Quantum Transmemetic Intelligence

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Congregados los sentidos, surge el alma. Haba que esperarla.
Madeleine estaba para la vista, Madeleine estaba para el odo,
Madeleine estaba para el sabor, Madeleine estaba para el olfato,
Madeleine estaba para el tacto: Ya estaba Madeleine.[1]

Adolfo Bioy Casares, *La invencin de Morel*

1 Introduction

Richard Dawkins put forward the fascinating idea of a meme – a self-replicating unit of evolution of human behaviour[2], that is analogous to a gene, the fundamental unit of biological evolution [Dawkins (1989)]. Although the memetic

[1] When all the senses are synchronized, the soul emerges... When Madeleine existed for the senses of sight, hearing, taste, smell, and touch, Madeleine herself was actually there.

[2] e.g. ideas, tunes, fashions, habits etc.

model of human consciousness and intelligence is not widely accepted by scientists investigating the phenomenon of human being it seems to be unrivalled with respect to the evolutionary paradigm so successful in biology. In some sense, it passes the Ockham's razor test of efficiency and holds out hope of unification of knowledge. It certainly deserves a thorough analysis from point of view of the qualitatively new perspective opened by quantum information processing [Nielsen and Chuang (2000)]. Restrictions, such as no-cloning theorems, imposed by the unitarity of quantum evolution would certainly shed new light on the otherwise interesting and bewildering aspects of Darwin's ideas [3]. The idea of a quantum meme (qumeme) offers a unique opportunity of interpretation of human consciousness as an element of material evolution. This holds out hope of overcoming the soul-matter dychotomy that has been dominating research since Descartes.

Although very interesting, the problem of whether the memetic structures are abstract ideas or could possibly be identified with some substructures of individual human brains is of secondary significance[4]. Whatever the answer is, it might be that while observing the complex ceremonial of everyday human behaviour we are in fact observing quantum games eluding classical description. If human decisions can be traced to microscopic quantum events one would expect that Nature would have taken advantage of quantum computation in evolving complex brains. In that sense one could indeed say that sorts of quantum computers are already playing games according to quantum rules. Even if this is not true, the investigation into the quantum aspects of information processing opens new chapters in information science - quantum mechanism might have the power to overcome complexity barriers stemming from the classical Turing theory. What that science will look like is currently unclear, and it is difficult to predict which results would turn out to be fruitful and which would have only marginal effect. The results of the research would probably influence the development of cryptography, social sciences, biology and economics.

[3] The reversed process can also be fruitful: Quantum Darwinism - the process by which the fittest information is propagated at the expense of incompatible information can be useful in the quantum measurement theory. The fittest information becomes objective and the incompatible redundant [Zurek (2004)].

[4] It is very difficult, if not impossible, to identify the algorithm being executed by a computer by, say, microscopic analysis of its hardware especially if one notices that often the computer in question might be only a minute part of a network performing parallel computation.

The emergent quantum game theory [Meyer (1999), Eisert (1999), Piotrowski (2004a), Piotrowski (2002)] is, from the information theory point of view, a proposal of a new language game [Wittgenstein (1961)] describing empirical facts that, although a having precise mathematical model, resist classical analysis[5]. It forms a promising tool because quantum theory is up to now the only scientific theory that requires the observer to take into consideration the usually neglected influence of the method of observation on the result of observation and strategies can be intertwined in a more complicated way than probabilistic mixtures. In this paper we discuss several simple quantum systems that resist classical (non-quantum) description. They form information processing units that can "proliferate" via scientific publications and experiments. We propose to call them qumems. We will neither consider here "technological" realization nor replication mechanisms of qumems[6] [Iqbal (2001)]. New artificial sensors might result in development analogous to that caused by transgenic plants in agriculture. But this time the revolutionary changes are brought about in human intelligence/mind theory. Since the first implementations of algorithms as computer programs, the information content has became an abstract notion separated from its actual (physical) realization– all such realizations (representations) are equivalent. Moreover, a way of division into substructures can be quite arbitrary, dictated only by conventions or point of view. Engineers commonly use analogies with natural evolution to optimize technical devices. If sciences, techniques, human organizations, and more generally all complex systems, obey evolutionary rules that have a good genetic model, even if genes and chromosomes are only "virtual" entities [Krähenbühl (2005)]. Thus, the genetic representation is not only a powerful tool in the design of technological solutions, but also a global and dynamic model for the action of human behaviour. Let us have a closer look at such as yet virtual objects. Following examples from classical logical circuits, David Deutsch put forward the idea of quantum logical circuits made up

[5]Full and absolutely objective information about the investigated phenomenon is impossible and this is a fundamental principle of Nature and does not result from deficiency in our technology or knowledge.

[6]Quantum states cannot be cloned but such no-go theorems do not concern evolution and measurements of quantum systems. The no-cloning theorem is not so restricting to our model as the reader might expect. The solution is coding the information in the statistics of a set of observables [Ferraro (2005)]. The concepts of both exact and approximate cloning of classes of observables can be introduced. Explicit implementations for cloning machines for classes of commuting observables based on quantum non-demolition measurements have already been proposed [Ferraro (2005)].

from quantum gates. Quantum gates seem to be too elementary to represent quantum operations that could be referred to as memes - rather they play the roles of RNA (DNA) bases in genetics. The qumeme functionality (as an analogue of a gene) can be attained only at the level of a circuit made up from several quantum gates representing, for example, tactics in a quantum game[7] – examples would be discussed below. The due ceremonial of everyday performance of quantum physicists and, possibly not yet discovered, natural phenomena outside the area of human activities might already be the theater of activity of qumemes that cannot be replaced by classical ones – they might participate in evolutionary struggle for survival with themselves, genes or mems[8]. Is the notion of a qumeme, a replicable quantum tactics or unit of quantum information living in a kind of quantum information soup that is being detected, a newly recognized autonomous class of replicators? In the light of recent speculations [Patel (2005)] a fascinating relationship between qumemes and mechanisms for functioning of the genetic code emerged. Does the chain of replicators driving the evolution ends at the qumemes stage or shall we look for a more fundamental modules. The theory of evolution can, to some extent, be perceived as decision making in conflict situations[9]. We will restrict ourselves to simple cases when memes can be perceived as strategies or tactics or, more precise, self-replicating strategies/tactics. Details of the formalism can be found in [Piotrowski (2004a)]. Game theory considers strategies that are probabilistic mixtures of pure strategies. Why cannot they be intertwined in a more complicated way, for example interfered or entangled? Are there situations in which quantum theory can enlarge the set of possible strategies? Can quantum memes-strategies be more successful than classical ones? Do they replicate in the way we suspect?

[7] From the information theory point of view (qu-)memes correspond to algorithms.

[8] The possibility that human consciousness explores quantum phenomena, although it seems to be at least as mysterious as the quantum world, is often berated. Nevertheless, one cannot reject the the idea that the axioms of probability theory are to restrictive and one, for example, should take quantum-like models into consideration. Such a possibility removes some paradoxes in game theory.

[9] For example, games against nature [Milnor (1954)]. These include those for which nature is quantum mechanical.

2 A quantum model of free will

The idea of human free will is one of most infectious memes. It can be illustrated in game theoretical terms as was shown by Newcomb [Levi (1982)][10]. M. Gardner proposed the following fabulous description of the game with pay-off given by the matrix (1) [Gardner (1982)]. An alien Omega being a representative of alien civilization (player 2) offers a human (player 1) a choice between two boxes.

$$M := \begin{pmatrix} \$1000 & \$1\,001\,000 \\ 0 & \$1\,000\,000 \end{pmatrix} \tag{1}$$

Player 1 can take the content of both boxes or only the content of the second one. The first one is transparent and contains \$1000. Omega declares to have put into the second box that is opaque \$1000000 (strategy $|1\rangle_2$) but only if Omega foresaw that player 1 decided to take only the content of that box ($|1\rangle_1$). A male player 1 thinks: *If Omega knows what I am going to do then I have the choice between \$1000 and \$1000000. Therefore I take the \$1000000* (strategy $|1\rangle_1$). A female player 1 thinks: *Its obvious that I want to take the only the content of the second box therefore Omega foresaw it and put the \$1000000 into the box. So the one million dollar* **is** *in the second box. Why should I not take more – I take the content of both boxes* (strategy $|0\rangle_1$). The question is whose strategy, male's or female's, is better? If between deciding what to do and actually doing it the male player was to bet on the outcome he would certainly bet that if he takes both boxes he will get \$1000 and if he takes the opaque box only he will get \$1000000. Why should he act in a way that he would bet will have a worse result? But suppose you are observing the game and that you know the content of the boxes. From your point of view the player should always choose both boxes because in this case the player will get better of the game. Does the prediction blur the distinction between past and future and therefore between what can and what cannot be affected by one's actions? One cannot give unambiguous answer to this question without precise definition of the measures of the events relevant for the pay-off. Quantum theory offers a solution to this paradox.

Suppose that Omega, as representative of an advanced alien civilization, is aware of quantum properties of the Universe that are still obscure or mysterious to humans. The boxes containing pay-offs are probably coupled. One

[10] In 1960 William Newcomb, a physicist, intrigued the philosopher Robert Nozick with the parable of faith, decision-making and free will [Nozik (1969)].

can suspect that because the human cannot take the content of the transparent box alone ($1000). The female player is sceptical about the possibility of realization of the Omega's scenario for the game. She thinks that the choice of the male strategy results in Omega putting one million dollar in the second box, and after this being done no one can prevent her from taking the content of both boxes in question (ie $1001000). But Meyer proposed recently a quantum tactics [Meyer (1999)] that, if adopted by Omega, allows Omega to accomplish his scenario. Omega may not be able to foresee the future [Gardner (1982)]. It is sufficient that Omega is able to discern human intentions regardless of their will or feelings on the matter. This can be accomplished by means of teleportation [Milburn (1999)]: Omega must intercept and then return human's strategies. The manipulations presented below leading to thwarting humans are feasible with contemporary technologies. The game may take the following course. At the starting-point, the density operator $\mathcal{W}$ acting on the Hilbert space of both players(1 and 2) $\mathcal{H}_1 \otimes \mathcal{H}_2$ describes the human's intended strategy and the Omega's strategy based on its prediction of human's intentions. The game must be carried on according to quantum rules that is the players are allowed to change the state of the game by unitary actions on $\mathcal{W}$ [Eisert (1999)]. The human player can only act on her/his q-bit Hilbert space $\mathcal{H}_1$. Omega's tactics must not depend on the actual move performed by the human player (it may not be aware of the human strategy): its moves are performed by automatic device that couples the boxes. Meyer's recipe leads to:

1. Just before the human's move, Omega set the automatic devise according to its knowledge of human's intention. The device executes the tactics $\mathcal{F} \otimes \mathcal{I}$, where $\mathcal{I}$ is the identity transform (Omega cannot change its decision) and $\mathcal{F}$ is the well known Hadamard transform frequently used in quantum algorithms: $\mathcal{F} := \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$.

2. The human player uses with probability w the female tactics $\mathcal{N} \otimes \mathcal{I}$, where $\mathcal{N}$ is the negation operator[11] and with probability $1-w$ the male tactics $\mathcal{I} \otimes \mathcal{I}$.

3. At the final step the boxes are being opened and the built-in coupling mechanism performs once more the transform $\mathcal{F} \otimes \mathcal{I}$ and the game is settled.

[11] $\mathcal{N}|0\rangle = |1\rangle$, $\mathcal{N}|1\rangle = |0\rangle$

Players' tactics, by definition, could have resulted in changes in the (sub-)space $\mathcal{H}_1$ only. Therefore it suffices to analyze the human's strategies. In a general case the human can use a mixed strategy: the female one with the probability v and the male one with probability $1-v$. Let us begin with the extreme values of v (pure strategies). If the human decided to use the female strategy ($v=1$) or the male one ($v=0$) then the matrices $\mathcal{W}_i$, $i=0,1$ corresponding to the density operators [Nielsen and Chuang (2000)]

$$\mathcal{W}_0 = \sum_{r,s=1}^{2} W_{0rs} |\mathsf{r}-1\rangle_1\, |0\rangle_2\, {}_1\langle \mathsf{s}-1|\, {}_2\langle 0|$$

and

$$\mathcal{W}_1 = \sum_{r,s=1}^{2} W_{1rs} |\mathsf{r}-1\rangle_1\, |1\rangle_2\, {}_1\langle \mathsf{s}-1|\, {}_2\langle 1|$$

are calculated as follows:

$$\begin{pmatrix} v & 0 \\ 0 & 1-v \end{pmatrix} \longrightarrow \tfrac{1}{2}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}\begin{pmatrix} v & 0 \\ 0 & 1-v \end{pmatrix}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} = \tfrac{1}{2}\begin{pmatrix} 1 & 2v-1 \\ 2v-1 & 1 \end{pmatrix} \longrightarrow$$
$$\tfrac{w}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} 1 & 2v-1 \\ 2v-1 & 1 \end{pmatrix}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} + \tfrac{1-w}{2}\begin{pmatrix} 1 & 2v-1 \\ 2v-1 & 1 \end{pmatrix} = \tfrac{1}{2}\begin{pmatrix} 1 & 2v-1 \\ 2v-1 & 1 \end{pmatrix} \longrightarrow$$
$$\tfrac{1}{4}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}\begin{pmatrix} 1 & 2v-1 \\ 2v-1 & 1 \end{pmatrix}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} = \begin{pmatrix} v & 0 \\ 0 & 1-v \end{pmatrix}.$$

It is obvious that independently of the used tactics, human's strategy takes the starting form. For the mixed strategy the course of the game is described by the density operator

$$\mathcal{W} = v\,\mathcal{W}_0 + (1-v)\,\mathcal{W}_1$$

which also has the same diagonal form at the beginning and at the end of the game [Piotrowski (2003)].

Therefore the change of mind resulting from the female strategy cannot lead to any additional profits. If the human using the female tactics (that is changes his/her mind) begins the game with the female strategy then at the end the opaque box will be empty and he/she will not get the content of the transparent box: the pay-off will be minimal (0). If the human acts in the opposite way the transparent box must not be opened but nevertheless the pay-off will be maximal (\$100000). Only if the human begins with the female strategy and then applies the male tactics the content of the transparent box is accessible. If restricted to the classical game theory Omega would have to prevent humans from changing their minds. In the quantum domain the pay-off M_{21} (female strategy and tactics) is possible: humans regain their free will but they have to remember that Omega has (quantum) means to prevent humans from profiting out of altering their decisions. In this way the quantum approach allows to remove the paradox from the classical dilemma. One can also consider games with more alternatives for the human player. The respective larger pay-off matrices would offer even more sophisticated versions of the Newcomb's observation. But even then there is a quantum protocol that guarantees that Omega keeps its promises (threats) [Wang (2000)]. Thus, even if there exists nothing like a quantum meme, the meme of quantum theory is likely to replicate using human hosts and to influence their behaviour so to promote its replication.

3 Quantum acquisition of knowledge

Acquisition of knowledge certainly belong to the class of behaviours that can be interpreted in terms of memes replication. Let us consider a collective game that has no classical counterpart and can shed some light on qumemes replication. We call it *Master and pupil*. Suppose Alice (A) is ready to sell some asset $\mathfrak{G}$ at low price and Bob (B) wants to buy $\mathfrak{G}$ even at high price. But Bob, instead of making the deal (according to the measured strategies), enters into an alliance[12] with Alice. Aftermath Alice changes her strategy and enters into an alliance with Bob. As a result an entangled quantum

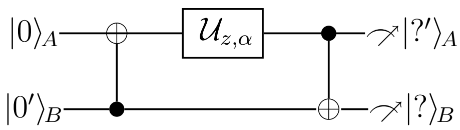

Figure 1: The game *Master and pupil* (dense coding).

[12] Alliances are represented by controlled NOT gates denoted here by $\mathcal{C}$ [Nielsen and Chuang (2000)].

state[13] $|z,\alpha\rangle_{AB} \in \mathbb{R}P^3 \subset \mathbb{C}P^3$ is formed, cf Fig. 1:

$$|z,\alpha\rangle_{AB} := \mathcal{C}\,(\mathcal{U}_{z,\alpha}\otimes I)\,\mathcal{C}'\,|0\rangle_A|0'\rangle_B = \tag{2}$$

$$\cos(\alpha)\,|0'\rangle_A|0\rangle_B + \mathrm{i}\,\sin(\alpha)\,\big(E_z(\mathcal{X})\,|0'\rangle_A|\mathrm{I}\rangle_B + E_z(\mathcal{X}')\,|\mathrm{I}'\rangle_A|0\rangle_B + E_z(\mathcal{X}\mathcal{X}')\,|\mathrm{I}'\rangle_A|\mathrm{I}\rangle_B\big)\,.$$

Although Bob cannot imitate Alice tactic $\mathcal{U}_{z,\alpha}$ by cloning of the state, he can gather substantial knowledge about her strategy when she is buying (he is able to measure proportions among the components I, $\mathcal{X}$, $\mathcal{X}'$ and $\mathcal{X}\mathcal{X}'$). The game is interesting also from the Alice's point of view because it allows her to form convenient correlations of her strategy with the Bob's one. Such a procedure is called dense coding in quantum information theory [Rieffel (2000)]. If Alice and Bob are separated from each other and have formed the entangled state $|0\rangle_A|0\rangle_B + |\mathrm{I}\rangle_A|\mathrm{I}\rangle_B$ (this is the collective strategy before the execution of $\mathcal{U}_{z,\alpha}\otimes I$) then Alice is able to communicate her choice of tactic (I, $\mathcal{X}$, $\mathcal{X}'$, $\mathcal{X}\mathcal{X}'$) to Bob (bits of information) by sending to him a single qubit. Bob can perform a joint measurement of his and Alice's qubits. Only one of four orthogonal projections on the states $|0'\rangle_A|0\rangle_B$, $|0'\rangle_A|\mathrm{I}\rangle_B$, $|\mathrm{I}'\rangle_A|0\rangle_B$ and $|\mathrm{I}'\rangle_A|\mathrm{I}\rangle_B$ will give a positive result forming the message[14]. Such concise communication is impossible for classical communication channels and any attempt at eavesdropping would irreversibly destroy the quantum coherence (and would be detected).

If one player forms an alliance with another that has already formed another alliance with a third player then the later can actually perform measurements that will allow him to transform his strategy to a strategy that is identical to the first player's primary strategy (teleportation [Bennet (1993)]). This is possible due to the identity (remember that $\mathcal{X}$, $\mathcal{X}'$, $\mathcal{X}\mathcal{X}'$ are involutive maps)

$$2\,(\mathcal{C}\otimes I)\,(I\otimes\mathcal{C})\,|z\rangle|0'\rangle|0\rangle = |0'\rangle|0\rangle|z\rangle + |0'\rangle|\mathrm{I}\rangle\mathcal{X}|z\rangle + |\mathrm{I}'\rangle|0\rangle\mathcal{X}'|z\rangle + |\mathrm{I}'\rangle|\mathrm{I}\rangle\mathcal{X}\mathcal{X}'|z\rangle\,.$$

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[13] We call any unitary transformation that changes agent's (player's) strategy a tactics. We follow the notation introduced in [Piotrowski (2004b)]: $SU(2) \ni \mathcal{U}_{z,\alpha} = \mathrm{e}^{\mathrm{i}\alpha\vec{\sigma}\cdot E_z(\vec{\sigma})} = I\cos\alpha + \mathrm{i}\,\vec{\sigma}\cdot E_z(\vec{\sigma})\,\sin\alpha$, where the vector $E_z(\vec{\sigma}) = \frac{\langle z|\vec{\sigma}|z\rangle}{\langle z|z\rangle}$ represents the expectation value of the vector of Pauli matrices $\vec{\sigma} := (\sigma_1,\sigma_2,\sigma_3)$ for a given strategy $|z\rangle$. The family $\{|z\rangle\}, z\in\overline{\mathbb{C}}$ of complex vectors (states) $|z\rangle := |0\rangle + z\,|\mathrm{I}\rangle$ ($|\pm\infty\rangle := |\mathrm{I}\rangle$) represents all trader's strategies in the linear subspace spanned by the vectors $|0\rangle$ and $|\mathrm{I}\rangle$.

[14] Answers to the questions *Would Alice buy at high price?* and *Would Bob sell at low price?* would decode the message.

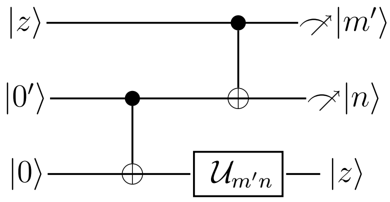

Figure 2: Teleportation of the strategy $|z\rangle$ consisting in measurement of the tactic $\mathcal{U}_{m'n} := \mathcal{X}^{[n=\mathrm{I}]}\mathcal{X}'^{[m'=\mathrm{I}']}$ (the notation $[true] := 1$ and $[false] := 0$ is used).

Recall that quantum strategies cannot be clonned (no-cloning theorem) and if there are several identical strategies their number cannot be reduced by classical means (no-reducing theorem). A possible working mechanism for replication is coding the information in the statistics of a set of observables [Ferraro (2005)]. Both exact and approximate cloning of classes of observables can be considered as a quantum replication of (qu-)memes.

4 Thinking as a quantum algorithm

Let us recall the anecdote popularized by John Archibald Wheeler [Davies (1993)]. The plot concerns the game of 20 questions: the player has to guess an unknown word by asking up to 20 questions (the answers could be only yes or no and are always true). In the version presented by Wheeler, the answers are given by a "quantum agent" who attempts to asign the task the highest level of difficulty without breaking the rules. Any quantum algorithm (including classical algorithms as a special cases) can be implemented as a sequence of appropriately constructed questions-measurements. The results of the measurements (i.e. answers) that are not satisfactory cause further "interrogation" about selected elementary ingredients of the reality (qubits). If Quantum Intelligence (QI) is perceived in such a way (as quantum game) then it can be simulated by a deterministic automaton that follows a chain of test bits built on a quantum tenor [Deutsch (1998)]. The automaton completes the chain with afore prepared additional questions at any time that an unexpected answer is produced. Although the results of the test will be random (and actually meaningless – they are instrumental), the kind and the topology of tests that examine various layers multi-qubit reality and the working scheme of the automaton are fixed prior to the test. The remarkability of performance of such an automaton in a game against Nature is by the final measurement that could reveal knowledge that is out of reach of classical information processing, cf the already known Grover and Shor quantum algorithms and the Elitzur-Vaidman bomb tester. Needless to say, such an implementation of a game against quantum Nature leaves some room for perfection. The tactics $CNOT$ and H belong to the normalizer of the n-qubit Pauli group G_n [Nielsen and Chuang (2000)], hence their adoption allows to restrict oneself to single corrections of "errors" made by Nature that precede the final measurement. It is worth noting that a variant of implementation of the tactics T makes it possible to postpone the correction provided the respective measurements methods concern the current state of the cumulated errors [Jorrand (2003)]. Therefore in this setting of the game some answers given by Nature, though being instrumental, have a significance because of the influence of the following tests. There is no need for the final error correction – a modification of the measuring method is sufficient. In that way the course of game is fast and the length of the game is not a random variable. This example shows that in some sense the randomness in the game against quantum Nature can result from awkwardness of agents and erroneous misinterpretation of answers that are purely instrumental. If only one error (lie) in the two-person framework is allowed fast quantum algorithm solving the problem exist (Ulams's problem) [Mancini (2005)]. There is a wide class of human behaviours that are adopted during the process of education (classical memes!) that manifests quantum-like character. If realization of own or some else behaviour is to be perceived as a measurement, then, contrary to the classical approach, there are restriction on conscious transfer of emotions [Ferraro (2005)] but appropriate measurement can help to became aware of emotions. In that way qumemes (replicated via education process quantum strategies) might represent forming of emotions that would be unique individual features. Moreover, The process of realization (measurement) of such quantum behaviourism would itself form a class of qumems.

5 Counterfactual measurement as a model of intuition

Mauritius Renninger has discovered a fascinating qumeme that allows to identify events that are possible but did not occur and distinguish them from events that are impossible [Renninger (1953)].

Let us now consider a modification of the method of jamming the strategy measuring game in which the circuit-breaker gate I/NOT [15] is implemented as a part in a separate switching-off strategy, cf. Fig. 3. To this end, the alliance $CNOT$ was replaced by the Toffoli gate (controlled-controlled-NOT). Contrary to the former case we are now interested in an effective accomplishment of the measurement. Therefore, we assume that there are no correlations between the state of the gate I/NOT and the strategy $|1/0\rangle$. The role of the gate NOT that comes before the measurement of the central qubit is to guarantee that the measurement of the state $|1\rangle$ stands for the switching-off the subsystem consisting of the two bottom qubits. To quantize

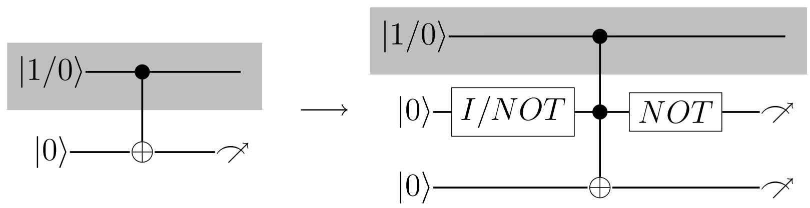

Figure 3: Modification of the system by adding a switching-off strategy.

this game we will follow Elitzur and Vaidman [Vaidman (1996)] who explored Mauritius Renninger's idea of the *negative measurement* [Renninger (1953)], see Fig. 4. The method is based on gradual unblocking the switching-off gate (n steps of $\sqrt[n]{NOT}$) and giving up the whole measurement at any step, if only the change of the third qubit is observed (measuring the first qubit). Hence, the game is stopped by the "exploding bomb" in circumstances when at some step the value of the auxiliary strategy measured after the alliance $CNOT$ is measured to be $|1\rangle$, see Fig. 4. The tactics $\sqrt[n]{NOT}$ of gradual unblocking is represented by the operator:

$$\sqrt[n]{NOT} := I \cos\tfrac{\pi}{2n} + NOT \sin\tfrac{\pi}{2n} \;=\; \mathrm{e}^{NOT\frac{\pi}{2n}} \in SU(2)\,.$$

The probability of continuation of the game after one step is equal to

$$\left|\langle 0|\sqrt[n]{NOT}|0\rangle\right|^2 = \cos^2\tfrac{\pi}{2n}$$

[15]The gate I/NOT is defined as a randomly chosen gate from the set $\{I, NOT\}$ and is used to switching-off the circuit in a random way. It can be generalized to have some additional control qubits [Miakisz (2006)]

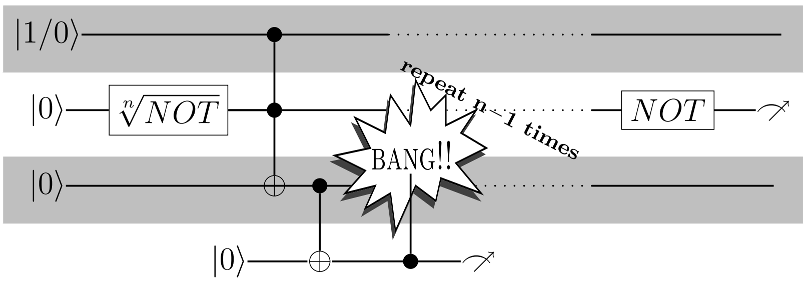

Figure 4: The Elitzur–Vaidman tactics of gradual unblocking the switching-off strategy.

and all steps are successfully accomplished with the probability $\cos^{2n}\frac{\pi}{2n} = 1-\frac{\pi^2}{4n}+\frac{\pi^4}{32n^2}+O(n^{-3})$. Therefore, in the limit $n\to\infty$ the probability of stopping the game tends to zero[16]. The inspection of the value of the first qubit with help of the third qubit acquires a transcendental dimension because if $|1/0\rangle = |1\rangle$ the measuring system is switched-off and if $|1/0\rangle = |0\rangle$ the switching-off strategy cannot be unblocked. The bomb plays the key role in the game because it freezes the second qubit in the state $|0\rangle$ — this is the famous quantum Zeno effect [Facchi (2000)]. However, the information about the state of the first qubit ($|0\rangle$ or $|1\rangle$) can only be acquired via the effectiveness of the unblocking the second qubit. The presented implementation and analysis of the Elitzur-Vaidman circuit-breaker paves the way for a completely new class of technologies that might be shocking for those unacquainted with quantum effects. For example, if the first qubit represents a result of quantum computation, then such a breaker allows the access in that part of the Deutsch Multiversum [Deutsch (1998)] where this computer is turned off [Mitchison (2001)]. If the first qubit of the circuit represented in Fig. 4 is fixed in the state $|1\rangle$, then this machinery can be used to nondestructive testing, for example, to select bombs with damaged fuse. The respective measuring system is presented in Fig. 5 (the shaded-in qubits in Fig. 4 are absent because they are redundant). The breaker $controlled-(I/NOT)$ that replaces the alliance $CNOT$ is in the state $I/NOT = I$ if the bomb fuse is damaged and in the state $I/NOT = NOT$ if the fuse is working. The result $|1\rangle$ of the measurement of the first qubit informs us that the bomb

[16] The limit can be found by application of the de L'Hospital rule to $\ln\cos^{2n}\frac{\pi}{2n}$.

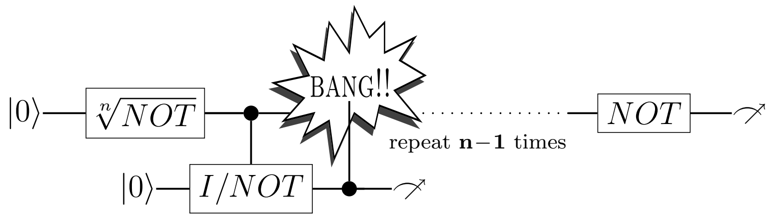

Figure 5: Safe Elitzur–Vaidman bomb tester.

is in the working order. This is due to the fact that the working bomb always reduces this qubit to $|0\rangle$ after the transformation $\sqrt[n]{NOT}$ (quantum Zeno effect). Without doubt such a bomb tester (and the Elitzur–Vaidman circuit–breaker) can be constructed on the basis of the quantum anti-Zeno effect [Facci (2001)]. In this case the working but unexploded bomb accelerates the evolution of the system instead of "freezing" it. Such an alternative tester is represented in Fig. 6, where the working bomb causes at any of the n stages the increase of $\frac{\pi}{2n}$ in the phase φ of the cumulative tactics $\mathrm{e}^{NOT\varphi}$.

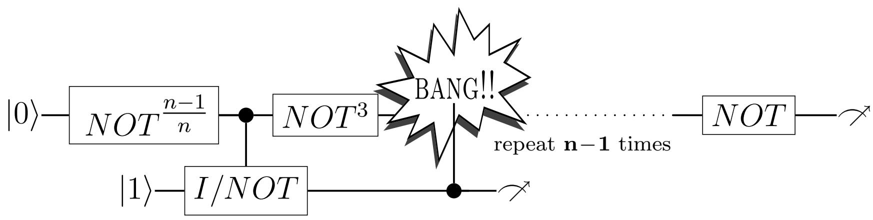

Figure 6: A bomb tester constructed on the basis of the quantum anti-Zeno effect.

Let us define $V(\beta) := NOT\cos\beta + (I\cos\alpha + H\cdot NOT\cdot H\sin\alpha)\sin\beta$. It is not difficult to show that $V(\beta_2)\cdot NOT^3\cdot V(\beta_1) = V(\beta_1+\beta_2)$. Therefore, we can replace the gate $NOT^{\frac{n-1}{n}}$ with any of the gates

$$NOT\cos\tfrac{\pi}{2n} + (I\cos\alpha + H\cdot NOT\cdot H\sin\alpha)\sin\tfrac{\pi}{2n}\,,$$

where $\alpha\in[0,2\pi)$. But only for $\alpha=0,\pi$ such gate belongs to the class $\mathrm{e}^{NOT\varphi}$ and we can claim that the transformation NOT results from the acceleration or freezing of the evolution of the system. For $\alpha\neq 0,\pi$ we observe kind of para-Zeno effect because the measurement of the qubit entangled with the qubit in question stops the free evolution corresponding to a damaged bomb.

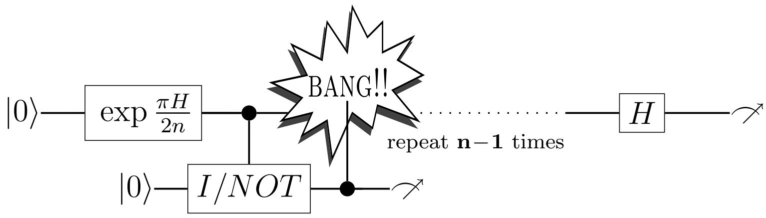

Figure 7: Supply-demand switch.

Consider a slight modification of the circuit presented in Fig. 7, where now $\exp\frac{\pi H}{2n} = I\cos\frac{\pi}{2n} + H\sin\frac{\pi}{2n}$. Again, there is a strong likelihood that we can avoid explosion because $(\,|\cos\frac{\pi}{2n}+\frac{i}{\sqrt{2}}\sin\frac{\pi}{2n}|^2\,)^n > \cos^{2n}\frac{\pi}{2n}$. In this case the information revealed by the breaker is more subtle because the "bomb" can only cause transition to a corresponding state in the conjugated basis [Wiesner (1983)]. Nevertheless, the bomb being in the working order causes strategy change.

6 Quantum modification of Freud's model of consciousness

In the former section we have put great emphasis on distinction between measuring qubits and qubits being measured. The later were shaded in figures. Analogously to the terminology used in the computer science, we can distinguish the shell (the measuring part) and the kernel (the part being measured) in a quantum game that is perceived as an algorithm implemented by a specific quantum process. Note that this distinction was introduced on the basis of abstract properties of the game (quantum algorithm, quantum software) and not properties of the specific physical implementation. Quantum hardware would certainly require a great deal of additional measurements that are nor specific to the game (or software), cf. the process of starting a one-way quantum computer. For example, consider a Quantum Game Model of Mind (QGMM) exploring the confrontation of quantum dichotomy between kernel and shell with the principal assumption of psychoanalysis of dichotomy between consciousness and unconsciousness [Freud (1923)]. The relation is as follows.

- Kernel represents the Ego, that is the conscious or more precisely, that level of the psyche that is aware of its existence (it is measured by the Id). This level is measured due to its coupling to the Id via the actual or latent (not yet measured) carriers of consciousness (in our case qubits representing strategies)

- Shell represents the Id that is not self-conscious. Its task is monitoring (that is measuring) the kernel. Memes, the AI viruses [Dawkins (1989)], can be nesting in that part of the psyche.

Memes being qutrojans, that is quantum parasitic gates (not qubits!) can replicate themselves (qubits cannot – no-cloning theorem). There is a limited knowledge of the possible threat posed by qutrojans to the future of quantum networks. In quantum cryptography teleportation of qubits might be helpful in overcoming potential threats posed by qutrojans therefore, we should only be concerned about attacks by conventional trojans [Lo (1999)]. If the qutrojan is able to replicate itself it certainly deserves the name quvirus. A consistent quantum mechanism of such replication is especially welcome if quantum computers and cryptography are to become a successful technology. Measuring apparatus and "bombs" reducing (projecting) quantum states of the game play the role of the nervous system providing the "organism" with contact with the environment that sets the rules of the game defined in terms of supplies and admissible methods of using of tactics and pay-offs [Piotrowski (2004b)]. Contrary to the quantum automaton put forward by Albert [Albert (1983)], there is no self-consciousness – only the Ego is conscious (partially) via alliances with the Id and is infallible only if the Id is not infected with memes. Alliances between the kernel and the Id (shell) form kind of states of consciousness of quantum artificial intelligence (QAI) and can be neutralized (suppressed) in a way analogous to the quantum solution to the Newcomb's paradox [Piotrowski (2003)]. In the context of unique properties of the quantum algorithms and their potential applications, the problem of deciding which model of artificial intelligence (AI) (if any) faithfully describes human mind is regarded as fascinating, though less important. The discussed earlier variants of the Elitzur-Vaidman breaker suggests that the addition of the third qubit to the kernel could be useful in modelling the process of forming the psyche by successive decoupling qubits from the direct measurement domain (and thus becoming independent of the shell functions). For example dreams and hypnosis could take place in shell domains that are temporary coupled to the kernel in this way. The example discussed in the previous section illustrates what QAI intuition resulting in a classically unconveyable belief might be like. It is important that QAI reveals more subtle properties than its classical counterparts because it can deal with counterfactual situations [Mitchison (2001), Vaidman (1996)] and in that sense analyze hypothetical situations (imagination). Therefore QAI is anti-Jourdainian: Molier's Jourdain speaks in prose without having knowledge of it; QAI might be unable to speak but QAI knows that it would have spoken in prose if it were able to speak.

7 Conclusion

Quantum intertwining of tactics creates unique possibility of parallel actions on practically unlimited number of strategies. Therefore quantum systems can adopt various types of ambivalent tactics[Makowski (2006)]. In probabilistic models live is kind of gambling scheme. Quantum tactics, being deterministic from the theoretical point of view, can represent fascinating and yet fully understood wealth of behaviours and the probabilistic nature emerges only after brutal interactions with classical environment[17] – measurements that extort information from the system. Not only God does not play dice! Morel, brought to existence by Casares' vivid imagination[18], neglected the fact that Madeleine is a being of intelligence that is not representable by classically computable functions. Does a quantum mathematics that, among others, investigates quantum-computable functions wait for its discovery? Will the paradoxes following from Gödel and Chaitin theorems survive? The specific character of quantum models of consciousness and thinking that consists in information barrier between conscious and unconscious activities (e.g computing) suggests a possibility for a complete understanding of the physical world[19] Would the dream of the Theory of Everything come true via a Quantum Metatheory of Everything. Quantum (artificial) sensor are already being used, mostly in physical laboratories. Humans have already overcome several natural limitations with the help of artificial tools. Would quantum artificial intelligence/live ever come to exitstence? Adherents of artificial intelligence should welcome a great number of new possibilities offered by quantum approach to AI.

[17] One can say, a brutal invasion of privacy of an isolated quantum system.

[18] Adolfo Bioy Casares, *La invencin de Morel, we do recommend reading this novel.*

[19] The world is not reduced to abstract idea such that the axiom of intelligibility is satisfied [Barrow (1992)].

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