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BRAIN DYNAMICS FOR GOAL-DIRECTED SOCIAL NAVIGATION

A NON-LINEAR STATISTICAL MODEL OF CONSCIOUSNESS

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INTRODUCTION

One of the most important results of neurosciences is the recent finding that the main associative hubs of the brain's cortex compose a gigantic network, the most probable function of which is to regulate, in default of specific tasks, the basic dynamics of the goal-directed social navigation of the self. The intrinsic organization of this resting state *default-reorienting* network reproduces well across subjects and its maturation is relatively independent of specific action-perception cycles of learning; moreover, it is most likely that this gigantic associative network is at the basis of self-consciousness.

This important result opens up new prospects in the theory of mental functioning, and the aim of this work is to show that it is possible to give a first, simplified, model of the complex dynamics which underlies the functioning (or malfunctioning) of this gigantic component of the brain.

This book is a new edition of *Brain dynamics for goal-directed social navigation. A statistical geometric model* (Aracne 2017): in this new revised edition, I try to give, as much as possible, a more concise, clear and systematic exposition of such a complex subject. My attempt is to evidence that some essential features of the complex dynamics of mind, which derives from the intrinsic organisation of the default-reorienting network, are deducible from the theory of bifurcation of critical points of open non-equilibrium non-linear systems.

A hierarchical sequence of states of self-organization of matter, given by *spontaneous symmetry breaking* of a huge population of particles – elementary particles, atoms, molecules… macro-molecules and cells –, each giving the units for a successive more ordered phase, is probably correlated to the increase of the entropy of expanding universe from big bang. Mind and self-consciousness may be considered as an ultimate ordered state of self-organization of matter given by the spontaneous symmetry breaking of a huge population of interacting neurons.

On the one hand, a *butterfly bifurcation model* of the spontaneous breaking of rotational symmetry of a huge population of cortical pyramidal current dipoles, whose reciprocal interaction by fast axonic excitations is regulated by the *basic four neuromodulators* of brainstem, gives three stable ordered macroscopic polarizations of default-reorienting network. These may stage to self-consciousness a meta-representation of the (normal or stressed) dynamics of the possible relations of the Self, Other and Goal Object imagined actants during the goal-directed social navigation of the self.

On the other hand, the spontaneous *breaking of rotational symmetry* of cortical pyramidal neurons – with *given spiking rate* – may give the dynamics of prefrontal and postero-parietal alpha cycles, with opposite phases, and of alpha waves traveling in opposite fronto-parietal directions, both resulting from crucial experiments. It is most likely that these opposite alpha cycles and waves compose the top-down shutter like mechanism of the default-reorienting network, which syncronizes the recruitment of internal (mainly emotional) and external (mainly visuospatial) bottom-up information at a multiplicity of different times.

A limit of the butterfly bifurcation model of default-reorienting network here proposed is that, to disentangle the complex space-time dynamics of cortical pyramidal neurons, I make an *adiabatic approximation* and examine the fast space propagation by reciprocal excitation and the slow time of relaxation of the same neurons separately, providing two different interpretations of their ordered macroscopic polarization. Traveling waves in opposite directions and cycles of relaxation with opposite phases, resulting from the macroscopic polarization of pyramidal neurons, have only one cause, the spontaneous breaking of their rotational symmety. However, two different interpretations, as Landau point bifurcation and as Hopf bifurcation of limit cycles, of only one equation may leave the reader disconcerted and give rise to some difficulties.

In Thom's topological classification of bifurcations with only one order parameter – the macroscopic polarization – there are non compact bifurcations not corresponding to proper phase transitions. I dare to extend the bifurcation model to consider also these non compact bifurcations, despite the difficulty to give a physical interpretation of their singular topology, as this extension may provide the possible dynamics of the *assemblage* (or *disassemblage*), probably gene-regulated, of the hubs of the default-reorienting network.

I employed Matlab for calculations of the figures 2, 4, 6, 14, 17, 18, 19, 23, 24, 26, 27 and 28 of this book.

I am grateful to Alessandro Pesavento, whose critical remarks allowed me to improve the clearness of exposition as regards psychiatric subjects. The responsibility for over-simplifications or errors in any case is mine.

CHAPTER 1

AN INTRINSIC ORGANIZATION OF BRAIN CORTEX: THE DEFAULT-REORIENTING NETWORK

Many recent functional imaging studies (fMRI and PET) and functional connectivity analyses have led many researchers to agree on delineating an intrinsic organization of brain cortex, called the *default mode network*. This network is spontaneously activated in a quiet relaxation state, while the subject, not engaged in any specific external task, is internally focused on tasks such as imagining the viewpoint of others, retrieving autobiographic memory or envisioning future events (Raichle et al. 2001, Fox et al. 2005, Buckner et al. 2008). The default network is composed of two main reciprocally interacting hubs, both belonging to the cortical midline, on which a set of subsystems converges. They are outlined in different colours in Fig. 1 (arrows indicate activation spreading), and are as follows (brackets denote areas regarding which researchers are not entirely in agreement):

i) *medial parieto-temporal hub*, mPPC/PCC-Rsp/(mTC), which includes the medial posteroparietal / posterior cingulate-retrosplenial / medial temporal cortices, with the ventral and dorsal regions of the hub as subsystems;
ii) *medial prefrontal hub*, mPFC/ACC/(insula), which includes the medial prefrontal / anterior cingulate / insula cortices, with the ventral and dorsal regions of the hub as subsystems.

There are also two ventrolateral subsystems belonging to this network:

i') *temporo-parietal junction*, TPJ ≡ IPL/STS, of the inferior parietal lobule with the superior temporal sulcus, which converges on the medial parieto-temporal hub;
ii') *temporo-frontal junction*, TP/(vlPFC), of the lateral temporal cortex, especially the temporal pole TP, with the ventrolateral prefrontal cortex (correlated to the TP by means of the uncinate fascicule), which converges on the medial prefrontal hub.

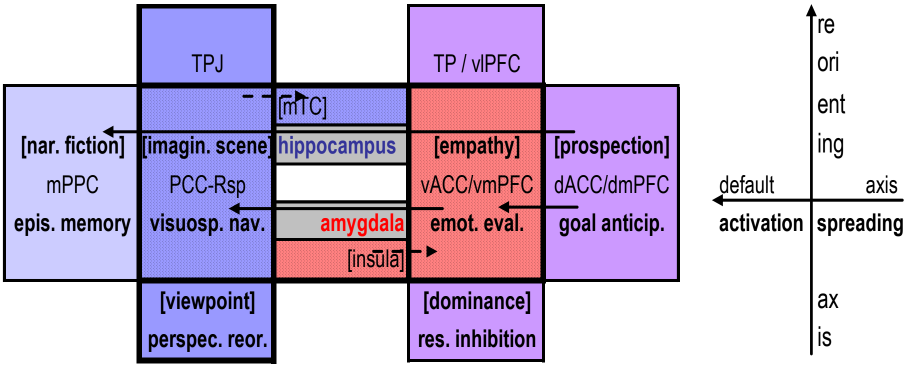

Fig. 1 Diagram of brain's default-reorienting network

Researchers also agree in noting that, when a subject is engaged in a certain external task requiring attention, the hubs of the *medial frontoparietal* default mode network decrease their activity, while the two adjacent hubs of a *dorsolateral frontoparietal* attention mode network increase it, and vice versa. Both brain association networks, the *internally focused* medial and *externally focused* dorsolateral networks, are intrinsically organized: within each, there are areas which are correlated with each other, even in a state of deactivation, by slow (< 0.1 Hz) spontaneous fluctuations in the functional MRI signal; but areas belonging to different networks are anti-correlated with each other. This intrinsic organization of the brain cortex into two gigantic anti-correlated components "provides a critical context in which to understand brain function" (Fox et al. 2005). These systems are the most globally connected regions of the brain, highly involved in coordinating and integrating information throughout it, temporarily coactivating to work (by