for the description of exocytosis at the synaptic cleft and can be influenced by mental intentions. Remember the basic key of quantum mechanics. The abstract field of probability is causally responsible of events.

In our opinion beck and Eccles and Walker have given the most promising explanations. It refers to particular mechanisms of information transfer at the synaptic cleft. The information flow between neurons in chemical synapses is initiated by the release of transmitters in the presynaptic terminal. As said, this process is called exocytosis, and it is triggered by an arriving nerve impulse with some small probability. In order to describe the trigger mechanism in a statistical way, thermodynamics or quantum mechanics can be invoked. A look at the corresponding energy regimes shows that quantum processes are distinguishable from thermal processes for energies higher than 10^{-2} eV (at room temperature). Assuming a typical length scale for biological microsites of the order of several nanometers, an effective mass below 10 electron masses is sufficient to ensure that quantum processes prevail over thermal processes.

The upper limit of the time scale of such processes in the quantum regime is of the order of 10^{-12} sec. This is significantly shorter than the time scale of cellular processes, which is 10^{-9}sec and longer. The sensible difference between the two time scales makes it possible to treat the corresponding processes as decoupled from one another. The detailed trigger mechanism proposed by Beck and Eccles was based on the quantum concept of quasi-particles, reflecting the particle aspect of a collective mode. The proposed trigger mechanism refers to tunnelling quantum processes of two-state quasi-particles, resulting in state collapses. It yields a probability of exocytosis in the range between 0 and 0.7, in agreement with empirical observations. Using a theoretical framework developed earlier the quantum trigger can be concretely understood in terms of electron transfer between biomolecules. Walker used the same quantum tunnelling approach obtaining excellent results confirmed experimentally.

Eccles and Beck in 1992 (Beck and Eccles, 1992; 2003; Eccles, 1990; Beck, 1996; Margenau, (1950; 1953; Wolf, 1989) obtained by direct calculations that the synapses in the cortex may respond in a probabilistic manner to neural excitation; a probability that, given the small dimensions of synapses, should be governed by quantum uncertainty. These authors produced direct estimations

that still today result very convincing. The first detailed quantum model of quantum conjunction synapse was given by the physicist, Evan Walker (Walker, 1977). In 1970 he proposed a synaptic tunnelling model in which electrons can "quantum tunnel" between adjacent neurons, thereby creating a virtual neural network overlapping the real one. It is this virtual nervous system that for

Walker produces consciousness and that it can direct the behaviour of the real nervous system. In short the real nervous system operates by means of synaptic messages while the virtual one operates by means of quantum tunnelling. I think that we arrive to a similar conclusion adopting the view of Eccles and of Margenau. It is the abstract field of probabilities that in quantum mechanics determines events. In his 1992 article, Eccles offered plausible arguments for mental events causing neural events via the mechanism of wave function collapse. Conventional operations of the synapses depend on the operation of ultimate synaptic units called buttons. Eccles states that, these synaptic buttons, when excited by an all-or nothing nerve impulse, deliver the total content of a single synaptic vesicle, not regularly, but probabilistically. In Eccles words;

> *Excitation of synaptic buttons delivering the total content of a single synaptic vesicle represents the first intrinsically probabilistic event in the brain. Eccles studied in detail the problem, evidencing that a refined physiological analysis of the synapse shows that the effective structure of each button is a paracrystalline presynaptic vesicular grid with about 50 vesicles. The existence of such a crystalline structure is suggestive of quantum physical laws in operation.*

Eccles focused attention on these paracrystalline grids as the targets for nonmaterial events. He discussed in detail how the probability field of quantum mechanics, which carries neither mass nor energy, can nevertheless be envisioned as exerting effective action at the microlevels of quantum events. In the event of a sudden change in the probability field brought on by the observation of a complementary observable, there would be a change in the probability of emission of one or more of the vesicles. The action of altering the probability field without changing the energy of the physical system involved can be found by the equation governing the Heisenberg principle of uncertainty.

To be clear: for cortical nerve terminals, the observed fraction of action potential pulses that result in exocytosis is considerably less than 100%. This can also be modelled classically, but the large

Heisenberg uncertainty in the locations of the triggering calcium ions, entails that the classical uncertainties will carry over to similar quantum uncertainties. At this stage of elaboration some different authors suggested that the sudden change in the probability field resulting from an

observation could be the mechanism by which mental events trigger neural events. Eccles concluded that calculations based on the Heisenberg uncertainty principle show that the probabilistic emission of a vesicle from the paracrystalline presynaptic grid could conceivably be

modified by mental intention in the same manner that mental intention modifies a quantum wave function.

For experimental evidence showing how mental events influence neural events, Eccles pointed to the papers by Roland *et al.*, in 1980 who recorded, using radioactive *xenon*, the regional blood flow

(rBF) over a cerebral hemisphere while the subject was making a complex pattern of finger-thumb movements. They discovered that any regional increase in rBF is a reliable indicator of an increased neuronal activity in that area. Another evidence, using the same technique of monitoring rBF, showed that silent thinking has an action on the cerebral cortex. For example, merely placing one's attention on a finger that was about to be touched, showed that there was an increase in rBF over the postcentral gyrus of the cerebral cortex as well as the mid-prefontal area. A lot of studies conducted in recent years by fMRI substantially indicate that this is the way.

Eccles concluded that non-material mental events in the brain are at individual microsites, the presynaptic vesicular grids of the buttons. Each button operates in aprobabilistic manner in the release of a single vesicle in response to a presynaptic impulse. It is this probability field that Eccles

believed to be influenced by mental action that is governed in the same way that a quantum probability field undergoes sudden change when as a result of observation the quantum wave function collapses. By this way we arrive to the following basic conclusion: mental events cause neural events analogously to the manner in which probability fields of quantum mechanics are causatively responsible for physical events as well as Wolf outlines. All these are important and fundamental elaborations. I have used terms as probability, link of quantum filed of probability and mental events, irreducible indeterminism. When a physicist starts to speak about structures that admit a so large number of abstract entities, he always feels to be panic-stricken. I am speaking about science or idealizations!

To be clear: all the scientific theories introduce mathematical models, and all they "approximate" or "idealize" in some manner our reality. When in such text I use terms as probability or quantum field of probabilities or "equivalence of probability with space of mental events", or still irreducible indeterminism, it is here that I see the risk of idealizations also if, generally speaking, the admissibility of idealizations in theorizing is and remains of main interest in science. To comment the previous conclusions by Walker, Eccles, Beck and Margenau, I certainly appreciate their highly fascinating content but on the other hand I must be care that some idealizations certainly avoid the

risk to result so extreme as to be considered physically inadmissible. As a rule, we need unquestionable verifications to accept any thesis in science. Therefore let us go on step by step. In order to take seriously in consideration the possibility that synaptic transmission is realized by quantum tunnelling and thus by the foundations and the rules of quantum mechanics, we have to perform direct calculations. In detail we need to calculate the MEEP, (miniature **e**nd **p**late **p**otentials) – Frequency of vesicle release as it is obtained by quantum mechanics and to compare such obtained theoretical results with the existing experimental data. Only such comparison may indicate if we have an agreement or not between experimental and theoretical data and, in case, such positive result may orientate in some manner our thesis that quantum mechanics has a fundamental role.

In quantum tunnelling model formulated by Walker (Walker, 1977) we have that an electron transfer is made between two macromolecules, proteins lying in the presynaptic dark projections of Gray and the postsynaptic density at the cleft. It is postulated that the charge transferred across the synapse results in raising the protein in the presynaptic dark projections of Gray at higher energy levels. As consequence, conformational changes in these molecules forming the vesicle gates in the cleft membrane alter their size determining the macrogates both to open and to eject a vesicle that is to say its contents realizing synaptic conjunction. If we have an electron bound in the molecule that is separated by the synaptic cleft from a second similar molecule, its energy E and the frequency ν by which the electron attempts to escape for realizing quantum tunnelling are well known experimentally. The frequency $\bar{\nu}$ by which the electron makes quantum tunnelling from the first to the second molecule realizing vesicle release results to be

$$\bar{\nu} = \nu P$$

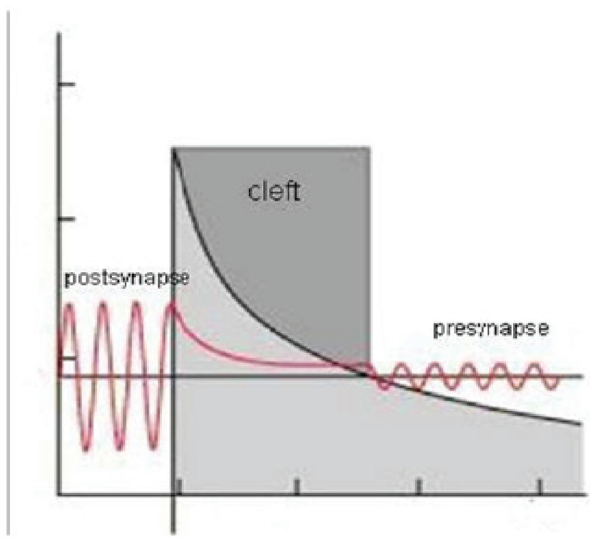
being P the probability of tunnelling that will be function $P(V_0, V_1)$ being V_0 the height of the potential barrier potential barrier. For purpose of calculations we assume here it having the value of 0.118 eV as it arises from the experimental data and V_1 being instead the presynaptic depolarization. The value, L , of the synaptic cleft is considered to be of 180 $A0$ as it is obtained from experimental data. We have performed direct such calculations and verifications on the basis of the quantum results that we elaborated The performed calculations give the following expression for the potential barrier:

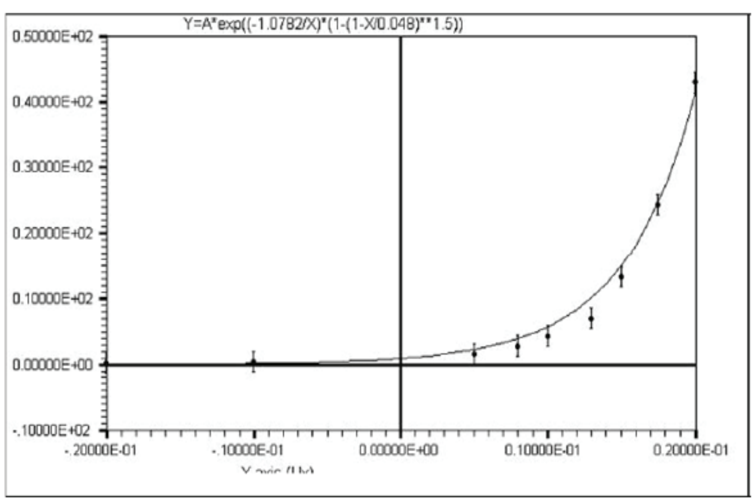
$$V(x) = \left(\frac{V_1 - V_0}{L}\right)x + V_0 \qquad 0 \le x \le L$$

and the value of probability quantum tunnelling results after calculations to be

$$P(V_o, V_1) = \exp(-\alpha \frac{(V_o - E)^{3/2}}{V_1}(1-(1-\frac{V_1}{V_o - E})^{3/2}))$$

$$\alpha = \frac{4\sqrt{2m}}{3\hbar} L$$





In Figure 2 In ordinate we have the values of Mepp-frequency (frequency of vesicle release in sec $_{-1}$) and in abscissa those of depolarization potential. We have the theoretical curve as given by the (1) with the (3) and the experimental values, represented by data points, as they were obtained by Liley in 1956. Liley studied the appearance of MEPPs in isolated rat phrenic nerve-diaphram preparations. More recently experimental results were obtained also by H. Von Gersdorff and coauthors (private communication) and they result very similar to those had by Liley time ago.

One verifies that the agreement between theoretical predictions and experimental data is excellent.

In conclusion we have a robust neurological basis. For brevity we will not discuss here other interesting approaches that were developed as example by Hameroff, Vitiello and still more other authors and the reason should be now clear. Several times, in the present paper, we have mentioned the term of information or flow of information that characterizes at the same time brain dynamics and mental entities. To this particular feature we are so much interested and thus basic approach is devoted to the psychological instead of neurological basis.

Quantum Information Processing in the Brain

Our research activity is to verify if the mathematical formalism and the conceptual foundations of quantum theory are valid to model cognitive phenomena such as information processing by human brain, decision making, human memory, concepts and conceptual reasoning, human judgment, and perception. The reader will take well in mind that this field clearly distinguishes itself from the hypothesis that there is something micro-physical quantum mechanical about the brain. Quantum application at perceptive/cognitive level is based on the quantum basic features that we illustrated and relating information processing by complex systems taking into account to ascertain if contextual dependence of information and probabilistic reasoning can be mathematically correctly described in the framework of quantum mechanical foundations. This field focuses on modelling phenomena in cognitive science considering those previous results that have resisted to traditional interpretation and investigations or where traditional models seem to have reached a barrier (e.g., human memory). Since the use of a quantum-theoretic framework is to use quantum mechanics that from its starting involves mind entities and cognition in particular, the identification of quantum structures in cognitive phenomena does not presuppose the identification of a direct existence of microscopic quantum processes in the human brain also if, as previously said, also at such neurological level we have direct experimental evidences.

In order to reach this objective we started to study processes at perceptive and cognitive level.

Let us explain in brief the formulation. Let us admit that we have selected a subject to which we are free to ask some questions. Suppose we have two questions of dichotomic character, that is to say, the subject may answer only or yes that for us has the conventional value +1 or not that for us has the conventional value -1. Call such questions A and B respectively. I select a group of subjects. To the first group of subjects I pose only the question A and each subject will respond or +1 or -1 so that we will arrive to have the probability for A=+1 and for A=-1 , indicated as p(A=+1) and p(A=-1). To each component of the second group we pose first the question B soon after followed from the posed question A.

Consequently we will have the following probabilities , p(B=+1),p(B=-1) and the subordinate probabilities p(A=+1/B=+1),p(A=+1/B=-1).p(A=-1/B=+1),p(A=-1/B=-1).

Following this experimental scheme, we are able to discriminate if quantum mechanics has a role or not in mind entities of the subjects.

If quantum mechanics has not a role, the classical well known Bayes theorem will hold. It is

p(A=+1)=p(B=+1)p(A=+1/B=+1)+p(B=-1)p(A=+1/B=-1) and similar relation for p(A=-1).

If instead quantum mechanics has a role, Bayes standard theorem will result to be violated and instead of the classical formula previously written , we will have that

p(A=+1)=p(B=+1)p(A=+1/B=+1)+p(B=-1)p(A=+1/B=-1) + quantum interference term

and similar relation for p(A=-1).

In brief we arranged a theoretical and experimental study that does not admit bad interpretations. If the dynamics of the experiment follows quantum mechanics we must have the presence of the quantum interference term in the calculations. If instead quantum mechanics has not room, we must have exactly the results given by application of Bayes theorem we performed the experiment on about 250 subjects. We analyzed subjects engaging their perceptive and cognitive functions using ambiguous figures, we also analyzed subjects engaging only their cognitive functions using Stroop effect. We also analyzed a group of subjects submitting tasks that usually give a great percentage of cognitive anomalies as it is the case, as example, of the well known conjunction fallacy.

All the experiments confirmed the presence of the quantum interference terms, confirmed that mind entities use the superposition principle of quantum mechanics and we were also able to reconstruct the quantum wave function for such subjects. We had complete verification that quantum mechanics has a role in mind entities at perceptive and cognitive level. I am aware that such concept of quantum interference is not clear so that I will now expose a psychological experiment in order to explain quantum interference in detail. It is well know and discussed in psychology.

Select a subject. We switch on the monitor of his computer and a monster appears. We ask to the subject if he decides to attack him or to withdraw. The subject will take a decision. Let us characterize such mental process by quantum mechanics. Again we have a dichotomic variable that we call A . It assumes the value +1 if the subject takes the decision to attack and -1 if he decides to withdraw.

Let us remember all the notions of quantum mechanics that we have exposed until here. We know that the mental condition of the subject will be characterized by a quantum wave function. Call it $|\psi\rangle$ and instead call the mental state responding to "I attack" by $|+1\rangle$ and the mental state " I withdraw" by $|-1\rangle$.

We know the principles of quantum mechanics at this point. When posing to the subject the question attack/withdraw we will pose his mental condition in a situation represented by the $|\psi\rangle$ that will be a potential superposition of alternatives. This is to say that the mental condition of the subject will be

$$|\psi\rangle = c_1|+1\rangle + c_2|-1\rangle$$

where the square modulus of c_1 is the probability that finally he will take the decision to attack while the square modulus of c_2 will represent the probability that the subject will decide to withdraw. Note that we have an initial condition of irreducible indetermination and that the subject will collapse the initial wave function selecting or to attack or to withdraw. Still note that such decision process will be context dependent in the sense that if such question will be posed to the subject to day may be that he will decide to attack. Tomorrow, changing his cognitive –emotive condition, he could also decide to withdraw. Probabilities arising from c_1 and c_2 are context dependent. Well. The subject will decide to attack with a probability p(A=+1) and to withdraw with a probability p(A=-1).

Just to fix our parameters admit that the subject will decide to attack with probability p(A=+1)=0.7 and thus p(A=-1)=0.3. Now we change the experiment. The subject look at the monster but this time we no more pose only one question but two questions. The first will be "Makes you angry or scared ?" and soon after we ask " Do you attack?" or "do you withdraw?". As in the first case, there exists one question only. Estimate now the probability that the subject will decide do attack or withdraw. Remember that they are p(A=+1) and p(A=-1). If we perform such psychological experiment really, in the greatest number of case the two probabilities p(A=+1) and p(A=-1). No more will give the same result. This is to say that, if in the first case we obtained p(A=+1)=0.7 and thus p(A=-1)=0.3., now we will obtain as example p(A=+1)=0.9 and p(A=-1)=0.1 or another different result. It is not important here the substantial difference in probabilities in the first case respect to the second case. The important thing is that the probabilities will be different. This is to say that the perceptive-emotive-cognitive apparatus of the subject functioned differently in the first case than in the second to make a decision.

Have we a theory that is able to explain such happening processes happening at cognitive level in our mind? Quantum mechanics is able to explain and to verify it experimentally. Reason in quantum mechanical terms. When we pose to the subject first a question and thus another we introduce two dichotomic variables. The first is the old A that we just considered. The other is the B consisting in “Makes you angry or scared2 If angry B=+1 and if scared B=-1 and corresponding probabilities p(B=+1) and p(B=-1).

Let us examine the quantum mechanical profile. When we pose to the subject the question B , as previously happened in the case of A , he realizes a mental condition that again is a quantum superposition . If we call $|1B\rangle$ and $|-1B\rangle$ the two possible mental states, the subject will pose him self in a wave function , quantum state

$$|\psi\rangle = b_1|+1B\rangle + b_2|-1B\rangle$$

Remember that the square modulus of b_1 will express the probability that the monster makes angry while the square modulus of b_2 will be the probability that the monster makes him scared. These are the probabilities p(B=+1) and p(B=-1) before mentioned . Now let us admit that the subject will decide that the monster makes him angry. This is to say that he will collapse the wave function posing himself in the mental state $|+1B\rangle$. At the moment in which you ask soon after if he attacks or withdraws, he no more starts , as in the case when you posed only the question A, from a generic quantum states in which he no more is asking him if the “monster makes him angry or scared” and he has not awareness and knowledge about such mental condition. In this second case the subject starts from a definite mental condition that is $|+1B\rangle$.(Monster makes me angry) and when we pose the second question (The A) the quantum function of the subject will be $|+1B\rangle$ and from here he will start to realize a new superposition about the new question posed by A . This is to say that he will realize a new mental condition in which this time we will have

$$|+1B\rangle = q_1|+1\rangle + q_2|-1\rangle$$

No more the subject will be in the mental state

$$|\psi\rangle = c_1|+1\rangle + c_2|-1\rangle$$

but he will be in the mental state

$$|+1B\rangle = q_1|+1\rangle + q_2|-1\rangle$$

In this case the square modulus of q_1 will give the probability p(A=+1) (I attack) and the square modulus of q_2 will give the probability of p(A=-1). Since q_1 and q_2 are different from c_1 and c_2, the probabilities will result different and we will have , as example , p(A=+1)=0.9 and p(A=-1)=0.1 or other possible results.

The first posed question (the B) has given quantum interference on the second posed question A.

The central question relating our cognitive mechanism of decision is that , by posing the question B, the subject has assumed explicit awareness of a mental condition that before was not explicitly evidenced. This is the well known importance of the "knowledge factor" that we outlined from its starting during the present exposition of the basic quantum principles in the present paper and relating the meaning of the quantum wave function. Obviously we have to conclude that by direct experimentation we have full confirmation that actually quantum mechanical predictions are correct.

Quantum Interference

Note that such process of quantum interference must not be intended in a so trivial manner. It could be possible to observe: such result is expected, if I pose first a question and soon after another it is obvious that the first in some manner will determine a kind of perturbation respect to the subsequent. The question of quantum interference is not so trivial. It relates directly the basic foundations of our mental entities and thus of our awareness and of our consciousness. It is well known, as example, that Rorschach ink blots are image that are able to recall conscious and unconscious conditions of our psyche. When a Rorschach table is given to the subject, the image in some manner evokes and invokes internal psychological situations that we have in our mind and in our psyche. It is not so much the perception of the image that enables the subject to recall in some manner his/her emotive condition. It is of fundamental interest that we ask to the subject what he see in that image. At this moment the whole emotive and cognitive system of the subject gives a cognitive answer that in some manner results linked to his/her inner condition. Our posed question enables him to activate a factor of knowledge that is subsequently translated in his/her comments on the picture. The first essential step is that he/she acquires knowledge by moving his/her cognitive-emotive functions starting with our posed question. Quantum interference is not only a matter to estimate how much our apparatus of decision making deviates from classical statistical case but it is the manner to verify that our mind entities have an intrinsic dynamics that is based essentially on the concept of awareness and thus of consciousness. Explicit awareness represents an important step in our cognitive dynamics. It is strongly linked to the concept of knowledge and knowledge is recognition of something that leads to a dynamics of mental states that is radically different from the condition when the recognition is not present in an explicit and conscious manner. This is basically principle that possibly must characterize our reality at each stage. There are stages of our reality in which its dynamics assumes patterns that are strongly dependent from the cognition that we have about it. Quantum mechanics not only gives a net identification of such basic feature of our reality but gives us also the possibility to quantify soon after with great care such basic features. This is of great importance not only when responding to the question to attempt to characterize our reality but also when passing as example at the level of the applications as in particular in diagnostic and therapeutic clinical fields.

Let us insist still about the concept of quantum interference and "knowledge factor" for the quantum wave function. Let us return to the basic quantum mechanical formulation of quantum mechanics. As previously said, according to the general formulation of quantum mechanics, a change in wave function happens during a measurement. It has been ascribed to an unavoidable physical interaction between measuring apparatus and the physical entity to be measured. In detail, N. Bohr in 1935 indicated that this unavoidable interaction is responsible for the uncertainty principle, and more specifically the inability to perform a simultaneous measurement of observable quantities described by non-commuting Hermitean operators. Feynman, Leighton, and Sands explained that the distribution of electrons passing through a wall with two suitably arranged holes to a backstop able to detect the positions of electrons, exhibits interference. The authors explained that this interference is characteristic of wave phenomena and that the distribution of electrons at the backstop indicates that each electron acts as a wave as it passes through the wall with two holes (Fig.1). Feynman et al. explained also that if one was to introduce a procedure in order to determine through which hole the electron passes, the interference pattern is destroyed and the resulting distribution of the electrons returns to be that of classical particles passing through the two holes. Let us follow the discussion of Epstein and of Snyder. For details see : P.S. Epstein, The reality problem in quantum mechanics, American Journal of physics, 13, 3, 127-136, 1945; D.M. Snyder, On the nature of the change in the wave function in a measurement in quantum mechanics (arxiv : quant-ph/9601006;) On the quantum mechanical wave function as a link between cognition and the physical world: a role for psychology, (Cogprints, ID code 2196, 30 Apr.2002, last modifies 12 Sept.2007)

One may think that the procedure may be to introduce a strong light source behind the wall and between the two holes. It illuminates an electron as it travels through either hole (Fig.2). The general quantum interpretation of this experiment is that in determining through which hole the electron passes, the electrons are unavoidably disturbed by the photons of the light source, and this disturbance destroys the interference pattern. In quantum mechanics the act of taking a measurement affects the physical world which is being measured. However, there is still an interesting feature that is at the basis of our approach. In the same experimental arrangement one may determine which of the two holes and electron goes by using a light source that this time is placed not between the two holes but it is placed near only one of the holes and it illuminates only the hole where it is placed (Fig.3). Also in this case in which we illuminate only one of the two holes, one determines which of the two holes the electron travels and again we have a distribution of electrons similar to that one obtains when the light source is placed between the holes. When the light source illuminates only one of the two holes, the electron passing through the other hole does not interact with photons from light source and yet interference is destroyed in the same manner as in the case in which the light source illuminates both the holes. Thus we arrive to the conclusion that was elaborated and discussed in detail by P.

Epstein in 1945 and in various and fundamental papers by D.M Snyder and that we structured at the basis of all our cognitive approach to quantum mechanics as elaborated in detail in this paper.. Quantum mechanics includes the description of some effects that cannot be ascribed to physical origin only, but they include our mental activity. Quantum mechanics is at the same time description of physical reality and human cognition process, semantic act. In fact, in the above described experiments, it is the "knowledge factor", that is to say, our cognitive function, that plays a decisive and unavoidable role. Thus, in conclusion, quantum mechanics is at the same time science of cognition other than physical theory of matter. We will arrive to explain in more detail such view point by the following arguments. Let us give the figures of the previous discussed question.

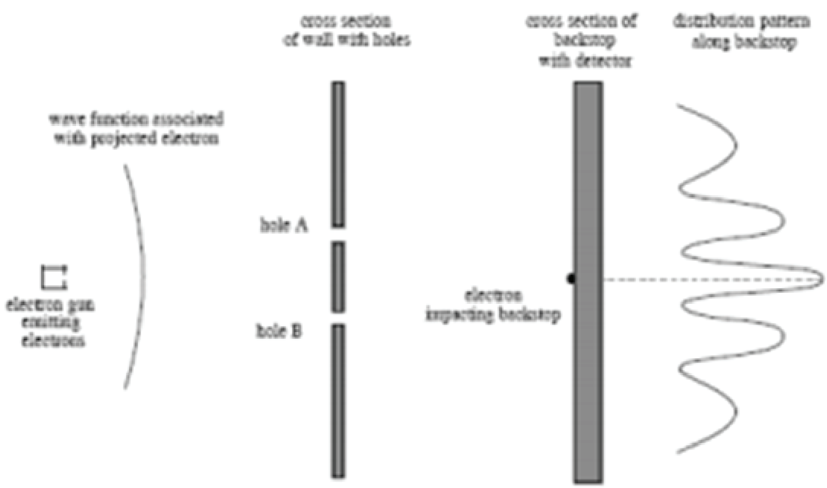


Figure 1

Two-hole gedankenexperiment in which the distribution of electrons reflects interference in the wave functions of electrons. (Gedankenexperiment 1)

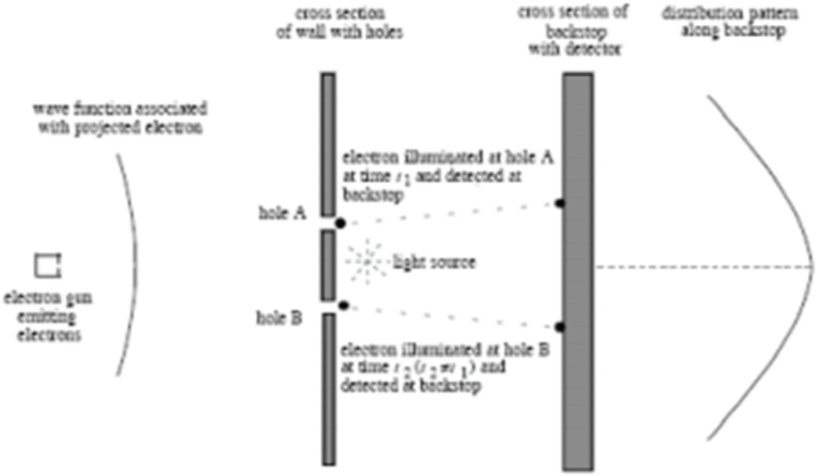


Figure 2

Two-hole gedankenexperiment with strong light source.
(Gedankenexperiment 2)

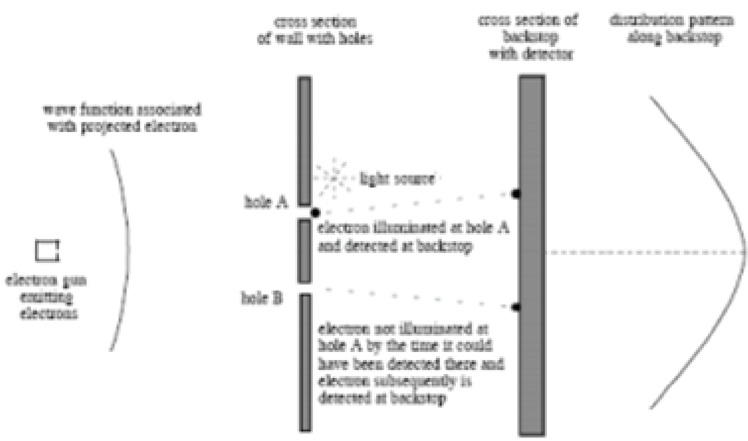


Figure 4

Two-hole gedankenexperiment with strong light source illuminating only one hole.
(Gedankenexperiment 3)

E.
Conte A Clifford algebraic analysis gives mathematical explanation of quantization of quantum theory and delineates a model of quantum reality in which information, primitive cognition entities and a principle of existence are intrinsically represented *ab initio*, World Journal of Neuroscience, 2013, 3, 157-170)

The basic and well known experiment in quantum mechanics has been previously explicated. As example , lectrons are produced from a source and move toward a wall with two slits. Let us admit that we install a device that runs as detection screen. It is posed behind the wall and in this manner we may record whether or not the electron hits at a point *x* along the wall. Let us examine different experimental cases. Close the first slit, the slit 1. The probability with which the electron hits different positions □□ *x* is given .

Now we open the slit 2 and close the slit 1. We call p(x/1) anNow we open the slit 2 and close the slit 1. We call □p(x/1) and p(x/2) the probabilities the particle hits pint x when slit 2 (1 respectively 1) is closed. Now we open both the slits. The probability distribution □□ p(x) becomes with a maximum centred at 0 and it has the well known superimposed interference fringes that we well know. Call this probability distribution for two open slits with □p(x/(1,2)) This is the probability the particle reaches x given it can travel through slit 1 or slit 2.

It is also evident that we expect some relation among □□p(x/(1,2), □□p(x/1) and p(x/2). Here is the core of our central question about quantum interference and the manner in which our mind entities run. In fact, if we use the classical theory of probability we have that p(x/(1,2)) = p(1/(1,2) p(x/1,(1,2))+p(2/(1,2)p(x/2,(1,2)) Here is the point because we , as psychologists or neurologists or as philosophers reveal our inability to understand the real nature of our mind entities and this is also the real motivation because we should arrive to give great emphasis to quantum mechanics and to the picture that it delineates of our mental reality. If we take our usual manner to think and we do not consider the reality as it is delineated from quantum mechanical contents, that of course is so distant from our ordinary manner to think and from our ordinary experience, we find that the previous statement , written in formula, is truly coherent.

And in fact if we read it step by step we are unable to detect only one defect. It says : the probability that the particle hits at a point x when both the slits are open is equal to probability of p(1/ (1,2)) (that is .. particle passes by slit 1 when both are open) multiplied by the probability that particles hits at x passing slit 1 when both slits are open plus p(2/(1,2)) that is obvious….. particle passes by slit 2 when both slits are open, multiplied by the probability that the particle hits point x passing by the slit 2 when both slits are open. No one of us is able to contest. This is a perfect reasonable thinking responding fully to our requirements of rationality.

Unfortunately it is not so. Quantum mechanics delineates a different model of reality and it is that one that is correct. Look at the limit of our previous reasoning according to quantum mechanics as in detail was also outlined by Bordley (Bordley, R.F. (1983) Modeling quantum behavior with standard (nonquantum) probability theory. (*Journal of Mathematical Physics*, **24**, 2411-2421. doi:10.1063/1.525622).

When we reason in classical terms we do a great cognitive anomaly. We assume that it is valid to consider p(x/1) = p(x/1,(1,2) and p(x/2)=p(x/2,(1,2) For us it is acceptable to admit that the particle hits at x when the particle passes by slit 1 is equal to the probability that particle hits at x passing by slit 1 when both slits are open. In the same manner for us it is acceptable to admit that the particle hits at x when the particle passes by slit 2 being equal to the probability that the particle hits at x passing by slit 1 when both slits are open .

This is the crucial error that we do and quantum mechanics arrives to help us indicating that reality does not run in this manner. The previous relations are in evident violation of the whole model that we have delineated in the present paper. We cannot admit that

p(x/1) = p(x/1,(1,2))

and we cannot admit that

p(x/2)=p(x/2,(1,2)

and the basic reason is that the above mentioned equations, on the basis of the arguments previously outlined, contain a basic difference. This difference is the "knowledge factor" (thus the logic statement and thus the primitive cognition act , the semantic act) that characterizes p(x/1,(1,2)) respect to p(x/1) and p(x/2,(1,2) respect to p(x/2) . Relating available information, that is knowledge and thus cognition features, the two previous relations cannot be admitted at some stages of our reality.

The basic reason is that we cannot ignore the cognitive feature that, as a quantum variable, is structured *ab initio* in our reality so that the two experimental conditions responding respectively to p(x/1) and to p(x/1,(1,2)) , and to p(x/2) and p(x/2,(1,2) are totally different. This last example should enhance our understanding of quantum mechanical basic foundations and enable us to convince that by this theory we have found for the first time the manner to actually study and understand the nature of our mind entities , of their basic role in the dynamics of whole our reality.

I have now to take a step on and go to explain in detail the statement that quantum mechanics delineates a model of quantum reality in which information, primitive cognition entities and a principle of existence are intrinsically represented *ab initio.*Let us return for an instant to the Clifford $A(S_i)$ algebra and consider the following its member that we call ρ

$$\rho = \frac{1 + e_3}{2}$$

Let us examine the important features of such member. Let us calculate its square

$$(\frac{1+e_3}{2})^2 = (\frac{1+e_3}{2})(\frac{1+e_3}{2} == \frac{1+e_3+e_3+1}{4} = \frac{2+2e_3}{4} = \frac{1+e_3}{2}$$

The very important property is that it gives

$$\rho^2 = \rho$$

that is to say, its square is itself. Clifford members responding to such properties are called idempotents. What is the important feature! They are encountered also in quantum mechanics and are called projectors. It was shown that they represent logical statements. In 1936 von Neumann showed that logic derives from quantum mechanics. In these last years, using Clifford algebra and its idempotents, we arrived to invert such demonstration. We demonstrated that quantum mechanics derives from logic. We showed that quantum mechanics, realized about indetermination and quantum interference, is constructed on the basis of logic.

I retain that this last result eliminates any possible doubt about the close ties that exist among cognitive functions, matter and capacity of quantum mechanics to be able to look simultaneously to both aspects of our reality. The other basis statement is that if we move in the framework of Clifford algebra and we perform the due transformations we arrive to obtain quantum interference exactly as we , instead to use logical statements, we should being to use physical systems as particles , matter in some manner. *Ab inito* cognition, primitive cognitive entities, mind entities and matter are profoundly linked and this is a great advance in our knowledge an in our understanding about our reality is made.

Of course there also exists a basic relation of quantum mechanics that supports this conclusion.

Consider a given quantum system and select an observable. Call it A. As you know, with certain probabilities, it may assume different values that we call $a_1, a_2, ..., a_n$ (eigenvalues). Quantum mechanics writes the operator A connected to the observable A in the following manner

$$A = \sum_{k=1}^{n} a_k \Lambda_k$$

where the Λ_k are just the projectors and thus the idempotents that we have identified in our Clifford formulation of quantum mechanics . Idempotents mean logic statements and logic statements imply cognition. Thus again, quantum mechanics links matter (the eigenvalues of the physical quantity A) with cognition . The basic key is that this theory delineates that matter and cognition are linked by an indissoluble bond.

We started this paper celebrating the Bohr model that used quantization. Recently the same link with idempotents and thus with cognition has been identifdied by us also in quantization of quantum mechanics. Therefore we have not doubt on this conclusion.

There are stages of our reality in which we no more may consider matter per se and this is to say independently from cognition that we have about it.

Clifford Algebra representing Cognition

Such conclusion completely overwhelms our traditional way of thinking and looking at reality. Matter and mind entities start both *ab initio*. Our primitive cognitive entities are represented in the Clifford algebraic structure. Of course Clifford members identify a space. By this space we may derive the basic metric of Einstein relativity. Therefore I conclude that primitive mind entities exist in a kind of prespace, that one of Clifford algebra with its basic elements, and the projection of this prespace is the space of our current every day experience. In this manner our research resolves also an old scientific as philosophical problem: that one of the location of our mind. We have obtained a lot of confirmation on this features and the results are published on Neuroquantology, on Advanced Studies on Theoretical Physics, on Electronic Journal of Theoretical physics, on International Journal of Theoretical physics, on International Journal of Consciousness Exploration and Research , on Chaos, Solitons and Fractals, on World Journal of Neuroscience . They are all on line and may be easily reached also if we will give detailed literature in a later presentation.

Conclusion

We have concluded, even if only partially, the initial exposure of our research. It remains to do only a brief comment about the problem of consciousness. I retain that also here the structuralism may help us in the attempt to discuss a question that is so complex. Previously we introduced the Clifford algebra and we introduced three basic elements e_1, e_2, and e_3 by which we learned to regard the members of this algebraic structure. We have to add here that such basic elements represent Clifford algebra at its lowest order that is n=2. In our research I also considered the problem that such order may be increased passing to subsequent orders at n=4,8,…….. . There is a salient feature. We may increase the order of basic elements going to infinity. Each time the complexity of such algebraic structure is increasing. The basic point is that going on and thus increasing the order, the basic elements become self-referential. This is to say that at each order they contain in their inner the self-reference to the previous order that was at their origin. At any order they preserve a self-image of themselves in a manner that preserves and recalls what we could call the awareness of their previous order. In such self-referential and self-image attitude we see the primary and primitive form of self-awareness and thus of consciousness.

We expect that the increasing order and complexity of such Clifford algebraic structure at the highest level should at the end be responsible for what we properly identify with the term consciousness. Let us see to go on giving some further explanation of such basic conclusion. Let us start attempting to give some necessarily partial definition of consciousness. Human experience involves various functions as images, intentions,thoughts, and beliefs. It consists of content plus the awareness of such content. Consciousness is a system which observes itself. It evaluates itself being aware at the same time of doing so. We may express such assertion in formal terms: Let x, y, z are statements describing contents of various experiences. They are (atomic) content statements. Starting from such statements, other content statements may be formed by Boolean functions. z = f(x, y,…..) are metha linguistic propositions or experience-describing statements themselves. We are forced to admit existing awareness statements that we call a, b, c, …, self-referential or auto

referential. They require auto referential definitions . What is the manner in which we write such self referential relations ? We follow Kromov (Khromov AG. Logical Self-Reference as a Model for Conscious Experience, Journal of Mathematical Psychology. (2001; 45: 720-731).

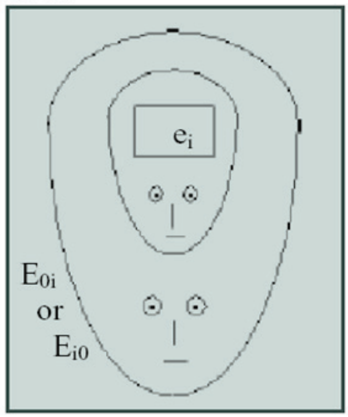
Let us write

$$a_i = F_i(a_1, a_2, ..., a_n; x_1, x_2, ..., x_n)$$

This is the manner to represent a self-referential process .

$$a = F(a, x)$$

is the most simple definition of a single auto referential statement a . For example, *x=this pet is a cat; a= I am aware of this.* Note that for the first time we have also introduced a self referential mathematical formalism. To explain such a referential mathematical operation, let us return to our basic algebraic scheme but evidencing what Lefebvre (Lefebvre V. The law of self-reflexion: A Possible Unified Explanation for the Three Different Psychological Phenomena 2002; http://cogprints.org/2927/) recently outlined. As we know, the central topic of Western philosophy, starting with John Locke, was the problem of representing mentally one's own thoughts and feelings. Actually, it is a very difficult concept to represent. This is the reason to use here a pictorial representation, the same figure that Lefebvre introduced to describe his formulation. We may express self attitude through the reflection. A subject having reflection may be conceived as a miniature human figure with the image of the self inside his head. We recover it here in the following figure. It represents with care the subject with reflection. We prefer to call it the picture of a subject having perception of itself.



In this figure, following Lefebvre, we may say that inside the subject's inner domain, there is an image of the self with its own inner domain. An image of the self is traditionally regarded as the result of the subject's conscious constructive activity. This is actually the mathematical operation that we realize when we use the basic Clifford elements $e_i\,(e_1, e_2, e_3)$ that are given at order n=2 and , starting from this basic step , we continue realizing Clifford algebra at higher levels n=4, 8,…. . We realize for the first time the mathematical structure of the awareness expressing our consciousness by using Clifford algebra. We may have an elaborated discussion later as this last statement concludes the first section of the exposition.