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The Brain Knows More than It Admits: a Quantum Model and its Experimental Confirmation

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Abstract: Neuroscience has realized valuable advances. As example, it has identified brain regions performing learning, memory, feeling and still more. The current tendency in neuroscience retains that adding pieces of knowledge day by day, we will finally arrive to an unified understanding of brain including the manner in which mind and consciousness arise and explain their functions. Also a number of empirical psychological results have been collected. However a profound gap remains between neuroscience advances and empirical psychological data .We retain that such existing gap is due to a missing theoretical model linking neuroscience to psychology . We have arrived to formulate a basic theoretical quantum model particularly of the perceptive – cognitive functions. The result is that quantum mechanics has a decisive role in human cognition. Our quantum model relates directly our mind entities. The model also finds the existing correlations between the brain time dynamics operating without direct awareness and the subsequent behaviour that is induced determining our subsequent behaviours. In the present paper we discuss in detail and for the first time such further basic features of the model. We perform one experiment on priming showing that its results agree with the given quantum mechanical basic model.

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1. Introduction

Our primary evidence is that quantum mechanics has it origin in the logic and thus its basic framework is in the sphere of the cognitive sciences. We have obtained a lot of theoretical as well as experimental results in this direction so that we will attempt to review them here briefly [1-21].

The main thesis is that "It from qubit" as David Deutsch outlined time ago opposing to the view "It from Bit " as in the well known celebrated article of John Wheleer (see the section further lectures in references) Here It states for matter, qubit states for information, knowledge, mental entity, and is represented by the three basic elements of Clifford algebra.

The thesis that we have shown is that quantum mechanics has its elective role on cognition because there are stages of our reality in which matter no more can be admitted by itself but the object no more may be separated from cognition that we, as human beings, have about it.

It and qubit both coexist.

For a detailed elaboration on "It from qubit" the reader may consider as example the article by this author , entitled "It from qubit . . . " that , at the time of the present paper, is in print on Neuroquantology or the review to the recent book Advances in Application of Quantum Mechanics to Neuroscience and Psychology : a Clifford Algebraic Approach (E. Conte, Nova Science Publishers, N.Y. 2012) that is appearing on the next issue of Clifford Analysis, Clifford Algebras and their Applications.

Let us take some interesting features from these papers.

As we said, our thesis is that there are stages of our reality in which we no more may consider matter per se, independently of the cognition that we have about it.

A discussion about *How Come Existence*?

No." *A Really Big Question* " .

A basic theme in which we evidence the large spectrum of possible applications of the methods of the theoretical physics.

We will not ever be pushing the reader on an adventure with ambitious questions that of course should require metaphysical discussions and answers. Rather we remember here the celebrated article of John Wheeler *It from Bit* where , we repeat, *It* states for matter (the objects. . . . . .) and the term *Bit* is an abstraction : a certain amount of information as we are accustomed to say.

And *Information* ?

Still there is here a very important problem.

As we said, and as David Deutsch correctly outlines : if we ask to a classical information theorist , a *bit* is an abstraction , in detail, a certain amount of information.

For a programmer a *bit* is a Boolean variable . For an engineer a *bit* is a flip-flop, a piece of hardware that is stable in either of the physical states .

And for a physicist?

Here the question becomes very complex. *Information* relates *cognition* . Anyway we

intend to mark the matter ,we cannot escape to admit that it relates a semantic act. By this abstract entity , we understand, we quantify real variables, we acquire knowledge , learning, memorization, possibility to transfer knowledge.
In classical physics it has not future.
David Deutsch dates back to the Stoics and to the Epicureans and even earlier when it was debated so long about whether the world is discrete or continuous.
Logic is discrete. It forbids any middle between true and false. In classical physics , discrete information processing is a derivative and rather awkward concept. Actually the fundamental classical variables vary continuously with time (and if they are fields .... with space). They obey differential equations. If classical physicists attempt to engage discrete observable quantities, they do idealisations. There is a continuum of possible states that we should be able to designate by different real numbers. Any two such sets of real numbers , however close, would refer to physically different states which would evolve differently over time and have different physical effects. . In addition we have deterministic chaos because of the possible instability of classical dynamics in some dynamic systems . Therefore Deutsch correctly estimates that since even one real variable is equivalent to an infinity of independent discrete variables , an infinite amount of in-principle –observable information would be present in any classical object.
It is under our eyes that this is an ontological extravagance.
Of course the continuum is a very natural idea. So is the idea that complicated process can be analysed as combinations of simple ones. In addition, it is the essence of information processing and of *It from Bit* .
It is impossible to reconcile such two trends.
Here Deutsch recalls the well known Zeno paradox. He considers the flight of an arrow as described in classical physics. The real valued position coordinates of the arrow are pieces of *information*. The arrow flight is a computation that processes this information.. We could try to analyse that computation as consequence of elementary computations. . But what should the elementary operation be in this case? If we think about the flight as consisting of a finite number of shorter flights , it follows that each of them is complicated as the whole flight. If , on the other hand, retain the flight as consisting of literally infinite number of infinitesimal steps , since there is no such thing as a real number infinitesimally greater than another , we cannot characterize the effect of such infinitesimal operation. We have not the possibility to characterise an elementary computation realized on what we are trying to regard as information..
It from Bit has no room in classical applied and basic physics.
And quantum mechanics? We did not mention it till now.
Quantum mechanics changes radically the picture of our matter..
Quantization. Still according to David Deutsch the old black body problem induced Max Planck to formulate the first quantum theory .This was also consequence of the infinite information- carrying capacity of the classical continuum.
Quantum mechanics evidences some specific peculiarities. Continuous observables no more fit naturally in its formalism. We have again a paradox. The converse of Zeno's

. The spectrum of an observable quantity as it arises by the possible outcomes of its measurement, is no more a continuous range but a discrete set. . What is the mechanism enabling transition from one of these values to another!

Quantum mechanics answers in detail to this question . The considered quantum system makes it continuously.

To be clear : we have here a basic descriptor of quantum reality. It is the quantum observable. The fundamental question is that it is a rather complex entity , not a classical variable like a classical degree of freedom ... says Deutsch. . . .It is not , simply, a discrete variable like a classical bit. We have here a more complex entity that has both discrete and continuous features.

In Heisenberg picture quantum observables change with time while the quantum state remains constant. The simplest quantum observable is here the Boolean observable defined as one with exactly two eigenvalues. This is the simplest quantum system .

Again. Have we *It from Bit* ? No more?

We have now

It from ?

Where (?) states because we have to identify the abstract entity to insert here.

Note. It is an abstract entity but at the same time it is a kind of physical system. Let us indicate it by C to characterize such God Giano two faces attitude.

We have thus

It from C

May we characterize C ?

Gottesmann showed in 1999 that we can describe such entity at time t using the Heisenberg picture and the triple $q(t) = (q_x(t), q_y(t), q_z(t))$ of the Boolean observable Q

They satisfy the following statements

$$q_x(t)^2 = 1$$

$q_x(t)q_y(t) = iq_z(t)$ and cyclic permutations over (x, y, z). (1)

It is rather trivial to remember here that a Clifford algebra is defined via the anticommuting basic elements

$(e_i)^2 = +1$ or -1 ;

$$e_ie_j = -e_je_i \quad ; \quad i \neq j; \quad i, j = 1, 2, ..., n,$$

Each Boolean observable C changes continuously with time , and , in addition, owing to the basic role of the (1) , retains its fixed pair of eigenvalues which are the only possible outcomes when we go to measure it.

In conclusion, there is no elementary entity in Nature corresponding to a bit

It is C , characterized by the (1), that occurs in Nature. And it pertains to Clifford algebra. , and it represents a multiversal model. We have C to be intended as $C(e_j, j = 1, 2, 3.)$.

Using a very restrictive language , devoted to computation purposes only, someone, as Gottesman, Deutsch , called C using the term *qubit* but acknowledging it as fundamental and complex entity as we said. Qubits are thus special physical systems. There is not elementary entity in Nature corresponding to a bit .

Qubits occur in Nature.

Our reality is made of qubits That is to say .. by C. Every answer to a question about whether something that we may observe in Nature is so or not, is actually a Boolean observable. Each Boolean observable is only a part of an entity , the C-the *qubit*, that is fundamental to our reality but very distant from our everyday experience. If we prepare the experience so that one Boolean observable is sharp, then , according to the uncertainty principle, other Boolean observables cease to be sharp.. There is no way to make the qubit as universal , whole homogeneous in our reality.

C-qubits are multiversal objects , says Deutsch. This is the reason because they are able to undergo continuous changes even though the outcome of measuring. or, equivalently, of being them is only ever one of a discrete set of possibilities.

They are ontological possibilities. Ontological potentialities marked from irreducible indetermination, ontological superposition of potentialities as the (1) manifestly indicate. We leave a reality in which what we experience to some degree of approximation as a world of single valued variables is only a section of a larger reality in which the full answer to a yes-no question is never just yes or no, but coexisting alternatives A quantum object is represented by the basic Clifford elements before mentioned.

What the conclusion if the basic scheme *It from* $C(e_j)$ is true!

What sort of experience would have an human being composed entirely of C(e_j)?

We may answer correctly to such question only in one case: if and only if we are able to overcome standard quantum theory. It is known that it is not a self-consistent theory since it admits the collapse of the wave function but remaining such mechanism an admitted process , added to the theory from the outside by postulates formulated by von Neumann. We have to demonstrate such basic von Neumann postulates giving so a final self-consistence to the theory. If it is so, we have that a coarse grained level of our reality looks as though classical physics is true. However, where and when quantum superposition of potentialities are under way there is no appearance and a more complex structure comes into play.

This is precisely the adventure in applied physics that we started years ago.

It is well known that the attempts to insert quanternions, and, in detail, Clifford algebraic approaches in quantum mechanics date back to decades ago. We neither attempt to quote a so large body of very valuable scientific activity since we have a disseminated body of contributions.

Our approach is different.

Starting with the basic framework of Clifford algebra , we attempted to delineate what in these years we called often a rough scheme of quantum mechanics. A bare bone skeleton of quantum mechanics that we realized so that to apply it in cognitive level of human beings.

Previously we outlined the importance to overcome the standard position of the quantum mechanics where the collapse of the wave function is admitted on the basic of some

postulates that were introduced by von Neumann.
Reconsider again the basic our statement *There are stages of our reality in which we no more may consider matter per se , independently of the cognition that we have about it.*
As said , this happens since quantum mechanics has its specific origins and peculiarities as Orlov previously evidenced Let us see to arrive to evidence the statement by this way..
Structurally, quantum mechanics is a result of applying non-Abelian symmetries to truth operators and their eigenvectors - wavefunctions. Wave functions contain information about conditional truths of all possible logical statements about physical observables and their correlations in a given physical system. These correlations are logical, hence nonlocal, and exist when the system is not observed.
It may be shown that quantum properties , so distant from our ordinary experience, appear because, in quantum mechanics, non-Abelian symmetries are applied to truth operators of logical statements about numerical values of physical observables, while in classical mechanics, symmetries are applied to numerical values of observables themselves. These truth operators are also quantum observables, nonlocal by nature, and are represented in quantum mechanics by density matrices of pure states that of course we may represent as elements of the Clifford algebra.
Logical elements pertain to logic and the logic pertains to human cognition
The question arises why logic and language and thus cognition have such a fundamental role in quantum mechanics, while in classical mechanics they have only an auxiliary one. The reason is as it follows.
The scientific knowledge of Nature exists only in the form of logically organized descriptions at some different scales of accuracy. When these descriptions reach an adequate high level of accuracy, the fundamental features of logic and language and thus of cognition, acquire the same importance as the features of what is being described. *At this level, we no more can separate the features of "matter per se" from the features of the logic and language and thus of cognition, used to describe it. At this level mind entities result involved directly.*
Consider here the particular feature that we evidenced at the first stage of the present note: it is the quantization that therefore becomes crucial at this level.
In addition, in classical logic we have a hidden, unformalized symmetry. A logical tautology remains the same tautology, regardless of how we change the meaning of the truth values of its constituent statements. In the case of quantum mechanics we lose the possibility of unconditionally defining truth (see Orlov for the appropriate deepening). Here obviously the definition of truth depends on how we observe the physical system, on the context in which we perform observation and thus our semantic act becomes necessarily linked to the same dynamics to be described.
In quantum mechanics, truths of logical statements about dynamic variables become indispensable dynamic variables themselves, because they depend on parameters of symmetry transformations that redefine truth values. This is the reason because cognition and mind entities enter with a so fundamental role in quantum mechanics.
Let us follow Orlov argument.

Consider K to be an observable with a set of possible numerical outcomes $(k_1, k_2, ...)$.
Consider the system to be in state $\mid \quad k_i \quad >$..
The logical statement Λ_{k_i}: "The system is in state $\mid k_i \quad >$."
or, equivalently

$$\Lambda_{k_i} :: \quad K \quad = \quad k_i$$

describes the real situation in this case and therefore is true.
We will prefer to evaluate truths of statements numerically; let the truth value "true" be assigned the number 1, and the truth value "false" the number 0. In our case, the truth of Λ_{k_i}:
is equal to 1.
This truth value can be examined by measurement. It in any case involves a semantic act.
We will measure$K$
If, after (theoretically infinitely) many repetitions of the same experiment, we obtain the same number, $K = k_i$, then the truth of Λ_{k_i}:is equal to 1, while all the other statements Λ_{k_j}, $j \neq i$, are false and their truths are equal to zero. Therefore, in quantum mechanics the truth of Λ_{k_i} is measured simultaneously with K and thus it is itself an observable. So, in quantum mechanics , we have in addition such unequivocal presence of a so called logical observable. We can represent this observable by the truth operator Λ_{k_i} with the central point that it commutes with the operator K representing the observable K.
Each truth operator possesses only two exact numerical values,(1 and 0), it is a projector:

$$\rho^2 = \rho$$

and thus a mathematical object that is well known in the corresponding Clifford algebra.
possible description.
In conclusion , we cannot escape . A strong link is established in this theory with logic, language, and , finally, human cognition and mind entities.
Since all the Λ_{k_i}commute with$K$ the eigenvectors of Λ_{k_i} and K are the same.
In diagonal representation we have

$\Lambda_{k_i}(k, k') = |k_i(k)\rangle \langle k_i(k')|$

Tr (Λ_{k_i}) =1

and, finally,

$$K = \sum_i k_i \Lambda_{k_i}$$

that definitively seals with its picture the profound link of the quantum theory with cognition from one hand and with the corresponding Clifford algebraic representation from the other hand.
We have here again
It with $C(e_j)$..
And

It from $C(e_j)$?

Here we should be able to demonstrate the logical origins of quantum mechanics.

The book considers in detail such question.
It is well known that J. von Neumann in 1932 showed that projection operators Λ_k ($\Lambda_k(\Lambda_k$-1)=0) and quantum density matrices must be interpreted as logical statements.
He showed that, starting with quantum mechanics, logic may be derived.
By using Clifford algebra we give inversion of this basic statement . Instead of constructing logic on the basis of quantum mechanics , we demonstrate that quantum mechanics is constructed from logic by using Clifford algebra.
Therefore the origins of quantum mechanics are on the logic and human cognition and mind entities.
We know that quantum mechanics runs about two foundations : indeterminism and quantum interference.
By using Clifford algebra we showed that such basic features may be exhibited starting with logic –cognitive statements.
We have briefly discussed some results. A feature is important to outline here.
We will not introduce here speculations in the sense of the theoretical philosophical or epistemological elaboration. We will introduce detailed theoretical results demonstrated by using quantum mechanics and experimental results derived from well arranged experiments.
Therefore they represent solid and robust points of reference that may be adopted in neuroscience as well as in psychology. Certainly neuroscience has obtained, particularly in the last ten years, very important results particularly by using fMRI imaging techniques.
Learning as well as memory brain areas, feelings, as well as other brain functional regions have been identified and studied carefully.
There is not doubt that they represent actual advances on the plane of the basic physiological as well as neurophysiological studies.
The tendency is to retain that adding piece after piece of knowledge at neurological as well as biochemical-neurological understanding, finally we will arrive to understand the advent of our mind and of our psyche.
On the other side we have the advances of psychology.
It is unquestionable that the situation is deeply different respect to neuroscience studies.
Here we have psychological empirical results and, in addition, some times it seems that they do not link the arising neuroscience results. Often they results conflicting.
In brief, we see a gap between neuroscience results from one side and psychological results from the other side.
Our opinion is that such existing gap is because between such two regions of our knowledge a basic theoretical fundamental model is missing.
We need a model that should be able to fill up the present hole.
In the light of the results that we have previously outlined, we retain also that such hole may be bridged by quantum mechanics and, in particular, by the quantum model that we have elaborated in detail in these years. The applied physics may attempt to overcome the gap.
We are aware that scientist in neuroscience as well as in psychology, may have often a

natural conceptual reservation against physics: Of course we are recalling here a theory of physics, the quantum mechanics, that, without any doubt, evidences so many difficulties in understanding to discourage also the most predisposed reader. On the other hand quantum mechanics, according to our results and, in general, to its basic foundations, appears, as previously outlined, as a Bifronte Giano (Giano two faces God) looking with one face to the intricate complex processes characterizing matter and, with the other face, looking at the mind entities. Therefore, also pending all the difficulties that out of doubt articulate the quantum model, it is necessary to attempt to perform any tentative of understanding because it results rather evident that the quantum model is the way that is required to us to cover the hole in the perspective to obtain an actual advance in our knowledge. In order to face such question we will use here a language that will not pertain properly to the usual scheme of physics and of the applied physics. We will attempt to follow the easiest way of exposition so that also neurologists as well as psychologists will be able to follow and in case to read with interest the results here reported.

2. Preliminary Information on Quantum Interfernce

It is well known that in psychology interference is intended as a theory relating substantially some features of memory. It is retained that interference occurs when learning of something new causes forgetting of older material on the basis of competition between the two. The main assumption about interference is that the stored memory is intact but it becomes unable to be retrieved owing to the competition created by novel acquired information The German psychologist Bergström conducted studies on interference starting with 1892. There is his classical experiment that in some manner recalls the well known Stroop effect . He required subjects to sort two decks of card with words into two piles. When the location was changed for the second pile, sorting was slower. This showed that the first sorting rules interfered with the learning of the new sorting rules. Bergstrom also conducted his studies with Müller and Pilzeker in 1900 [22] studying what is currently named the Retroactive Interference. Georg Elias Müller used associative Hemmung (inhibition) as a blanket term for retroactive and proactive inhibition. Another important contribution was realized from Benton J. Underwood in 1915. The result of studies was that the more lists were learned, the less the last-learned list was retained after 24 hours. In 1924 Jenkins and Dallenback [23] showed that everyday experiences can interfere with memory with an experiment evidencing that retention being better over a period of sleep than over the same time devoted to activity. In 1932 also with the studies of McGeoch [24], it was advanced the indication suggesting that **a** Decay Theory should be replaced by an Interference Theory. Finally, Underwood substantially sustained that proactive inhibition is more relevant than retroactive inhibition in accounting for forgetting.

The Proactive Interference identifies a feature that appears to us to be of importance. It relates the forgetting of information due to interference from the traces of events or learning that occurred prior to the materials to be remembered.

The particular relevance arises for us since it admits that it happens when, in a given context, past memories inhibit the subject's full potential to retain new memories. It has been admitted that forgetting from working memory would be non-existent if not for proactive interference.An actual example of Proactive Interference is often considered to be that one, as example, of a subject having the same credit card number for a number of years. He memorizes this number over time. Therefore, if a new card is given to the subject, he/she would then have great difficulty memorizing the new credit card number as the old credit card number is so established in his/her mind. The competition between the new and old credit card numbers causes Proactive Interference.

The term on which we need to fix our consideration here in relation to our arguments, is that one of competition.

We must now evidence that some neuro-correlates have been identified. Proactive Interference in the brain has been studied in the following manner. A subject is submitted to a task in which he/she must commit a given set of items to memory and it is asked to recall a specific item which is indicated by a probe. Using this "Recent-Probes" task, the brain mechanisms involved in the resolution of Proactive Interference results by FMRI to be the ventrolateral prefrontal cortex and the left anterior prefrontal cortex.

Still, It is known that Span performance refers to working memory capacity. It is currently admitted that we have a limited span for performance in language, comprehension, problem solving and memory. Span performance on later experimental trials is lower than performance of earlier trials. This indicates that Proactive Interference affects susceptibility to span performance.

Also the theory of the Retroactive Interference seems of interest. Its content is that Retroactive interference prevents the retrieval and performance of previously learnt information due to newly acquired and practiced information. Also in this case we have a classical example, that one of a subject that memorizes a page of a great book and then after a few instants he/she memorizes another page number, using this second number more. When the recall of the first number is needed, the recollection will be lower because the last number was the item practiced the most. This is Retroactive Interference.

Retroactive Interference has been localized to the left anterior ventral prefrontal cortex by MEG studies investigating Retroactive Interference and working memory in elderly adults. Subjects 55–67 years old showed less magnetic activity in their prefrontal cortices than the control group. Executive control mechanisms are located in the frontal cortex and deficits in working memory show changes in the functioning of this brain area.

Retroactive Interference has also been investigated using pitch perception as the learning medium. The researchers found that the presentation of subsequent stimuli in succession causes a decrease in recalled accuracy.Massaro [25] found that the presentation of successive auditory tones, confused perceptual short term memory, causing Retroactive Interference as the new tone inhibits the retrieval of previously heard tones.

Retroactive Interference also increases when the items are similar, increasing association between them as shown by spreading activation. Barnes and Underwood found that when participants in the experimental condition were presented with two similar word lists, the recollection of the first word list decreased with the presentation of the second word list. This finding contrasts the control condition as they had little Retroactive Inference when asked to recall the first word list after a period of unrelated activity.

Finally, we have the Output Interference. It is based on the happening that the initial act of recalling specific information interferes with the retrieval of the original information.

Henry L. Roediger and Schmidt [26] found that the act of retrieval can serve as the source of the failing to remember. They performed several experimentations testing the recall of categorized and paired associative lists. Three experiments were carried out where subjects were first presented with category lists and then asked to recall the items in the list after being shown the category name as a cue. The further test position from the category resulted in a decline of the recall of words. A fourth experiment revealed that only recent items were present in output interference in paired associative lists.

Smith found that if categories with corresponding items were successfully recalled, a systematic decline would occur when recalling the items in a category across the output sequence. He conducted multiple experiments to determine the conditioned input necessary to produce Output Interference.

Both short and long term memories are centralized to the hippocampus and the amygdale. In both short-term memory and long-term memory Smith measured output interference in three age groups (aged 20–39, 40-59, 60–80 years). The results of recall performance revealed significant differences due to age where the older group recalled fewer items than the middle group who recalled fewer items than the youngest group. Overall Smith concluded that memory decline appears with increased age with long-term memory forgetting rather than short-term memory forgetting and short-term memory was unaffected by age. However output interference was unable to explain the memory deficit seen in older subject.

Recent research of adult subjects free recall and cognitive triage, evidenced similar findings of recall performance being poorer in older adults compared to younger adults. Although it was also indicated that older adults had an increased susceptibility to Output interference compared to younger adults and the difference increased as additional items were recalled.

Decay theory holds about a classical conceptual counterpart that is rather frequent in science. In our case it outlines that memories weaken over time despite consolidation and storing. In other terms, although the subject may remember a specific detail, over time he/she may have greater difficulty retrieving the detail you encoded. Decay theory links possibly Interference Theory in the way that old memories are lost over time. Memories are lost in Decay Theory by the passing of time. In Interference Theory, memories are lost due to newly acquired memories. Both Decay and Interference Theories are involved in psychological elaborations about forgetting.

Decay and Interference Theory differ in the sense that Interference Theory has a second stimulus that prevents the retrieval of the first stimulus. Decay Theory is caused by time itself. Decay Theory is a passive method of forgetting as no interference is produced. Interference Theory is an active process because the act of learning new information directly prevents the recollection of previously stored information.

Dual task Interference is a kind of interference that occurs when two tasks are attempted simultaneously. As we will outline in detail in our following exposition, this is a feature that has great importance in our approach.

Harold Pashler [27] based his research on the fact that, when one attempts two or more tasks at the same time, it arises that in some cases they are successful in completing their task and in other cases not. We recommend strongly the reader to hold such results when after we will speak about compatible and incompatible observables in quantum mechanics.

Pashler proposed that the brain contains one mental entity to where all tasks must be carried out. When the brain is attempting to complete two tasks, both tasks are present in the same mind area and compete for processing ability and speed. This relates to Interference Theory as the tasks compete. Interference Theory indicates that the learning of new information lowers the retrieval of older information and this is true in Dual Task Interference. The dominant task of the two, inhibits the other task from completion. Just as Interference Theory states, the completion of new tasks inhibits the completion of previously completed tasks due to capacity sharing.

We now introduce the so called Cross talk. It relates the communication between sensory inputs, processing and the thoughts of the individual. The theory is that if two processes are being activated and they are not similar in any way, the brain will have difficulties as separate cognitive areas are being activated and there is conflicting communication between the two. Obviously, if the two processes are similar, there will be less cross talk and a more productive and uninterrupted cognitive performance.

Navon and Miller [28]claim that Dual Task Interference is caused by the arising conflict which is a result of one task producing outputs, or side effects that are harmful to the processing of the other task.

These are the basic notions usually retained in psychology and neurology. Before to conclude, let us recall also some comments of Freud.

Freud [29-33] in his Vorlesungen zur Einfuhrung in die Psychoanalyse in years 1915-1917 quotes the term interference when he speaks about the so called Freudian slip.

It results from the interference of two different intentions, and he considers one as perturbing and the other as perturbed.

It is the Freud hypothesis that gives us the possibility to introduce a quantum mechanical approach to the argument. As example, in page sixty four of his quoted book , he explains that the disturbing element arises from a sequence of thoughts that had their collocation soon before our mind and produce soon after their effect independently from the fact that they have found their direct representation in the talk.

The thoughts, outputs and side effects of one task either affect the previous or subsequent recall.

Starting with 1983, we have developed our activity to study the possible quantum interference in perceptive –cognitive processes in humans. Let us see briefly as quantum interference must be intended in psychology. It has been discovered by us that it has a more general perspective but we will consider here only some sectioned features for

brevity. Limit ourselves to categorization.
The principle appears to be as it follows:
Every time a subject performs an operation of categorization, we must expect that possibly such cognitive performance will possibly induce a quantum interference with the subsequent performed cognitive act [1,8,11,15,18,20]
Let us give a direct example in order to support our evidence and statement about the meaning of quantum interference in the sphere of cognitive functions.
First, let us expose the concept of categorization. Said briefly, it is an operation that the human subject operates starting from some stimuli organizing them in categories. Categorization in little children passes by analogy . Progressively it engages our logical faculties as well as our emotive status.
For brevity we cannot enter here in the details of our quantum model, the reader is invited to read the large body of papers that we have published on this matter. At the moment we outline here only some features [1-21].
Quantum mechanics runs about the concept of observable. This theory selects a system to be studied, and the human experimenter decides to perform measurements on such system selecting some quantity of interest to be measured. As example, we may select as system an electron and decide to measure its spin. In this case the spin is the so called quantum observable in relation to the system that we have selected to study.
However, there is in quantum physics an important and unexpected novelty that we are not accustomed to acknowledge in our ordinary experience. Some quantum observables result incompatible. This means that they cannot be measured simultaneously obtaining both definite values without uncertainties. If we obtain valuable precision in measuring one of such two incompatible observables, not for technical limitations but for the intrinsic irreducible indetermination of reality at the quantum level, we never will obtain satisfactory precision in the measurement of the other observable.
Now let us transfer such our reasoning in the sphere of our direct interest.
Let us admit that mind entities respond to the rules of quantum mechanics.
We repeat here. This is not a net abstraction that we introduce without justification. We have given a lot of results confirming the elective role and presence of quantum mechanics at the level of mind entities [1-21].
Consider a subject in some cognitive status. It will represent thus a subject being in some quantum cognitive condition.
Suppose we consider two dichotomic non commuting quantum observables A, and B. In psychological framework: let us admit that we have two tasks, A and B, and a subject may answer A= yes /not and B= yes/not. For A we have $a_+ = yes$, $a_- = not$. For the task B, we have $b_+ = yes$,$b_- = not$.
For the test A we have the state of the subject when performing the task A. This is to say in our psychological approach that we consider the mental state of the subject with respect to the task A.
Here we have the core of the quantum model.
It may be explained in the following manner.

According to the basic rules of quantum mechanics, until the subject has not reached a final decision about the task A (yes, not), its mental state is in a so called potential superposition of possible states.
This is the difficult concept to accept.
The superposition of potential states is expressed by the sum and the subject mental states is thus in the superposition of the state /a$_+$ > and of the state /a$_-$ >.
This potential superposition of states is thus expressed in the following terms.

$$\mid \psi >= \cos\theta_a / a_+ > + sen\theta_a / a_- >$$

Here $|\psi\rangle$ represents the mental state of the subject respect to task A. $|a_+\rangle$ represents the mental state of the subject when he/she answers yew and $|a_-\rangle$ represents the mental state of the subject when he/she answers *not*.
$\cos\vartheta_a$ and $sen\vartheta_a$ represent instead the so called probability amplitudes. This is to say that their square modulus will indicate, respectively, the probability that the subject will answer *yes* to the task A and the probability that the subject will answer instead *not* to this task.
This is all the basic difficulty to understand our quantum model.
We may summarize it.
First: for A task, the mental state is expressed by $|\psi\rangle$, or in the standard language of quantum mechanics, by the so called wave function.
This is to say that when the stimulus is given to the subject (the task A is formulated), the subject poses him/her self in a condition of potential superposition of states *yes* and *not*. Potential superposition here means that he/she will be at the same time in both such mental states.
Soon after it will happen what in quantum mechanics is called the process of actualization. The subject will do transition from the condition of potentiality to that one of actualization. He will decide. He will do transition, with a given contextual probability, or in the mental state that will induce him/her to answer yes or, with some probability, to the mental state that will induce him/her to answer *not*.
Here $\cos^2\theta_a$ represents the probability that the performance $a_+ =$ *yes* will be actualized, while instead $sen^2\theta_a$represents the probability that the performance $a_- =$ *not* will be actualized.
In our opinion the difficulty in understanding the quantum model of mental entities is not in the mathematics, not in the physics or in the formulas since the reader has seen with his/her eyes that we are engaged only in one simple formula. The real difficulty is in understanding deeply their meaning and learn to manipulate such basic concepts.
The first one is that of potential superposition. At some stages the reality at mental level is not actualization but potentiality, and potentiality means mutual and simultaneous coexistence of alternative mental states marked from irreducible indetermination.
This is the first basic concept.
The second basic concept is that one of actualization.
Our mental performance is able to perform actualization. This means that it is able to

transitate from the stage of potentiality to that one of one actualized mental state [2,3]. We may say that our consciousness operates as an agency of selection. In a probabilistic, context dependent manner, our consciousness operates a selection between alternatives reducing potentiality to actualized state with awareness about the performed cognitive act and selected decision.

Let us verify if we have been engaged in such quantum model.

Let us admit that, instead of A, we decide to submit our subject to a different task that we call B.

It will happen the same thing. The same elaboration may be written for the task B. We will have again a superposition of potential states and thus a subsequent actualization. For the superposition of potential states this time we will write

$$| \psi >= \cos \vartheta_b / b_+ > + sen\vartheta_b / b_- >$$

where $\cos^2 \theta_b$ will represent this time the probability that the performance $b_+ =$ *yes* will be actualized and $sen^2\theta_b$ will represent the probability that the performance $b_- =$ *not* will be actualized.

Let us compare the situation respect to the case of the task A. As previously said, his/her mental state in the potential form will be

$$| \psi >= \cos \theta_a / a_+ > + sen\theta_a / a_- >$$

and he will perform the actualization $a_+ =$ *yes* with probability $\cos^2 \theta_a$, and assuming the mental state $|a_+\rangle$. Instead he will actualize $a_- =$ *not* with probability $sen^2\theta_a$ and assuming the mental state $|a_-\rangle$.

In conclusion, for the only task A, the subject will categorize $a_+ =$ *yes* with probability $\cos^2 \theta_a$, and assuming the mental state $|a_+\rangle$. He will categorize $a_- =$ *not* with probability $sen^2\theta_a$ and assuming the mental state $|a_-\rangle$. For the task B he/she will perform the actualization $b_+ =$ *yes* with probability $\cos^2 \theta_b$, and assuming the mental state $|b_+\rangle$. Instead he will actualize $b_- =$ *not* with probability $sen^2\theta_b$ and assuming the mental state $|b_-\rangle$.

Now we change our experiment.

We ask to the subject to categorize first the task B, followed soon after from decision of task A.

From the experimental view point, the arrangement is clear. We first ask to subject to perform the task B. According to our model he/she will pose him/her self in a condition of superposition of potential states and finally will actualize a decision on A. Suppose that, during the categorization of task B, he will actualize $b_+ =$ *yes*, thus assuming this time the mental state $|b_+\rangle$. When, soon after, he/she will be asked to perform the task A, its mental state $|b_+\rangle$, according to quantum mechanics, will be expressed again in the potential superposition of states (alternatives relating the task A), and thus his/her mental states will be

$$/b_+ >= \cos \varphi / a_+ > + sen\varphi / a_- > .$$

The mental state, following the categorization due to the task B is now profoundly changed ($|b_+\rangle$)

respect to the case in which it was asked to him/her to perform the task A only (he assumed $|a_+\rangle$or $|a_-\rangle$). Since, performing first the task B and soon after the task A, the subject assumes the potential states

$$/b_+ >= \cos\varphi/a_+ > +sen\varphi/a_- >$$

the probability that, performing the task A, he now decides on $a_+=$ *yes* will be given from $\cos^2\varphi$, and $a_-=$ *not* from $sen^2\varphi$.
In conclusion, if the subject performs the task A only, the probability to actualize $a_+=$ *yes* is $\cos^2\theta_a$, and its mental state is $|a_+\rangle$. If instead it is asked him to perform first the task B with categorization and soon after the task A, its mental state is first $|b_+\rangle$ and soon after, performed decision, it will be $|a_+\rangle$, and, in particular, his probability to categorize $a_+=$ *yes* will be now $\cos^2\varphi$.
In brief with the only statement A the probability for $a_+=$ *yes* will be $\cos^2\theta_a$. For the case of first statement B followed soon after from the task A, the probability for $a_+=$ yes will be $\cos^2\varphi$.
Obviously $\cos^2\theta_a \quad \neq \quad \cos^2\varphi$.
So we expect that the subject will decide in a different manner in case A only, respect to categorization B followed by decision A and he will give very different performances as answer to A and B [
The reason is that the two mental states, respectively in the two conditions of experimentation, will be totally different. The possibility to explicit such standard mental situation with so rigorous details gives implications that under the psychological and mental profile are obviously of very remarkable importance.
The same thing happens when the subject categorizes actualizing $b_- = not$. He will assume this time the mental state $|b_-\rangle$. When, soon after, he will be asked to perform the task A, its mental state $|b_-\rangle$, according to quantum mechanics, will be expressed by the following potential state

$$/b_- >= -sen\varphi/a_+ > +\cos\varphi/a_- >$$

The probability that, performing the task A, he now decides $a_+=$ *yes* is given from $sen^2\varphi$.
In conclusion, if the subject performs the task A only, the probability to actualize $a_+ =$ *yes* is $\cos^2\theta_a$, and its mental state is $|a_+\rangle$. If instead it is asked him to perform first the task B with categorization and soon after the task A, its mental state is first $|b_-\rangle$ and soon after, performed categorization, it will be $|a_+\rangle$, and, in particular, his probability to categorize $a_+=$ *yes* will be now $sen^2\varphi$.
In brief, with the only statement A the probability for$a = +$ will be $\cos^2\theta_a$. For the case of first statement B followed soon after from the task A, the probability for $a_+ = yes$ will be $sen^2\varphi$.
Obviously $\cos^2\theta_a \quad \neq \quad sen^2\varphi$.
So we expect that the subject will categorize in a different manner in case A respect to the case of B followed by A and he will give very different performances as answer to A and B.

The interpretation in terms of quantum mechanics is that any intermediation of an actualized categorization induces a possible modification of the mental states and a profound modifications of the probabilities in performing single tasks or task with categorized intermediation [1,18,34,35].

We may see that, using quantum mechanics, we may arrive to analyze in detail mental states and the profound modifications that we may observe in their inner probabilistic dynamics in function of the manner in which we perform our thinking and our process of decision making**.**

We may now explain what in the quantum model is called quantum interference.

The experimental situation is clear. We select two psychological tests A and B to be given to a subject. Let us realize such A and B tests so that such variables A, B are dichotomic. This is to say that they may assume only two values (±1) being, as example, +1 Yes and −1 Not. Let us admit now that we select two appropriate populations of subjects, the group C and the group D. To each component of the group C, we give the test A. Each subject will answer with Yes or Not so that at the end of the experiment we will have the probability $p(A = +1)$ and the probability $p(A = -1)$ with

p(A=+1) + p(A=-1) = 1.

Now we consider the group D. To each of such subjects we give first the test B immediately followed by the test A.

In this case we will estimate the probabilities $p(B = +1)$, $p(B = -1)$, *p(A=+1/B=+1), p(A=+1/B=-1), p(A=-1/B=+1)*, and *p(A=-1/B=-1)*

With *p(B=+1) + p(B=-1)=1 p(A=+1/B=+1) + p(A=-1/B=+1) = 1*, and

p(A=+1/B=-1) + p(A=-1/B=-1) = 1.

Let us remain here at the most simple basic step that, as it is well known, is represented by the well known Bayes theorem.

Here we have a formula that should not represent a problem for the reader. The Bayes theorem is well known at all. As we know, according to Bayes, we obtain that

$$p(A = +1) = p(B = +1)p(A = +1/B = +1) + p(B = -1)p(A = +1/B = -1)$$

Therefore we have a basic statistical calculus that assures about the results that we should find if at cognitive level classical statistics and not quantum mechanics should apply. It is that

$$p(A = +1) = p(B = +1)p(A = +1/B = +1) + p(B = -1)p(A = +1/B = -1)$$

We repeat. It pertains to classical probability theory.

What is the important datum. It is that it is violated in the case of quantum mechanics. In quantum mechanics a further quantum interference term appears and, instead of the

$$p(A = +1) = p(B = +1)p(A = +1/B = +1) + p(B = -1)p(A = +1/B = -1)$$

we obtain

$$p(A = +1) = p(B = +1)p(A = +1/B = +1) + p(B = -1)p(A = +1/B = -1)+$$

$$+2\sqrt{p(B=+1)p(A=+1/B=+1)p(B=-1)p(A=+1/B=-1)}\,\cos\omega$$

Therefore, in the case of quantum interference, we have a further term [1,4,6,8,11,12,15,18,20,36-40].

$$2\sqrt{p(B=+1)p(A=+1/B=+1)p(B=-1)p(A=+1/B=-1)}\,\cos\omega$$

respect to the classical case. Obviously, a similar relation hold in the case of $p(A=-1)$. We are thus in the condition to perform experiments devoted to acquire evidences on such existing or not quantum interference term

$$2\sqrt{p(B=+1)p(A=+1/B=+1)p(B=-1)p(A=+1/B=-1)}\,\cos\omega$$

and to estimate $\cos\omega$.
All the performed experiments by us have confirmed in these years the presence of the quantum interference term.
Have we reached well known experimental confirmations on the case of categorization followed by decision as previously discussed ?
Also in this case the answer is positive.
We retain that the first evidence of a possible quantum interference effect in our cognitive performance was reported by an experiment that was conducted eleven years ago. Townsend, Silva, and Spencer – Smith [conducted a closely related test of interference. Decision makers were presented faces belonging to one of two categories (i.e. good guys, bad guys) and they were asked to decide to choose between two actions (i.e. attack or withdraw). Two different conditions of experimentation were realized here. In the first kind of the experiment to the subject was asked to decide only , or attack or withdraw. In the second version of the experiment, instead, to the subject was first asked to categorize (good guys, bad guys) and then take decision (attack or withdraw).
In substance in the second experimental situation to the subjects was asked Decision /Categorization just as we formulated previously by our quantum model.
In this version of the experiment the subjects were asked to first categorize the face, and then decide how to act. These experiments were used to investigate the interference effect of the category task on the decision task. Townsend et al. reported that participants produced statistically significant deviations just as predicted previously by our quantum model.
In our opinion this experiment gives great evidence of existing quantum interference effect.

3. May we describe Introspection and Priming in our quantum model?

In the previous section we have introduced two principles that characterize our quantum model.
The first principles is that mental entities and mental states obey the principle of quantum simultaneous superposition of quantum mental states.

The second principle is that such mental states have the context dependence to actualize. This means that they tend to pass from the state of potentiality to that one of actualization. At the potential state only potential mental alternative exist . At the actualized state our consciousness operates as an agency of selection operating a direct actualization of one and only one alternative among the all possible existing.
It seems that we have reduced our quantum model to two simple principles that at the first inspection do not appear so complicated to be accepted.
It is not so. The scheme of a mental reality that may proceed by two different directions is enormously complicated. We should to understand in detail what we intend by potentiality and explain in particular what is such transition from potentiality to actualization. This is of course a very important discussion that we have developed in detail in other published papers [1-21] so that we will not enter in the details here for brevity.
Let us accept that the two principles hold.
It follows that quantum mechanics has a role in brain dynamics and the characterization of our mental entities.
If it is so, our vision of brain dynamics is assigned to change profoundly.
As we know brain may be represented as very high complex system. It is the highest example of system in Nature.
If the principle of superposition of states holds for brain, we must expect that at the potential level, brain involves mental entities that continuously perform superposition of potential states at large scale. Consequently brain explains activity at a very large extent of action and, the most important feature, is that, being at the level of potential alternatives without direct actualization, it escapes to our direct observation and awareness.
Again we find here a profound link with some findings of neuroscience.
In fact, most of neuroscientists by this time agree that human decision making and finally behaviour is based on and influenced by cognition- and emotion-related information processing some of which takes place without simultaneous awareness.
Every one may acknowledge that this statement actually overlaps with our quantum model.
Phenomena such as priming [42-52] and implicit memory are well known and demonstrate that stored information is able to change human behaviour in the complete absence of any awareness.
Also this is a statement that as we will evidence soon, overlaps with our quantum model.
To what extent such non-conscious information processing contributes to even highest forms of
brain functions remains unclear to the present experimental knowledge but we will evidence here that a strong support may be found by the quantum model. In fact, evidence accumulates leading
to the notion that astonishingly much of our most sophisticated brain functions work totally independent from consciousness. Discrepancies between self report and objective measurement have been reported. The brain knows more than it admits.

In substance we have the basic problem to demonstrate that information processing in the absence of awareness (non-conscious information processing) is able to manage and influence even complex human cognitive and emotion-related information processing and thus guides human behaviour outside subjective experience.
This final part of our present article is dedicated to the effort to demonstrate that this is precisely what quantum mechanical model evidences
In order to take this step on we fix a rough term that possibly will discourage neuroscientists. However, we will use it not in the usual sense of this terms but just to represent all that brain dynamics could perform outside the filed of our subjective experience.
We will use the term Introspection. Certainly it is inappropriate but the reader must operate the effort to retain that in this particular case it is a symbolic term that represents the whole complex of mental and brain operations that we have just recalled and that, according to the previous thesis, enter in the domain of all that operations and most sophisticated brain functions that work totally independent from consciousness. We have said that brains knows more than it admits. We relate all such behaviours by this inappropriate term.
Let us now arrange an experiment
Let us consider that a subject aims to establish that it does not exist difference between two pairs of cognitive performance that he decides to submit to its mental elaboration .
We have four cognitive performance that we call here a, b, c, d, and he aims to ascertain that it does not exist difference between the pair of cognitive performance ab and cd.
In brief he is called to examine

$$M = ab - cd = 0$$

He must perform tasks simultaneously. Thus, as example he may apply his cognitive performance simultaneously on the pair ab. According to the rules previously mentioned, let us admit that his mental structure runs so that a and b are compatible observables.
Remember that quantum compatible observables means that they may be simultaneously observed and evaluated. On the contrary in the quantum model we have also incompatible observables.
The subject can actualize or categorize both a and b simultaneously.
Still c and d are compatible observables.
The subject can actualize or categorize both c and d simultaneously.
Still, also a and c are compatible observables as well as b and d
However, the subject has also some incompatible observables. They are a and d has also some that is to say… he is unable to actualize both a and $d$simultaneously, as well as he is unable for $b$and c.
Let us admit that he starts at time t_1, and he starts at time t_1, and he attempts to perform his INTROSPECTIVE ACTIVITY on the pair (c, d).
Let us apply our quantum model [1,9,10,15]. First of all note that in the quantum model, the subject does not perform an actualization or a categorization in t_1. He stores information without simultaneous awareness He performs sophisticated brain
functions working the brain totally independent from consciousness. In this phase the

brain develops more than we may admit.
From our quantum mechanical model view point, this means that the subject is using potentiality for his brain dynamics, posing himself in a potential superposition of states. Therefore, in this time the subject poses himself/herself in a superposition of potential mental states, and we may write

$$\sum_{n,m} c_{n\,m}(c,d)\psi_{n\,m} = \sum_{n,m} c_{n\,m} g_{n\,m}\psi_{n\,m}$$

where $\psi_{n\,m}$are the potential mental states (mental states due to introspection), $g_{n\,m}$is the products of the possible values $c_n$and $d_m$not directly actualized and the $c_{n\,m}$are the complex coefficients with probabilities given by $|c_{n\,m}|^2$for any potential-introspective mental state to be actualized.
The formula may appear difficult to be understood but it is no more than the superposition of states previously discussed but this time generalized to a number of different alternatives that the subjects has. We may understand that we do not explain our brain dynamics only by using dichotomic observables. We may have observables that may assume different values and thus different mental states coexist.
Therefore, the reader must not be discouraged not intending the complex formula. It only says that many alternatives of potential mental states are now superimposed in the brain dynamics of the subject. Of course it is not so determinant to understand the formula in its mathematical details. It is important to follow the basic concept that it represents.
Let us admit now that at the time t_2, $t_2 > t_1$(soon after!) the subject is posed a question on (a, b) and this time he /she realizes a mental status in which both a, b,and their product

$$ab = n_{rs}$$

assume a determined value.
In quantum mechanical terms we write that

$(a, b)\varphi_{rs} = a_r b_s \varphi_{rs} = n_{rs}\varphi_{rs}$

where $a_r$is the value that he actualizes for a, $b_s$is the value that he actualizes for b, and $n_{rs}$is the product of a_r and b_s.$\varphi_{rs}$is the mental state of the subject.
Thus, in conclusion. The first time the subject performs a mental action without having direct awareness. And thus remaining in a state of superposition of potential alternatives. In the subsequent time instead he observes, categorizes or takes decision about a new pair of mental tasks and this time first realizes, as previously explained, a superposition of potential states and subsequently he goes on to actualization arriving to decide or to select, and thus attributing definite values to the observables that have been posed to his attention. This time he has full awareness of the performed operation.
We may now summarize the dynamics at the times $t_1$and t_2. We have that

(at the time t_2): $(n_{rs} - a_r b_s)\varphi_{rs} = \sum_{n\,m} c_{n\,m}(g_{n\,m} - c_n d_m)\psi_{n\,m}$: (at the time t_1).

We remark that the subject, performing an introspection at time t_1, and an actualization at time t_2, only two cases may encounter.

The first is that the value of actualized condition, n_{rs}, results equal to the numerical values of introspection,$g_{n\,m}$, thus

$$n_{rs} = g_{n\,m}.$$

The second possibility is that the actualized value n_{rs} does not result equal to numerical values of $g_{n\,m}$

$$n_{rs} \neq g_{n\,m}.$$

Obviously there are not possible other cases.
Let us explicit the first case

$$a_r b_s = c_n d_m$$

Fixed a value α, we may say that

$$a_r(t_2)b_s(t_2) = \alpha$$

$$c_n(t_1)d_m(t_1) = \alpha$$

This is a system that may be promptly solved. It gives that

$$a_r(t_2) = kd_m(t_1)$$

$$c_n(t_1) = kb_s(t_2)$$

for any given value of k. We have also that

$$d_m(t_1) = \frac{\alpha}{kb_s(t_2)}$$

and

$$c_n(t_1) = \frac{k\alpha}{a_r(t_2)}$$

we may now formulate some conclusion. We have here a quantum mechanical model of the manner in which actualization from one hand and introspective activity on the other hand may be handled from the subject. To be clear: the subject at time $t_2$actualizes or categorizes the basic tasks leading to $a_r(t_2)$, $b_s(t_2)$, and thus $n_{rs}(t_2)$responses and mental state φ_{rs}. At the time t_1, he /she formulates only an introspective activity that leads to a superposition of potential – introspective mental states $\psi_{n\,m}$with potential –possible values $g_{n\,m}$.
The theory leads us to establish that they happen the following facts:
if $n_{rs} = g_{n\,m}$.
It happens that

$$a_r b_s = c_n d_m,$$

$$a_r(t_2)b_s(t_2) = \alpha$$

$$c_n(t_1)d_m(t_1) = \alpha$$

and

$$a_r(t_2) = kd_m(t_1)$$

$$c_n(t_1) = kb_s(t_2)$$

and

$$c_n(t_1) = kb_s(t_2)$$

for any given value of k. We have also that

$$d_m(t_1) = \frac{\alpha}{kb_s(t_2)}$$

and

$$c_n(t_1) = \frac{k\alpha}{a_r(t_2)}$$

These are the relations that the reader must observe carefully. These relations delineate a typical dynamics.
This is the crucial point: a bridge is realized between the stage of the introspection at time t_1 and that one of the actualization or categorization at time t_2. See the

$$a_r(t_2) = kd_m(t_1)$$

$$c_n(t_1) = kb_s(t_2)$$

and the

$$d_m(t_1) = \frac{\alpha}{kb_s(t_2)}$$

$$c_n(t_1) = \frac{k\alpha}{a_r(t_2)}$$

It is easy to deduce that the values $a_r(t_2)$, $b_s(t_2)$ at time t_2 (time in which the subject actualizes, becomes awareness of his decision) are interconnected to the possible values $c_n(t_1)$and $d_m(t_1)$, are interconnected with the values that he did not actualized, realized only in a potential stage, stored as information without simultaneous awareness He performed sophisticated brain functions working the brain totally independent from consciousness. This was the phase in which the brain developed more than we may admit. As example we see that

$$a_r(t_2) = kd_m(t_1)$$

and

$$b_s(t_2) = \frac{\alpha}{kd_m}(t_1)$$

This means that the human introspective activity at the time t_1 strongly correlated what the subject will actualize or categorize at time t_2 In some sense we have a time symmetric phenomenon in which in some sense what it happens at time $t_1$determines the future action of the subject at time $t_2$and viceversa. We realize what we call here psychological pseudo-correlations. To the same conclusions we arrive considering the case $n_{rs} \neq g_{n\,m}$.

In the last one hundred lines we have written well twenty eight formulas and this is a condition that certainly will discourage our reader not engaged in mathematic and physics.
Of course we have to consider the basic features of our paper. We are examining a basic matter moving in an hybrid background that simultaneously takes from physics and from neuroscience.
Form one side we have to meet the reader that has a profound engagement in physics. This reader considers and understands the matter if and only if it is exposed with the rigour of the formulas. It is the only language that he is able to accept. For this reason we have explained here the whole argument explaining it with twenty eight formulas. It is true that they pertain to our quantum model that is well known and thus also such our previously formulas were previously published on specialized journals of theoretical physics. However, we have attempted to meet such kind of requirement giving again here the rigorous theoretical formulation.
On the other hand we have to satisfy the greatest requirement. The scholar in neuroscience and /or psychology has not direct competence in mathematical and physics and thus we consider his great discomfort that he has filed approaching all such mathematical and physical formulation.
Such reader has all the elements to eliminate his hardships. It is only required that he understands carefully what are the results that we have obtained.
Let us summarize all such results.
In brief, we have considered an human subject and we have admitted to give him a perceptive input stimulus at affixed time t_1 that has not induced simultaneous awareness in the subject.
This is the content of the first formula that we wrote.
According to our quantum model, we know that, following the input at the time t_1, the subject poses him self in a superposition of potential mental states but he does not reach simultaneous awareness.
The formula is actually the physical picture of the human condition of the subject.
Soon after we have admitted to have given to the subject a new perceptive stimulus at a subsequent time t_2 giving this time to the subject to reach complete actualization, that is to say complete awareness in relation to the given input.
This is physically written in the following formula.
At this stage of our elaboration we have posed to ourselves the following question: if brain dynamics has operated so that at the time t_1 has not reached awareness in relation to the given input stimulus and instead at time t_2 has reached awareness about the new stimulus, are we able to examine the dynamics that elapsed between the time interval of time $(t_2 - t_1)$.
This is what we asked writing the following formulas and going on in developing the physical elaboration.
As it always happens during a final physical elaboration , the scholar stops its formulation when the theoretical elaboration has been completed. Rigorous physical results are

reached at this point.
In our casein such results were obtained.

(1) In time t_1 a stimulus was given to the subject but he had not the time to reach awareness (his mental states realized what in our quantum model is called superposition of potential states)
(2) In a subsequent time t_2 another stimulus was given to the same subject but having this time to reach complete awareness about it.
(3) Brain dynamics acted so that what happened in time t_1(also in absence of awareness) determined what the subject made aware in time t_2. The thing that we must realize with extreme clearness is that what the brain realizes at time t_1 (under a given stimulus that we call A) and without condition of awareness correlates (and this term means "influences", "determines") the brain dynamics when in a subsequent time $t_2$the subject will be submitted to a different stimulus (call it B) but being in this case the subject in condition of awareness respect to B. This is the basic thing predicted by our quantum model and this is the content of the other physical formulas that we wrote previously. The reader does not need to understand the formulas, it is sufficient to understand the contents of points (a), (b), and (c).

In brief, we may conclude that, according to our quantum model, an input stimulus given in a time t_1 to the brain also in absence of awareness for the subject determines the behaviour of the brain when in a subsequent time t_2 the subject will be given a different input stimulus but having this time the subject the sufficient time to reach awareness of such new administered stimulus.
In other words, according to our quantum model, we have given physical demonstration about a matter that some neuroscientists support from some time. They agree that human decision making and finally behaviour is based on and influenced by cognition- and emotion-related information
processing some of which takes place without simultaneous awareness.
Every one may acknowledge that this statement actually overlaps with our quantum model. In particular our model clears and gives demonstration on the manner in which the brain dynamics develops in the two stages (previous not awareness- subsequent awareness and decision).
Phenomena such as priming and implicit memory are well known and demonstrate that stored information is able to change human behaviour in the complete absence of any awareness.
Also this is final statement overlaps with our quantum model.
To what extent such non- conscious information processing contributes to even highest forms of
brain functions no more remains unclear to our present experimental knowledge since we have now a strong support based on a detailed quantum model. In particular such model explains and supports with the rigorous mean of the physics the previous evidences accumulated and leading to the notion that astonishingly much of our most sophisticated brain functions work totally independent from consciousness. The brain knows more than

it admits.
There is still a final consideration to add.
Theoretical physics is able to formulate strong and robust theoretical formulations about the phenomena relating our reality. Obviously they cannot be ascribed to science up to experiments confirm the predictions of the given theoretical formulation.
This was as example the case of Einstein relativity. It appeared immediately to physicists a great and robust, and advanced new theory but it was not accepted in science up to detailed experiments confirmed Einstein prediction.
The same thing happened for quantum mechanics. It was accepted in science only when it overcame the experimental controls that in fact have been extended for eighty years always confirming the predictions of the theory.
In the restricted framework of the matter representing the subject of the present article, we have to follow the same methodology. We cannot say a priori to have found elaboration and demonstration about the basic statement that “brain knows more than it admits”, just to mention the conclusion that we reported some lines before.
We have to perform some detailed experiment and find results that agree with the predictions of our model.
This is precisely the objective of the next section.

4. Materials and Methods.

Forty normal subjects were recruited in our laboratory of clinical electrophysiology in an initial group of one hundred subjects.
The study was conducted in accordance with our local clinical research regulations, and informed consent was required from all subjects.
All subjects underwent clinical evaluation and neurological and neuropsychological psychophysiological, and psychological and psychiatric examinations. The behavioural and global perceptive and cognitive evaluation was performed using the standardized multidimensional assessment, including Rey and SCID II.
Subjects were selected with age ranging from 26 to 50.
Five classes of age were selected (26-30, 31-35, 36-40, 41-45, 46-50).
By a computer algorithm two groups of subjects were realized selecting at random four subjects for each class, two pertaining to a group that we indicate here by A and two to a group that we call B.
The stimulus arrangement was realized in the following manner. We used a computer monitor having standard resolution. Each subject was posed in front of the monitor (distance 65 cm) and his/her perceptive condition was standardized so to reach the subject the most favourable perceptive condition.
This optimized condition may be obtained using a particular software that we used also in some previous experiments using ambiguous figures and it has been described in detail in our previous publications[6,8,11,14,19].
In addition, we ascertained to give to each subject a stimulus with well calibrated features

measuring the induced electric field at each eye of the subject that resulted to be about 6.6 mV/m ($0.1\mu W/m^2$)and the power of the administered stimulus. It was estimated by us to give a stimulus with power about 20-35 $\mu W/cm^2$, a final particular value was chosen within this range and it was constantly monitored before starting the experiment.
We estimated the Sensory Modality Test. For each subject we determined the primary Sensory Modality of each subject. It is well known that by this test a subject may result Visual in the sense that his/her mind responds better to visualization input or techniques, may result instead Audio if his mind responds better to audio input or techniques, or visualization combined with Audio and, finally, may be kinaesthetic if his /her mind responds better to using feeling and emotions. Of course there are the three basic modalities the brain uses to process information.
The modality used to process information is based on culture personality and even genetic factors. Most people use a simple dominant modality (especially memories). However there are those who encompass a balance between two or, in some cases, all three.
In the present experiment we dismissed subject not having at least 58% as Visual, 23% as kinaesthetic, and 19% as Auditory.
Measurements of the Reaction Time (RT) were also performed on each subject, and subjects out of the range 200-370 milliseconds were dismissed.
The experiment was performed using Italian language.
After appropriate previous explanation, at the group that we have called A we gave the syllable TA asking them to tell us the first Italian word recalled in their mind in a time varying from 2 to 5 seconds.
On the other hand we examined the group B.
This experiment consisted in two steps. In the first stage of the experiment the world TAVOLINETTO (little table) appeared on the monitor for a time of 50 milliseconds and thus disappeared. and after 500 milliseconds the experiment went on as in the previous group. We gave the syllable TA asking them to tell us the first Italian word recalled in their mind.
In substance, to the group A we asked to tell us the first Italian word starting with TA (completion). To the second group first we gave a stimulus of 50 milliseconds, appearing on the monitor the word TAVOLINETTO (Little Table) and thus asking them to tell us the first Italian word starting with TA as in the other group.
In both cases of experimentation, we expected the subjects to answer easily Tavolo (Table) or Tavolinetto (little table), and thus we considered a dichotomic variable that we call here W. We considered W to assume the value +1 when the subjects answered (recalled–completed) Tavolo (Table) or Tavolinetto (Little Table) and the value -1 if instead they answered (recalled and completed) with a different word.

5. Results

We may now discuss the results of our experiment.
Let us summarize again the experimental scheme.

We selected two groups of subjects, called respectively A and B.
We also selected a word, in particular the word TAVOLO (TABLE) or TAVOLINETTO (Little Table). We connected to the task a dichotomic quantum observable that we called W. This is obviously a quantum cognitive entity. We established to attribute to W the value +1 when really the subjects recalled and answered to the task with Table or Little table, and instead we attributed to the quantum observable W the value -1 when the subjects did not recalled and answered by such word.
Group A: remember that to such subject we asked to say us the first word coming to their mind after appearing on the monitor the syllable TA.
The results was as it follows

p(W=+1) = 0.05 and p(W=-1) = 0.95.

p states here for probability. Therefore, in relation to the group A the subjects answered with the word Table or Little Table with probability of 0.05 and gave instead different answer with probability 0.95.
These are the results for the group A.
Now we pass to consider the results that we obtained when we examined the group B.
We may remember the to this group we first gave a stimulus appearing on the monitor the word Tavolinetto (Little Table) but realizing specific condition of no-awareness for the subject and soon after we asked them to say us the first word coming to their mind. Therefore also in this case we had that a quantum observable W was engaged, a quantum cognitive entity.
Also in this case we had thus the possibility to estimate the probability p(W=+1) and p(W=-1).
For the case p(W=+1) we obtained

p(W=+1) = 0.40

and for the case P(W=-1) we obtained

p(W=-1)= 0.60

Let us compare the results.
Group A : p(W=+1) =0.05 against p(W=+1)=0.40 of Group B
Group A : p(W=-1) =0.95 against p(W=-1)=0.60 of Group B
In our evaluation, there is no doubt that in condition of stimulus (also in absence of awareness) we had interference respect to the subsequent answer given us to the subjects. It remains only a question to explore.
What was the nature of the interference that we found experimentally?
May be that, according to our quantum model and to all our previous formulation of the present paper did it respond to quantum interference so to conclude that such model and thus quantum mechanics had a specific role in the brain dynamics that we measured by the two groups A and B?
The only way to ascertain such question is to give in input to our quantum model [6] the experimental data that we obtained for the group A and verify if, under the condition of stimulus without awareness that we realized experimentally, we obtain as results that we obtained experimentally.

If such confirmation should be reached we could conclude that possibly quantum mechanics had its elective role during the brain dynamics characterizing our experimentation.
This is just the last attempt that we performed.
Let us comment the step that we are performing.
We obtained previously the results of an experiment. We had subjective psychological data about a thesis that has relevance from many time in neuroscience as well as psychology. According to it our brain should be able to perform a brain and psychological dynamics also receiving a stimulus at the level of perception but not having the subject the time to have awareness about it.
This is a fundamental question, and our attempt is to give for the first time accreditation of such process not by neuroscience techniques but using only subjective psychological data but supported this time from a model that is based on science, thus not on subjectivity but on the objective rigours of the scientific knowledge. Based on physics, in particular. Thus based on one of the strong and robust scientific profile of our knowledge. Certainly we may remember here that the debate about separation between mind and matter has passed through hundreds of years engaging many disciplines from philosophy to physics to neurology to psychology. About the physics the debate was so particular and its conclusions were accepted for years about discussion. Matter per se is here. Physics study its mechanics, its electromagnetism, its thermodynamics. Body is matter. Mind is an abstract entity not having common points with matter. The determinism was accepted as basic rule of all experiencing processes characterizing matter. If we call matter .... It ...... and mind entities qubits..... the basic rule was that It and qubits leave in two separate worlds and It has not common points of contact with qubits with the only exception that the human being may observe, study, analyze, understand what It realizes in the dynamics of our reality.
Quantum mechanics radically changed this basic view point. Such net distinction started to run out. Accepting quantum mechanics, we have arrived to our quantum model and one of the basic features of such model is that quantum mechanics relates mental entities. In details, quantum mechanics has its origin in cognition, thus in what we call the filed of cognitive sciences. Thus it is not It ... and .. qubit.... But It from qubit. The basic indication of our quantum model is that there are stages of our reality in which we no more can separate matter per se from the cognition that we have about it.
The old distinctions between matter and mental activity result unified in a quantum mechanical model.
By the experiment we gave a look to subjective psychological results but the conceptual approach is that It from qubit so that we gave look to the whole complex of brain dynamics and interfaced mental activity.
There is still a point that we have to debate here.
Classical physics in its standard conceptual elaboration was based on determinism. Let us remember the Laplace approach: tell me what were the initial conditions of the universe and I will calculate in time, step by step, its future dynamics.
The determinism has been shattered from quantum mechanics. This theory, as well as our

models, speaks about an intrinsic, irreducible indeterminism governing our reality. The matter is probability not certainty. Let us think a moment to exocytosis in brain dynamics. According to Eccles and Margenau it is the true, real indeterministic event occurring in brain dynamics. Let us think to the constructive role of noise in brain dynamics. Stochastic resonance, ruled by noise, has resulted so important in brain dynamics.

Thus probability field is the abstract entity that regulates our reality and brain dynamics as well as our psychological activity. Think only an instant to a cognitive human action. It is always regulated from uncertainty, indetermination, probability. Every human being, respect to the posed question, has a storage of information that we call I. A decision is matter of probability. Decision about the posed question A or about response to a stimulus A, is no other that matter of probability p(A(/I). This is to say that .a subordinate probability that the human being decides (ore responds in a given manner) about A with subordination to the stored information I. Decision, as example, is taken using plausibility. The human being decides about A with a matter of probability p(A/I) estimating what he/she retains to be more plausible. In brief, it is the concept of probability field that holds.

Note that this is not the probability that we are accustomed to use every day. Traditional concept of probability relates our ignorance in relation to an event. If we have a fixed pack of cards, we may estimate the probability that the subject will draw the card five – heart but this is not the probability concept that we use in quantum mechanics. In the case of the pack of the cards, the disposition of every card in the packet is prefixed. We are in the impossibility to know what card we will draw, but the pack has a predetermined and well fixed stricture , a well established subsequent disposition of the cards. We have the impossibility to look at such hidden disposition but it exists, and it exists independently of our subsequent selection or not. This is not the probability of quantum mechanics.

In quantum mechanics it is the structure in itself that is affected from irreducible indetermination. Remember the principle of superposition of states that we introduced in the first section. We have superposition of potentialities simultaneously coexisting and it is here the origin of the irreducible indeterminism and of the quantum probability field that regulates the processes entering in the domain of quantum mechanics.

In conclusion, we may now consider the results of our experiment.

We have to look at probabilities, in particular we have to look at probabilities p(W=+1) and p(W=-1) that, as we explained, were at the basis of our experiment.

In our quantum model, fixed the prompt condition of the subject, we know that we gave him a perception calibrated impulse for a time of 50 milliseconds. We have to follow the time behaviour pf the probabilities p(W=+1) and of p(W=-1) starting with the prompt of the subject (time zero).

The results are given in Figure 1.

We have packets of oscillating values relating respectively p(W=+1) and p(W=-1).

Such oscillations in the probability values result to be subsequently decreasing and thus dampened until they arrive to assume a final minimum value. The cycle of the oscillation soon after restarts and we give evidence of such behaviour for a time of 700 seconds.

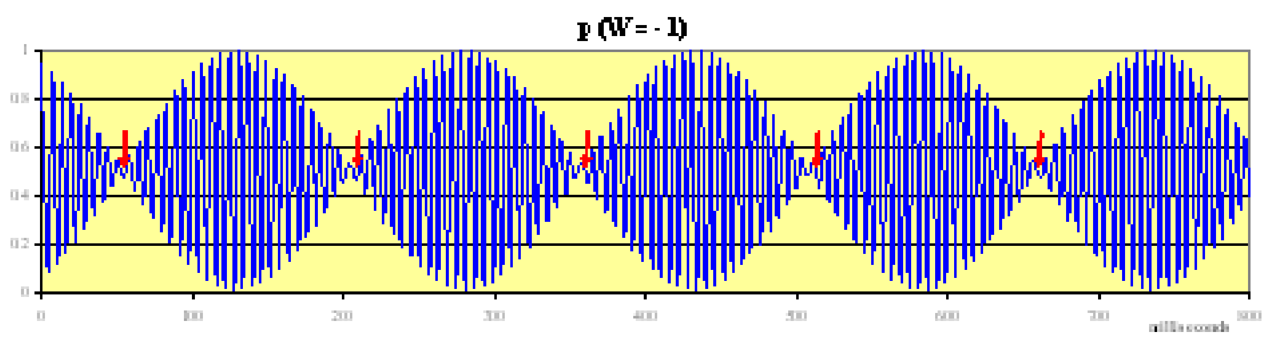
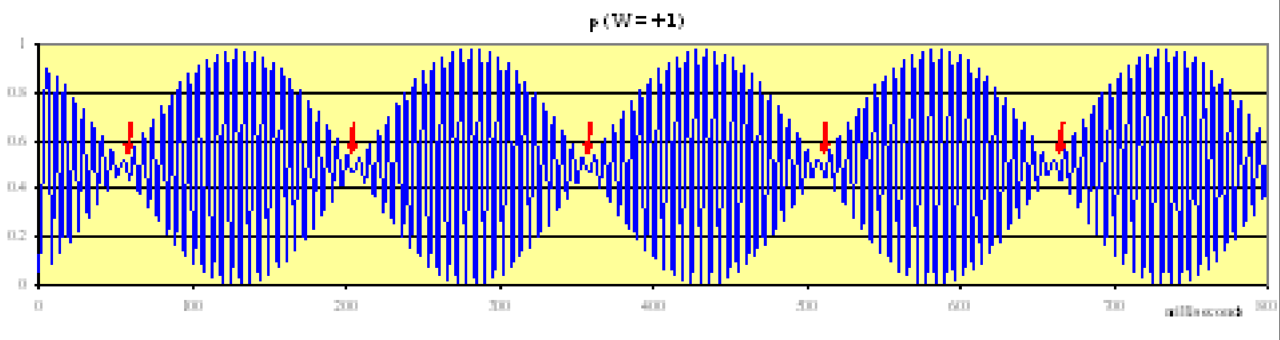


Figure : Quantum Probability Estimation of Subjects Submitted to perception stimulus for 50 Milliseconds (absence of awareness).



The simultaneous oscillations of the p(W=+1) and p(W=-1) probability values, as it is seen, are synchronized in the sense that when p(W=+1) =1 consequently p(W=-1)=0 and viceversa.

By inspection of this behaviours we deduce that, received the stimulus at the time zero, immediately the subject answered to such input realizing a condition of maximum uncertainty (oscillations of p(W=+1) and of p/W=-1) that subsequently in the next milliseconds assumed the net trend to decrease until to reach the first minimum valued signed by the red arrow.

Started the input, the subject immediately perceived it, initially in condition of maximum uncertainty and progressively reducing such uncertainty in the time of 50 milliseconds.

The important evidences are that immediately the subject activated a field of probability as previously explained, in addition he/she reached a stable condition just in 50 milliseconds that was really the time in which the stimulus was posed to the perception of the subject. The final important result is that, after the initial uncertainty, the subject reached probability values about p(W=+1)=0.40 and p(W=-1)=0.60 that were just the results that we obtained experimentally.

Therefore, it is confirmed that a field of quantum probability is activated, it is confirmed that in 50 milliseconds the subject stabilized his/her probabilities (just the experimental time of the stimulus) and there are also confirmed the values of probability that we obtained experimentally.

Let us take now a step on.

After 50 millisecond the stimulus disappeared from the monitor. The subject returned in its condition of uncertainty. Its brain dynamics started to work in order to store the information and to stabilize the probabilities (see the different red signed arrows). The brain work was of about 153 millisecond for each cycle. He maintained this brain dynamics for the subsequent time. Let us observe that, after 500 milliseconds, the subject was shown the syllable TA and it was asked to tell us the first recalled word. In this time he optimized his brain dynamics. The values indicated by the red arrow did not remain constant in time. Each time they resulted lightly corrected until to reach the final values of p(W=+1) and p(W=-1) that really we observed experimentally.

Conclusion

In conclusion we retain to have obtained evident confirmation of the quantum model compared with the experimental data that we realized in the course of the experiment. The data and the quantum model actually confirm that brain dynamics is more complex. Sophisticated brain functions work totally independent from consciousness. Brain knows and develops more than it admits. Quantum mechanics is able to analyze such sophisticated brain functions.

We suggest also such further lectures.

(1) Peres, A. Two simple proofs of the Kochen-Specker theorem. *J.Phys. A: Math. Gen.* **1991**, 24, L175-L178, and *Quantum Theory: concepts and methods.* Kluwer Academic Press, New York 2002.

(2) Kochen, S.; Specker, E. *J. Math. Mechanics* **1967**, 17, 59-87.

(3) Einstein, A.; Podolsky, B.; Rosen, N. Can quantum mechanical description of physical reality be considered complete?, *Phys. Rev.* **1935**, 47, 777-781.

(4) Peres, A. Recursive definition for elements of reality. *Found. of Phys.* **1992**, 22, 357-361.

(5) Mermin, N.D. Quantum mysteries revisited. *Am. J. Phys.* **1990**, 58, 731-734.

(6) Aerts, D. ; D'Hondt, E. ; Gabora, L. Why the disjunction in quantum logic is not classical. *Foundations of Physics* **2000**, 30 (9), 1473-1480.

(7) Aerts, D.; Gabora, L. A state-context-property model of concepts and their combinations I: The structure of the sets of contexts and properties. *Kybernetes* **2005**, 34 (1,2), 167-191.

(8) Aerts, D.; Gabora L. A state-context-property model of concepts and their combinations II: A Hilbert space representation. *Kybernetes*, **2005**, 34 (1,2), 192-221.

(9) Aerts, D.; Broekaert, J.; Gabora, L. A case for applying an abstracted quantum formalism to cognition. *New Ideas in Psychology* **2011**, 29 (1), 136-146.

(10) Babich, F.R.; Jacobson, A.L.; Bubash, S.; Jacobson, A. Transfer of a response to naive rats by injection of ribonucleic acid extracted from trained rats. *Science* **1965**, 149**,** 656-657

(11) Beck, F. Can quantum processes control synaptic emission? *International Journal*

Neural Systems **1996**, 7 (4), 343-353.
(12) Beck, F.; Eccles J.C. *Quantum Processes in the Brain: A scientific basis of consciousness.* In N. Osaka (Ed.), *Neural Basis of Consciousness.* Amsterdam, Philadelphia, John Benjamins, 2003.
(13) Blutner, R.; Hochnadel, E. Two Qubits for CG. Jung's theory of personality. *Cognitive Systems Research* **2010**, 11, 243-259.
(14) Bouda J.; Buzek V. Entanglement swapping between multi-qubit systems. *J. Phys. A: Math. Gen.* **2001**, 34, 4301- 4311.
(15) Braun, D. Creation of entanglement by interaction with a common heat bath. *Phys Rev Lett.* **2002**, 89 (27), 277901
(16) Conte, E. *Biquaternion quantum mechanics.* Pitagora Editrice, Bologna,-Italy, 2000.
(17) Conte, E.; Todarello, O.; Federici, A.; Vitiello, F.; Lopane, M.; Khrennikov, A.Y. *A Preliminary Evidence of Quantum Like Behaviour in Measurements of Mental States. Quantum Theory: Reconsideration of Foundations.* Vaxjio Univ. Press, 2003; pp. 679-702.
(18) Conte, E.; Vena, A.; Federici, A.; Giuliani, R.; Zbilut ,J.P. A brief note on a possibile detection of physiological singularities in respiratory dynamics by recurrence quantification analysis. *Chaos, Solitons and Fractals* **2004**, 21 (4), 869-877.
(19) Conte, E.; Federici, A.; Zbilut, J.P. On a simple case of possible non-deterministic chaotic behavior in compartment theory of biological observables. *Chaos, Solitons and Fractals.* **2004**, 22: 277-284.
(20) Conte, E. Testing Quantum Consciousness. *Neuroquantology* **2008**, 6 (2), 126-139.
(21) Cox, R.T. *The algebra of possible inference.* Johns Hopkins, Baltimora, MD, 1961.
(22) Crick, F. ; Koch, C. Consciousness and Neuroscience. *Cerebral Cortex* **1998**, 8,97-107.
(23) Dugic, M.; Rakovic, D. Quantum mechanical tunneling in associative neural networks, *Eur. Phys.* **2000**, *B*13, 781-790
(24) Von Neumann, J. *Mathematische Grundlagen der Quantenmechanik* Springer-Verlag, 1932.
(25) Gabora, L.; Aerts, D. Contextualizing concepts using a mathematical generalization of the quantum formalism. *Journal of Experimental and Theoretical Artificial Intelligence* **2002**, 14 (4), 327-358.
(26) Gabora, L.; Aerts, D. A cross-disciplinary framework for the description of contextually mediated change. *Electronic Journal of Theoretical Physics* **2007**, 4(15), 1-22.
(27) Gabora, L.; Aerts, D. A model of the emergence and evolution of integrated worldviews. *Journal of Mathematical Psychology* **2009,** 53, 434-451.
(28) Hu, H.; Wu, M. Spin-Mediated Consciousness Theory. arXiv:quant-ph/0208068v5 2002.
(29) Hu, H.; Wu, M. Spin as Primordial Self-referential Process. *NeuroQuantology* **2004**, 2(1), 41-49
(30) Kempe, J. Quantum random walks: an introductory overview. *Contemporary Physics*

2003, 44 (4), 307-327 and references therein

(31) Lefebvre, V. The law of self-reflexion: A Possible Unified Explanation for the Three Different Psychological Phenomena http://cogprints.org/2927/ 2002.

(32) Liley, A.W. An investigation of spontaneous activity at the neuromuscular junction of the rat. *J. Physiol.* **1956**, 132 (3), 650-666.

(33) Margenau, H. *The Nature of Physical Reality*, McGraw Hill 1950.

(34) Margenau, H. *Physics - Principles and Applications*, McGraw Hill 1953.

(35) Mauford, D. *The Dawning of the age of stochasticity*, Mathematics: Frontiers and Perspectives Amer. Math. Soc. 2000.

(36) McIntyre, M.E. *On thinking probabilistically.* Extreme Events (Proc. 15th ‘Aha Huliko‘a Workshop), SOEST, U. of Hawaii, 2007; pp 153–161.

(37) Pitowsky, I. *Quantum Probability–Quantum Logic.* Lecture Notes in Physics. 321 Sprinter –Verlag, New York 1989.

(38) Roland, P.E.; Larsen, B.; Lassen, N.A.; Skinhøj, E. Supplemental motor area and other cortical areas in organizations of voluntary movements in man. *Journal Neurophysiology* **1980,** 43 (1), 118-136.

(39) Schneider, J. Quantum measurement act as a "speech act". arXiv:quant-ph/0504199v1 2005.

(40) Vena, A.; Conte, E.; Perchiazzi, G.; Federici, A.; Giuliani, R.; Zbilut, J.P. Detection of physiological singularities in respiratory dynamics analyzed by recurrence quantification analysis. *Chaos, Solitons and Fractals* **2004**, 22 (4), 857-866.

(41) Ventura, D.; Martinez, T. *An Artificial Neuron with Quantum Mechanical Properties*. Proceedings of the International Joint Conference on Neural Networks, 1998; pp 509-513.

(42) Walker, E.H. Quantum mechanical tunneling in synaptic and ephatic transmission. *International Journal of Quantum chemistry* **1977**, 11, 103-127.

(43) Wolf, F.A. On the Quantum Physical Theory of Subjective Antedating. *Journal Theoretical. Biology.* **1989**, 136, 13-19.

(44) Wu, L.A.; Lidar, D.A.; Schneider, S. Long-range entanglement generation via frequent measurements *Physical Review. A* **2004,** 70, 032322.

(45) Yaynes, E.T. Probability Theory, The logic of science. Cambridge University Press 2003.

(46) Zak, M. Non-Lipschitzian dynamics for neural net modeling, *Applied Mathematical Phys*ics **1989**, 2 (1), 69-74.

(47) Zak, M. Dynamical simulations of probabilities. *Chaos, Solitons and Fractals* **1997**, 8 (5), 793-804.

(48) Ilamed, Y.; Salingaros, N. Algebras with three anticommuting elements.I. Spinors and quaternions. *Journal of Mathematical Phyics.* **1981**, 22, 2091-2095.

(49) Imaeda, K. Quaternionic Formulation of tachyons, superluminal transformations and a complex space time. *Il Nuovo Cimento B* **1979**, 50, 233-294.

(50) Edmonds, J.D. Classical electrodynamics. *American Journal of Physics.* **1974**, 42, 220-234.

The expression Bare Bone Skeleton of Quantum Mechanics is due to Jordan that used it time ago in his book with different purpose and finalities :

(51) Jordan, T.F *Quantum Mechanics in simple matrix form.* Wiley Interscience Publications 1985.
(52) Jordan, T.F. Quantum mysteries explored. *Am. J. Phys.* **1994**, 62, 874-880.
(53) Orlov, Y.F. The Logical origins of quantum mechanics. *Annals of Physics* **1994**, 234, 245-259.
(54) Orlov, Y.F. Peculiarities of quantum mechanics: origins and meaning, 1996 arXiv:quph/9607017/19
(55) Orlov, Y.F. Quantum-type Coherence as a Combination of Symmetry and Semantics, 1997 ar Xiv: quant-Phys. 9705849v1.
(56) Orlov, Y.F. Wave calculus based upon wave logic. *International Joural of . Theoretical. Phys*ics **1978**, 1, 585-598.
(57) Orlov, Y.F. The wave logic of consciousness: a hypothesis. *International Journal of Theoretical Phyics* **1980**, 21, 37-53.
(58) Altafini, C. On the generation of sequential unitary gates from continuous time Schrödinger equations driven by external fields 2002 arXiv:quant-ph/0203005
(59) Conte, E.; Todarello, O.; Federici, A.; Zbilut, J.P. Mind States follow Quantum Mechanics during Perception and Cognition of Ambiguous Figures: a Final Experimental Confirmation. 2007 arXiv:0802.1835
(60) Jordan, T.F. *Quantum Mechanics in simple matrix form*, John Wiley and Sons, New York, 1985.
(61) Eccles, J.C. A unitary hypothesis of mind-brain interaction in the cerebral cortex. *Proceedings of the Royal Society of London* **1990**, *B*240: 433-451.
(62) Feynman, R.; Leighton, R.B.; Sands, M. *The Feynman lectures on physics: quantum mechanics,*. Reading Massachusettts: Addison–Wesley, 1965.
(63) Epstein, P.S. The reality problem in quantum mechanics. *American Journal of Physics* **1945,** 13 (3), 127-136.
(64) Snyder, D.M. On the nature of the change in the wave function in a measurement in quantum mechanics arxiv : quant-ph/9601006.
(65) Snyder, D.M. 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
(66) Jauch, J.M. *Foundations of Quantum Mechanics*, Addison Wesley, Massachusetts, 1968.
(67) Eddington, A.S. *Fundamental Theory*, Cambridge 1946; see also
(68) Beck, F. ; Eccles, J. Quantum aspects of brain activity and the role of consciousness. *Proceedings of National Academy Sciences (USA)* **1992**, 89, 11357-11361.
(69) Margenau, H. *The miracle of existence*, Armando Editore, 1984.
(70) Aerts, D.; Aerts, S.; Broekaert, J.; Gabora, L. The violation of Bell inequalities in the macroworld. *Foundations of Physics* **2000**, 30 (9), 1387-1414.

(71) Aerts, D. ; Durt, T. Quantum, classical and intermediate, an illustrative example. *Foundations of Physics* **1994**, 24, 1353-1369.

(72) Aerts, D.; Gabora, L. A state-context-property model of concepts and their combinations I: The structure of the sets of contexts and properties. *Kybernetes* **2005,** 34 (1,2), 167-191.

(73) Aerts, D.; Gabora, L. A state-context-property model of concepts and their combinations II: A Hilbert space representation. *Kybernetes* **2005**, 34 (1,2), 192-221.

(74) Ashby, F.G.; Maddox, W.T. Relations between prototype, exemplar, and decision bound models of categorization. *Journal of Mathematical Psychology* **1993**, 37, 372-400.

(75) Blutner, R. Hochnadel E. Two Qubits for C.G. Jung's theory of personality. *Cognitive Systems Research* **2010**;11(3), 243-259.

(76) Khrennikov A. *Contextual Approach to Quantum Formalism (Fundamental Theories of Physics).* Springer Verlag, Heidelberg, Berlin, New York, 2009.

(77) Khrennikov A. The Quantum-like Brain on the Cognitive and Subcognitive Time Scales. *J Consciousness Studies* **2009**, 15, 10-25.

(78) J. Wheeler , *Quantum Theory and Measurement*, edited by J.A. Wheeler and W.H. Zurek, Princeton Univ. Press,1983

(79) D. Deutsch , *It from Qubit* , Science and Ultimate Reality, J. Barrow, P.Davies, C. Harper, Eds Cambridge Univeristy Press,2003

(80) D. Gottesman, Proceedings of the XXII International Colloquium on Group Theoretical Methods in Physics, (Group 22), S.P. Corney, R. Delbourgo, P. D. Javis, Eds 32-43, International Press, Cambridge ,M.A.,1999. See also Nature,402,390-393,1999

(81) Elio Conte, Advances in Application of Quantum Mechanics in Neuroscience and Psychology: A Clifford Algebraic Approach. Edited by Nova Science Publishers., Inc, New York, June 2012. ISBN 978-1-61470-325-9 ;
https://www.novapublishers.com/
catalog/product_info.php?cPath=23_48_69&products_id=26712.

References

[1] Conte, E. *Advances in application of quantum mechanics in neuroscience and psychology.* Nova Science Publishers, 2012.

[2] Conte, E. A Reformulation of von Neumann's Postulates on Quantum Measurement by Using Two Theorems in Clifford Algebra. *International Journal Theoretical Physics* **2010**, 49, 587-614.

[3] Conte, E. An Investigation on the Basic Conceptual Foundations of Quantum Mechanics by Using the Clifford Algebra. *Advanced Studies on Theoretical Physics*, **2011**,5 (11), 485-544.

[4] Conte, E. On the Logical Origins of Quantum Mechanics Demonstrated By Using Clifford Algebra: A Proof that Quantum Interference Arises in a Clifford Algebraic Formulation of Quantum Mechanics. *Electronic Journal of Theoretical Physics* **2011**, 8 (25), 1-18.

[5] Conte, E. A proof of von Neumann's postulate in quantum mechanics *Quantum Theory* Edited by American Institute of Physics (AIP), June **2009**, 201-206.

[6] Conte, E.; Todarello, O.; Federici, A.; Vitello, F.; Lopane, M.; Khrennikov, AY.; Zbilut, JP. Some Remarks on an Experiment Suggesting Quantum Like Behaviour of Cognitive Entities and Formulation of an Abstract Quantum Mechanical Formalism to Describe Cognitive Entity and Its Dynamics. *Chaos, Solitons and Fractals* **2007,** 31, 1076-1088.

[7] Conte, E.; Pierri, GP.; Federici, A.; Mendolicchio, L.; Zbilut, J.P. A model of biological neuron with terminal chaos and quantum like features. *Chaos, Solitons and Fractals.* **2006**, 30, 774-780

[8] Conte, E.; Khrennikov, A.Y.; Todarello, O.; Federici, A.; Zbilut, J.P. Mental States Follow Quantum Mechanics during Perception and Cognition of Ambiguous Figures. *Open Systems & Information Dynamics.* **2009,** 16 (1), 1-17.

[9] Conte, E. On ψ retrocollapse in quantum mechanics. *Lettere al Nuovo Cimento.* **1981**, 31 (11), 380-382.

[10] Conte, E. A predictive model of ψ collapse-retrocollapse of quantum mechanics. *Lettere al Nuovo Cimento*, **1981,** 32 (9): 286-288.

[11] Conte, E.; Khrennikov, Y.A.; Todarello, O.; Federici, A.; Zbilut, J.P.. On the Existence of Quantum Wave Function and Quantum Interference Effects in Mental States: An Experimental Confirmation during Perception and Cognition in Humans. *NeuroQuantology* **2009,** 7, 204-212.

[12] Conte, E. Exploration of Biological Function by Quantum Mechanics. Proceedings 10^{th} International Congress on Cybernetics, 1983 16–23, Namur-Belgique.

[13] Conte, E. Testing Quantum Consciousness. *NeuroQuantology* **2008**, 6,126-139.

[14] Conte, E.; Khrennikov, Y.A.; Todarello, O.; Federici, A.; Zbilut, J.P. A Preliminary Experimental Verification On the Possibility of Bell Inequality Violation in Mental States. *NeuroQuantology* **2008,** 6, 214-221.

[15] Conte, E.; Khrennikov, Y.A.; Todarello, O.; De Robertis, R.; Federici, A.; Zbilut, J.P. On the possibility that we think in a quantum mechanical manner: an experimental verification of existing quantum interference effects in cognitive anomalies conjunction fallacy. *Chaos and Complexity Letters* **2010**, 4, 1-15.

[16] Conte, E. An example of wave packet reduction using biquaternions. *Physics Essays* **1994**, 6, 4-10.

[17] Conte, E. Wave function collapse in biquaternion quantum mechanics. *Physics Essays* **1994**, 7, 14-20.

[18] Conte, E. On the possibility that we think in a quantum probabilistic manner. Special Issue on quantum cognition dedicated to some recent results obtained from prof. Elio Conte. *Neuroquantology* **2010**, 8 (3), 349-483.

[19] Conte, E.; Todarello, O.; Laterza, V.; Khrennikov, Y.A.; Mendolicchio, L.; Federici, A. Preliminary Experimental Verification of Violation of Bell Inequality in a Quantum Model of Jung Theory of Personality Formulated with Clifford Algebra. *Journal of Consciousness Exploration and Research* **2010**, 1, 785-887.

[20] Conte, E.; Khrennikov, A.Y.; Todarello, O.; Federici, A.; Zbilut, J.P. On the Existence of Quantum Wave Function and Quantum Interference Effects in Mental States: An Experimental Confirmation during Perception and Cognition in Humans. *NeuroQuantology* **2009**, 7 (2), 204-212.

[21] Conte, E. On The Logical Origins of Quantum Mechanics. *Neuroquantology* **2011**, 9 (2), 231-242.

[22] Müller, G.E.; Pilzecker, A. Experimentelle beiträge zur lehre von gedächtnis. *Zeitschrift für Psychologie* **1900**, 1-300

[23] Jenkins, J.J. Remember that old theory of memory? Well, forget it! *American Psychologist* **1974**, 29, 785-795.

[24] McGeoch, J.A. Forgetting and the law of disuse. *Psychological review* **1932**, 39 (4), 352-370**.**

[25] Massaro, D.W. Retroactive Interference in Short Term Memory for Pitch. *Journal of Experimental Psychology*, **1970**, 83, 32-39.

[26] Roediger, H.L.; Schmidt, S.R. Output interference in the recall of categorized and paired associative lists. *Journal of Experimental Psychology: Human Learning and Memory* **1980**, 6, 91-105.

[27] Pashler, H. Dual-Task Interference in Simple Tasks: Data and Theory. *Psychological Bulletin by the American Psychological Association. Inc.* **1994,** 116 (2), 220-244.

[28] Navon, D.; Miller, J.O. Role of outcome conflict in dual-task interference. *Journal of Experimental Psychology: Human Perception and Performance*, **1987**, 13, 438-448.

[29] Freud, S. Zur Dynamik der Übertragung, in *S. Freud Studienausgabe*, 1912/1982**,** 3, Psychologie des Unbewußten, Frankfurt a. M.: Fischer.

[30] Freud, S. Zur Disposition zur Zwangsneurose. Ein Beitrag zum Problem der Neurosenwahl, in *S. Freud Studienausgabe*, 1913/1982, 7, Zwang, Paranoia und Perversion, Frankfurt a. M.: Fischer.

[31] Freud, S. 13. Vorlesung: Archaische Züge und Infantilismus des Traumes, in *S. Freud Studienausgabe*, 1916/1982, 1, Vorlesungen zur Einführung in die Psychoanalyse und Neue Folge, Frankfurt a. M.: Fischer.

[32] Freud, S. 21. Vorlesung: Lidoentwicklung und Sexualorganisation, in *S. Freud Studienausgabe*, 1917/1982, 1, Vorlesungen zur Einführung in die Psychoanalyse und Neue Folge, Frankfurt a. M.: Fischer.

[33] Freud, S. 33. Vorlesung: Die Weiblichkeit, in *S. Freud Studienausgabe*, 1917/1982, 1, Vorlesungen zur Einführung in die Psychoanalyse und Neue Folge, Frankfurt a. M.: Fischer.

[34] Busemeyer, J.R.; Wang, Z.; Lambert-Mogiliansky, A. Empirical comparison of Markov and quantum models of decision making. *Journal of Mathematical Psychology*, **2009**, 53(5), 423-433.

[35] Busemeyer, J.R.; Wang, Z.; Townsend, J.T. Quantum dynamics of human decision making. *Journal of Mathematical Psychology*, **2006**, 50, 220-241.

[36] Khrennikov, A.Y. *Ubiquitous Quantum Mechanics: from psychology to Finance*, Springer 2009

[37] Khrennikov, A.Y. Linear representations of probabilistic transformations induced by context transitions. *J. Phys. A: Math. Gen.* **2001**, 34, 9965-9981.

[38] Khrennikov, A.Y. Interference in the classical probabilistic framework. *Fuzzy Sets and Systems* **2005**, 155, 4-17.

[39] Khrennikov, A.Y. Quantum-like brain: Interference of minds. *BioSystems* **2006**, 84, 225-241.

[40] Khrennikov, A.Y. The principle of supplementarity: A contextual probabilistic viewpoint to complementarity, the interference of probabilities, and the incompatibility of variables in quantum mechanics. *Foundations of Physics* **2005**, 35 (10), 1655-1693.

[41] Townsend, J.T.; Silva, K.M.; Spencer-Smith, J.; Wenger, M.J. Exploring the relations between categorization and decision making with regard to realistic face stimuli. Invited article in special issue of *Pragmatics & Cognition: Facial Information Processing: A Multidisciplinary Perspective* **2000,**8, 83-105. I. E. Dror and S. V.Stevenage Eds.

[42] Debner, A.J.; Jacoby, L.L. Unconscious perception: Attention, awareness and control. *Journal of experimental psychology, Learning memory and cognition* **1994**, 20 (2), 304-317.

[43] Draine, S.C.; Greenwald, A.G. Replicable unconscious semantic priming. *Journal of experimental psychology, general* **1998**, 127 (3), 286-303

[44] Dehaene, S.; Changeux, J.P.; Naccache, L.; Sackur, J.; Sergent, C. Conscious, preconscious, and subliminal processing: a testable taxonomy. TRENDS in *Cognitive Sciences* **2001**, *l*9, 191-199.

[45] Commentary on Erdelyi M.H. Unconscious perception: Assumptions and interpretative difficulties. *Consciousness and Cognition* **2004**, 13, 117-122

[46] Dell'Acqua, R.; Grainger, J. Unconscious semantic priming from pictures. *Cognition* **1999**, 73, B1-B15.

[47] Carruthers, P. *Phenomenal Consciousness* Cambridge University Press, 2000.

[48] Kouider, S.; Dehaene, S. Levels of processing during non-conscious perception: a critical review of visual masking. *Philosophycal Transactions of Royal Society B* **2007**, 362, 875-875.

[49] Eimer, M. Links between conscious awareness and response inhibition: evidence from masked priming. *Psyconomic Bulletin and Review* **2002**, 9 (3), 514-520.

[50] Mitroff, S.; School, B.J. Forming and updating object representations, without awareness: evidence from motion – induced blindness. *Vision Research* **2005**, 45, 961-967.

[51] Jacquot, L.; Monnin, J.; Brand G. Unconscious odor detection could not be due to odor itself. *Brain Research* **2004**, 1002, 51-54.

[52] Benfenati, F. Synaptic plasticity and the neurobiology of learning and memory. *Acta Biomedica* **2007**, 78 (1), 58-66.