Progress in Biophysics and Molecular Biology 130 (2017) 15–25

Contents lists available at ScienceDirect

Progress in Biophysics and Molecular Biology

journal homepage: www.elsevier.com/locate/pbiomolbio

The quantum basis of spatiotemporality in perception and consciousness

Abir U. Igamberdiev [a,*], Nikita E. Shklovskiy-Kordi [b]

[a] Department of Biology, Memorial University of Newfoundland, St. John's, NL A1B 3X9, Canada
[b] National Research Center for Hematology, Moscow, 125167, Russian Federation

ARTICLE INFO

Article history:
Received 1 December 2016
Accepted 16 February 2017
Available online 21 February 2017

Keywords:
Cytoskeleton
Molecular computation
Neuron
Quantum measurement
Spatiotemporality

ABSTRACT

Living systems inhabit the area of the world which is shaped by the predictable space-time of physical objects and forces that can be incorporated into their perception pattern. The process of selecting a "habitable" space-time is the internal quantum measurement in which living systems become embedded into the environment that supports their living state. This means that living organisms choose a coordinate system in which the influence of measurement is minimal. We discuss specific roles of biological macromolecules, in particular of the cytoskeleton, in shaping perception patterns formed in the internal measurement process. Operation of neuron is based on the transmission of signals via cytoskeleton where the digital output is generated that can be decoded through a reflective action of the perceiving agent. It is concluded that the principle of optimality in biology as formulated by Liberman et al. (BioSystems 22, 135–154, 1989) is related to the establishment of spatiotemporal patterns that are maximally predictable and can hold the living state for a prolonged time. This is achieved by the selection of a habitable space approximated to the conditions described by classical physics.

Contents

1. Introduction: quantum principles in biology

The process of spatiotemporal pattern formation that includes perception of signals, morphogenesis and evolutionary phenomena, in biological systems can be analyzed within the framework of quantum measurement (Matsuno, 1995; Igamberdiev, 2004). Matsuno (1996) introduced the concept of internal measurement as a continuous change in pattern probability of the potential field. Detection of the introspective boundary conditions between the internal and external occurs as a local event that takes time for its execution. What is now measuring internally cannot be measured simultaneously, it can be measured only subsequently, therefore the time interval is introduced that keeps the system's internal space according to the quantum Zeno paradox. The internal measurement generally follows the Everett pattern, while the external measurement generates the events that can be better approximated by the Copenhagen interpretation. In fact, both are the

* Corresponding author.
E-mail addresses: igamberdiev@mun.ca (A.U. Igamberdiev), nikitashk@gmail.com (N.E. Shklovskiy-Kordi).

http://dx.doi.org/10.1016/j.pbiomolbio.2017.02.008

extreme cases of decoherence in the consistent history approach. According to Matsuno (1996), the *self-induced* ongoing variation drives internal measurement, while the external measurement owes its driving factor exclusively to the outside observer. "Internal measurement thus incorporates into itself the capacity of generating and producing variations indefinitely. Internal measurement is endogenously generative, while the external counterpart is generative only exogenously" (Matsuno, 1996). The relation of the output of external measurement to the content of the internal measurement process has a sign relation, i.e., the fixed external observation designates the internal process, which is emphasized in the semiotic interpretation of quantum measurement by Christiansen (1985) and reflected in quantum Bayesianism (Asano et al., 2015a).

The quantum principles in biology exhibit themselves at the macroscopic level via the transition to macroscopic times of quantum oscillators and thus to extremely low dissipation of energy during conformational relaxation of biomacromolecules (Igamberdiev, 2004). This time rescaling results in extremely high robustness of biological networks and correspondingly to low actual temperatures of the internal quantum states, within nanokelvin and lower ranges (Igamberdiev, 2004, 2007). In the process of conformational relaxation, biomacromolecules concordantly hold the coherent state and perform mechanical movement (Igamberdiev, 2012). The duration of coherent state and the parameters of physical movement depend on the shape of macromolecules, and stretching them to long distances allows holding the prolonged coherence times and performing long-range spatial movements at the macroscopic scale. This is achieved via assembly of the spatially stretched enzyme complex called cytoskeleton. The mode of action of a single enzyme molecule is magnified to the macroscopic temporal and spatial scales via cytoskeleton. The cytoskeleton structure, called cell state splitter, may control embryo and, in particular, brain morphogenesis (Gordon and Brodland, 1987). While in muscle cells, cytoskeleton serves mainly for the mechanical movement supported by the energy of ATP, in neural cells cytoskeleton performs preferentially the maintenance of the coherent state which is used for digitalization and transmission of perceived signals within neural networks. This is achieved by the transformation of the energy compound ATP to the information (messenger) compound cyclic AMP (cAMP) that transforms the original signal, allowing it to be transmitted through cytoskeleton, and to generate the output resulting in opening or closing of ion channels on the membranes. The formation of cAMP thus represents a buildup of a single information carrier, while the polymerization of ATP and other nucleotides into nucleic acids serves to generate the long-term digital storage and processing of cellular information.

Kineman (2010) introduced the idea that consciousness (and thus perception) might be explained in terms of "space-time selections" within quantum isolated space-time domains not exactly in the sense of Hameroff and Penrose (1996) who claimed the existence of real physical process of "the gravitational collapse", but rather in correspondence with the relational paradigm of Robert Rosen (1991). In this concept, relativity is a continuous form of space-time *isolation* rather than the objective phenomenon of the physical world, and it is realized through the contextual relation between the local and non-local space-time dimensions. The geometry properties of space-time are formed via this self-similar relation, which is established between a non-local domain (a domain defined by imaginary numbers) and locally measurable space-time (as a real number domain). According to Kineman (2012), individual biological systems should be considered as separate relational domains that "rescue and organize their natural autonomy by internalizing and thus isolating entailments from external information".

This view corresponds to the philosophy of space and time arising to Leibniz (see Igamberdiev, 2015). It assumes the existence of dual time reference frames – intrinsic and observational (extrinsic), which was originally proposed by Aristotle in *Physica* (see Igamberdiev, 2007). This geometry in the frames of internal measurement arises as the actual local self-representation mapped from the non-local imaginary space-time dimensions. The relationship between the imaginary Minkowski radial domain and local space-time can be modeled as a relationship between phased time (ict, $i\theta$) and local space-time (d, t). From that relationship an 'intrinsic time' of a system can be calculated, yielding the relationship between the intrinsic time (τ) and the observational time, t. The multiscale differences between intrinsic times and observational times have been originally discussed in the paper (Igamberdiev, 1993), where a high precision of output and correspondingly low dissipation of energy during conformational relaxation of biomacromolecules were explained on the basis of the theory of quantum non-demolition measurements developed by Braginsky et al. (1980). Biological systems expand the difference between the intrinsic time and the observational time (by slowing down of single operations by many orders of magnitude) to conform the principle of optimality (minimum influence of measurement and calculation) (Liberman, 1989). This phenomenon results in the complex observed spatial curvatures of living systems formed during morphogenesis and generated during evolution.

Observability from the quantum mechanical point of view means a possibility to perform multiple quantum measurements in such a way that their results are compatible and can form the pattern which corresponds to our trivial sense of the absolute space-time common to all beings. Thus the challenge to physics is not to resolve the problem of relational versus substantial space-time but to explain how the observable substantial perception of spatiotemporality arises from the set of relations generated by multiple perceptions of individual monads. There is no preferred scale of space-time, and therefore the observed scale of time has only a relational meaning.

The formation of the habitable four-dimensional space-time continuum occurs on the interface of non-local and local domains. It represents the Kantian *a priori* form of perception and its $3 + 1$ D structure corresponds to the optimality of this continuum as satisfying the minimum influence of internal measurement and calculation on the structure of systems inhabiting it. The physical laws in the observed space-time thus have an intentional origin in Husserl's sense. Without considering time, we stay within the frames of pure mathematics. When time is introduced, we sink from the mathematical to the physical world, and in this world physical laws correspond to the limits of computation (Igamberdiev, 2004). Computation has its physical limitation, which belongs to the fact that any calculation action has a price (Liberman, 1989), e.g., the addition of one takes energy, and this energy cannot be reduced to zero values. Computation is related to the basic metamathematical action, which defines the structure of physical world and provides a possibility of its observation, i.e., of the internal activity that detects the rest of the world.

Time appears as a countable parameter of the ordered internal quantum measurement. In fact, quantum measurement itself is not equivalent to time because it does not generate a measurable duration (which itself should be measured). But when an internal description appears inside the system performing internal measurement, memorizing measurement result, then time can be counted and thus this system becomes an internal autonomous clock that distinguishes the past (memory), the present (life), and the future (anticipation model) (Igamberdiev, 2014). "By reason of time we count" (Schopenhauer, 1844). Aristotle in *Physica* defined