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Comment

A change of paradigm in cognitive neurosciences
Comment on: "Dissipation of 'dark energy' by cortex in knowledge retrieval"
by Capolupo, Freeman and Vitiello

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"Brains are thermodynamic systems that use chemical energy to construct knowledge from information" [1]. This challenging statement, posed at the beginning of the review we are commenting, requires a systematic justification of the relationship among "energy", "information", and "knowledge" it affirms. We want to offer some hints in this direction.

The core of the approach here presented consist in applying the dissipative QFT algebraic formalism for modeling W. J. Freeman's experimental discoveries of the long-range correlation waves observed in brain dynamics, modulated in amplitude and/or in frequency, by the "active engagement" of a brain with its environment during cognitive, *intentional acts* [2,3,4]. Effectively, only the long-range correlations, which propagate in real-time along wide areas of the brain because of the purely informational nature of their quantum constituents, the Nambu-Goldstone (NG) bosons – that are massless like photons (=gauge bosons), but do not mediate like them the energy interactions, rather the *modalities* of such interactions – can offer a suitable dynamical basis of an intentional act, always involving the simultaneous interaction among emotional, sensory and motor neural components, located in very far areas of the brain. So, differently from gauge bosons, the NG bosons vanish when the coherent state of matter they organize disappear (e.g., phonons in crystals), since there is no energy conservation principle they must satisfy. They thus manifest themselves macroscopically as non-intersecting "chaotic" trajectories, that constitutes also the dynamic "texture" of *long-term memory* phenomena, and that cannot be explained in terms of the usual axon-synaptic networking, too slow and too limited in space and time, for giving an effective explanation of such requirements [5,6]

So, the reference to the intentional approach in cognitive neuroscience, opens the possibility of using *modal logic* (ML) as the proper formal tool for a rigorous, systematic enquiry between cognition and brain computation, according to the QFT approach. In fact, it is well established in formal logic, since almost one century [7], that the so-called *belief statements* (or "first (singular/plural) person statements" of the form: "I/we believe that…"), typical of the intentional approach to the cognitive science, cannot be analyzed in terms of the *extensional, mathematical logic*. They are to be analyzed in terms of the *intensional* (with "s"), *philosophical logics* (e.g., "alethic", "epistemic", "deontic" logics), all *interpretations* (intensional models) of the common axioms of the modal syntax [8,9]. Since the 80's of the last century, however, the growing interest for ML in theoretical computer science depends on the demonstration that it is possible to give also an *algebraic interpretation* of ML, overall of S. Kripke's *relational semantics*, based on the notion of "frame" [10,11]. In this way, ML can be defined as the common syntax of the interdisciplinary dialogue between the humanistic (intensional) and the scientific (extensional) disciplines.

Particularly, the ML can be defined as the proper logic of the *co-algebras* [12], that has a well-established application in the mathematical formalism both of QM and QFT, and directly in the "mirroring" between NG quanta condensates A (algebra) and $\tilde{A}$ (co-algebra) illustrated in Sect. IA and in Appendix B of the review we are commenting, where the number N of condensed A and $\tilde{A}$ couples acts as a code labeling these states (for a synthesis, see [13]).

This last remark about coding, opens the way to the ML interpretation of such an algebraic QFT formalism, and hence, in perspective, to an original "natural computation" approach to quantum computing, based not on the "decoherence of the wave function", like in QM, but on the "input driven coherentization of the quantum vacuum". In fact, as I demonstrated elsewhere [14], it is possible to define a modal calculus of relations of which, by an iterated application of the simplest Euclidean relation $\langle(u\mathrm{R}v \wedge u\mathrm{R}w)\rightarrow v\mathrm{R}w\rangle$, it is possible to obtain a *transitive, reflexive* and *symmetrical* relation (i.e., a logical equivalence) between the second two's, starting from the transitive and serial, never symmetrical (i.e., semantically, only "causal") relation of the first one with each of them. That is:

For $\langle\forall u,v,w\ (u\mathrm{R}v \wedge u\mathrm{R}w) \rightarrow v\mathrm{R}w\rangle$; hence, for seriality, $\langle\forall u,v\ (u\mathrm{R}v \rightarrow v\mathrm{R}v\rangle$; finally, $\langle\forall u,v,w\ (u\mathrm{R}v \wedge u\mathrm{R}w) \rightarrow (v\mathrm{R}w \wedge w\mathrm{R}v \wedge v\mathrm{R}v \wedge w\mathrm{R}w)\rangle$. From the logical standpoint, such a procedure exemplifies the *naturalistic* formal ontology solution, based on the modal system **KD45,** of the reference problem, in which the equivalence (identity) relation between an argument and its predicate characterizing any definite description connoting a rigid designator (e.g., "Aristotle is *the* Philosopher", as distinguished from the generic description "Aristotle is *a* philosopher") is obtained by a procedure of "double saturation" between them, causally driven by the input. Of such a double saturation, the doubling of the NG quanta just discussed constitutes evidently its algebraic modeling. Effectively, the input, by determining the partial domain of the unary predicate (i.e., the unitary non-equivalent coherence domain) A, of which it is destined to become the only, not-separable argument, as its entangled double $\tilde{A}$, at the same time *labels* such a unary predicative relation in an *intrinsic, non-arbitrary* way, that Kripke's modal theory of reference and truth [15] cannot have.

This opens the way to the development of a QFT based approach to natural computation, in which the principles here discussed ought to manifest all their effectiveness.

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