Invited Article

Quantum Neurodynamics and the Relation to Conscious Experience

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Abstract
The main function of the brain is to allow adaptation and mentation and any 'explanation' of these functions requires a relation of the neurophysical (brain processes) to the neurophenomenal (experience). In this paper it is argued that such a relation can plausibly be established by applying Bohm's principle of implicate quantum-physical order to the neural state space. In this context, the main role behind neural dynamics is to 'explicate' universal signals into a Cartesian space-time representation and interaction selective neural activities. The diagrammatic principles that help to conceptualize these processes are explained.

Key Words: neural dynamics, brain, quantum physics, Cartesian space-time

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INTRODUCTION

Whereas adaptive brain processes involving synaptic plasticities such as learning and memory have seen a convincing amount of clarification during the recent years of brain science, the conceptually most challenging phenomena such as perception, cognition and emotions remain enigmatic. The last decades of sensory neurobiology have been based on the neuron doctrine stating that i) all sensory information stems from real-time observations of the activity of the organisms own neurons (e.g. Bialek, et al., 1991), ii) the state of neural firing at a given instant of time is a necessary and sufficient condition to explain sensory processes (Barlow, 1972) and iii) neural transformation involves the early segregation or separation of single features belonging to one percept among millions of widely distributed cortical neurons -population coding- (e.g. Knudsen, et al., 1987). What is completely missing however, are explanations how the spatio-temporal variation in the firing rate of a large collection of place-specific neurons is composed into a coherent and unique experience or percept. Although candidate processes such as synchronization of

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firing rates on fine temporal scales have been proposed (Gray, & Singer, 1989; Singer, 1995), the neural equivalent of a sensory 'experience' is still a complete mystery.

Because of this deficit some consens has evolved that it needs an extension of the neuron doctrine into a more broad brain-theory that renders the relation of the neurophysical to the neuro-phenomenal, providing predictions on first-person experiences that are possibly based on physical concepts. More recent approaches have used the notion of quantum physics, involving action orders of 10^{-34} [kg m^2 s^{-1}] (Hameroff & Penrose, 1996; Stapp, 1996; Bernroider et al., 1996; Bernroider, 1997). These views are accompanied by an enduring dispute whether these very small action orders at the atomic scale can be of any significance to the concepts of electrophysiology (Scott, 1996). After all, it is hard to see, how quantum phenomena could effect the propagation of nerve impulses described by the Hodgkin-Huxley model. However, this problem has many shades and there is an increasing list of empirical evidence for the decisive role of local gating charges and electrodynamics at the Planck-scale that puts neural quantum concepts into a new and very promissing frame.

The view of the present work is that a theory dealing with the phenomenon of 'experience' which is intrinsic to the notion of perception, cognition and emotion, is principally incompatible with the traditonal neuron doctrine. Instead these doctrine have to become expanded to account for i) the construction of higher level brain issues from the lowest level above physical significance, ii) non-local interactions of neural systems or states according to quantum properties in physics and iii) a transition from purely physical information states into their underlying phenomenal properties.

DIAGRAMMATICS

Here we look at the universal objective and the observing brain as a continuous connected whole – where both entities become only partly and transiently separated by phase transitions. From an ontological perspective this is in accord with the 'holistic' or 'conceptually monistic' view of brain function (e.g. Pribram, 1991; Winkler, 1997) or 'Mach's principle in perception' (Mogi, 1997). To describe some ideas for short, it needs a 'diagrammatic aid' to visualize the principles. Processes of the present type could be seen from the traditional Cartesian view outlining point events in space-time and available from diagrammatic perturbation theory based on Feynman's diagrams (Figure 1) as discussed previously (Bernroider, et al., 1996).

From Huygen's construction of Feynman graphics (FG) one is led to the opposite view of an enfolded geometric structure proposed by Bohm (1993). Bohm interpretes time in Feynman's graphics as related to an 'implication parameter' that reflects the degree of enfoldment of universal structures. Differences in time are presented by differences of radii of contacting spheres. The laws of temporal evolution of a system or state are implicit in this representation. Points in FGs become centers of spheres, either converging or diverging, with incoming waves decreasing to spheres of zero radius (points) and outgoing waves increasing. The implication parameter is represented by the radius of spheres – converging spheres therefor 'unfold' to a specific space-time point in the FG notion. BGs show the entire space-time trajectory of particles or signals at once – as an unbroken wholeness provided by a succession of contacting spheres.

The view available from Bohm's diagrams very closely reflects the way how a neural dynamic state space in the sense of the present work could be arranged. The dynamic configuration behind it discerns continuous 'brain lines' rather reflecting on discrete state shifts.

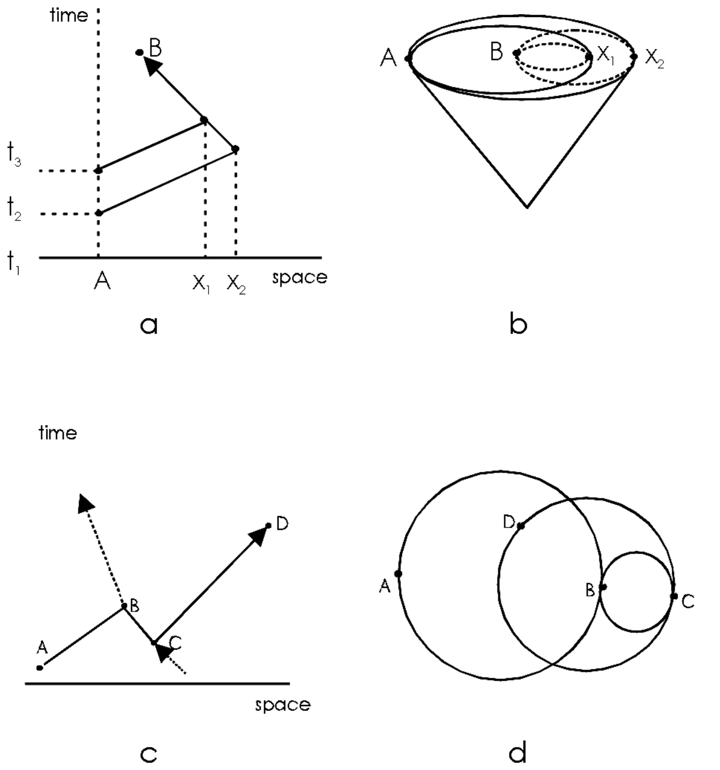

Figure 1. Neural state space presentations using Feynman diagrams (a) and (c) and their Huygen counterparts as Bohm graphics (BG) (b) and (d).
In (a) signals are emitted from source A at times t_2 and t_3 and reflected back onto location B from an intermediate layer X_1 and X_2.
In the paths involve a backward turn in time from B to C. The BG equivalents in (b) and (d) are based on Huygen's principle of a spherical evolution of light signals – here the radii of contacting spheres reflect differences in time as the signal propagates.

UNFOLDING THE NEUROPHYSICAL – OR BOHM'S PRINCIPLE IN EXPERIENCE

To implement the ideas expressed above and put them into practice for brain modelling one needs to address now at least two points: 1) what are the signals and 2) what are the constraints impossed by the brain to exchange these signals. To cut it short, both questions cannot be answered yet with confidence. The signals must be provided by passive and active membrane properties of neurons, but cannot be reduced to the macroscopic exchange of action potentials without violating the drammatic role of dendritic potentials as temporal coincidence detectors and temporal filters (e.g. Pribram, 1991). Organizational constraints on signal exchange may obviously be provided by the brains specific anatomy. However, to identify the decisive aspects of organization is far beyond reach at the very state of art. The view adopted here is in favour of Mogi's idea that the firing of neurons should be seen rather as an interaction-connected activity than a selective response activity (Mogi, 1997). In other words, spiking of neurons does not signal a particular (e.g. sensory) information but it signals the particular 'role' a neuron plays in relation to all other neurons at a given instant of time with respect to a particular situation.

One obvious way to message this role would be to eliminate the 'predisposed' or 'stimulus conditioned' situation of a neural unity – e.g. a single cell. As mentioned above the 'segregation' of information along wide spread neurons is what can be clearly identified from sensory processes. Quite logically the elimination of segregated information implies to focus these signals onto one point in space-time – one point on Feynman's diagram or converging spheres in Bohm's diagram. In the sense of Bohm that is to 'unfold' the brains activity into an 'explicate' order, reducing the implication parameter provided by the radius of Huygen's spheres to a circle with zero extension.

The present theory has led to the implementation of interaction-modulated neural activities unfolding a set of brain states onto a single space-point according to the FG in Figure 1a or the BG equivalent in Figure 1b. The details of this implementation have been reported previously (Bernroider, et al., 1996). The basic modul of this concept is a pair of neurons in close and reciprocal contact (Figure 2a) – signals can go anywhere. It is the emerging arrangement of neurons (the anatomy of a larger set of neurons) that gradually guides the signals propagation into particular paths, an initially diffuse 'network' that self-organizes the exchange of information. The only and basic constraint is provided by the explication onto a single space-point at a given instant of time.

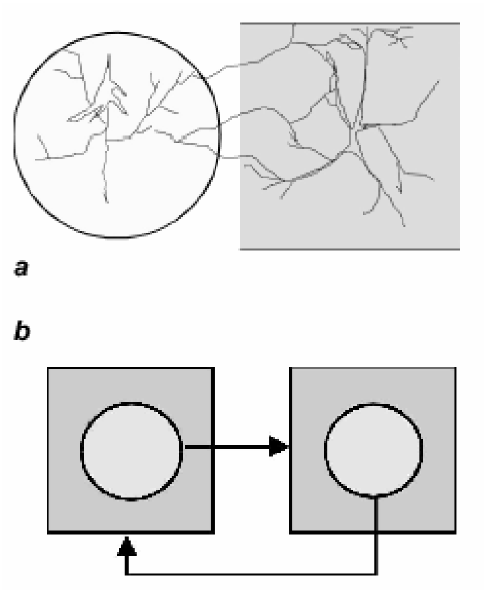

Figure 2

a) the basic modul of a focusing signal concept – the axonal source domain is given spherical – the dendritic target domain is shown square

b) a schematic outline of a reciprocally connected modul with feedforward and recurrent connections

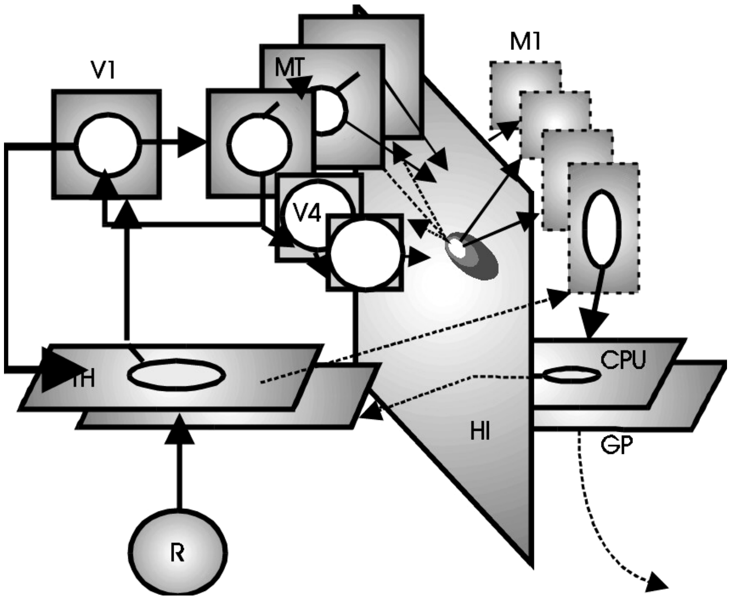

Figure 3 Modellistic reconstruction of major parts of a mammalian forebrain based on the above moduls and using explicating (space-time focusing) arrangements as described in the text.

CONCLUSION

The classical neuron doctrine of a stimulus coding exchange of action potentials among place-coded nerve cells is not compatible with the ‘binding problem’ of segregated features into a single and conscious percept. Instead I adopt a notion that is based on the self-organizing spread of passive and active membrane properties under the constraint of an ‘explicating’, i.e. space-time focusing principle of signal propagation. Neural codes are less response-selective but more ‘interaction-selective’ – focusing of stimulus-caused segregated signals onto single points carries the message behind a neurons role within a large population of engaged cells.

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