Original Articles

Testing Quantum Consciousness

Elio Conte

Abstract

We give here a review of the experiments that we performed in the last few years to conclude that mentals states follow quantum mechanics. As theoretical basis we give explanation of the quantum interference effects, quantum probabilities, and a posteriori reconstruction of quantum wave functions by the approach that was previously introduced by us. In the cases that we study, the classical formula of total probability does not hold true in quantum systems unless a quantum interference terms is added. All the experiments were carried out on normal subjects during perception and cognition of ambiguous figures. The results confirmed the presence of such quantum interference effect also for mental states. From here our unequivocal conclusion that mental states follow quantum mechanics. A position of quantum mechanics as Giano Bifronte, the two faced God of mythology, is discussed with respect to its role in the analysis and characterization of mental entities.

Key Words: quantum consciousness, context depending probabilities, perception, cognition, ambiguous figures, quantum mechanics, mind entities

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Introduction

Let us start attempting to give some necessarily partial definition of consciousness. Human experience involves various functions as images, intentions, thoughts, and beliefs. It consists of content plus the awareness of such content. Consciousness is a system which observes itself. It evaluates itself being aware at the same time of doing so.

We may express such assertion in formal terms: Let x, y, z are statements describing contents of various experiences. They are (atomic) content statements. Starting from such statements, other content statements may be formed by Boolean functions. z = f(x, y,…..) are metha linguistic propositions or experience-describing statements themselves. We are forced to admit existing awareness statements that we call a, b, c, …, self-referential or auto referential. They require auto referential definitions such as $a_i = F_i(a_1,.....,a_n; x_1, x_2,......,x_n)$, $(i = 1,2,....,n)$ where F_i are Boolean functions. $a = F(a, x)$ is the most simple definition of a single auto referential statement a. For example, *x=this pet is a cat; a= I am aware of this.*

If one day we would arrive identifying at all or in part the basic physical, scientific, philosophical principles and rules that act in our reality in order to determine consciousness and mind in humans, we would have moved in the way of a new great

Corresponding author: Elio Conte
Address: Department of Pharmacology and Human Physiology – TIRES – Center for Innovative Technologies for Signal Detection and Processing, University of Bari- Italy; and School of Advanced International Studies for Applied Theoretical and Non Linear Methodologies of Physics, Bari, Italy
e-mail: elio.conte@fastwebnet.it

advance in our knowledge. This review moves in such direction and perspective in a precise sense. Here we synthesize some experimental results that we have obtained in several years of experimental research. Our position is that we have reached a rather robust verification and confirmation that mental states of human beings follow quantum mechanics. In order to obtain such confirmation we have always employed the methodology to engage subjects during perception and cognition in perspective reversals of ambiguous visual patterns. There are not particular reasons to have followed strictly this arrangement except for the theoretical quantum mechanical elaboration that we use and that, as every one will deduce reading the following sections, it fits very well to the experimental scheme that we have predisposed.

The Quantum Theoretical Approach

Previously we have given here a logical self-reference mathematical model of conscious experience. It is due to A. G. Kromov (Kromov, 2001), and it represents an excellent approach to the problem. However, we now that consciousness represents the hard problem for scientific, epistemological and philosophical knowledge (Whitehead, 1929, 1933; Stapp, 1993; Shimony, 1997). Present physical theory does not dispose of a definite theoretical framework to describe conscious systems. However, we cannot exclude that future generalizations of the present physical knowledge will be able to approach such basic problem. Our position, however, is that an indication arises from quantum mechanics. All we know that quantum theory represents the most confirmed and celebrated theory of science. Started in 1927 by founder fathers as Bohr, Heisenberg, Schrödinger, and Pauli (Bohr, 1987), it has revolutionized our understanding of the physical reality in both scientific and epistemological fields. It was introduced to describe the behaviour of atomic systems but subsequently its range of validity has turned out to be much wider including in particular some macroscopic phenomena like superconductivity or superfluidity. There is a salient and crucial feature for this theory. We are convinced that quantum mechanics is a "Giano Bifronte", a two faced God of mythological antiquity. It from one side looks at the physical processes but simultaneously, from the other side, it relates mind entities and their dynamics. There is an important statement to outline here. At some stages of description of our reality it becomes impossible to operate such separations between "described" and "what is being described", and the features of simultaneous their fusion become an essential counter part of reality itself. The most relevant confirmation of such tendency in quantum theory resides in its formalization: (Conte, 2000; see also Jordan, 1985) we may derive all traditional quantum mechanics as quantisation, hydrogen atom, harmonic oscillator, time evolution, angular momentum, E.P.R. with Bell inequality and so on, using only three abstract algebraic elements (e_1, e_2, e_3), and we have given a lot of papers to this regard (Conte, 2000, 2006, 2007). Orlov (Orlov, 1982) gave the first important indication on the status of the matter affirming textually "every atomic proposition of classical logic (and thus of our thinking) can be represented by a diagonal operator – the third component of the Pauli algebra e_3". It has been included by us in the three abstract algebraic set (e_1, e_2, e_3) that actually becomes simultaneously necessary to describe actual processes of our mind. So in conclusion, by quantum mechanics we describe physical processes on one hand but also the basic foundations of our mind entities on the other. We have also profound historical recalls and initial intuitions of such existing link the conceptual structure and the axiomatic foundations of quantum theory repeatedly suggested, from its advent and in the further eighty years of its elaboration, that it has a profound link with mental entities and their dynamics. From its advent such theory was strongly debated and often also criticized just for its attitude to prospect a model of reality that results strongly linked to mental entities and their dynamics. From its starting the standard formulation of quantum mechanics seemed to fix the necessity to admitting the unequivocal role of mental properties to represent properties of the physical objects. This statement is true. The novel feature is that we identify that such profound link is realized by the abstract algebraic set (e_1, e_2, e_3) as, in our opinion; it was initially indicated by Orlov. We retain that such unusual feature of the theory represents its important mark instead a limit. However, there is the problem to correctly interpreting the connection between quantum mechanics and mental properties in the sphere of reality. We are out from any interpretation of such statement in reductionism terms. It must be clear that one cannot have in mind a complete quantum physical reduction of mental processes. N. (Bohr, 1987) borrowed the principle of complementarities, which is at the basis of quantum mechanics, from psychology. He was profoundly influenced from reading the "Principles of Psychology "by W. James (James, 1890). However, N. Bohr never had in mind quantum-reductionism of mental entities. Starting with 1930, there was also an important correspondence between W. Pauli and C.G. Jung that culminated in the formulation of a theory of mind-matter synchronization (Meire, 2001). Also in this case these founding fathers as Pauli and Jung were very distant to consider a quantum-reductionism perspective. V. Orlov (1982) proposed to use quantum logic to describe brain function but also he did not look for reduction of mental processes to quantum physics. The correct way to frame the problem is not to attempt a quantum reduction of mental processes. The most profitable applications of quantum mechanics in cognitive sciences and psychology can be obtained not by any attempt of quantum physical reduction but giving experimental evidence that cognitive systems are very complex information systems, to which also some laws and principles of quantum systems can be applied. Just the reaching of such objective would represent a very great advance in the domain of knowledge. In fact, starting with such experimental evidence, we could elaborate some future developments knowing this time the principles to use, the formal criteria to follow in order to approach with higher rigour the framing of the nature of mental entities and of their dynamics.

We retain that in this perspective we have given here a first contribution with our experimentation since we have given here for the first time experimental confirmation that mental states, at some stages of human perception and cognition, can be described by the formalism of quantum mechanics. Thus for the first time, also if not under a reductionism perspective, we have the chance to understand what are the principles and rules acting as counter part in human mind.

The Role of Probabilities in Quantum Mechanical Formulation

To fully agree with the present paper, the reader must take care the following crucial point: quantum mechanics has its unique law of transformation of probability distribution. It is well known that the main feature of quantum probabilistic behaviour is the well known phenomenon of interference of probabilities. Such interference regime may be obtained only in quantum systems, e. g., in the celebrated two slit experiment that has been confirmed at any level of experimental investigation (Ballentine, 1970; Zelingr, 1966). The interference gives the experimental basis of the superposition principle and this latter is the basis foundation of the physical and philosophical system of view that we call quantum mechanics. This is the essential peculiarity that we aim to investigate in the present paper. A contribution to the problem on the existence of quantum wave functions and quantum interference effects in biological dynamics and in mental states arose years ago (Conte, 1983; Khrennikov, 2001; Conte et al., 2003-2007). In particular, by Khrennikov, the problem was extended to the so called calculus of contextual probabilities. One essential feature of this elaboration is that by it we may be able to ascertain the presence of quantum like behaviour in systems that exhibit context quantum like behaviour as physical, cognitive, and social systems. Let us enter in some features of the problem while all the features are given in detail in the quoted literature.

We study transformations of conventional and thus of classic probabilities and we consider that they are induced by the context transitions. It is shown that the transition from one complex of conditions to another complex may induce a perturbation of the classical rule for addition of probabilistic alternatives that will be called in our case as trigonometric interference. Let us make an example to be clear.

In the classical rule for addition of probabilistic alternatives we have that

$P = P_1 + P_2$.

In the case of quantum rule we have instead that

$$P = P_1 + P_2 + 2\sqrt{P_1 P_2}\cos J$$

Let $S = S_1 \mathbf{U} S_2$ and $S^{'} = S_1^{'} \mathbf{U} S_2^{'}$

be two different complexes of conditions.

The trivial rule

$$P(B/S) = P(B/S_1) + P(B/S_2)$$

now may be rewritten as

$$P(B/S) = P(B/S_1^{'}) + P(B/S_2^{'}) + d(S, S^{'})$$

and the perturbation term $d(S, S^{'})$ must be accounted in the case of the experiments. B is obviously some selected random variable.

The essence of the method is thus based on the following step. Let A and B be two dichotomous questions which can be asked of people, G, with possible answers "yes (+) or not (-)". In our case we consider A and B two mental quantum like observables of people G under investigation. We split the given ensemble G of humans into two sub ensembles U and V of equal numbers. To ensemble U we pose the question A with probability in answering, given respectively by

$p(A=+)$ and $p(A=-)$,and

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

We pose the question B immediately followed by the question A to the ensemble V. We calculate conditional probabilities $p(A=+/B=+)$ and $p(A=+/B=-)$ and equivalent probabilities for the case ($A=-$). Now we have reached a no evadable feature of such experiment.

Let us recall the fundamental law of classical probability theory, the well known formula of total probability (FTP):

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

It plays the known fundamental role in classical statistics and decision making. However, it is violated for statistical experiments with quantum systems. As example, the two slit (interference) experiment is a basic experiment violating FTP. In physical literature such a viewpoint on this experiment was discussed in detail by Feynman (Feynman and Hibss, 1965). By itself the appearance of interference fringes was not surprising for him: in principle, interaction with a screen with slits may produce any kind of distribution of points on the registration screen. Probabilistic mysteries appear if one considers three different experiments: a) only the first slit open (say B=+1), b) only the second slit is open (say B= -1), c) both slits are open. Here the random variable B determines the slit. We now choose any point at the registration screen. The random variable will be A= +1 if a particle hits the screen at this point and A=-1 in the opposite case. For classical particles, FTP should predict the probability $p(A=+)$ for the c-experiment (both slits are open) on the basis of probabilities

$p(B=+)p(A=+/B=+)$ and

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

which are provided by the a and b-experiments. But, as was already mentioned, FTP is violated for quantum particles: an additional cosine-type term appears in the right-hand side of FTP. This is nothing else than interference of probabilities. Feynman characterized this feature of the two slit experiment as the most profound violation of laws of classical probability theory. Our aim is to show that this fundamental law of classical probability can be violated even by cognitive systems. In this case we may derive quantum wave functions for an ensemble of systems, starting directly from experimental data (Conte, 1983), and finally, we calculate the quantity representing deviation from the classical probabilistic law:

$$l = \frac{p(A=+) - p(B=+)p(A=+/B=+) - p(B=-)p(A=+/B=-)}{2\sqrt{p(B=+)p(A=+/B=+)p(B=-)p(A=+/B=-)}}$$
$$= \frac{\Delta p}{2\sqrt{p(B=+)p(A=+/B=+)p(B=-)p(A=+/B=-)}} \quad (2.1)$$

We recall that the conventional quantum formalism implies that, (if one considers quantum observables A and B ($AB \neq BA$ (Conte,1983)), l is not equal to zero (opposite to classical statistics). If in our experiments for cognitive systems (with questions A and B) it results that $l \neq 0$, it will be certain that we are in presence of quantum like behaviour for mental states owing to the presence of interference terms for the calculated probabilities. In the case l =0 we will conclude that quantum like behaviour is absent in the dynamic regime of our mental states. We also recall that in quantum mechanics (for physical systems) the coefficient l can be represented as $l = \cos J$, where J is obviously a well known angle of phase. We may expect a similar result for cognitive systems.

We may also proceed giving a quantum wave function framework of mental states (Conte, 1983; Khrennikov, 2001). Let us remember that, according to Born's probability rule, we have

$$P(A=\pm) = |j(\pm)|^2 \quad (2.2)$$

In the case in which the experiment confirms quantum mechanics in dynamics of mental states, we write a quantum wave function $j_S(\pm)$ relative to the mental state S of the population investigated, and it will be represented by the complex amplitude as for the first time elaborated in and applied in our previous papers (Conte et al, 2003-2008).

$$f_S(x) = \left[P(B=+)P(A=x/B=+)\right]^{1/2}$$
$$+e^{iJ(x)}\left[P(B=-)P(A=x/B=-\right]^{1/2}$$
with $x = \pm$ (2.3)

This is the essence of the theory and of the experimentation that we have used in these years. It is seen that it gives great evidence in testing the presence of quantum consciousness.

Arrangement of the Experiment

The experiment was based on the search of quantum behaviour in mental states during human perception and cognition of ambiguous figures.

Before of all let us recall the manner in which perception and cognition are realized by the brain in such cases. In general, the brain organizes sensory input into some representation of a given environment. Studies of perception indicate that the mental representation of a visually perceived object at any instant is unique even if we may be aware of the possible ambiguity of any given representation. The well known example is the Necker cube (Necker, 1832) where we see the cube in one of two ways but only one of such representations is manifest at any time. We may be able to see the ambiguity of the design and even we may be able to switch wilfully between representations: we can be aware that multiple representations are possible but we can perceive them only one at time that is serially.

Bi-stable perception arises whenever a stimulus can be thought in two different alternatives ways. The essential points are here on the terms "be aware of ambiguity" and "manifest state of only one percept at time". The critical observation of such facts has enabled us to introduce a quantum model of consciousness that may be also tested. We are in the condition to introduce a quantum mechanical counterpart of such mind processes. Also previously (Conte et al., 2006-2007), we proposed to describe bi-stable perception with the formalism of a two quantum superposition system. We elaborated in detail the theory of such possible approach. In our quantum like model of mental states and consciousness we admit that an individual can potentially have multiple representations of a given choice situation, but can attend to only one representation at any given time. This appears to be the crucial point of our work, and it is in correspondence with facts that we actually observe. In this quantum mechanical framework we distinguish a *potential* and an *actual* or *manifest* state of consciousness. The state of the *potential consciousness* will be represented by a vector in Hilbert space. If we indicate for example a bi dimensional case with potential states $|1>$ and $|2>$, the potential state of consciousness will be given by

$$y = a|1> + b|2> . \quad (3.1)$$

Here, a and b represent probability amplitudes so that $|a|^2$ will give the probability that the state of consciousness, represented by percept $|1>$, will be finally actualised or manifested during perception. Conversely $|b|^2$ will represent the probability that state (percept) $|2>$ of consciousness will be actualised or manifested during perception. It will be $|a|^2 + |b|^2 = 1$. Also E. Manousakis (Manousakis, 2007) proposed a model with a wave function between perceptual events describing a state of potential consciousness and collapse of wave function when perceptual event is manifested. Let us return to give an example: the ambiguous picture given in Figure-1. The state of *potential* consciousness is

$$y = a_{vase}|1> + b_{faces}|2>$$

In manifest or actual state of consciousness the subject will select or the vase or the faces.

In conclusion we have two states of consciousness. One will be of potential kind; in our case it responds to the possibility of multiple representations of a given choice situation. The other will be of actual or manifest kind, corresponding to the case in which the subject attends to only one representation at any given time. Also according to Manousakis (Manousakis, 2007), the (3.1) is correlated with neural brain states. When conscious observation happens, the actual perceptual event in consciousness will link to neural correlate brain states. In this manner $|1>$ and $|2>$ represent states having distinct neural correlates of consciousness in brain. The arising model, that we fully accept, as due to Eccles and Beck (Eccles and Beck, 1992), is that one of the mind as a quantum field of probability.

Figure 1. Ambiguous figure inducing two different representations, vase or faces. The subject is aware that different representations are possible, but he can perceive only one of the two possible percepts at any one time.

Experiment Set Up

Generally speaking, the problem is to explain how, given multiple possibilities of representation; a particular representation can take place over our attention. In the case of Necker cube transitions between percepts, it may be possibly stochastic, but in more complex mental and psychological situations some underlying factors may give the edge to one representation over another. Recent or repeated prior use of a representation may play role in advantaging one representation over the other. This is the reason to project the experiment carefully. Otherwise the study of ambiguous figures has intrigued and still is of valuable interest for psychologists and neuroscientists. A variety of theories has been published (Kahler, 1940; Attneve, 1971;

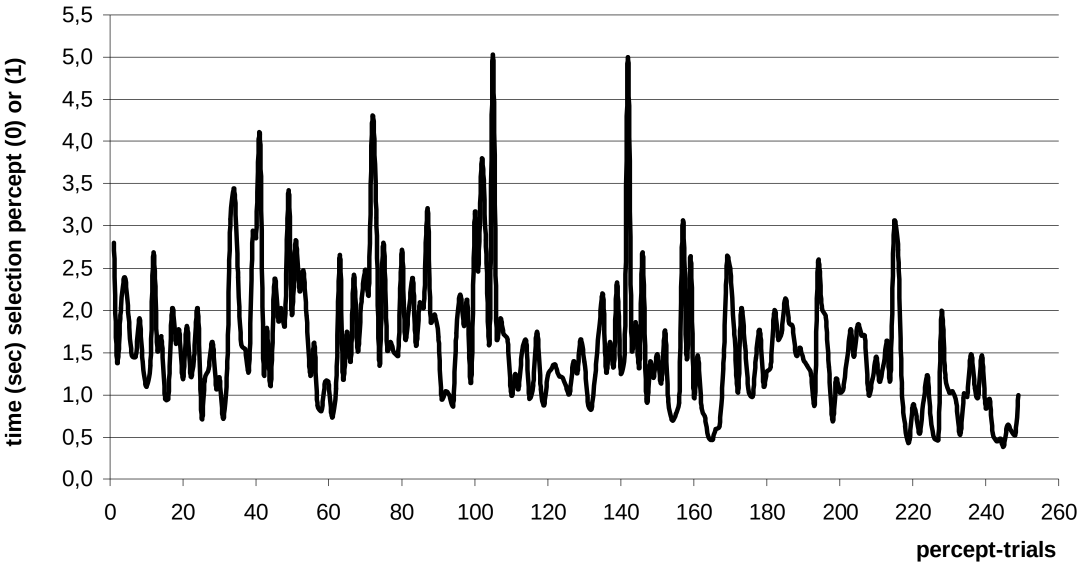
Turvey, 1977; Gibson, 1950; Mitroff, 2005, Sakai, 1993, 1994). For the purposes of our experimentation we evaluated that two types of observers exist: 1) fast observers, having larger frequency of perspective reversals and 2) slow observers whose frequency is lower. The time of staying one of the two percepts are on average on the order of two seconds, but may also approach about five seconds. To further confirm our quantum model with potential and actual states of consciousness, we have a further phenomenological datum. Subjects demonstrate uncertain time in percepts states. Uncertain times about 1 sec were experimentally ascertained on average for fast subjects (Kahler, 1940; Attneve, 1971; Turvey, 1977; Gibson, 1950; Mitroff, 2005; Sakai, 1993, 1994). In conclusion, two kinds of times are identified during experiments with ambiguous figures: a time persisting one of the two possible percepts which we call time persisting for percept A, but it is quite similar to time persisting percept B. Additionally, we have a time of uncertainty for which neither of the percepts is certain for the subject, which mirrors the previous quantum model on potential state of consciousness. Experiments have confirmed that the distribution of the persistent time in uncertain states is quite different from those corresponding to percepts A and B that rather result instead of the same order of value. There are still two basic different approaches in studies of perception of ambiguous stimuli. One is the behavioural response to a stimulus based on psychological or mental processes. This is obtained using the frequency of reversals. The second approach looks instead to neural correlates of psychological processes triggered by stimuli.

There were analysed EEG recorded from parietal and frontal areas, focusing on gamma band phase synchronization between these two areas. A recent neuroimaging study, using functional magnetic resonance imaging (fMRI), has suggested that conscious detection of visual changes relies on both parietal and frontal areas (Struber, 2000, 2004; Kleinschmidt, 1998). The same areas also show activation in perceptual switching experiments. These areas, therefore, seem to play an important role in detecting changes in our perception, whether they are caused externally or internally (Kahler, 1940; Attneve, 1971; Turvey, 1977; Gibson, 1950; Mitroff, 2005; Sakai, 1993, 1994). The temporal characteristics of the relationship between these two areas are not well understood. However, it has been proposed that transient synchronization of oscillatory activity, in particular in the gamma band of the EEG, plays an important role in building coalitions between areas (Struber, 2000, 2004; Kleinschmidt, 1998). Moreover, transient gamma band synchronization induced by sensory stimulation is considered important for perceptual feature binding of distributed representations (Struber, 2000, 2002; Kleinschmidt, 1998). For this reason, transient gamma band synchronization is important in our investigation. The time scale of 3 sec results from a state of being conscious and this time scale is also significant for cognitive processes beyond the bistable perception of ambiguous stimuli. Experiments have been performed (Struber, 2000, 2002; Kleinschmidt, 1998) concerning capabilities of discriminating and sequencing temporally separate perceptual events. Important studies have been performed by Atmanspacker (Atmanspacker, 2004) In conclusion there are two cognitive time scales that one should take in consideration in experimentation on perception and cognition of ambiguous figures. There is an additional important result. In Figure 2 we give the behaviour in time on the manner in which a subject selects one of the two percepts for a given ambiguous figure. In ordinate we have the times of selection for percepts and in abscissa the percept trials for such subject. The ambiguous figure in this case was that given in Figures 6 with the rabbit signed by (1) and the stork signed by (0). The experiment was performed for ten minutes. The arising time series, at a preliminary level of analysis, revealed that we are in presence of a very complex dynamics regime, possibly chaotic. This datum confirms our initial statement. Brain is a very complex system, whose regime is also regulated from quantum mechanical contributions but also from basic, classical regimes. Reductionism has no sense in respect of such very complex system.

In future it will be of great importance the analysis of time series as those given in Figure 2 for a subject. By it we may experience the spontaneous changing percept of a given human being. In this manner we will explore the dynamics on the manner in which a subject resolves his perceptual ambiguity in stimuli that offer multiple possible interpretations. First of all, our studies will resolve if we are in presence of a dynamics entirely based on pure random, or instead if it follows a deterministic pattern. In particular, it will be of interest to explore if it will result of chaotic nature, and, in particular, what kind of chaos it will be present, and, in case, the presence of quantum-chaos will be also ascertained. In detail we will measure the degree of complexity of the whole perceptual-cognitive system, in particular, by using quantification of recurrence analysis, in the manner in which it was introduced by Joseph Zbilut and C.L. Webber Jr. We will estimate basic variables of the perceptual-cognitive system as its Recurrence (in some sense in analogy with the periodicity of the system in consideration), its Determinism, its Entropy, and its local Lyapunov exponent behaviour. The knowledge of all such variables will result of valuable importance in final understanding and explanation of our quantum model of consciousness, but also in explaining the complexity of the whole brain system that we have in examination where, at its inside, basic quantum rules develop a decisive role. In particular, our analysis will be decisive in attempting to solve the problem if the perceptual-cognitive system is assisted by some mechanism of a self-organization and/or fractal tendency when it deals with ambiguous information.

The Methodology of our experiments

Our experiments were conducted for several years and were all based on the analysis of the (2.1). In the first phase of the experimentation we used the ambiguous pictures that are given in figures 3 and 4, Tests A and B. We performed three experiments (Conte, 2003) of this kind based on ninety eights subjects. In the last experimentation, performed more recently, we used instead the ambiguous pictures given in Figures 5 and 6. We investigated a group of twenty six subjects. It must be clear that in the case of the last twenty six subjects, we used more light conditions of perception in the sense that we used figures with more immediate induction of ambiguity respect to the ambiguous figures that we used previously, that, based on geometrical evaluation, resulted to our probes to offer more stringent conditions in perception and awareness of ambiguity. The choice of such different pairs of ambiguous figures results to be of importance in the course of experimentation since, as we reported previously, studies conducted by EEG and fMRI have evidenced the net existence of neurophysiological correlates that are established in some well defined brain regions under observation and perception of figures in condition of ambiguity. In addition, according to our quantum model on quantum consciousness, previously discussed, we consider that an individual can potentially have multiple representations of a given choice situation, but he can attend to only one percept representation at any given time. Strong or more immediate ambiguity as induced in the present case by tests A and B of Figures 3 and 4, and 5 and 6, respectively, would consequently induce the subject to suspend his potential consciousness state more quickly and soon after followed from actualised or manifest state of percept of his consciousness. All these are physical, psychological and neurological features that in perspective will require more detailed investigations. In conclusion, by the last phase of experimentation, we retain that we performed any effort to guarantee the most favourable and quickly conditions to verify if quantum mechanics enters in the dynamics of mental states during perception of ambiguous figures. We had also elements of comparison respect to the results that were previously obtained using different ambiguous figures.



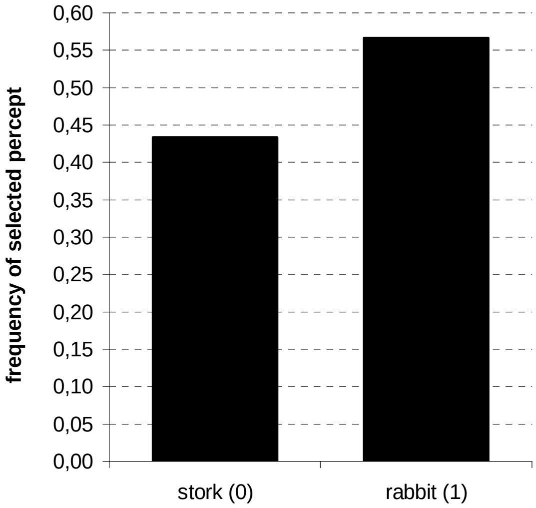


Figure 2a (Upper). Irregular behaviour, possibly chaotic, for times of percepts during percept-trials of a subject observing Test of Figure 6. Figure 2b (Left). Frequency of percepts for Stork (0) and Rabbit (1), respectively.

Let us add now some features on the manner in which the experimentation actually proceeded. All the subjects were selected with about equal distribution of females and males, aged between 19 and 22 years. All had normal or corrected-to-normal vision. All they were divided by random selection into two groups (1) and (2). Group (1) was subjected to test A (Figure 3 and 5, respectively) while the group (2) was subjected to Test B (Figure 4 and 6, respectively), and soon after to Test A. The time interval between Test B and A was about 800 msec. As said, after choice for test B, test A was given for group (2).

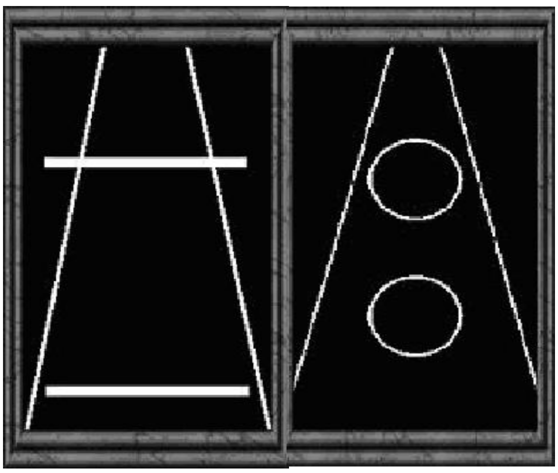


Figure 3: Have the two lines the same length?

Figure 4: Are equal the two circles or not?

It has been shown that perception and cognition in ambiguous figures is influenced by visual angle (Borsellino,1985). Therefore a constant visual angle $V = 2arctg(S/2D) = 0.33\, rad.$ was used with S object's frontal linear size and D distance from the center of the eyes for all the subjects. Each observer was seated at a table with a monitor and computer, and was told to look binocularly at the figure, with no fixation point provided. The observer was requested to stop by pressing a key at the computer when he was aware of having thought of one percept and only one after direct verification of the existing ambiguity in the figure. The ambiguous figures were placed in front of the eyes of the observer at a distance of 60 cm, and illuminated by a lamp of 60 W located above and behind the observer's head. The experimental room was kept under daylight illumination. The constant visual angle was realized for each subject using an S object's frontal linear size of about 26 cm for the figure on the monitor.

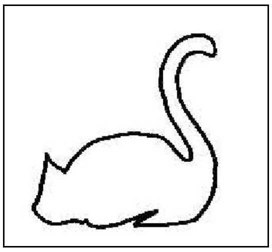


Figure 5. Test A: cat or swan

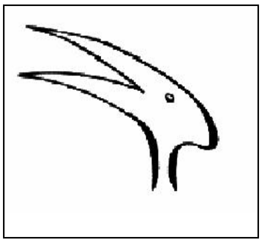


Figure 6. Test B: stork or rabbit

Results

The results that we obtained in such long experimentation confirmed that mental states follow quantum mechanics during perception and cognition of ambiguous figures. According to our previous formulation, they indicate that human beings can potentially have multiple representations of a given choice situation, and can attend to only one percept representation at any given time via a quantum mechanical jump. This is to say in our quantum mechanical framework that we have to distinguish a potential and an actual or manifest state of consciousness. The state of the potential consciousness is represented by a vector in Hilbert space. If we indicate for example a bi dimensional case, with states indicated by $|1>$ and by $|2>$, the potential state of consciousness will be given by $y = a|1> + b|2>$. In this case, the (2.1) must is verified. The results that we obtained are reported in Table1 for the case of the last test that we performed. It is seen that we obtained $\cos J(+) = -0.307$, and thus $J(+) = 1.882.$ This result unequivocally confirms that mental states follow a quantum mechanical regime in presence of perception and cognition of ambiguous figures. In this manner, according to the (2.3) we may also write the quantum wave function $j_S(+)$ of the mental state S of the group of human beings investigated, and results (see the 2.3):

$$f(+) = [0.615 \times 0.750]^{1/2}$$
$$+ e^{iJ(+)}[0.385 \times 0.800]^{1/2} \approx 0.679 + 0.554\, i$$

for mental variable A with assumed value +.

Analogously we may calculate $j(-)$ relative to the mental variable A with assumed valued $A = -.$ In Table 2 we summarize the results of the experiments that we performed in the past years. All they gave values of $\cos J$ and of J different from zero. They confirm our main thesis that mental states follow quantum mechanics In Table 2 a statistical analysis of the data is also added, using Student's T-test. The level of significance for our analysis resulted greater than 90%. This result may be considered of valuable importance since we are operating by mental observables, obviously subjected to rather consistent uncertainty. Finally, we performed also a third kind of analysis. Finally, we grouped all the 124 subjects that we employed in all the experimentation, considering it as only one group, independently of the nature of Tests A and B that we used. In this case we proceed to the calculation of $\cos J$ and thus of J . As seen by Tab.3 we obtained the value $J = 1.6942$. Considering instead the group of the four experiments that we performed in the previous years, we calculated $J = 1.722367 \pm 0.173423$ that seems to be in accord with the result found in the case of the last experimentation.

Table 1. Results obtained respectively for Tests A,B, and A/B

	Test A		Test B		A/B	
Subject	CAT (+)	SWAN (-)	STORK (+)	RABBIT (-)	CAT (+)	SWAN (-)
1		*	*		*	
2		*	*			*
3	*		*		*	
4	*		*		*	
5	*			*	*	
6	*		*			*
7	*			*	*	
8		*	*		*	
9	*			*	*	
10		*	*		*	
11		*		*		*
12		*	*		*	
13	*			*	*	
	p(A=+)	p(A= -)	p(B=+)	p(B= -)	p(A=+/B=+)	p(A=+/B= -)
	0.538	**0.462**	**0.615**	**0.385**	**0.750**	**0.800**
D**p=-0.231**			**cos** q**=-0.307**		q**=1.882**	

Conclusions

We retain that by our studies we have reached some important results: the first thing is that our model of quantum consciousness, related to the dynamics of mental states, during perception and cognition of ambiguous features, follows quantum mechanics. Our testing quantum consciousness admits very restricted possibility of doubts before of all for the experimental arrangement that we realized, for the statistical significance that we reached considering that we observed and measured mental observables, for the long period of experimentation that we employed, but also for the differentiation that we used in the use of ambiguous figures, and still for the elaboration of the theoretical method that we used. It, on the other hand, is based on the formulation of quantum probabilities and search of quantum interference effects. In our viewpoint, it results free from any possible defect. Note that by this method we have also provided for the first time the possibility to calculate quantum wave functions for mental states, and this result seems to us of valuable importance. In fact, this means that we have shown that quantum wave function exists in the brain. In this case quantum probability amplitudes preside over brain dynamics and mind becomes a quantum probability field, in accord with Eccles and Beck. Note that in our experiments we engaged only normal subjects. In future such our methodology could be applied also in the case of mental pathologies.

Table 2. Statistical analysis: Student's t-test

	I	II	III	IV	V	VI	VII
Experiments	**p(A=+)**	**p(A= -)**	**p(B=+)**	**p(B= -)**	**p(A=+/B=+)**	**p(A=+/B= -)**	**p(B=+)p(A=+/B=+)+ p(B=-)p(A=+/B=-)**
1	0.6923	0.3077	0.9259	0.0741	0.6800	0.5000	0.6667
2	0.5714	0.4286	1.0000	0.0000	0.7000	0.0000	0.7000
3	0.4545	0.5455	0.7000	0.3000	0.4286	1.0000	0.6000
4	0.5380	0.4620	0.6150	0.3850	0.7500	0.8000	0.7692
Mean Value	0.5641	0.4360	0.8102	0.1898	0.6397	0.5750	0.6840
St. Dev.	0.0986	0.0986	0.1823	0.1823	0.1437	0.4349	0.0704

Number of examined subjects n=124.

t-test results: p value=0.0951 (significance, p> 90%) t=1.979

Table 3. Results obtained when considering one experiment for the whole set of 124 subjects

p(A=+)	p(A= -)	p(B=+)	p(B= -)	p(A=+/B=+)	p(A=+/B= -)	p(B=+)p(A=+/B=+) +p(B=-)p(A=+/B=-)	cos(theta)	theta
0.5968	0.4032	0.8387	0.1613	0.6346	0.8000	0.6613	**-0.1231**	**1.6942**

In relation to the experimental data that we used in the present paper we have to outline still an important point. When we write the (3.1), representing the superposition potential states of consciousness, as previously said, we have $|a|^2$ representing probability for state $|1>$, and $|b|^2$ representing probability for state $|2>$. The variable $\left||a|^2-|b|^2\right|$ represents the amount of doubt, or of inner conflict, or, still, of intrinsic in determination that the subject has at the moment he performs a percept-cognitive selection respect to a given ambiguous figure. It is clear that this variable may assume different values in relation to the subjective psychological condition of the subject, here including cases of what in quantum mechanics we call of possible degeneration.

In conclusion, we intend to outline here what we have theoretically elaborated in this paper and tested experimentally. Human consciousness is an entity having a quantum representation, a quantum entity with states corresponding to potentiality and actuality or direct manifestation of our human mind. Starting directly from experimental data we may test quantum consciousness and quantum interference effects. Still, generally speaking, we retain that the basic algebraic structure, given by (e_1, e_3, e_3), has the basic role to represent mind entities, able to give to quantum mechanics that particular role of a "Giano Bifronte" that we mentioned and discussed previously. We have given also mathematical proof on some of these results (Conte, 2006, 2007). In these papers we give proof of the basic properties of the algebraic structure given by the three basic elements (e_1, e_2, e_3) but we give also proof of such existing algebra when *a human mind* attributes to e_3 the value of truth of +1 (true) or –1 (false). We have given proof of these statements, and our approach shows that they characterize mind entities. Again we like to repeat here that it was the great teacher Y. Orlov (Orlov, 1982) that first considered the possibility to consider mind entities by quantum formalism, writing textually "every atomic proposition of classical logic can be represented by a diagonal operator – the third component of the Pauli algebra e_3" . On the basis of such results we are convinced that we think in a quantum mechanical manner.

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