Uniwersytet
Kardynała Stefana Wyszyńskiego
w Warszawie

Towards a Contemporary Ontology

The New Dual Paradigm in Natural Sciences: Part I

Module 7: Universal Coalgebra and the Interpretation of QFT Systems as STS

Course WI-FI-BASTI1

2014/15

Introduction

Module 6: “The DDF Principle of QFT, its Cosmological Relevance and Its Ontological Interpretation”

Course modules

Modules	Topic	Suggested Readings
	SECTION ONE	
0.	*Introduction and Course Overview*	
1.	The Birth of Modern Science	Refs.: **1**, chs. 0, 1, 2.
2.	The Question of Truth in Modern Science	Refs.: **1,** chs. 3, 4.
	SECTION TWO	
3.	The Information Theoretic Interpretation of QM	Refs.: **4-10**.
4.	QFT interpretation as 'Second Quantization' and the Physics of the Condensed Matter	Refs.: **11**, pp. vi-xii, 1-35, 137-178; **12; 13**.
	SECTION THREE	
5.	The (Co)Algebraic Interpretation of QFT as q-deformed Hopf Algebra / Coalgebra	Refs.: **11,** pp. 131-185; **14**.
6.	The DDF Principle of QFT, its Cosmological Relevance and Its Ontological Interpretation	Refs.: **14-19**; **1**, ch. 5.
	SECTION FOUR	
7.	Universal Coalgebra and the Interpretation of QFT Systems as STS	Refs.: **16**; **20**
8.	*Conclusions*	

Bibliography

Bibliography of the Module 7

Bibliography

- **Main References**:
  - G. BASTI, *QFT: An Evolutionary Interpretation Of Nature From Cosmology To Neuroscience* [Lecture Notes:attached].
  - G. BASTI, *Some principles for a QFT optical computing*, 2014b (draft) [attached].
- **Other References**:

1. A. CAPOLUPO, W. FREEMAN, G. VITIELLO, “Dissipation of 'dark energy' by cortex in knowledge retrieval”, *Phys. Of Life Review,* 10(2013), pp. 85-94 [attached]
2. G. BASTI, ”Dissipation of 'dark energy' by cortex in knowledge retrieval”, *Phys. Of Life Review,* 10(2013), pp. 97-98 [attached]
3. G. VITIELLO, *My double unveiled. The dissipative quantum model of the brain,* John Benjamins Publ., Amsterdam, 2002 [attached]

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4. J. RUTTEN, “Universal coalgebra: a theory of systems”, *Theoretical computer science,* 249,1(2000), pp. 3-80 [attached].

5. G. BASTI, “The quantum field theory (QFT) in fundamental physics and the semantic information content and measure in cognitive science”. In: M. Bishop *(Ed), Proceedings of the AISB-50 Convention, Symposium on :"Representation and Reality. Humans, Animals and Machines", 1-4 April 2014, Goldsmith - University of London, UK.* (Accepted for Refereed Publication) [attached].

Module 7

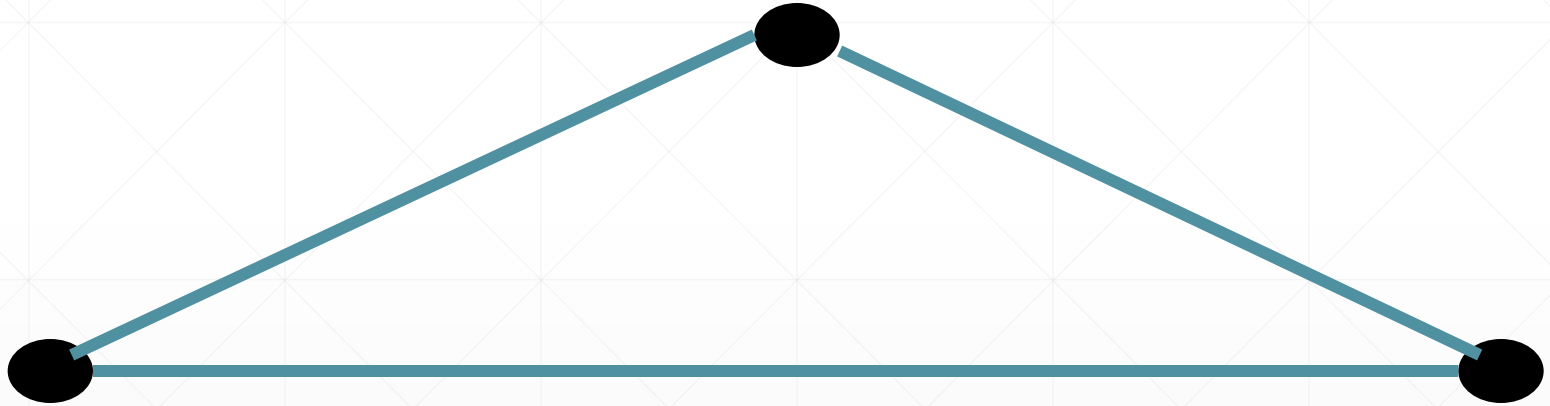
“Universal Coalgebra and the Interpretation of QFT Systems as STS”

From philosophy, to mind science the AI beginning

- **Informatics: extensional** logic/mathematical recursive calculation can be implemented in an **isomorphic way** into a modification of a physical **linear activation circuit** (and/or in an algebraic **transition probability matrix** ((11→1;10→0;01→0;00→0)≡p∧q)*;* (11→1;10→1;01→1;00→0)≡p∨q*;*).
- **Cognitive neurosciences:** to each mental intentional operation corresponds a neural array activation (at microscopic, mesoscopic and macroscopic level) + the (intensional /extensional) logical process compatible with our cognitive modeling of the intentional operations of the acting subject
  - Fulfilling of the modern science revolution: **Galileian method (mathematical+experimental)** extended to study knowledge against Cartesian separation between *res cogitans – res extensa*.
  - Study of mind no longer object of the only philosophy (epistemology and metaphysics) but also of natural and logical sciences (neurophysiology, psychology, informatics → cognitive sciences).

CS Triangle: Conscious *vs.* Neural & Computational

Conscious →Intentional *I-talk*
→ Intensional Logic

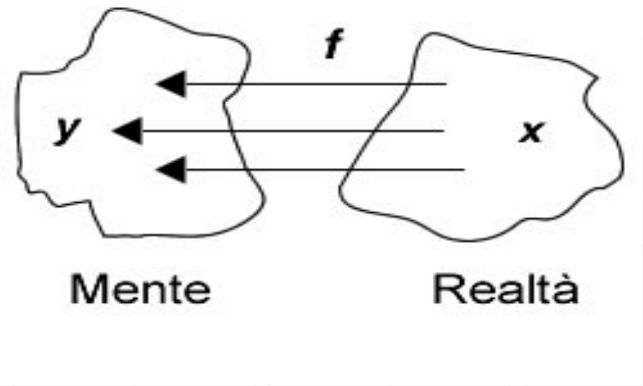


Computational /Simulatory
→ Extensional/Intensional Logic

Neural → Observational
→ Extensional Logic

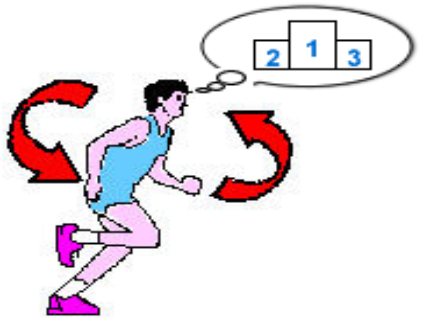
Representational *vs.* Intentional

- **CS development:** from representational and extensional to intentional and intensional.
- **Representational approach:** knowledge as representation (in set theory sense), i.e., functional correspondence environment-brain (→ human mind is **passive**: symbols pre-constituted by evolution and culture: truth as *aequatio,* functional identity satisfaction*: y* = f(*x*)) → **functionalism**



Intentional *vs.* Representational

- **Intentional approach:** knowledge as self-modification (*actio immanens*) of the dispositional states to action of the organism toward the environment in order to pursuit a goal.

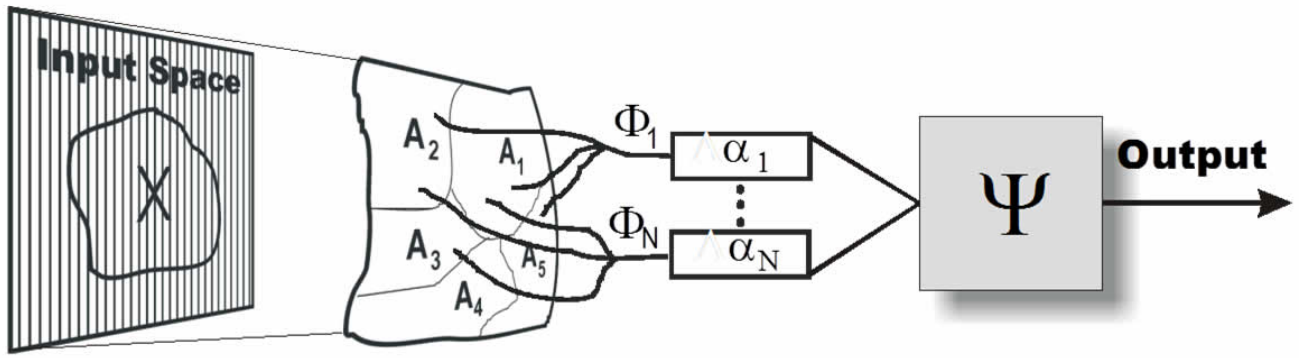


Azione immanente

  - **Truth as *ad-aequatio*,** modification of dynamic/inductive categories intended as **dispositions to action (virtual forms** or *habits)* by which assimilating ourselves to reality for the “maximum grip” to it.
  - → Human mind is **active**. Only in a secundary way “calculates” on symbols already constituted (*secundary reflection, reasoning,* representational *thought),* but primarily it is continuously (re-)constituting them on the outer reality to satisfy human “rational instinct to truth” (*first reflection, intellect , intentional thinking)*.

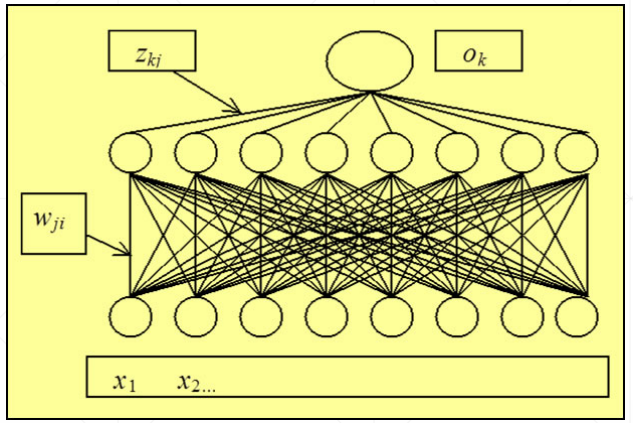
The problem of neural network simulation of parallel brain computing

- In a famous book, *Perceptrons,* published in its first edition on 1969 at MIT, M. Minsky and S. Papert (the founders of Medialab at MIT) demonstrated that it is impossible to implement a parallel neural network able to simulate brain computing as fa as mathematics is founded on ZFC set theory and its second order semantics.
- In other terms, to make **the geometrical perceptron** filter **adequate** to each input it is necessary to solve the ψ-one-in-a-box theorem (each disjoint subset of the filter on which the support of the functions calculated by the perceptron is defined must contain at least one point of the input set, for each different case). Because the filter so defined is a **choice set of the input** it depends on the **choice axiom of ZFC** and hence it cannot be calculated, at least till mathematics is founded on ZFC. I.e., the perceptron require **a supervisor looking at the whole input and defining the adequate filter (a second order device: the programmer) → no automatic parallel computing (in late 80's → no stellar shield).**

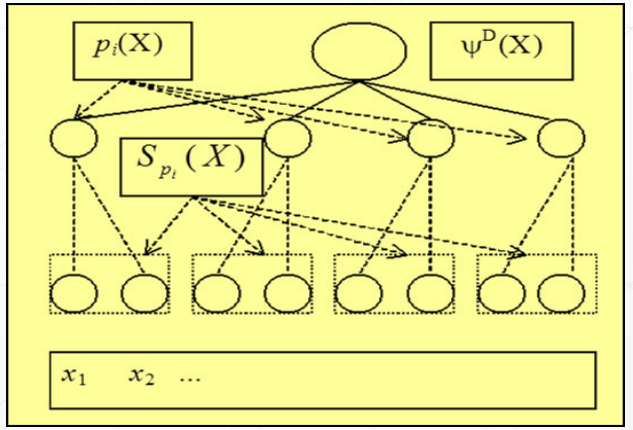


The false and the possible solution of the problem

- **The back-propagation algorithm**



- **The dynamic perceptron**



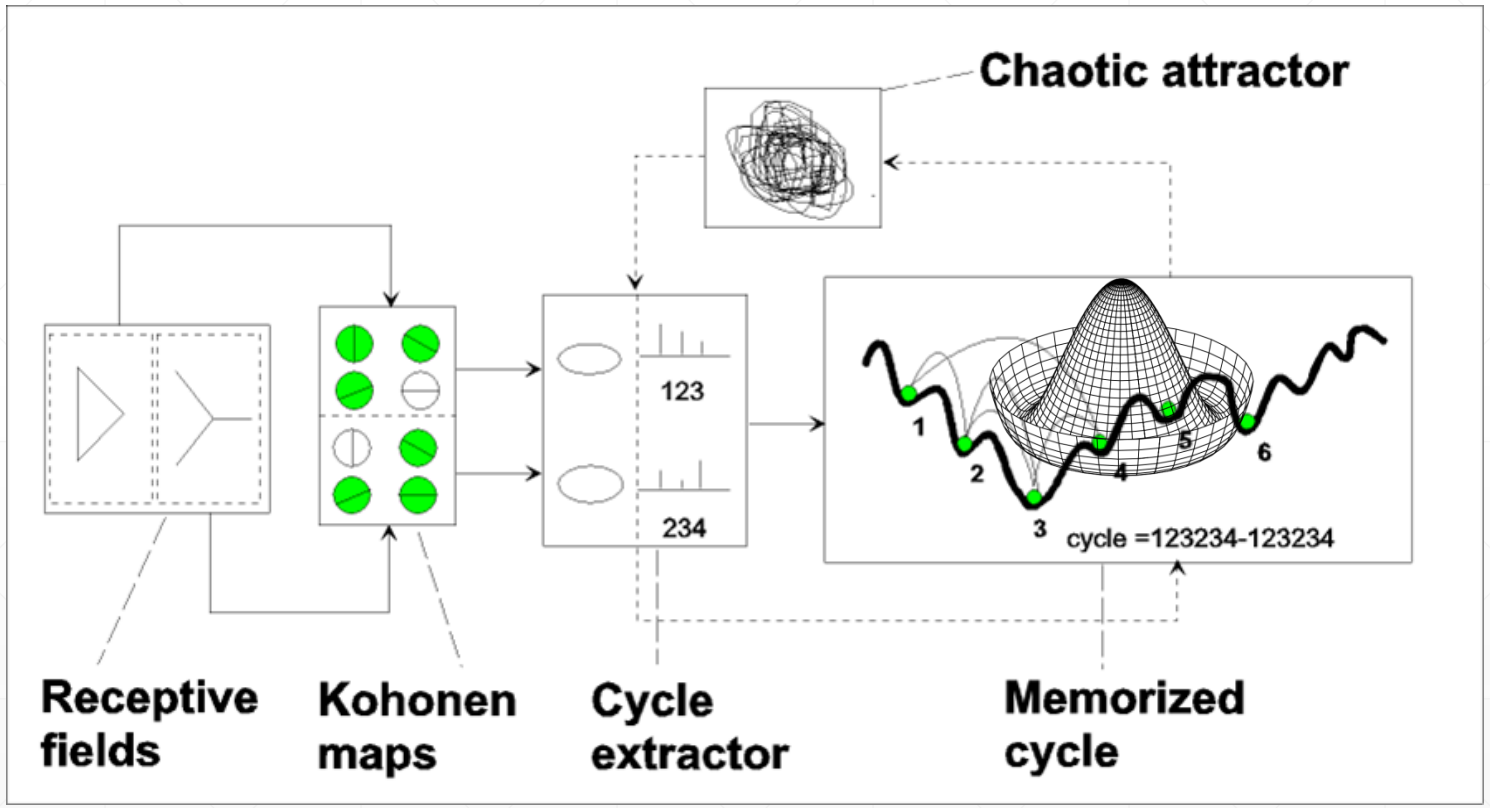
The background I

- As Perrone and myself emphasized in several papers on the physical basis of intentionality (Basti & Perrone, 1995; Basti & Perrone, 2001; Basti & Perrone, 2002; Basti, 2009), only **the long-range correlations**, which propagate in real-time along wide areas of the brain, and manifest themselves as **aperiodic "chaotic" oscillations**, can offer **a valid dynamical basis of an intentional act**, always involving **the simultaneous interaction among emotional, sensory and motor components**, located in very far areas of the brain.
- Such a coordination, that constitutes also the dynamic "texture" of **long-term memory** phenomena, **cannot be explained** in terms of the usual axon-synaptic networking, too slow and too limited in space and time, for giving a suitable explanation of this requirement.

The background II

- On the other hand, Walter J. Freeman and his collaborators, during more than forty years of experimental research by the Neurophysiology Lab at the Dept. of Molecular and Cell Biology of the University of California at Berkeley, not only shared **our same theoretical convictions**, but **observed, measured and modelled this type of dynamic phenomena** in mammalian and human brains during intentional behaviours.
- The huge amount of such an experimental evidence found, during the last ten years, **its proper physical-mathematical modelling** in the **QFT interpretation of biological, condensed matter dynamics** of Vitiello and his collaborators, **applied to neural field many body dynamics,** so to justify the publication during the last years of several joint papers on these topics (see, for a synthesis, (Freeman & Vitiello, 2006; Freeman & Vitiello, 2008)).
- The trajectories among different phases of a QFT systems are indeed **chaotic trajectories** (Vitiello 2002).

Dynamic percpetron scheme



The background III

- To sum up (Vitiello G., 2009), Freeman and his group used several **advanced brain imaging techniques** such as multi-electrode EEG, electro-corticograms (ECoG), and magneto-encephalogram (MEG) for studying what neurophysiologists generally consider as the **background activity** of the brain, often filtering it as “noise” with respect to the usual axon-synaptic activity of neurons, they are exclusively interested in.
- By studying these data with computational tools of signal analysis to which physicists, differently from neurophysiologists, are acquainted, they discovered **the massive presence of patterns of AM/FM phase-locked oscillations**. They are intermittently present in resting and/or awake subjects, as well as in the same subject actively engaged in cognitive tasks, requiring interaction with the environment.
- In this way, we can describe them as features of the **background activity of brains**, modulated in amplitude and/or in frequency by **the “active engagement” of a brain with its surround**. These “wave packets” extend over **coherence domains** covering **much of the hemisphere in rabbits and cats** (Freeman W. J., 2004a; 2004b; 2005; 2006), and regions of linear size of **about 19 cm** in human cortex (Freeman, Burke, Holmes, & Vanhatalo, 2003), with near zero phase-dispersion (Freeman , Ga'al, & Jornten, 2003). **Synchronized oscillations** of large scale neuron arrays in the β and γ ranges are observed by MEG imaging in the resting state and in the motor-task related states of the human brain (Freeman & Rogers, 2003).

The problem of a neural field theory and intentionality (see Vitiello, *My double unveiled,* 2002, p. 88)[attached]

- For a long time, Lashley's experimental work was suggesting that "masses of excitations ... within **general fields of activity**, without regard to particular nerve cells" (Lashley 1942; Pribram 1991) were involved in the determination of behavior.
  - Historically we have to remember that Lashley evidence was used by the supporters of the ***Gestalttheorie*** during 40's of last cent. (W. Koehler, K. Lewin, M. Wertheimer) against the **associationism hypothesis** in psychology of J. Watson **behaviorism.**
- While the activity of the **single neuron is experimentally** observed in form of **discrete and stochastic pulse trains and point processes**, the **macroscopic activity of large assembly of neurons** appears to be **spatially coherent** and **highly structured in phase and amplitude** (Freeman 1996, 2000).
- Lashley's question: **"What sort of nervous organization might be capable of responding to a pattern of excitation without limited, specialized paths of conduction?"** did of course not exclude that *also* single neurons and paths of neurons were involved in the brain activity.
- This problem is especially evident when we are asking about the neural basis of intentionality where this spatially unlimited coherent neural patterns of activity are involving **limbic system structures** and **motor/sensory cortices** distant million of synapses from each other.
- Roughly speaking, given that the average neuronal response is of the order $\approx 10^{-1}$sec., and that the number of seconds per year is $\approx 10^{6}$ sec., for a linear pulse transmission through millions of neurons, a transmission time of $\approx 10^{5}$ sec. would be necessary, i.e., **some months!,** while a perceptual intentional state is $\approx 10^{-1}$sec., i.e., **in real time!** Only QFT entanglement at the **macroscopic level** of condensed matter dynamics can «solve the mistery».

Dynamic neural fields of intentional behavior

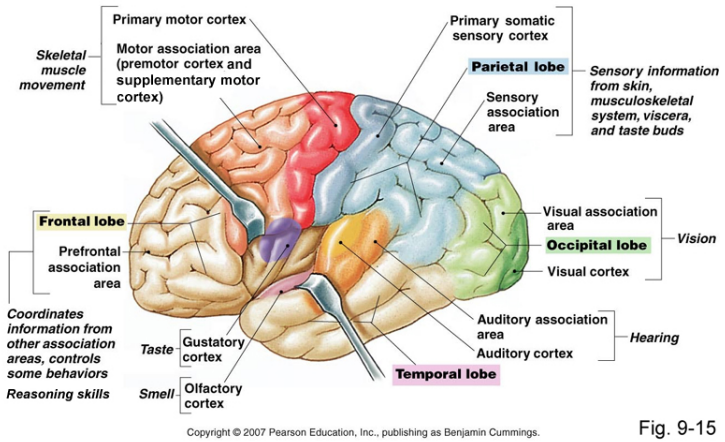
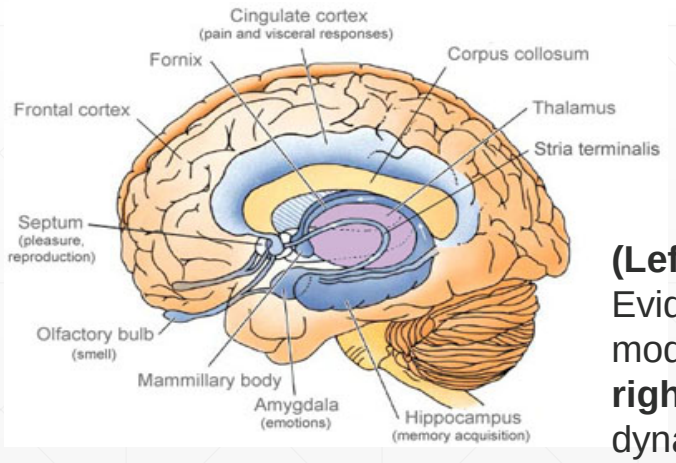
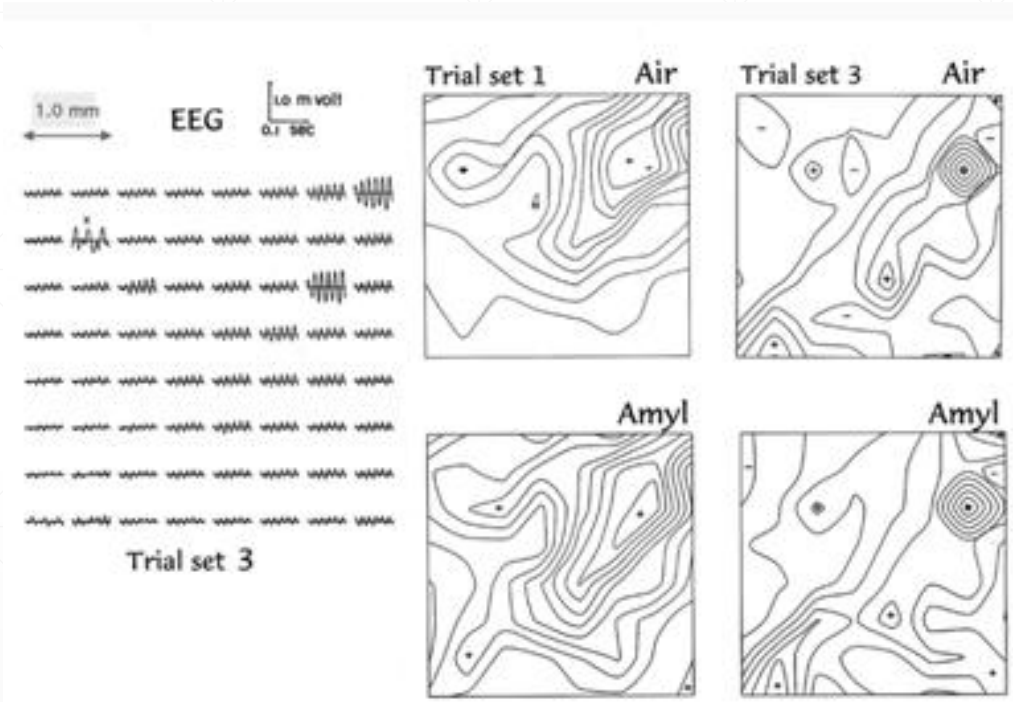


Fig. 9-15





(Left). Schematic representation of human cortex (top) and limbic system (down). **(Right: left).** Evidence of the intentional behavior of olfactory bulb: the same olfactory stimulus induces a modulation in amplitude (top) when the cat is hungry, and no modulation when it is full; **(Right: right).** Dynamic attractors (closed curves: coherent states) in the overall unstable brain field dynamics related with intentional pattern recognition. Their occurrency is of the order of $\approx 10^{-1}$sec.!

Descriptive account of QFT neural field dynamics I

1. Generally, in a dissipative (non-equilibrium) quantum system, there are (in principle) **infinitely many quantum vacuum's (ground or zero-energy) states**, on each of which a **whole set of non-zero energy states** (or "state spaces" or "representation states") can be built.

2. Each input triggers one possible irreversible time-evolution of the system, by inducing **a "symmetry breakdown" in one quantum vacuum**, i.e., by inducing in it an ordered state, a coherent behavior, effectively **"freezing" some possible degrees of freedom of the constituting elements behaviors** (e.g., by "constraining" them to oscillate on a given frequency), at the same time "labeling" it as the coherent state induced by that input, as **an "unitary non-equivalent state"** of the system dynamics.

   - In fact, such a coherent state persists in time **as a ground state** (in biological matter, DWQ are not energetic bosons, are Goldstone bosons) **as a specific "long-term" memory state** as long as, of course, the brain **is coupled with its environment**. On the other hand, a brain no longer coupled with its environment is either in a pathological state, or it is directly dead.

Descriptive account of QFT neural field dynamics II

3. **At this point the DDF principle emerges** as **a both physical and mathematical necessity of the model**. Physical, because a dissipative system, even though in non-equilibrium, **must anyway satisfy the *energy balance***. **Mathematical, because the 0 energy balance requires a "doubling of the system degrees of freedom".** The *doubled* degrees of freedom, labeled ***Ã,*** (the tilde NG quanta ***Ã*** labelling the environment degrees of freedom**,** where the non-tilde NG quanta ***A*** label the brain degrees of freedom), thus **represent the environment to which the brain is coupled**. The environment (state) is thus represented as the **"time-reversed *double*"** of the brain (state) on which it is impinging. The environment is thus "modeled on the brain", according to the finite set of degrees of freedom the environment itself elicited (entangled). Anyway, **which are the degrees of freedom among the infinitely many available** (the UIR's of Haag's theorem in QFT) to be elicited, for that input depends on the brain itself that, for this reason, is effectively a ***self-organizing*** **system,** as far as "living", i.e. entangled with its environment.

- Of course, the point 3 represents the essential idea of the "algebra doubling" (algebra/co-algebra dual equivalence) formalism, constituting the mathematical core of the dissipative QFT model of brain.

The proper of QFT as to other QM interpretations of brain dynamics

- **QFT** approach is thus very different from other interpretations of cognitive neuroscience **based on QM**, **like Penrose's *Shadows of mind*** one, in which the quantum effects occur only at the **microscopic** level of **microtubule structures** in neurons.
- On the contrary, in **QFT**, the effects of quantum events at **microscopic level,** because based on large correlations (phase coherence domains) with an intrinsic **change of scale,** display themselves as ***macroscopic quantum states,*** due to the *coherence* of the correlation modes.
- This makes possible that the interaction between such a mechanism and the electrochemical activity of neurons and synapses, observed by neurophysiologists as the first response to the external stimuli, **occurs effectively *only at the macroscopic level*,** as the relationship between the **background activity (memory)** and its **ongoing activity (synapses),** in the global interaction between the brain and its environment.

QFT interpretation as modeling the chaotic behavior of brain dynamics

- Another success of the dissipative QFT model is that **the irreversible time evolution** because of the **dissipative condition** of each "unitary non-equivalent coherent state" (each coherent state is constituted of a brain-environment "doubled, "entangled", non-separable state) the trajectories among them can be characterized macroscopically **as an *input-labelled* chaotic trajectory**, in the **brain-environment phase space**, as it was experimentally observed.
- I.e., they are trajectories, in the **infinite limit**:
  - i) **bounded** and never intersecting with itself;
  - ii) **non intersecting with others** for different initial conditions;
  - iii) **diverging in time** also for small differences in the initial conditions.
- On the other hand, **in the finite conditions of real systems**, **the presence of noise** and other constraining conditions make possible the phenomena of the **"chaotic itinerancy**" among different attractors, the **fusion of attractors and/or of chaotic trajectories** differing for only few degrees of freedom, and other phenomena **of "associative memories".** The real dynamics so lives **in a continuous interplay between "noise" and "chaos**" for which Freeman invented the neologism of **"stochastic chaos**" for characterizing the dissipative QFT dynamics of the brain.

QFT model of brain dynamics and the intentional notion of the «extended mind»

- Finally, because QFT coherent states are “entangled states” between tilde (environment) and non-tilde (brain) DWQ’s, it is evident that also this approach supports **the localization of mind** and of its logical machinery not “inside” the brain, but **in the dual (energy/information) interplay between the brain and its environment** (Vitiello G. , 2004), like all the approaches based **on the intentional and not representational theory of mind,** i.e. the so-called theory of **the extended mind** (Basti & Perrone, 2001; Basti, 2009; Bateson, 2002; Marturana & Varela, 1980; Clark, 2008) (Noë, 2009). This last remark opens the way to an **ontologica**l and hence **logical** and **epistemological** interpretation of the DDF scheme.

- The notion of the «soul as containing the body» is indeed proper of **Aquinas ontological theory of the mind-body problem**, as well as the the ontological core of his **epistemological and logical theory of *adaequatio intellectus et rei*,** as we discuss in the Section 3 of this course.

Multivocal notion of information

- The word ‘information’ has been given different meanings by various writers in the general field of information theory. It is likely that at least a number of these will prove to be useful in certain applications to deserve further study and permanent recognition. It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of the general field (Shannon 1950, p.80).

Classical Semantic Information (CSI)

- Bar-Hillel and Carnap built **CSI** around a monadic predicate language. The number of possible worlds is calculated accordingly.
- Where there are *n* individual constants (standing for *n* individuals) and *m* primitive monadic predicates, the number of atomic sentences will be *nm*, the number of possible worlds 2^{nm}, and the number of "*Q*-predicators" 2^{m}
  - (*Q*-predicators are individuations of possible types of objects given a conjunction of predicates whereby each primitive predicate occurs either negated or un-negated (but not both)).
- A full sentence of a *Q*-predicator is a *Q*-sentence where a predicate is attached to a term. Hence a possible world is a conjunction of *nQ* sentences because each *Q* sentence describes a possibly existing individual.

CSI and Bar-Hillel & Carnap (BHC) Paradox

- **CSI** (Bar-Hillel and Carnap, *op. cit.*) is *semantic information* precisely because it is concerned with the information contained in the content *of* a sentence, as opposed to the surprise value of receiving a message (which is the subject matter of Shannon and Weaver's (1948) *statistical theory of communication* (**MTC**)).
- CSI approach is based on **Carnap theory of intensional modal logic**. In this theory, given *n* individuals and *m* monadic predicates, we have **2nm possible worlds and 2m Q-predicators**, intended as individuations of possible type of objects, given a conjunction of primitive predicates either un-negated or negated.
- A full sentence of a Qpredicator is a **Q-sentence**, hence **a possible world is a conjunction of n Q-sentences,** as each Q-sentence describes a possible existing individual. Hence a possible world is a conjunction of *nQ* sentences because each *Q* sentence describes a possibly existing individual. The intension of a given sentence is taken to be the set of possible worlds that make true the sentence, i.e., included by the sentence.

The core of the BC Paradox

- This is related with **the notion of *semantic information* in CSI**, here referred as *content* of a declarative sentence *s* and denoted by 'Cont(*s*)'. Of course, **larger** is the sub-set of possible worlds that a sentence is able **to exclude**, richer is its **semantic content**.
- 'Cont(*s*)' is taken thus as the set {*x*} of all possible worlds making *s* false, i.e., the set of all possible worlds that make true $\neg s$:

$$\text{Cont}(s)=_{df} \{x \in W: x \vDash \neg s\}$$

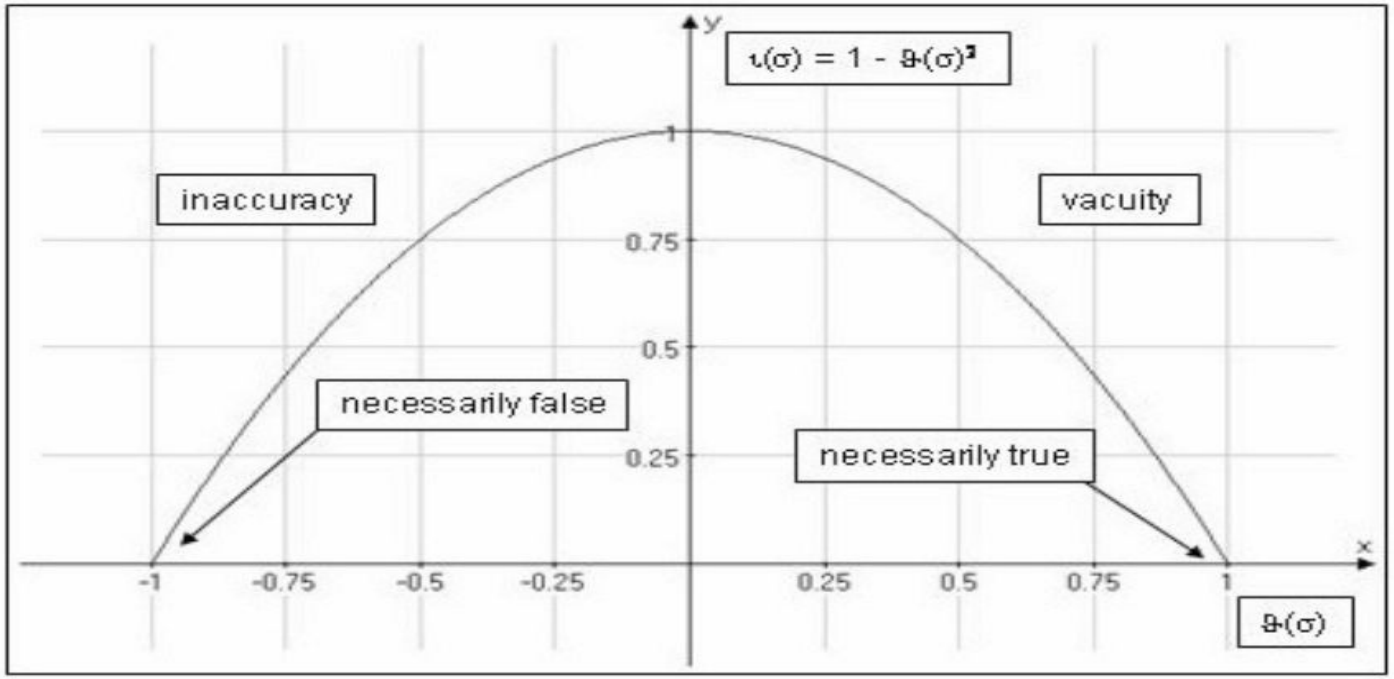
- Where *W* is the set of all possible worlds. So, for any *logically true* sentence $\top$ (=true for all the possible worlds), $\neg\top$ (false) will exclude any possible world:

$$\text{Cont}(\top)=\varnothing$$

- Then, any contradictory sentence $\bot$, $\neg\bot$ will include *any possible world,* that is a first formulation of BCP, i.e.,

$$\textbf{Cont}(\bot)=\boldsymbol{W}$$

Floridi's Wigner function for contingent propositions



θ = distance between the semantic content σ of a sentence *s* and the actual word *w;*

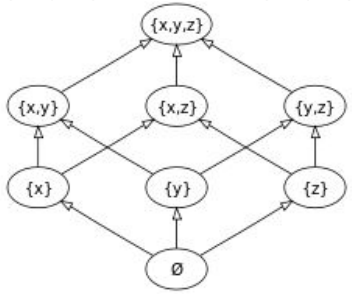
(T) there may *or* may not be some guests for dinner tonight (θ=1); or
(F) There will be *and* not will be guests for dinner tonight (θ=-1); or
(V) there will be *some* guests tonight (θ=0.25); or
(P) there will be *three* guests tonight (θ=0).

Universal algebras/coalgebras

- Following Rutten the three main notions sufficient for defining a Universal Coalgebra as the dual of a Universal Algebra are:
  1. Algebra ≈ Coalgebra (= system)
  2. Algebra homomorphism ≈ Coalgebra homomorphism
  3. Congruence (equivalence/substitution relation) ≈ Bisimulation (observational) equivalence
- On this basis, Rutten reformulated and proved some standard results from Universal Algebra for a large class of coalgebras:
  1. The relation between bisimulation (observation equivalence) and lattices of subcoalgebras
  2. Simple coalgebras and coinduction
  3. Similarity between Birkhoff's variety theorem in algebra and a covariety theorem in coalgebras.

Dual equivalence between q-deformed Hopf algebras/coalgebras and semantic information content

- Any duality q-deformed algebra/coalgebra «depicts» a topology i.e., **a partial ordering,** on the infinite possible sets of the universal coalgebra (QV).



- → Any **entangled state** system/thermal bath correspond to a **lattice of propositions** corresponding to the Wigner distribution of Floridi's theory,
- I.e.:

The theorem (see Basti 2014b)

- **Remark 5.2.1:** Moreover, it follows from **Prop. 5.2** that, given a subset *S* of (the carrier of) a coalgebra A, there is a largest subcoalgebra of A (of which the carrier is) contained in *S*: its universe is given as the union or *join* of all open subsets of *S* ($\vee S$). It also follows from **Prop. 5.2** that the collection of τ_A of open subsets of *A* forms *a complete lattice* under set inclusion. Hence, given a subset *S* of *A*, there is an open set $U \subseteq A$ which is the *meet* ($\wedge S$) of the collection In a partially ordered set (poset) *P*, the *join* and *meet* of a subset *S* are respectively the *supremum* (least upper bound) of S, denoted <$\vee S$>, and infimum (greatest lower bound) of S, denoted <$\wedge S$>.