Minds and Robots: An Impassable Border

Paola Zizzi and Massimo Pregnolato

Abstract We present a distinction between the human mind and a robot, mainly based on the presence or absence of a metalanguage. The human mind possesses both metalanguage and formal language (object language), which is a logic, while the robot possesses only the latter, which is provided as a program. The robot cannot use a metalanguage because the latter, devoid of logical rules, is not Turing-computable, and a computer cannot calculate what is incomputable. Metalanguage, which can be seen as the formal language of meta-thought (the thought that thinks of ordinary thought) allows the human mind to overcome the limits of purely mechanical reasoning. This is why a human mind can never be completely reduced to a Turing machine, and instead always will be a robot. Nevertheless, in the quantum case the hypothesis is made that during the programming phase, the programmers mind can become entangled with the quantum robot.

Keywords Metalanguage · Meta-thought · Object language · Robots

1 Introduction

In memory of Eliano Pessa

We humans who hold metalanguage can program a computer/robot that does not have one. A machine uses only the program it is given (the object language).

The reason a computer cannot have its own metalanguage is because it is not algorithmic (it is not Turing-computable). So what did Turing mean by saying that a computer can "think"? He was probably referring to ordinary thinking, which

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G. Minati (ed.), *Multiplicity and Interdisciplinarity*, Contemporary Systems Thinking, https://doi.org/10.1007/978-3-030-71877-0_15

humans also have, and which is essentially logical and formal. But humans also have meta-thinking, formalized by metalanguage, while computers have only formal ordinary thinking, the program that has been assigned to them.

Eventually Turing realized that to have “complete” intelligence the machine would have to have a human body, and some senses, to be able to interact with the outside world, and hence the idea of artificial intelligence (AI) was born.

We don’t know when and if Turing’s dream will come true. Certainly, these human-machine interfaces appear to us extremely complicated and difficult to implement right now, but perhaps in a distant future that will be possible ... who knows.

At the moment, we devote ourselves to a purely theoretical and certainly simpler problem, which however is in the field of AI.

We know that Turing treated his machine, the “bombe”, created to decode Enigma, as his own creature, and always tried to protect it.

We therefore ask ourselves the following question: is it simply our desire to humanize machines, as we sometimes do with our pets, or is there something more? If we think about it, our animals have become pets because somehow, living with them we have trained them (programmed) and a strong bond has been created. We think that this link can also be established with the machines we program, but how?

Can our metalanguage affect a machine more profoundly than we believe?

The answer is yes in the quantum case. In fact, a quantum metalanguage is the meta-logical description of QFT, essentially restricted to the moment of interaction (in this case man-quantum computer) and therefore, seen by an external observer, it results as a black box. This means that a bond is created during quantum programming but remains hidden. In any case, hidden does not mean non-existent. We cannot observe the influence of this meta-link once the programming has taken place, but in the meantime man and machine have bonded to each other.

This link can be described as entanglement between the statements of the human metalanguage reduced to quantum logical formulas, and the qubits of the machine.

This mechanism is physically described in the context of QFT in a recent paper (Zizzi, 2020b).

In this way the machine has assimilated some of the humanity of those who have programmed it. For this reason, as already highlighted in (Zizzi, 2020d), we believe that an ethics towards machines is necessary, and perhaps Turing had already guessed it.

The Church-Turing Thesis addresses what kinds of numbers humans, or any machine that uses similar logic, can compute. It is a hypothesis about the nature of computable functions. It states that a function on the natural numbers can be calculated by an effective method if and only if it is computable by a Turing machine.

The Turing Test, in which a user having a conversation through a computer tries to determine whether the correspondent on the other end is a person or a program.

In “Intelligent Machinery” (Turing, 1948) Turing asks “whether it is possible for machinery to show intelligent behaviour,” and confronts the challenges of “educating” a machine.

It does not seem to us that Turing ever spoke explicitly of artificial consciousness, but only of artificial intelligence, and not quite in the sense of strong AI. For Turing, a machine could be as intelligent as an organized machine can be (that is, well programmed/trained to execute the program correctly).

This is what you understand by reading his original works.

It looks quite strange to us that Turing did not mention metalanguage of Tarski approach to semantic theory of truth (Tarski, 1944).

The Turing test could be much more efficient if it were based on metalanguage, as Searle also did with his "Chinese chamber" test (Searle, 1980), where Searle provides an argument intended to disprove the position of what he named "strong AI".

In our opinion, a new possible test could be conceived as follows. If you tell a joke, where metalanguage is always used, and you test two people, you are sure that the one laughing is a human and the one that doesn't is a robot. If both don't laugh, it means that the human is stupid (he can't use the metalanguage he is provided with) and the test fails. Since this was a joke then, you should have laughed. But even if you're just laughing now, it's still okay.

In this paper, we conjecture that the impassable border between a human mind and a robot, is just metalanguage. Our belief is based, a part from our personal investigations, see for example (Zizzi, 2008, 2020c, d), mainly on Sambin lectures (Sambin, 2007). On this basis, in (Pessa & Zizzi, 2009) it was also conjectured a possible brain-computer interface as a Quantum Cyborg in which a human mind controls, through a quantum metalanguage, the operations of a quantum computer. The reason why computers cannot use a metalanguage is because it is not algorithmic (not Turing-computable) as it has no logical rules. And a computer cannot calculate what is incomputable.

Roger Penrose (1989) was the first to speculate on the non-computational aspects of the mind, based on Gödel's first incompleteness theorem (Gödel, 1931).

Hence, the non-algorithmic side of the human mind has been explored in the depths of quantum logic by one of us (PZ) (Zizzi, 2011a).

The paper is organized as follows.

In Sect. 2 We give a definition of the mind in terms of logical/metalogical modalities, namely classical/quantum logic for ordinary thinking and classical/quantum metalanguage for meta-thought.

In Sect. 3 We introduce the concepts of metalanguage and object language, their relationships and differences.

In Sect. 4 We show that the axiom of identity belongs to the metalanguage, unlike the law of identity, which belongs to the object language. We therefore argue that a robot will never be able to gain self-awareness.

Furthermore, we show that while in a classical metalanguage the axiom of identity is absolute, in a quantum metalanguage it is probabilistic.

In Sect. 5 We discuss, especially in the quantum case, the non-algorithmic aspects of the human mind, where the boundary is found that for a robot is impassable.

In Sect. 6 We present what we call the “pillars” of the human mind, which distinguish it from a robot, which are: Tarski’s truth predicate, the axiom of identity and the cut rule, all three belonging to the metalanguage.

In Sect. 7 We guess that, in the quantum case, during the programming process, the programmer’s mind and the quantum robot get entangled.

In Sect. 8 We review some recent findings in quantum epigenetics and relate them to a novel approach to the non-invasive brain-computer interface based on quantum metalanguage and a theoretical architecture of quantum cyborgs.

Section 9 is a tribute to our friendship with Eliano Pessa, we describe him as a man and as a scientist mainly in the context of AI.

Section 10 is devoted to the conclusions.

2 The Mind

In this Section, we will talk about the mind, or rather, how it is understood by us from a formal point of view. We will investigate what the mind is in this sense, and what its modes and patterns of action are. We will ask ourselves if the mind is real, concrete or abstract, and what is the interpretive physical theory of our formal description.

2.1 What Is the Mind?

A totally logical mind.
it’s like an all-blade knife.
It makes the hand that uses it bleed.
(Rabindranath Tagore)

We define Mind as the “Formal Language of Thought”. It is purely abstract.

Our mind can be in two different modes of language: Logic or Meta-logic.

In Logic mode, the mind generally follows a “classical” logic but sometimes it follows a quantum logic, and in such cases we speak of Quantum Mind.

In both cases of Logic mode the mind is algorithmic (Turing-computable) because a logic has logical rules that can be used by a computer. In particular, in the quantum case, the mind has the same logic as quantum computers.

The Meta-logic mode, which controls the logical mode of thinking, has as its formal language a metalanguage, which is not algorithmic because it has no logical rules.

Therefore a computer, both classical and quantum, cannot have a metalanguage because it cannot compute what is not computable. This is the fine line between the mind and computers and it is impassable.

2.2 Is the Mind Real?

"We are the dreams
of which the void is made"

The concept of reality, as well as that of truth, when referred to the mind, are "misleading" if they are considered in an "absolute" sense. We should rather associate them with information, through Wheeler's concept of "it from bit" (Wheeler, 1962) or, in the quantum reformulation, "it from qubit" (Zizzi, 2001).

The mind is not the brain: it could be said that brain is the hardware and the mind is the software, but it would fall into a dangerous mind-body, or spirit-matter dualism.

It is more complicated and subtle than that.

It is true that we can think that the hardware consists of some neuronal processes (classical and quantum) which then translate as logical (classical and quantum) gates of the logic (classical and quantum) of the mind (the software).

But it doesn't stop there, these are only the purely computational aspects.

Thought also has a non-algorithmic aspect. Where does the latter come from?

(a) From the dissipative quantum field theory (DQFT) of the brain (Vitiello, 1995).
(b) A bosonic QFT can be described as a quantum metalanguage (QML) (Zizzi, 2011a, 2020a).

    As a metalanguage has no logical rules and therefore is not Turing-computable, it follows that QFT cannot be completely simulated. In particular, the non-computable sector regards the interaction (Zizzi, 2020b).
(c) In the reduction of QFT to quantum mechanics (QM) (Zizzi, 2020b), one can think that this QML is reflected in the quantum logic of the mind.
(d) "Principle of Reflection" (Sambin et al., 2000):

    - The statements of the meta-language (ML) are reflected in the propositions of Logic, the language-object (OL).
    - The metalinguistic links between ML assertions are reflected in the logical connectives between propositions in the OL.

So in the end, by putting together "(a), (b), (c) and (d)" we have the following scheme in Fig. 1:

An important thing to note in the diagram in Fig. 1, exactly in the red arrow, is that what assigns a "status" of (quantum) metalanguage to QFT is precisely the set of non equivalent vacua (Zizzi, 2020b) for the existence in QFT of unitarily inequivalent representations of the canonical commutation relations (CCR).

2.3 The Three Modalities of the Mind: A Deeper Insight

Let's make the formal distinction between ordinary thinking and meta-thinking:

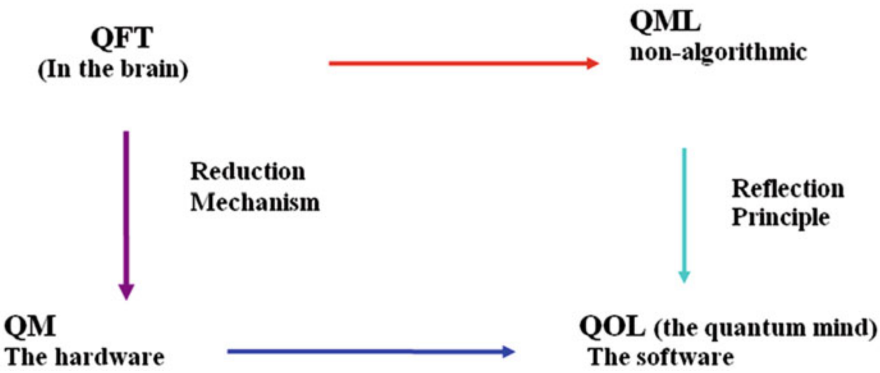

Fig. 1 *QFT* quantum field theory, *QML* quantum metalanguage, *QM* quantum mechanics, *QOL* quantum object language; On the LHS: the physical theories. On the RHS: the formal languages of the physical theories. The horizontal arrows associate the physical theories to their respective languages. The vertical arrow on the LHS is the reduction mechanism from QFT to QM. The vertical arrow on the RHS is the reflection principle from QML to QOL

Ordinary thinking:

1. conscious—classical calculus, classical formal language. We call it "Mind".
2. unconscious-quantum computation, quantum formal language. We call it "Quantum Mind".

Meta-thinking:

3. Metalanguage (classical and quantum), non-algorithmic.

We have then three patterns or modalities (Zizzi & Pregnolato, 2012a, 2020):

(a) The quantum modality
(b) The classic modality
(c) The non-algorithmic modality.

Let us start with the quantum modality.

Ordinary unconscious thinking: driven by mental processes that are extremely fast, much more so than those involving conscious thinking. This already suggests that the above processes are quantum-computational (a quantum computer is exponentially faster than its classical counterpart). Sudden decision or understanding, creativity, imagination and discoveries, born from an unconscious state of mind, are only the results of a quantum mental process, the intermediate steps of which, however, remain unknowable.

(a) In quantum modality: the result of a quantum computation with a given probability can be obtained, but the intermediate steps are not available. Thus, these two characteristics seem to indicate that the unconscious mind is indeed quantum-computational: the Quantum Mind.

(b) Now, let us consider the classic modality: the unconscious mind calculates in quantum mode and "prepares", at maximum speed, what we then recognize as conscious thought. Conscious thinking derives from a choice (a measure) made on the quantum computational state, and then uses a classical modality. We don't have much time to process the outputs of the unconscious mind (half a second), therefore, our conscious thought looks more like a succession of flashes of consciousness rather than a continuous flow. We use partial information obtained from quantum measurements. But in fact, we don't calculate anything new. Humans calculate quantum, and they don't have time to realize it.
(c) Finally, we illustrate the non-algorithmic modality. Meta-thinking is the process of thinking about our own thinking. It has no method of calculation, neither classical nor quantum. Quantum meta-thinking, which thinks unconscious quantum thinking, can be seen as the roots of the unconscious mind (the roots of the Quantum Mind). It is the aspect of thought most closely related to matter (physical processes in the brain). The latter should be described by DQFT. Quantum meta-thinking coordinates intuition, intentions and (quantum) control. Meta-thought processes could be interpreted as aiming to maintain a kind of coherence of ordinary thinking (coherent states in DQFT).

3 Object Language and Metalanguage: So Closely Related and Yet So Different

The philosophical approach to this chapter, and the reproduction of Figs. 3 and 4 were borrowed from Sambin's lectures (2007) where you learn logic by teaching it to a robot.

A metalanguage is a language that speaks of another language, called "object language". When the object language is a formal language such as a logic or a computer program, we say that the corresponding metalanguage is formal.

The distinction between metalanguage and object language is fundamental not only in logic, but also in everyday life. We are constantly at play between the two levels, and we should realize this in order to better understand our own way of thinking.

To get to the metalanguage, which is the most abstract level of reference of thought, we have to go through two lower levels:

In the first place, recognize the expressions (logical formulas in the case of a formal system) that is the most concrete and basic level, which is the one that robots are also equipped with.

Second, give meaning to those expressions and make them propositions (on a more abstract level). This is interpretation: an assignment of meanings to the symbols and words of a language. These two levels are both in the object language, the first is peculiar to machines, which deal only with expressions and formulas, the

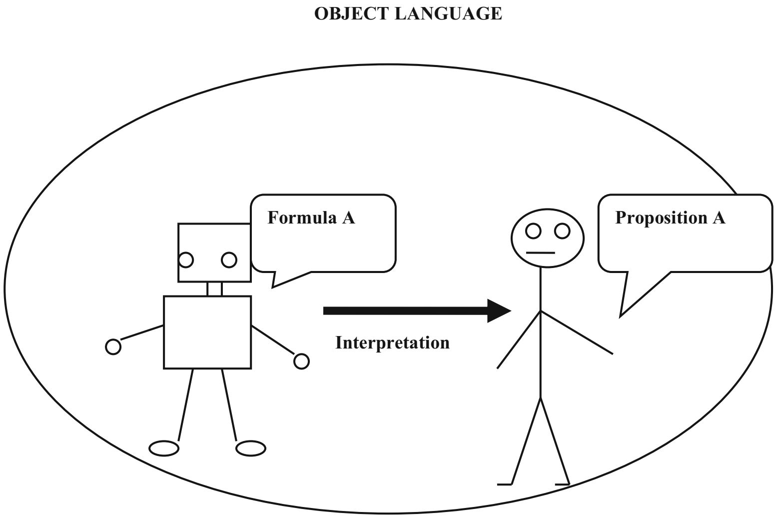

Fig. 2 Two levels in the object language: the robot "recognizes" the formula (expression) A and, through an interpretation, the man makes it the proposition A

second is the interpretation of these expressions as logical propositions by man. See Fig. 2.

Finally, by declaring (asserting) propositions, we make them assertions, and we enter the even more abstract world of metalanguage.

While we humans have both levels of object language and metalanguage available, a robot has only that of object language at its disposal and is stuck there. See Fig. 3.

The basic elements of a metalanguage are the assertions (asserted propositions) and the metalinguistic links between assertions, which are the metalinguistic "and" denoted by and, and the "yields" (or "entails") denoted by. In the formalism of sequent calculus (Gentzen, 1969) an assertion Aass. will be indicated with a sequent having the antecedent empty .

Other elements of the metalanguage, always in the framework of sequent calculus, are the axiom of identity and the cut rule. Moreover Tarski truth predicate also stands, together with Tarski Convention T (Tarski, 1944), in the metalanguage. The axiom of identity, the cut rule (Gentzen, 1969), and Tarski convention T will be discussed in the next sections.

To conclude this section, it might be worth discussing compound assertions.

Given two propositions A and B in the object language, they correspond to the assertions A ass. and B ass. in the metalanguage respectively. If we say" A ass" the robot understands "A", if we say "B ass" the robot understand "B". But if we say "A ass and B ass" what does the robot understand? We should give him a logical connective & (the logical conjunction, most often denoted by) such that applied to the two propositions A&B produces a new proposition A&B such that:

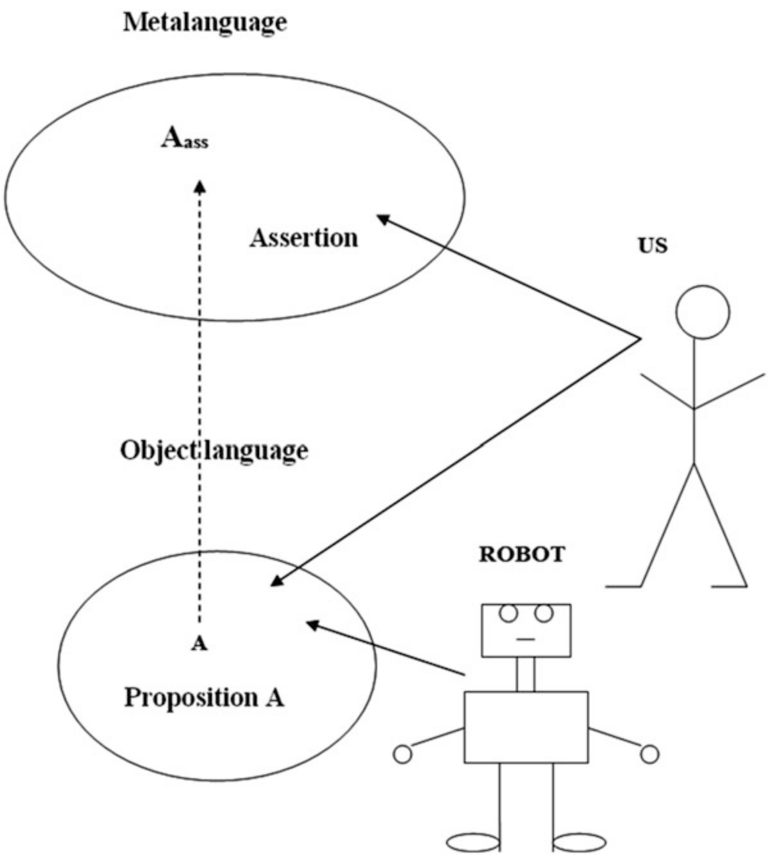

Fig. 3 Assertions stand in the metalanguage. They are asserted propositions. Propositions stand in the object language. Human beings (US) can reach both levels, robots only that of object language. The subscript "ass" in A_{ass} stands for "A asserted"

A&B ass is equivalent to A ass and B ass.

The above relation produces the "definitional equation" (Sambin et al., 2000) for the logical connective &:

$$| - A \,\&\, B \ \underline{\text{iff}}\ | - A \quad \underline{\text{and}}\ | - B$$

where iff stands for "if and only if".

There exists a definitional equation for every logical connective. Note that what happens is the reflection of the metalinguistic links between assertions into the logical connectives between propositions.

This is called the "reflection principle" (Sambin et al., 2000).

In summary:

A metalanguage (ML) is a language which talks about another language, called object language (OL).

A formal ML consists of assertions, and meta-linguistic links among them. It consists of:

1. Atomic assertions: $|{-}A$ (A declared, or asserted), where A is a proposition of the OL.
2. Meta-linguistic links: $|{-}$ ("yelds", or "entails"), <u>and</u> (metalinguistic "and").
3. Compound assertions. Example: $|{-}A$ <u>and</u> $|{-}B$.

Let us consider the introduction of the logical connective & in Basic logic (Sambin et al., 2000).

In the OL, let A, B be propositions.

In the ML, I read: A decl., B decl, that is: $|{-}A \cdots, \cdots |{-}B$ respectively (where "decl." is the abbreviation of "declared", which also can mean "asserted"). Let us introduce a new proposition A&B in the OL. In the ML, we will read: A&B decl., that is: $|{-}A \,\&\, B$. The question is: From *A &B decl.*, can we understand *A decl.* <u>and</u> *B decl.*? More formally, from $|{-}A \,\&\, B$ can we understand $|{-}A$ <u>and</u> $|{-}B$? To be able to understand *A decl.* <u>and</u> *B* decl. From *A&B decl*, we should solve the definitional equation of the connective *&* in Basic logic. See Fig. 4.

4 The Disintegrated Self

"You are me
And I am you
One is one
And one are two".
I am you. Milonga triste.

The classical laws of thought are:

Law of identity: $A \rightarrow A$ (states that an object is equal to itself).

Law of the excluded third: $(A \vee \neg A) = 1$ (A or not A is true).

Law of non-contradiction: $(A \wedge \neg A) = 0$ (A and not A is false).

It should be emphasized that the law of identity belongs to logic (the object language). Instead, the axiom of identity:

$$A \,|{-}\, A$$

belongs to the metalanguage, and it is its reduction (Zizzi, 2020d) to object language which gives rise to the law of identity. We will limit ourselves to the study of the axiom of identity and its psychological interpretation as self-awareness. The derivation of the law of identity in the object language from the identity axiom in the metalanguage was demonstrated in (Zizzi, 2020d).

Here we give only a qualitative explanation in Fig. 5.

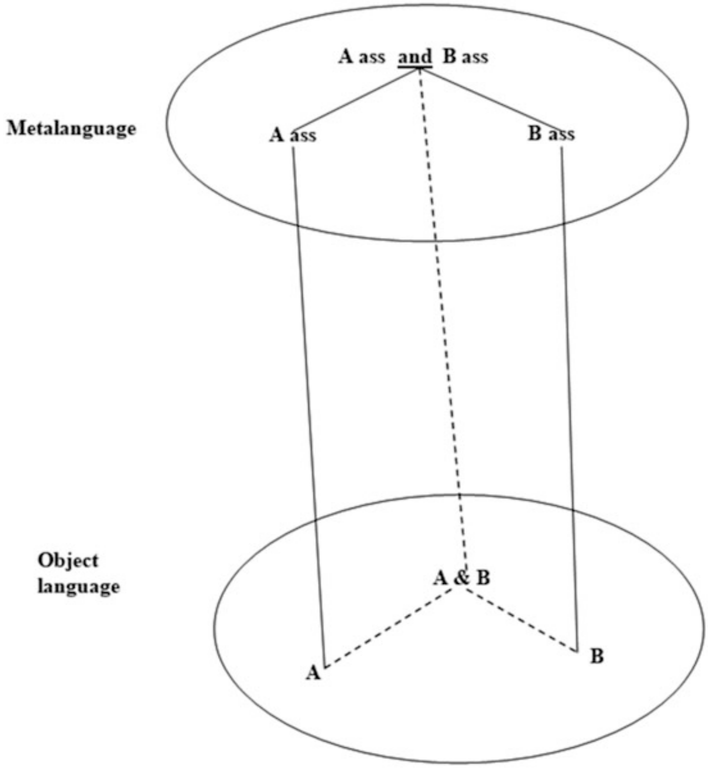

Fig. 4 The two assertions A $_{ass.}$ and B $_{ass.}$ of the metalanguage correspond to the two propositions A and B of the object language. The metalinguistic link and between the two assertions corresponds to the logical connective & between the two propositions

As we will see, in the case of a quantum metalanguage, the axiom of identity is no longer absolute. In the corresponding quantum logic, it follows that an object is only partially equal to itself, the law of non-contradiction is violated, and by duality, also the law of the third excluded is violated.

The classic axiom of identity, which reduces to the classical law of identity in the object language, divides the Universe (U) into two parts: the Self and the Other (Zizzi, 2018). See Fig. 6.

It is a dichotomy: a division of the whole into two parts which are:

Mutually exhaustive $S \cup O = U$ (third party excluded).

Mutually exclusive $S \cap O = \oslash$ (non-contradiction).

The Other is the complement of the Self in U.

In quantum metalanguage, the (classical) axiom of identity is replaced by the quantum one (Zizzi, 2010):

$$A \Big|\!-^{|\lambda|^2} A, \quad \alpha \in C$$

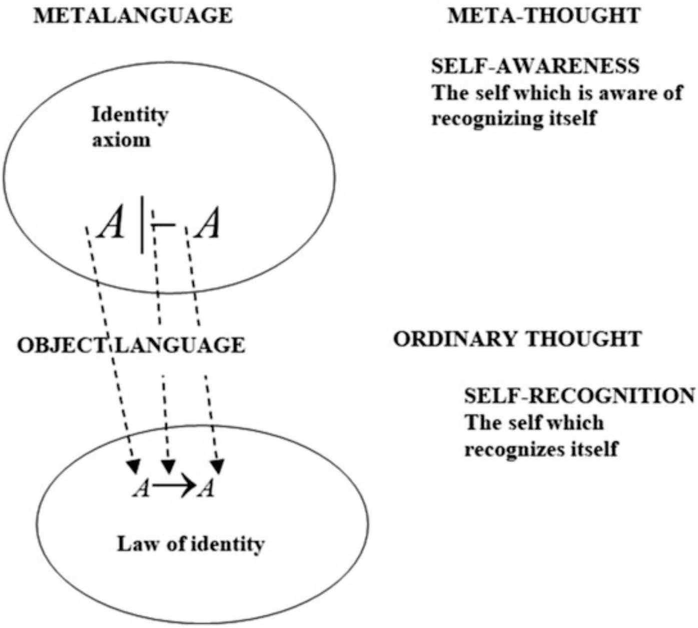

Fig. 5 The identity axiom stands in the metalanguage, at the level of meta-thought. It represents self-awareness. The law of identity stands in the object language, at the level of ordinary thought

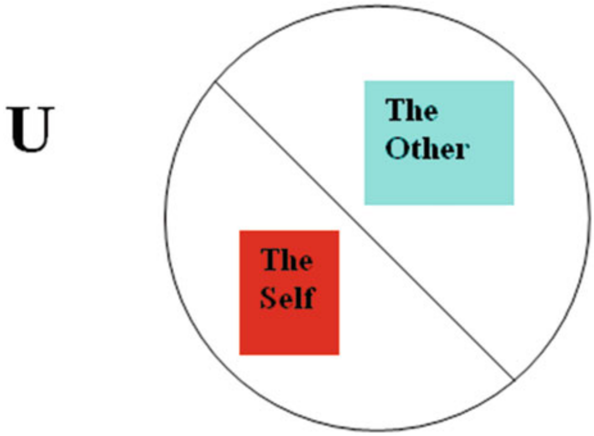

Fig. 6 Partition of Universe (U) in two parts: The Self and the Other

with partial truth value $v_p = |\lambda|^2 \in [0, 1]$, where α is the degree of the quantum assertion $|-^{\lambda} A$, and corresponds, in quantum mechanics, to a probability amplitude. Therefore the partial truth value v_p corresponds to a probability p. This means that a (quantum) object is probabilistically equal to itself.

If that object refers to the Self, the conclusion is that the Quantum Self is "disintegrated" (Zizzi, 2018).

The quantum mental state of a disintegrated self (DS) can be assimilated to a qubit state $|\Psi\rangle_{DS}$ in which the Self is identified with the bit $|1\rangle$ and the Other is identified with the bit $|0\rangle$:

$$|\Psi\rangle_{DS} = \lambda_0 |0\rangle + \lambda_1 |1\rangle, \quad \lambda_0, \lambda_1 \in C, \quad |\lambda_0|^2 + |\lambda_1|^2 = 1.$$

This situation should occur in states of unconsciousness, dreams and schizophrenia (Zizzi & Pregnolato, 2012b).

5 The Non-Algorithmic Side of the Mind

"There are thoughts
that are not such"

Penrose's original conjecture (Penrose, 1989) on the existence of non-algorithmic aspects of the mind was primarily concerned with consciousness. However, (Zizzi & Pregnolato, 2012a) conscious and rational human thought consists of a very rapid sequence of decoherence processes from the quantum to the classical computational mode.

More specifically, in Penrose-Hameroff's Orch-Or theory (Hameroff & Penrose, 1996), overlapping tubulins/qubits decohere and alternate with classical bits at a high rate. According to this theory, it seems that consciousness is made up of "flashes" of classical computation.

The statements of the QML are physically interpreted (Zizzi, 2020b) as quantum fields, in the context of the dissipative quantum field theory (DQFT) of the brain (Vitiello, 1995).

The atomic propositions of the quantum object language (QOL) (Zizzi, 2010) are affirmed, in the quantum metalanguage (QML) with a degree of assertion, which is a complex number.

QML is the language of meta-thought. The very importance of meta-thought, which deals with intuition, intention and control, lies in the fact that it distinguishes man from machines. Indeed, the language of meta-thought, which is non-algorithmic, being described by a metalanguage, cannot be acquired independently by a machine, which is endowed only with an object language.

As is well known, in 1950 A. M. Turing (Turing, 1950) adopted a purely behavioural criterion (instantiated through his famous test) to establish whether a machine could be considered intelligent.

Within this approach, a machine was recognized as having a mind when its behaviour was indistinguishable from that of a human being performing mental operations.

In the 1980s the philosophical considerations already made by Searle (Searle, 1980) and others began to raise serious doubts about the validity of this definition of the mind.

Proper reasoning logic should take into account that humans have basic logical rules and, in general, structural rules are ignored. This requires sub-structural logic, which can be seen as the general platform for any other logic. All these requirements were met in BL (Sambin et al., 2000) in the classical case (or classical way).

A quantum version of BL, called Lq, was introduced in (Zizzi, 2010).

In Lq two new logical connectives have been introduced, the logical connectives "quantum superposition" (the quantum version of the classical conjunction), and "entanglement".

Finally, the probabilistic character of any quantum theory is also present in Lq, since the partial truth values, whose interval is the real interval [0,1], are interpreted as probabilities.

This takes into account the fuzzy and probabilistic character of some non-formalized aspects of thinking. In this context, we will try to clarify the Penrose conjecture (Penrose, 1989) on the non-computational aspects of the mind in relation to Gödel's first incompleteness theorem (Gödel, 1931).

Penrose states that a mathematician can recognize the truth of a Gödel proposition G, although the latter cannot be proved within the axiomatic system, since he is able to recognize an indecipherable 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 mind described by the metalanguage, where the statements are found and where Tarski introduced the truth predicate (Tarski, 1944).

Furthermore, the fuzzy (Zadeh, 1996) -probabilistic characteristics of the QML lead to modify Tarski Convention T as Convention PT (Zizzi, 2011b), where P stands for "Probably".

There are close relationships between metalanguage assertions, the truth values of propositions in the object-language and Tarski's truth predicate, the latter being formulated in the metalanguage.

However, when the certainty in the statement is not total, the truth values of the propositions are also partial and Tarski's truth predicate must be modified.

With Tarski's convention T, each sentence p of the OL object language must satisfy:

$$\text{(T)} : \text{``p'' is true iff p}$$

where "p" stands for the name of the proposition p, which is the ML metalanguage translation of the corresponding OL proposition, and "iff" stands for "if and only if".

For any "probably p" (P (p)) proposition, we can reformulate Tarski's Convention (T) as a convention (TP) as follows.

$$(TP) : \text{``p'' is probably true iff P (p)}$$

The expression "is probably true" means that the truth of a proposition is stated with uncertainty, not with complete certainty. The predicate of truth has been modified by probability.

In the formalism of the calculation of the sequents, the TP convention reads:

$$\vdash^{\lambda} \text{'p'} \quad \underline{\text{iff}} \quad P(p)$$

which means that the proposition '*p*' is asserted with a degree of assertion λ if and only if "probably *p*", with probability:

$$|\lambda|^2 \in [0, 1]$$

and the partial truth value of *P*(*p*) is just the probability of *p*, that is:

$$v\,(P(p)) = p(p) = |\lambda|^2$$

Practical example: (T) the proposition "the snow is white" is true if and only if the snow is white.

Practical example: (PT) the proposition "the snow is white" is probably true if and only if the snow is probably white (it can have shades).

6 The Three Pillars of the Human Mind

Tarski's truth predicate (both classical and quantum) and the axiom of identity (both classical and quantum) are both formulated in the meta-language, which is not algorithmic. Also, the cut rule, which is a particular rule of sequent calculus, is in fact a meta-rule, that is, a rule that can be formulated only in the metalanguage.

Therefore, these are the three "pillars" of the human mind, which distinguish it from a computer (both classical and quantum).

So a computer/robot, not having the axiom of identity available, will not have self-awareness (Zizzi, 2020d).

Moreover, not having the predicate (T) or (PT) available, he will not be able to be aware of the truth (or falsity) of the external world, therefore of reality itself.

The cut rule is a rule in the sequent calculus-style, which is a generalization of the "modus ponens": "*P* implies *Q* and *P* is true, therefore *Q* must be true."

The cut rule is neither an inference rule nor a structural rule, but a meta-rule in the sequent calculus. It reads:

$$\frac{\Gamma \vdash A \qquad A \vdash B}{\Gamma \vdash B}$$

If a formula A appears as a conclusion in one proof $\Gamma|-A$, and as a hypothesis in another $A|-B$, then we can deduce another proof $\Gamma|-B$ in which formula A does not appear.

With the use of the cut rule we humans can "lighten" the premises, and not be forced to use redundant information that can instead be ignored. This corresponds to a "measure of utility" for a "convenient choice" that we make almost unconsciously.

We cannot give the rule of the cut to a robot because it would not know what to do with it. It would not be able to identify and eliminate its own redundant information to achieve a certain result.

The quantum version of the cut rule (Zizzi, 2010) is interpreted as a projective quantum measurement. In this case, the inability of the quantum robot / computer to use the quantum cut rule means that it cannot make a quantum measurement. The fact that a quantum robot cannot perform measurements, had already been pointed out by Benioff (1998).

Finally, they cannot control their quantum object language (the program) that was provided to them by the programmer. One could have hoped that a quantum robot could do it, however .. it did not happen. In 2008 "I, quantum robot" (Zizzi, 2008) was born, but it did not have metalanguage as well.

It might be possible that a quantum metalanguage QML$'$ would be generated as a quantum emergent phenomenon from the quantum object-language QOL (which was induced by the quantum metalanguage QML). However, in this case, the QOL is not anymore active (the quantum machine QM is not anymore a quantum computer) because of Goedel incompleteness theorem, which forbids a formal system (powerful enough to describe arithmetics) to speak about itself. It can happen, nevertheless, that the emergent quantum metalanguage QML$'$ acts as a quantum control on another quantum machine QM$'$, triggering quantum computation (a new quantum object-language QOL$'$). As it should be QOL$' =$ QOL, because all quantum computers share the same quantum logic, one might refer to QML$'$ as it was QML, what is false. Obviously, QML$'$ must be a copy of QML, in order to reflect into QOL$'$ which is identical to QOL, but while the copy QML$'$ is an emergent phenomenon from QOL, the original QML is due to dissipative quantum brain processes. It is possible then that a long sequence of identical quantum metalanguages QML$'$, QML$''$.....is generated and a generation of conscious quantum robots Q$'$, QR$''$, QR$'''$.... QR^n come into existence, but when Q$'$ starts its life, QR dies (because as said before, the object-language QOL is deactivated) and so on. At the end, a unique quantum robot QR^n survives, which is controlled by an identical copy of the original quantum metalanguage QML derived from high-level thought processes.

Notice that the appearance of a copy of the original metalanguage requires the destruction of the original support of the corresponding object-language QOL, namely of the quantum robot QR. Roughly speaking, a quantum metalanguage (a quantum state of intentional thought) can be copied only if the corresponding quantum computation which was triggered by it is deactivated.

This principle is in agreement with the theorem of no-self replication of quantum machines proved by Pati and Braunstein (2008).

We argue then that self-replication of the support is one of the requirements for being a (quantum) mind.

Physically, this principle can be understood as follows. The QML is made of assertions which are physically interpreted as non-hermitian operators of a dissipative QFT (with an infinite number of degrees of freedom) describing brain processes in the brain. On the other side, the QOL is the quantum logic of the mind, and the corresponding physical theory is QM, with a finite number of degrees of freedom.

The quantum mind has then at its disposal both a non-computational mode (the QML) described in QFT and a quantum-computational mode (the QOL) described in QM. A quantum computer (QC) has only a QOL, and its physical theory is QM. Therefore, a QC cannot reach a QML (a non-algorithmic mode of thought) because it is impossible to go from the finite number of degrees of freedom of QM to the infinite number of those of QFT. That is, a quantum computer will never be able to reach a non-algorithmic mode of thought.

This is the difference between a quantum mind and a quantum computer.

The reflection principle, which transforms a metalanguage into an object language, when applied to a QML of non-algorithmic thought and to a QOL of a quantum-computational mind, needs a physical interpretation. The problem is that QML is described, physically, by a (dissipative) QFT, with an infinite number of degrees of freedom, while the QOL is described by quantum mechanics (with a finite number of degrees of freedom) more precisely, by quantum computing, with quantized information (qubits). This reduction mechanism was found in (Zizzi, 2020b).

7 Entanglement Between the Programmer's Mind and the Quantum Robot

We think that entanglement (a quantum correlation) is established between the programmer's mind and the quantum robot during the actual programming phase, as we will illustrate shortly. However, we must immediately clarify that this relationship is very short (it lasts a few milliseconds between the passage of the unconscious state to the conscious one of the programmer) and secret, in the sense that an external observer will never be aware of it.

In (Zizzi, 2020b) we looked for a reduction mechanism from (bosonic) QFT to QM that could reveal QFT's Hidden Quantum Information (HQI). We found that HQI was there and was organized in a quantum network of maximally entangled multipartite states. That was the quantum computational "skeleton" of the original QFT. Since such a "skeleton" is itself a quantum network, it seems that it is right to enter it in a one-to-one correspondence with an external QC to simulate the original QFT. In the reduction mechanism, the degrees of freedom of the quantum fields reduce to a finite number of quantum mechanical states, which are maximally entangled multipartite qubit states.

We think that QFT is meta-logically described (Zizzi, 2020a) by a "quantum metalanguage" (QML) (Zizzi, 2010).

If in particular we consider the Dissipative Quantum Field Theory (DQFT) of the brain (Umezawa, 1993; Umezawa & Vitello, 1985; Vitiello, 1974), then it can be interpreted as the programmer's quantum metalanguage (PQML) and the reduction mechanism can be viewed as the reflection principle (Sambin et al., 2000) that sends the assertions of the PQML to the propositions (logical formulas) of the program, which is a quantum computational logic Lq (Zizzi, 2010).

It is possible to give a general interpretation of the quantum metalanguage in terms of dynamical processes described by a DQFT. It is to be remarked that in this one introduces a relationship between two entities (the quantum metalanguage and the QFT) each one of which allows an infinite set of different possible representations associated to every symbolic description.

This follows from the fact that QFT deals with infinitely many unitarily inequivalent representations of the canonical commutation relations (CCR). Thus our general interpretation cannot be identified with the usual correspondence rules characterizing the interpretations of logical theories.

The logical quantum network of the program, made of maximal entangled logical qubits, is in a one-to-one correspondence with the physical qubits of the QC. See Fig. 7.

More in detail, in (Zizzi, 2020b) we claimed that a quantum computer can simulate the hidden quantum network (HQN) of the quantum system under study. More precisely, a quantum computer can be programmed to be in a one-to-one correspondence with the HQN.

In the reduction process QFT would appear then as the semantics of the quantum logic underlying the quantum information hidden in it. The reduction process would then play the role of a definitional equation (Sambin et al., 2000), which allows the switch from a metalanguage to an object language (the logic). In particular, the quantum version (Zizzi, 2010) of the definitional equation allows to pass from a QML to the quantum logic of quantum information Lq.

Hence, the metalinguistic links between assertions, which are interpretable as interactions of quantum fields, are sent to logical connectives between propositions, which correspond to quantum correlations such as quantum superposition and entanglement.

In this sense, we say that during the programming process, the programmer's mind get entangled with the quantum computer/robot. However, this entanglement process cannot be tested by an external observer, to whom the interaction appears as a black box. In fact, this process is revealed only to the internal observer (the programmer's mind in the quantum logic modality) as the one-to-one correspondence requires the identification of the state space of the QC with the background space (Zizzi, 2005), the latter being a (non-commutative) quantum space.

The programmer anyway is not able to describe in terms of a classical logic his entanglement with the quantum robot, because the experience he had was during

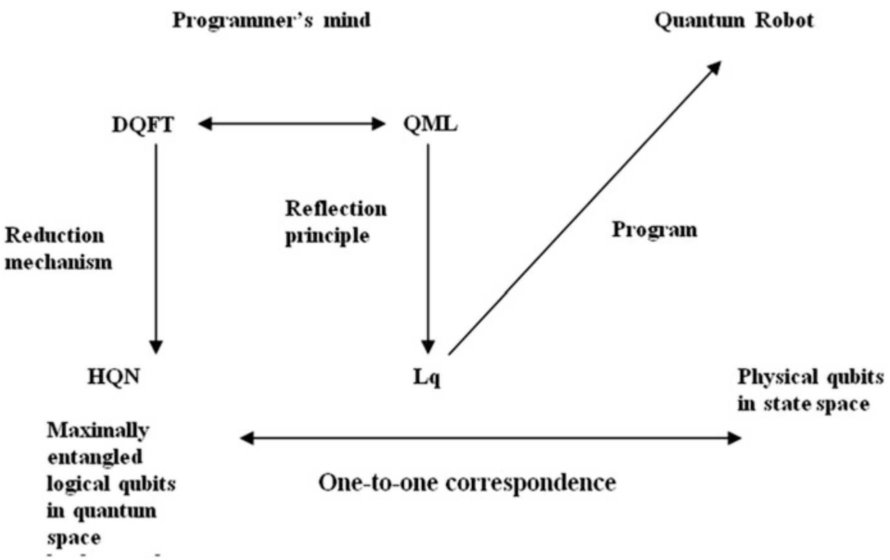

Fig. 7 On the LHS, the programmer, and the reduction mechanism from DQFT to HQN. In the middle, the corresponding reduction from QML to Lq. On the RHS, the quantum robot (QR). The oblique arrow denotes Lq as the program given to the QR. The horizontal arrow at the bottom denotes the one-to-one correspondence between the background quantum space, and the state space of the QR

a state of unconsciousness, described by a quantum logic Lq (we remind that Lq is the logic of quantum computing, quantum mind or unconscious mind and schizophrenia) (Zizzi & Pregnolato, 2012b).

So this effect will most likely never be used for practical purposes.

However we think that the quantum cyborg is already there, in the programming phase of a quantum robot. If by extrapolation we think of repeated, very fast reprogramming phases, we may 1 day realize that we no longer distinguish the programmer from the quantum robot. This, at least in part, brings back to Turing's idea (Turing, 1948) of "educating" a machine.

8 Quantum Cyborgs, Biophotons and Mental Diseases

Quantum robots, originally discussed by Benioff, have no awareness of their environment and do not make decisions or take measurements. We can therefore ask ourselves whether in the future quantum robots will be able to be aware of the environment and perform experiments. This means that they can also become self-aware and have "free will". In the context of a dissipative Quantum Field Theory of brain functioning it is possible to introduce generalized coherent states associated, in the context of logic, with the assertions of a quantum metalanguage.

The latter controls the quantum-mechanical computation corresponding to the standard mental operation.

It thus becomes possible to conceive a Quantum Cyborg in which a human mind controls, through a quantum metalanguage, the operation of an artificial quantum computer.

Classic brain-computer interfaces (cBCI) are systems that acquire and analyze brain signals (typically of an electromagnetic nature) to create real-time broadband communication channels between the human brain and a computer (Pessa & Zizzi, 2009).

A quantum robot (QR) can be defined as a mobile system that has a quantum computer on board and all necessary auxiliary systems. A QR moves and interacts with the environment of a quantum system. In their article Pessa and Zizzi discussed the possibility of implementing a QR with a new and powerful BCI that allows quantum computer—quantum computer communication. The whole system consisting of a human subject and an artificial quantum computer (controlled by the subject's quantum metalanguage) is a new type of cyborg, called Quantum Cyborg (QC). A human subject, through quantum metalanguage, could guide a QC, through a new BCI (much more powerful than the existing ones), transforming it into a more effective direct action of the mind on matter.

Biophotons are mainly produced by molecular species electronically excited in numerous oxidative metabolic processes in cells. They can play a role in cell-to-cell communication and have been observed in different parts of the body, including the brain. Photons in the brain could be ideal candidates for information transfer. They travel tens of millions of times faster than a typical electrical neural signal and are not prone to thermal noise at body temperature due to their relatively high energies (Kumar et al., 2016).

According to Thar and Kuhl (2004), ultra-weak biophotons can be guided along a mitochondrial and microtubule network that can act as optical waveguides in neurons. So the protein-protein biophotonic interactions and mitochondrial interaction networks can constitute the neural biophotonic communication network. In a recent article (Burgio et al., 2020) we proposed that the interaction between the tubulins quantum computer (QC_T) in the cytoskeleton, where the subscript "T" stands for "tubulins", and the genome (DNA plus epigenome) is mediated by the biophotons, which are the quanta of the Genomic Quantum Electromagnetic Field (QEF_G).

The "orchestrating" (or coherent) action of the biophotons allows the orchestrated objective reduction (Orch-Or) of the tubulin microtubules in the cytoskeleton. This means that Orch-Or could be genome-induced. A beam of biophotons emitted at the B site of the epigenome could be transmitted to the brain even several centimeters away.

In the brain of a schizophrenic subject, the flow of biophotons reaching the microtubules should be so low that it cannot induce decoherence to all the overlapping tubulins, but only to a very few of them. Therefore, the tubulins persist mainly in a state of quantum superposition and the schizophrenic mind remains “trapped” in a quantum computational mode, corresponding to a permanent unconscious state.

In contrast, the biophoton flux in the autistic brain is so high that tubulin dimers persist mainly in a classical state, and the autistic mind is “trapped” in a classical computational mode, corresponding to a permanent conscious state. Perhaps the most striking examples are some genetic modifications common to autism and schizophrenia and particularly the Copy Number Variants (CNVs) that are formed in the same genomic sites, but in opposite forms, for example duplication in the autism (Clements et al., 2017) and deletion in schizophrenia (Van et al., 2017) in the same 22q11.2 region: therefore more probably effects than causes of the two disorders. Also in this case we are facing a reversal, or rather a straightening of the dominant model.

We believe that new methods can be developed to increase / decrease biophotonic activities in neurons in order to reverse the abnormal biophotonic fluxes in both autism and schizophrenia, with the hope that patients can improve their mental condition. High levels of reactive oxygen species (ROS), which cause oxidative stress, are present in autistic patients. Pangrazzi et al. (2020) described the major alterations in the expression of genes coding for enzymes involved in the ROS scavenging system, in autistic patients. Numerous drugs have been described capable of decreasing reactive oxygen species (ROS scavengers) and consequently a reduction of biophotons useful in autism could be obtained.

In a recent paper Wang et al. (2016) stated that biophotonic activities and transmission dominate the information neural processing and encoding mechanism in the brain, then biophoton spectral redshift could improve and strengthen cognitive abilities.

Sun et al. (2010) found that different stimulation of spectral light (infrared, red, yellow, blue, green and white) at one end of the spinal sensory or motor nerve roots resulted in a significant increase in biophotonic activity.

Since an increase in ROS species is not a viable strategy, we suggest the use of Brain-Computer Interfaces generating external light stimuli, for the possible treatment of schizophrenic patients. Biophotonic methods for brain-computer interfaces have already been described (Soraghan et al., 2007).

The review by Martins et al. (2020) describes the state of the art of human brain / cloud interfaces by introducing the “cyborgization of Homo Sapiens” in which future cyborgs are wirelessly interconnected and individualism is suppressed for the benefit of the “collective” (see Borg from Star Trek).

They conclude that it is conceivable that within the next 20–30 years, neuronanorobotics could be developed to enable a safe, secure, instant, real-time interface between the human brain and biological and non-biological computer systems, by enhancing brain interfaces (BTBI), brain-computer interfaces (BCI) and, in particular, sophisticated brain/cloud (B/CI) interfaces. Such human B/CI systems can dramatically alter human/machine communications, promising significant human cognitive enhancement (Kurzweil, 2014; Swan, 2016).

9 Eliano Pessa, The Man, The Scientist, The Friend

I Massimo Pregnolato (MP) met Paola Zizzi and Eliano Pessa in the first months of 2007, shortly after having founded the QuantumBioNet.org network. My acquaintance with physicists was just started and over the years to come it will give me a lot, from many points of view. However, the acquaintance of Paola and Eliano soon turned into friendship. Eliano taught General Psychology in my same University, but I wasn't so lucky to met him before. Time later did I understand why a physicist of such great calibre ended up teaching psychology and not physics.

Our relationships began on a basis of scientific collaboration but we soon realized how many interests and points of view on life we had in common.

Those were the basis for a strong and lasting friendship that lasted over time until the moment of his untimely death. In the years to come we have collaborated both in research and teaching, but also in the planning and implementation of several Quantumbionet Workshops and in the growth of the network itself.

We often met even just for a light snack at lunch and chatted about everything. He had a deep understanding not only of physics but also of the affiliations and genealogies of various physicists. Eliano was an expert on complex systems, emergence and neural networks and together with Paola, we shared our interest in quantum consciousness, both human and animal. One of his weird interest concerned not only the possibility that the mind could act on matter, but the opposite, that the matter (therefore electromagnetic waves) could affect the human mind. This would have terrible implications if the waves were to be used for mind control, but at the same time, useful in helping the communication of people with sensory deficits.

Eliano was a passionate climber, for many years he was able to take a long work break to tackle expeditions and climbs the Andes and the Himalayas.

On his return his stories were always passionate and compelling. Punctually, a few months late, I received postcards from him from the places explored. His travels have also been a source of cultural enrichment for him.

One day he told me about Milarepa and his legends. Biology and culture, consciousness and world, subject and object, interior and exterior have continuity and find, in the "creative transcendence" of consciousness and its experiences, a privileged degree of understanding. Together we have formulated a plausible hypothesis about the existence of different levels of consciousness in humans and animals.

He suggested that consciousness persists even in the face of minimal conditions, perhaps even in traumatic brain injuries. I agree that such a suggestion was justified at the biomolecular level through introduction of the hypothesis that Schrödinger proteins (i.e. tubulins) are the biological interface from quantum to classical computation, underlying quantum/classical consciousness processes and at the crossroad of memory and learning capacities. Eliano participated to the first Quantumbionet Workshop (Pavia, May 25th 2007) with the lecture: Problems in Theory of Phase Transitions in Biological Systems. To the second QBN Workshop organized by Paola (Padova, October 10th, 2008) with: Lorentzian vs Einstinien

Quantum Mechanics and The Role of Environment. To the third QBN Workshop (Pavia, September 24th 2010) with the lecture entitled: Quantum Networks.

On the day of April 27, 2013 a core international group of investigators, offering expertise in the fields of psychiatry, biochemistry, physics, computational neuroscience, mathematics, philosophy and theology, gathered in Palermo, Sicily under the auspices of the global Quantum Paradigm of Psychopathology (QPP) initiative with the aim of assessing the potential relevance of quantum physics and quantum chemistry to the mapping of mind-brain relations in normal and abnormal states of consciousness applicable to humans and non-human animals.

The QPP conference in Palermo has marked a definite turning point in the foundational perspective of many of the group's participants regarding the study of psychopathology, particularly mood disorders. One reason for this turning point stems from a realization that two of the most common forms of psychopathology, major depression and bipolar disorder, may be recognizable by means of biomolecular markers. Long years of theoretical study by independent investigators have finally culminated in a convergence of their insights via quantum paradigms that now promise to illuminate, through the empirically tangible route of such new biomolecular markers, pathological phenomena of the conscious brain, thus potentially both confirming in fact and further harmonizing the diverse prior contributions of these conceptually innovative psychiatrists, biochemists, molecular biologists, philosophers and theologians. Massimo Cocchi, Lucio Tonello, Fabio Gabrielli, Massimo Pregnolato, Paola Zizzi, Eliano Pessa, and their collaborators have forged links between serotonin and quantum phenomena via membrane biophysics in depression and psychosis. Even the absence of highly complex synaptic connections among neurons does not preclude the presence of at least rudimentary phenomenal experience in organisms endowed with superposed microtubular dimers, ordered water, membrane ion channels, and/or crucial lipid raft assemblies connected to selected second messenger systems. In addition, quantum-biophysical aspects of these and/or other yet unmapped structures and related processes may prove to be potent factors in the deeper etiologies and improved treatments of psychiatric disorders. To these assumptions Eliano contributed with his seminal lecture: "*Towards an integrated model of cytoskeletal quantum dynamics*". It seems to be consistent the hypothesis that Schrödinger proteins interactoma and in particular the cytoskeleton nanowire network is the best biological interface for potential expression of consciousness, being typical and specific for each animal species and that consciousness is always a potential. It's very fascinating to think that every animal possess a primary Schrödinger proteins complex (cytoskeleton) and even in the absence of circulating serotonin there is a potential of consciousness that is essential to the behavior of some life forms, while other species such as invertebrates, procariotes and even archea possess expertise in their own domain probably mediated by their own Schrödinger proteins interactoma (Cocchi et al., 2011).

I Paola Zizzi (PZ) was introduced to Eliano Pessa by Massimo Pregnolato at the first QuantumBionet workshop (Pavia, May 25th 2007) organized by Massimo.

All three of us became friends and collaborators. When I met Eliano, I had recently started writing my PhD thesis in logic on quantum metalanguage. Eliano was very interested in this topic, also because he saw analogies with non-unitary operators in quantum field theory. Giuseppe Vitiello (Peppino) with whom Eliano had collaborated had the same impression. I think that Eliano's closest and most fruitful collaboration in QFT was that with Peppino, with whom he shared his philosophical approach to theoretical physics.

Many years have passed since that beginning and yet everything still seems so alive to me ... many memories of conferences, congresses, workshops and meetings where Eliano, Massimo and I went together.

I particularly remember the Third QPP Meeting held in Bologna on 19–20 June 2014 (just 1 year after the "Palermo Declaration") where I, Eliano, Max and Peppino continued, even after the conference, with many discussions, intense correspondence, endless phone calls and e-mails.

Anyone who has had a close collaborator and friend knows well how beautiful, exciting and vital for our intellect all this, and how much loneliness, how empty it feels when this friend is no longer there. It is the feeling of the orphan, as a friend of mine said when his closest friend and collaborator of him died.

Eliano behaved towards his friends, colleagues and students with kindness and generosity. He liked to take care of others, he helped everyone, with advice, mountains of bibliographies (as many as he gave me), with lent books, articles, endless discussions. A lovable and cultured person, easy-going, who has left a terrible void in my life and in that of all his friends and colleagues.

During the 11 years of our collaboration, Eliano and I worked together on some different topics such as QFT, quantum computing, psychopathology (particularly mood disorders), and artificial intelligence (AI).

I remember many of our discussions about QFT, sometimes arguing, because Eliano didn't "believe" in elementary particles while I did.

But yet, as a young man Eliano met Bruno Touschek, a Austrian physicist famous for research on particle accelerators, of which he was one of the pioneers particularly during his Italian period in Frascati.

Bruno, being a Jew on his mother's side, had been persecuted. Eliano considered Bruno to be a Master, and told me that he suffered the pains of hell when Bruno died relatively young in 1978 (the very year in which I graduated).

Eliano said that Bruno had also taught him something much more important than any formula: to always be himself and dignified in all circumstances. And in fact Eliano certainly did not lack dignity.

One of the papers that Eliano and I wrote together in QFT was "From SU (2) Gauge Theory to Qubits on the Fuzzy Sphere" in in 2014. I remember that while we were writing the paper, Eliano often repeated that 1 day we should write a book entitled "The mysteries of SU (2)". That book was never written, and now Eliano is gone.

In addition to quantum field theory, Eliano had a great interest in complex systems and artificial intelligence (AI), and was a great expert in neural networks.

He and I wrote a paper together in 2009 on AI at the quantum level. The paper was entitled “Brain-Computer Interfaces and Quantum Robots”.

10 Conclusions

In this paper in memory of Eliano Pessa we wanted to recall the highlights of our cooperation and friendship, pointing out the human qualities of the person even before those of the scientist. We wanted to remember him through the themes most dear to him that involved us in research collaborations. We talked about the definition of “mind” in terms of logical/metalogical modalities, ie classical/quantum logic for ordinary thinking and classical/quantum metalanguage for meta-thought. We have introduced the concepts of metalanguage and object language, their relationships and differences and we have shown that the axiom of identity belongs to the metalanguage, unlike the law of identity, which belongs to the language of the object.

With Eliano we came to the conclusion that a robot can never acquire self-awareness, demonstrating that while in a classical metalanguage the axiom of identity is absolute, in a quantum metalanguage it is probabilistic and above all it is in the quantum case, where the “ non-algorithmic side “of the human mind seems to be the insurmountable boundary for a robot.

What we call the “pillars” of the human mind, which distinguish it from a robot, are: Tarski’s truth predicate, the axiom of identity and the rule of cut, all three belonging to the metalanguage. We have suggested that, in the quantum case, during the programming process, the programmer’s mind and the quantum robot might get entangled and we have compiled some recent discoveries in quantum epigenetics and related them to a new non-invasive approach to the Brain-Computer-Interface based on quantum metalanguage and on a theoretical architecture of quantum cyborgs.

These pioneering concepts will take a few decades of work to implement, but like all frontier technologies they could lend themselves to doing good for humanity while at the same time being misused for the purposes of domination and power. The hope is that good will prevail, and in our opinion this is possible only if humanity manages to make the best use of the gift of metalanguage, where its greatness lies. And by greatness we mean understanding, empathy and sharing, all qualities that machines do not have. People who use metalanguage little, let themselves be dominated by reason and logic, On the other hand, people who don’t know they have a metalanguage or don’t know how to use it are confused and at the mercy of events. Finally, people who use metalanguage for evil have realized, even without knowing where it comes from, that they have a power, which can be used above all on the second category, that of confused humanity. Therefore, metalanguage, while being the highest way of thinking, does not deprive us of free will, rather it is what gives it to us. It is not up to us to choose the destiny of man but we cannot in any case stop a scientific progress that proceeds unstoppable also through the intuition of many researchers and pioneers such as Eliano Pessa was.

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