Letter to the Editor

A Brief Comment on Some Recent Evaluations by Basieva and Khrennikov, Wang *et al.*, Boyer-Kassem *et al.*, on Order Effects in Quantum Cognition

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Quantum cognition is a recent field of application of quantum mechanics in neuroscience and psychology. It enters in the large sector of computational neuroscience.

My studies on this matter started in years 1980-1986 and continued in years until today. I do not report here the quotation of my contributions and of the other authors since they may be found as references in a recent paper that I have published on *Journal of Modern Physics* (Conte, 2015) to which I will refer as basic integration of my present comments. The reader is invited to read preliminarly such paper and takes vision of the contents of this publication and of the all the quoted references.

I see that continue to appear papers by some authors (Boyer-Kassem, *et al.*, 2015; Wang and Busemeyer, 2013; Wang, *et al.*, 2014; Basiova and Khrennikov, 2015) in which they continue to elaborate a question that they retain of basic importance in quantum cognition studies, relating the order of the posed questions to the subjects.

To summarize: we have performed a number of experiments and the aim has been to identify the possible role of quantum mechanics in human perception and cognition during presentation of ambiguous figures, during Stroop effect, in cognitive anomalies as conjunction fallacy, in priming, and recently also we considered a study on integration of emotion and cognition in children (Conte, 2015a). The previously mentioned theoretical and experimental results (Conte, 2015; 2015a) and a recent study (Conte, 2015b) evidence that quantum cognition should not be intended as an empirical tentative that uses quantum theory as guidelines in an empirical cognitive modelling since it seems to give better results respect to classical ones. Quantum cognition is a solid structure having robust foundations holding in quantum mechanics from one hand and in psychology and neurology from the other hand (Conte, 2015; 2015a; 2015b).

Returning to the basic question posed from these authors , we have to summarize that in quantum cognition experiments, we have posed to a group of subjects a task relating a dichotomic variable A, admitting thus only possible answers or A=+1 or A =-1. To another group we have

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posed first a task B, consisting still of a dichotomic variable, thus admitting possible answers B=+1 or B=-1, and soon after the task A, and thus evaluating probabilities;

p(A=+1),

p(A=-1),

p(A=+1/B=+1),

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

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

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

There are two basic questions.

In our approach, states of mental entities are represented by quantum wave functions. The states of our consciousness may be represented by a wave function and thus respond to all the requirements that have been fixed in quantum mechanics by this abstract entity (Conte, 2015; 2015a; 2015b). In this manner, we consider the wave function psi, the state $|\psi\rangle$, (the state of the mental entities), and cognition, logic statements $|\psi\rangle\langle\psi|$, that result to be fused ab initio in this solid formulation.

As said, wave function is the basic starting key. Projectors $|\psi\rangle\langle\psi|$, having cognitive and logic basic features, derive from wave function. The question is to establish how we determine such wave function when we are involved in studies on quantum cognition.

On a general plane this question may be posed in two completely different ways and ignoring such two basic features we risk indicating directions that may result misunderstanding and confusing.

The first way that we could be attempted to retain that we are pursuing in current studies on quantum cognition, may be reassumed in posing the question on how is one to determine experimentally a situation describable by a given wave function. Competence in quantum mechanics enables us to know that this problem may be solved by performing a complete measurement of a set of commuting observables upon a *single* system. Scholars in quantum mechanics know well that this cannot be the case of studies on quantum cognition.

The second way is posed instead in the following manner: how is one to acquire *a posteriori* knowledge about the fact that a system was described by a wave function? This is the case of quantum cognition studies. Note that confounding the basic difference posed between such two completely different questions, means to reset completely the full understanding around the ongoing studies on quantum cognition. We cannot risk talking with maximum ease of wave functions, of probability amplitudes and probability in quantum cognition studies having long since lost the compass indicating the correct direction.

The wave function, as rough mathematical representation of a mental state, cannot be measured in the usual sense of this word. As a mental state, wave function is an abstract entity and it cannot be observed directly. Nevertheless, it may be determined *a posteriori* provided that one has an ensemble of similar systems, each described by the same wave function, psi (ψ). The robust position in quantum cognition is clear: the function psi is not an observable and cannot be measured, but, *being subjected to the well-known probabilistic interpretation, may be estimated statistically, provided that a large number of systems are available.* Be care, this cannot represent the reason for confusion leading to the conclusion that quantum mechanics applies exclusively to ensembles but not to individual systems. One cannot mix two different concepts, that one of measurement of observables applying to single systems and estimation of a wave function that is expected to represent the system.

This is basic quantum mechanics. If, as previously outlined, one integrates this basic approach with the number of results reported in (Conte, 2015) and recently in (Conte, 2015b), one obtains that quantum cognition has all the features of a well-structured theory and not a tentative of studies that, having as guidelines quantum mechanics, result promising since seem to give better results respect to classical standard cognitive models. Returning to the status of the probabilities that, in consequence of the previous exposition, are determined experimentally, the central question is that by application of standard and classic Bayes theorem, we should have

p(A=+1)=p(B=+1)

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

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

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

Instead, if quantum mechanics has a role, the classic Bayes relation no more holds and in addition we obtain the appearance of the well-known quantum interference term.

Consequently, such experiments have represented a turning point in order to establish if quantum mechanics holds at perceptive and cognitive level in humans and the field of quantum cognition has arisen receiving large and valuable consideration.

Some authors, however, have recently outlined that in quantum mechanics we have as a law that p(c/d) = p(d/c) and that such restriction should appear violated in some performed experiments.

This observation has induced some authors also to attempt to introduce criteria to test such experiments.

I have to introduce here all my rejections. It is certainly satisfactory that researchers have entered finally to elaborate about the possible role of quantum mechanics in human cognition.

However, all we know, quantum mechanics is also wild and difficult discipline, it delineates a model of reality that results often so distant from the basic evidences of our current every day experience and requires application to constantly deepen its implications when using it.

p(c/d)=p(d/c) cannot be questioned as well as it arises by the inner formalism of quantum mechanics based only on the well-known use of the Hilbert space. On the other hand, I have all my devote consideration for the elective role of mathematics at a so high extent that I have reformulated the whole quantum mechanics by using only the Clifford algebra (see reference Conte 2015 and all the references therein) and for the first time, only using Clifford algebra, I have given demonstration of the basic von Neumann postulates on quantum measurement and quantum collapse. Of course we have three basic sections about quantum theory. We have mathematics, we have the mathematical physics that has its peculiar features that I do not outline here since they are well known, and, finally, we have also the physics.

How is it possible to consider the question p(c/d)=p(d/c) ignoring the physics! It is impossible.

When we consider also the physics, we find the profound reason of being p(c/d)=p(d/c).

Starting with the physical content, quantum mechanics is an intrinsically time symmetric theory regulated by a basic theorem that passes under the name of CPT theorem, where P states for parity symmetry, C state for charge conjugation symmetry and T states for time symmetry. The profound *physical* reason of p(c/d)=p(d/c) resides in the intrinsic time symmetric basic feature of this theory. In my recent article published on Journal of Modern Physics (Conte, 2015), I have exposed in detail as quantum mechanical collapse involves the use of advanced and retarded waves as Costa de Beauregard outlined several times in his papers (collapse-retrocollapse) as well as Feynman in his celebrated papers without accounting also my modest contributions. How may we ignore such important features of quantum mechanics and time symmetry and CPT theorem?

Of course when we examine mental entities performing our experiments, we are examining physical, neurological and psychological conditions marked from a cascade of "clicks", that is of happened quantum collapses, and in this condition time asymmetry follows not as law like but as fact like. Finally, when we perform experiments using mental entities not only we are operating at macroscopic level but we are using open systems as well as all human being systems are.

In conclusion, no one of the previously mentioned observations may be accepted.

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