# On the cognitive experiments to test quantum-like behaviour of mind

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**Abstract**

We describe cognitive experiments (based on interference of probabilities for mental observables) that could verify quantum-like structure of mental measurements. In principle, such experiments could be performed in psychology, cognitive and social sciences.

The recognition of the exclusive role that averages should play in the theory of mental measurements induces the impression that quantum-like models could be useful to describe mental states.

From the beginning we should underline that for us quantum theory is merely a special theory of statistical averages. The main distinguishing feature of quantum theory of averages (compare to classical statistical mechanics) is that here we have the deterministic equation (Schrödinger equation) not for probabilities, but for square roots of probabilities, quantum states.

The main experimental consequence of special quantum probabilistic behaviour is the interference of probabilities, see e.g. [1], [2] and see e.g. [3]-[5] for the detailed analysis. In classical statistical physics the probability of the event $C = A$ or $B$, where $A$ and $B$ are alternatives, is equal to the sum of probabilities. In quantum physics there appears an additional additive term, interference term, see [1]-[5] for the details.

By using such a point of view to quantum theory we can use its methods not only to describe measurements over elementary particles, but also over other systems that could demonstrate quantum probabilistic behaviour, see [6]. We plan now to do this for mental measurements, see also [7], [8]. We underline from the beginning that:

**Our quantum-like mental model would not have any coupling with quantum reductionist models, see e.g. [9]-[20], in that cognitive processes are reduced to quantum mechanical processes in microworld! (e.g. quantum gravity).**[1]

In the opposite to [10]-[20] I think that the main motivation to use quantum-like formalism for mental measurements is not composing of cognitive systems (and, in particular, brains) of elementary particles (that are described by quantum mechanics), but high sensitivity of cognitive systems as macroscopic information systems, see [3]-[7] on the general discussion on the domain of applications of quantum-like probabilistic formalisms.[2]

**Remark.** (Collapse) In our model the quantum-like state is a purely mathematical quantity used to describe rather special behaviour of probabilistic densities for ensembles of systems that are very sensitive to perturbations produced by interactions (including self-interactions). It is important to underline, that despite the presence of a 'wave function' $\psi(x)$ in our model, it has nothing to do with quantum logic models of thinking, see e.g. Orlov [9]. By quantum logic model brain is in a **superposition** of a few mental states described by a wave function. The collapse of the wave function (self-measurement) gives the realization of one concrete mental state. This is quantum logical process of thinking. In our model we do not use the notion collapse of a wave function. The process of thinking (in the opposite to quantum logic approach) is not a series of self-measurements.

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[1]On the other hand, statistical quantum-like viewpoint to cognitive measurements might have some coupling to the holistic approach to cognitive phenomena based on Bohmian-Hiley-Pilkkänen theory of active information, [21], [22].

[2]For example, by trying to prepare a mental function in one concrete mental information state we would disturb the cognitive system so strongly that mental energy would be uniformly distributed. In series of works, see [7], [8] and bibliography in these works, we developed the $p$-adic model for the space of mental information states. In this model neural pathways (and not individual neurons!) are considered as elementary mental processing units. States of neural pathways are naturally coded by so called $p$-adic numbers. However, the present paper is not directly related to Neural Pathways Thinking Model developed in [8]. We would like to present the general quantum scheme of cognitive measurements that is independent from the concrete mathematical model of the space of mental states.

As we have already noticed one of the main distinguishing features of quantum-like statistical theories is the interference of probabilities. If such an interference be found in measurements of mental observables, then such a result should be interpreted as the evidence in the favour of the use of quantum-like formalism for the description of mental measurements, see [7], [8].

We describe mental interference experiment.

Let $A = a_1, a_2$ and $B = b_1, b_2$ be two dichotomic mental observers: $a_1$='yes', $a_2$='no', $b_1$='yes', $b_2$='no'. They can be two different questions or two different types of cognitive tasks. We prepare an ensemble $\mathcal{E}$ of cognitive systems (e.g. human beings) having the same mental state[3]. Then we perform measurements of $A$ over elements of $\mathcal{E}$ and get ensemble probabilities:

$$p_j^a = \frac{\text{the number of results } a_j}{\text{the total number of elements}}.$$

So $p_j^a$ is the probability to get the result $a_j$ under the measurement over cognitive systems belonging to $\mathcal{E}$. In the same way we find probabilities $p_j^b$ for the $B$-observable[4]. The next step is to prepare two ensembles $\mathcal{E}_i^b, j = 1, 2$, of cognitive systems having the states corresponding to values of $B = b_j, j = 1, 2$. Ensembles $\mathcal{E}_j^b$ could be prepared by using e.g. filtrations with respect to values (e.g. answers) $B = b_j, j = 1, 2$.

We perform now the A-measurements for elements of ensembles $\mathcal{E}_j^b, j = 1, 2$, and get the probabilities:

$$p_{ij}^{a/b} = \frac{\text{the number of the result } a_j \text{ for the ensemble } \mathcal{E}_i^b}{\text{the total number of elements in } \mathcal{E}_i^b}$$

So, e.g., the probability $p_{12}^{a/b}$ is obtained as the frequency of the answer $A = a_1 = \text{'}yes'$ in the ensemble of cognitive system that have answered $B = b_2 = \text{'}no'$.

The classical probability theory tell us that all these probabilities have to be connected by the so called formula of total probability, see e.g. [23]:

$$p_j^a = p_1^b - p_{1j}^{a/b} + p_2^b p_{2j}^{a/b}, j = 1, 2.$$

[3]Well, with some approximation

[4]We pay attention to the fact that we need to prepare a new ensemble $\mathcal{E}$ (in the same state) to perform the $B$-measurement. We could not perform $A$ and $B$ measurements on the same system, since the $A$-measurement perturbs essentially the mental state.

However, if the theory is quantum-like, then we get the quantum formula of total probability:

$$p_j^a = p_1^b p_{1j}^{a/b} + p_2^b p_{2j}^{a/b}, +2\sqrt{p_1^b p_2^b p_{1j}^{a/b} p_{2j}^{a/b}} \cos\theta_j.$$

Here $\theta_j$ is the phase of the $A$-interference between the state of mind in the ensemble $\mathcal{E}$ and the ensembles $\mathcal{E}_j^b$.

In the experiment on the quantum statistical test for mental theory we calculate

$$\cos\theta_j = \frac{p_j^a - p_1^b p_{1j}^{a/b} + p_2^b p_{2j}^{a/b}}{2\sqrt{p_1^b p_2^b p_{1j}^{a/b} p_{2j}^{a/b}}}.$$

If $\cos\theta_j \neq 0,$ then we would get the strongest argument in the support of quantum-like behaviour of cognitive systems. In this case, starting with (experimentally calculated) $\cos\theta_j$ we can proceed to the Hilbert space formalism, see [3]-[5]. We could introduce a 'mental wave function' $\psi$ (or quantum-like mental state) belonging to this Hilbert space. We recall that in our approach a 'mental wave function' $\psi$ describes the preparation (selection) procedure used to prepare an emsemble of individuals to a mental measurement. The next step would be find mental energy operators and decribe by Schrödinger equation the evolution of mental state, compare to [7], [8].

We are very much interested in performing experiments (described in this paper, see [24]) in various domains of cognitive psychology to text quantum-like behaviour of cognitive systems, in particular, people.

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