Article

Mind, Logic and Mental Diseases

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Abstract

We give a short review of the most recent work done on the logical structure of the mind and on the peculiar logical aspects of some mental diseases like schizophrenia and major depression. Then, we illustrate the computational aspects and the physical interpretation of such logical structures. In this context, we also consider a quite important feature of the mind, namely its non-Turing-computable side. The latter is responsible for the fundamental difference between a human mind and a computer, classical or quantum whatsoever.

Keywords: mind, quantum mind, quantum field theory, quantum metalanguage, quantum object language, non-algorithmic mind, schizophrenia, major depression.

Introduction

What is a Mind? What makes the difference between a healthy mind and a pathological one? What is the peculiar feature which allows one to distinguish a mind from a computer? Is the Mind the same as the brain?

All of us can answer what a brain is, but what is a mind is a more difficult question not only for the mind-body debate but also as a personal quest. We think that everyone should define his own personal philosophical approach before talking about the Mind. Our approach (Zizzi, 2012a) is very simple: the Mind is to us, the logic used by the brain.

A quantum mind is then the quantum logic of the brain, when quantum effects become relevant in some particular physical processes occurring in the brain.

Logic is a formal language, and then the mind is the formal language of the brain. The mind (either classical or quantum) can be compared to a computer (classical or quantum respectively). The classical computer is the conscious mind, while the quantum computer, much faster than its classical counterpart, is the unconscious mind, which "prepares" the job for the conscious mind (Zizzi, 2012b).

However, there are some aspects of the human thought, which are not Turing-computable (Zizzi, 2012c). The existence of a non-algorithmic side of the mind was conjectured by Penrose (1989) on the basis of Godel's first incompleteness theorem. Then in this case, the concept of the mind as a logic fails. In fact, the non-algorithmic "mind" is a metalanguage. The physical interpretation of the quantum "meta-mind" (the quantum metalanguage of the brain) is Quantum Field Theory (QFT), dealing with

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systems (the fields) characterized by an infinite number of degrees of freedom and allowing creation and annihilation of particles.
In other words, the non-computable mind is the language of the brain when the physical processes occurring in it are described by a Quantum Field Theory. In this regard we quote the introduction of a generalization of QFT, named "Dissipative QFT" (DQFT) (Vitiello, 2001). It appears as the most convenient tool, so far introduced, for dealing with quantum effects in biological matter.

On the other side, the quantum computable mind, or the quantum logic of the brain (or simply, the quantum mind) is the language of the brain when the physical processes occurring in the brain can be described by Quantum Mechanics (QM), which deals with systems made by a finite and fixed number of particles.

It is to be supposed that the interaction with the environment can induce decoherence processes, so that we can predict the occurrence of a new logical level, described by Classical Logic and responsible for the physical outcomes of mental processes.

DQFT thus allows one to relate the processes occurring within the brain, at the different levels, with a very interesting logical scheme of the whole mental activities. Such a scheme, already proposed by Zizzi (2010) is based on three different levels: the first of (quantum) metalanguage (QML) the second of (quantum) object language (QOL) and the third of classical language.

The quantum metalanguage represents the non-computational aspects of mind and is related to DQFT underlying the brain processes. It reduces to quantum object language and the process underlying this reduction parallels the one which allows one to reduce QFT to QM. The level of QOL is the logical level of (Quantum) computational Mind. Finally the level of classical logic, produced by decoherence process, is the one of (classical) computational Mind, like the one taken in consideration by traditional Psychology and standard Artificial Intelligence. The latter is the seat of consciousness, while the Quantum Mind coincides with the unconscious. This description has been possible owing to the introduction of a new form of Quantum Logic (Zizzi, 2010) in which QML atomic assertions carry assertion degrees which are complex numbers, interpreted as probability amplitudes.

It is to be noticed that a quantum computer (QC) has a QOL, whose physical counterpart is QM. Therefore a QC will never be able to have a QML because it is impossible to go from a theory with a finite number of degrees of freedom, like QM, to one with infinite number of freedom, like QFT (while the reverse is possible). Also, we wonder about the difference between the healthy and the schizophrenic mind. We argue that the difference stands in the fact that while the healthy mind fast oscillates between the classical and the quantum computational modes, the schizophrenic mind uses only the quantum mode (Zizzi, 2012d). Finally, we suggest that the quantum metalanguage of major depression (Cocchi, 2012) is given in terms of the negated assertions of the quantum metalanguage of schizophrenia.

The Logical Structure of the Mind

In a previous paper (Zizzi, 2012a) we discussed about the modalities by which humans should (and in fact, do) compute. That is, we investigated about the logical languages and the computational modes of

human reasoning and the corresponding physical interpretation. In this context, however, the classical world (physical, logical, and computational) does not seem sufficient to provide a complete description of the Mind. In fact, the Mind accomplishes different tasks, where it exhibits, alternatively, both classical and quantum features. There are some novelties in two important issues: the long-standing debate on the mind-body relationship and Turing's question about a possible identification of the Mind with a computer.

We humans do invent the logics, make the computer programs and formulate physical theories. All that originates from our minds and then we wonder what the logical, physical and computational aspects of the Mind itself are. The Mind should not be confused with a mere by-product of the chemical and physical processes occurring in the brain, although its material roots are in there. There is much more involved. When we talk of the Mind, we should consider the fact that the latter is a logical language, which can be interpreted, like any logic endowed with a model. This means that we are faced with the semantics, not only with the syntax, and then we have to consider a metalanguage controlling the logic of the Mind.

Thus, the Mind can be a program too, like any logic plus a control. But a metalanguage is, on its own, non-algorithmic (non-Turing-computable) because it is only part of the program. This means that there is a side of the Mind which is non-algorithmic. Also, if we give a physical interpretation to the logic of the Mind, then the physics should be that of the material support, the brain. From the above considerations it follows then that the physical theory of the brain, corresponding to the metalanguage, should be as well non-Turing-computable.

We asked ourselves where the physical world meets the mathematical one in the Mind and how computation is involved in all of that. We suggested then that the Mind has three different operational modes (Zizzi, 2012b):

1- the quantum computational mode
2- the classical computational mode
3- the non-algorithmic mode.

The quantum and classical computational modes pertain to ordinary thought processes, while the non-algorithmic mode (Zizzi, 2012c) pertains to metathought, which is the peculiar process of thinking about our own ordinary thought.

The logical descriptions of the above modes are the following: for the quantum computational mode, the logic is the quantum computational logic Lq, described in Zizzi's PhD thesis (2010), which is a special quantum version of Basic Logic (BL) (Sambin, 2000); for the classical computational mode the logic is BL; for the non-algorithmic mode there is no logic, but a quantum metalanguage (QML) (Zizzi, 2010).

A QML differs from a classical one by the fact that the quantum assertions, which are expressed with partial certitude, have a degree of assertion, which is a complex number, while classical assertions have assertion degree equal to one. Consequently, the propositions of the quantum object-language (QOL), Lq, are probabilistic, and fuzzy at the same time, and satisfy a logical uncertainty principle (Zizzi,

2013). Moreover, there are some particular quantum propositions, which minimize the logical uncertainty relation, called quantum-coherent propositions.

The physical interpretations of the logical structures of the three computational modes of the Mind are the following: the non-algorithmic mode is physically described by a Dissipative Quantum Field Theory (DQFT) of the brain (Vitiello, 2001); the quantum coherent assertions of the quantum metalanguage are interpreted as Glauber coherent states (Glauber, 1963), which are very robust against decoherence. We find that "cat state" like assertions are the only compound assertions which are quantum-coherent. However, in the corresponding physical theory, the "cat" coherent states (Haroche, 2006) are very fragile with respect to decoherence, and then we argue that this applies also to the quantum metalanguage.

Incoherent quantum assertions correspond to propositions of Lq, the qubit-like ones, which logically "decohere" to classical propositions of BL. In this sense, the classical mode can be obtained by decoherence of the logical qubits.

The quantum mode, which is quantum computation, is physically described by Quantum Mechanics (QM). The classical mode, which is classical computation, is physically described by Classical Physics.

The Non-Algorithmic Mind

In the paper "The non-algorithmic side of the mind" (Zizzi, 2012c), we developed a meta-language for the non-algorithmic mode involving a fuzzy modality "*Probably*".

More precisely, our philosophical point of view was the following. There are three different ways by which fundamental high-level mental activities manifest themselves (Zizzi, 2012b). Two are algorithmic (Turing-computable): the classical computational mode, and the quantum computational mode. The third is non-computable.

Each of the three modes of the mind can be formalized in a mathematical way (the first two by a logic, the third by a metalanguage) and also acquires a physical interpretation, and a psychological status.

The quantum mode concerns extremely fast mental processes of which humans are mostly unaware of, and is logically described by the logic Lq (Zizzi, 2010) of quantum information and quantum computation. The atomic propositions of Lq are interpreted as the basis states of a complex Hilbert space, while the compound propositions are interpreted as qubit states. Therefore, the physical model of the quantum mode of the mind is Quantum Information. The classical mode concerns those mental processes, which humans are aware of. It arises from the decoherence of the quantum computational state, and is logically described by Basic Logic (BL) (Sambin, 2000) which is a sub-structural, non-classical logic. In a sense, the quantum mode "prepares" the classical mode, which otherwise would take very long to perform.

The atomic propositions of the quantum object-language (QOL) (Zizzi, 2010) are asserted, in the quantum metalanguage (QML) with an assertion degree, which is a complex number. We showed that this fact requires that the atomic propositions in the QOL are endowed with a fuzzy modality

"*Probably*" (Hajek, 1998) and have fuzzy (partial) truth-values (Zadeh, 1996) which sum up to one. In this context, we tried to clarify Penrose's conjecture (1989) on the non-computational aspects of the mind in relation with Gödel's First Incompleteness Theorem (1931). Penrose claims that a mathematician can assert the truth of a Gödel sentence *G*, although the latter cannot be demonstrated within the axiomatic system, because he is capable of recognizing an indemonstrable truth due to the non-algorithmic aspect of the mind.

In our opinion, the fact that the mathematician can assert the truth of *G*, is that he is using the non-computable mode of metathought described by the metalanguage, where assertions stand, and where Tarski introduced the truth predicate (Tarski, 1944).

Furthermore, the fuzzy-probabilistic features of QML induce to modify Tarski Convention *T(true)* as Convention *PT* (where *P* stands for "*Probably*"), that is, *"probably true"*.

The Logic of Schizophrenia

In the paper "Quantum logic of the unconscious and schizophrenia" (Zizzi, 2012d) we suggested that the logic of the normal unconscious may be coextensive with the logic of schizophrenia. One might very plausibly argue that, while healthy minds employ both the classical logic of consciousness and the quantum primary process logic of the unconscious, schizophrenic minds use primary process thinking not only in their unconscious psychodynamics but also as their dominant conscious operating mode. We formalized the logics of both the unconscious and schizophrenic thinking in order to make the case that they are the same. We did start by recognizing that sudden flashes of creative insight and other intuitive "leaps" arise from states of mind through intermediate steps that commonly remain hidden beneath consciousness. Such ultra-fast processing entailing hidden intermediate step is consistent with quantum computation.

The logic of the normal unconscious mind and of schizophrenic consciousness may then be Lq, the logic of quantum information (Zizzi, 2010). For a healthy mind the passage from the unconscious state to the conscious state is marked, according to the Orch-Or model of Penrose and Hameroff (1996) by a decoherence of tubulin qubits. This may be understood in terms of very fast switches from the quantum logic of the unconscious to the classical logic of consciousness. We argued that in schizophrenia these switches are not fast enough, and therefore the schizophrenic mind remains trapped in the unconscious logical mode too long.

In Lq, propositions are configured in qubits, quantum information units, which are linear superpositions of classical bits. It is in this sense that the formal interpretation of the unconscious mind may be potentially understood as quantum-informational. The quantum concept of truth within Lq is different from that of classical truth, insofar as classical truth is single-valued and deterministic while in contrast quantum truth manifests itself as many-valued (fuzzy) and probabilistic (Zizzi, 2013).

The metalinguistics of primary process thinking and related psychopathological phenomena should be well modelled by QML with particularly apt application to schizophrenia, in which a surplus of quantum propositions dominates the classically logical discourse (Zizzi, 2012). In such a framework it

was possible to introduce the theoretical notion of an Internal Observer (IO) (Zizzi, 2005) which seemed to be a useful tool in developing a new kind of therapy for schizophrenia.

The Logic of Major Depression

In a recent paper Cocchi et al (2012) considered the results obtained by biochemical experimental data on platelet membrane fatty acids processed by a Self-Organizing Map (SOM) (Cocchi, 2008) from apparently healthy, bi-polar (BD) and major depressive subjects (MD). The SOM showed that MD subjects belong to an area which is completely disconnected from that of healthy and bi-polar. Looking at the location of the data over the SOM, we found also a region which we attributed to psychotic subjects according to the clinical diagnosis.

The SOM highlighted the peculiar characteristic of the fatty acids triplets for each group of subjects considered. Each subject had a specific degree of viscosity of the membrane, which was expressed by means of a specific index, called the B_2 index, based on the sum of the percentages of Arachidonic Acid, Linoleic Acid and Palmitic Acid, which represent the majority of the total platelet fatty acids in relation to their molecular weights and melting points. The distribution of the B_2 index in the one-dimensional map showed negative and positive indexes belonging, the first to the major depressive subjects, the second to the bi-polar subjects.

Then, in the light of the experimental data, humans can have either positive or negative values of the B_2 index. Those humans having positive values of B_2 are normal (N), bipolar (B) and psychotic (P) people. On the contrary, major depressed people (MD) have negative B_2 values.

In order to build a theory describing such a circumstance we started from the language of set theory. In this framework, we considered the Set "Humankind" as the Universal set, U. Then, we made a bipartition of U. In the cell A, there are all the elements characterized by a positive value of B_2. In the cell A^C, which is the complement of A in U, there are all the elements characterized by a negative value of B_2.

We suggested a possible theoretical explanation of the reason why MD people, who have a negative value of the B_2 index, fall in a completely separate category from the rest of humankind, having instead a positive value of B_2. By introducing a metaphor based on Quantum Field Theory, we viewed the splitting of positive and negative values of the B_2 index averages as due to a kind of spontaneous symmetry breaking. The initial B_2 expected value (e.v.) can be interpreted as the e.v. before symmetry breaking, while the final B_2 e.vs. can be read as the two e.vs after the symmetry breaking. We found a similarity with the situation occurring in a well-known model used in the Quantum Field Theory $\lambda\varphi^4$ (Itzykson, 1986).

The partition of the Universal set concerns set theory and equivalence relations on sets. The Symmetry breaking, instead, concerns classical and quantum field theories. These two apparently disconnected issues are unified by logic when the partition is a bipartition and the original symmetry is the discrete Z_2 symmetry. The latter is equivalent to the logic gate "XOR", which is the logical conjunction of the two logic gates "NAND" and "OR". A bipartition is equivalent to the pair of the two logic gates "NAND", "OR" into which the "XOR" can be split. The logical connective "OR" plays a relevant role

in the logic of human thinking, together with its dual, the "AND". Instead the "XOR" (the aut-aut) seems to be better suited for artificial intelligence (AI). In fact, the "XOR" is active only before the symmetry breaking.

After the symmetry breaking, we have the "OR", which is common in reasoning performed in our everyday life, if we are supposed to belong to the equivalence class with a positive value of B_2, and the "NAND", which instead we do not use. The "NAND" then must pertain then to the logic of people in the other equivalence class with a negative value of B_2. Such an argument is supported by a number of experimental findings about the reasoning abilities of human subjects. In fact, the "NAND" (the negation of the conjunction of two propositions) can be rewritten as the disjunction of two negated propositions. Then, MD subjects have a different logic from the one of normal, bipolar and psychotic subjects. This also means that the MD metalanguage is different as it consists of negative assertions, which are the symptoms of pessimism and negative mood.

When the negative assertions are the only possibility, that is, when they cannot alternate with positive assertions (because only the connective "NAND" is available) MD takes place. Also, we found that MD subjects use permanently a quantum metalanguage (Zizzi, 2010) which is the negation of the quantum metalanguage used permanently by schizophrenic subjects.

Then, we suggested the use of a (negative) quantum metalanguage for the psychotherapy of MD subjects, as we did for the use of a (positive) quantum metalanguage for the psychotherapy of schizophrenic people (Zizzi, 2012d).

Conclusions

The mysterious aura surrounding the concept of Mind has no more reason to exist in our modern times. The cure is given by logic (and metalogic) whose model is the physics of the brain. There is logic for the conscious thought, logic for the unconscious thought and schizophrenia, and logic for major depression (MD). The real problem is to prepare a new generation of psychotherapists who can use the adequate metalanguages to communicate with psychotic and MD people. We believe that our logical approach might be applied also to the case of autism (work in progress).

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