Review Article *Open Access*

Journal of Modern Classical Physics & Quantum Neuroscience

ISSN: 3068-4196

DOI: *doi.org/10.63721/25JPQN0123*

Liquid Water as a basic Carrier of Working Memory in Living Things

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Citation: Alexander Shimkevich (2025) Liquid Water as a basic Carrier of Working Memory in Living Things. J.of Mod Phy & Quant Neuroscience 1(3), 1-13.WMJ/JPQN-123

Abstract

Brain functions are inextricably associated with a content of liquid water that plays an active role in communication of cells by receiving and sending vital information to them. One assumes that liquid water is an effective carrier of cognitive functions of living things integrating phonological, visual, and other information of a broad range of sensory signals into working memory encoded as oscillations with different frequencies. Indeed, liquid water in the cerebral tissue is an acceptor of these signals embodied in synchronized proton vibrations in helices of hydrogen bonds with the different number of water molecules. Only such carrier of information can generate collective working memory about "past experience" of microbes using communication capabilities of liquid water in self-organizing colony with high adaptability to environment.

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Submitted: 28.07.2025 **Accepted:** 18.08.2025 **Published:** 26.08.2025

Keywords: Liquid Water, Information Carrier, Living Things, Working Memory, Thoughts, Intentions

Introduction

The term "working memory" (WM) is emerged in the work [1] and used in the 1960s for denoting a short-term memory in the brain as it in a computer [2]. It turned out that WM in living things allows manipulating with stored information in contrast to the short-term memory in computer that can only store information [3, 4]. The working memory manipulates with information for activating living things (breathing, coordinated moving muscles and limbs) and simultaneously for solving affective and cognitive tasks [5, 6]. Somehow or other, this concerns microbes, insects, birds, and mammals including man whose working memory requires a high level of focused attention. These categories are inseparable though WM involves more than just attention, as there is usually some demand for short-term storing the information for its processing as well as specific cognitive operations for this without forgetting what we are doing. The working memory as a temporary storage of information in the brain connects it with other information in helping the brain to record modified information into a long-term storage [7], i.e. the brain is not just processing information, it creates that [8].

As a brain function, the working memory consists of three components [3]: 1) the central executive system for controlling attention, 2) the visual-spatial one for manipulating visual images, and 3) the phonological loop for manipulating speech-based information. This involves an active processing of information with feedback rather than passive storage. Moreover, Baddeley has included a fourth component into this model, the episodic buffer for temporary storing of information from the sensory systems of brain and the long-term memory in the form of a united episodic representation [9]. The modified model is focusing attention on integration of all aspects of information (rather than on individual functioning of the brain informational patterns) in order to make better the executive control of the complex working memory.

One should note that the central executive system directs attention to relevant information and inhibits attention to irrelevant information and actions unrelated to the task, i.e. working memory depends on selective and focused control by the executive attention [7]. Even Drosophila has a span of responses that alternates competing perceptions with an exact temporal alternation structure of attention [10]. Just the attention is the major determinant of a fluid intelligence as ability to reason abstractly in new conditions and for reacting to external signals. In this connection, plants are definitely intelligent living things. Their intelligence is in the capacity to sense the environment, responding to any signal synergistically modified by the all others [11].

Thus, the structured working memory is and attention, and shot-term memory, and perception with cognition and affecting where the last ones have independent information sources and can influence each other so that the cognitive appraisal can enforce emotions [5, 6]. One can identify various cognitive functions or cognitive "domains", responsible for regulation of specific behavior or action. These functions operate synergistically at different hierarchic levels of working memory that allows encoding, to store, to retrieve, and to manipulate information. At the same time, affects with high motivations can narrow the cognitive scope whereas low-motivational affects broaden it [12]. Moreover, the emotions (as a feedback) can serve as a selective retrieval cue for information processing to stimulate a goal-directed activity of any living thing [13, 14].

Though birds and primates seem very different, there is evidence of strong similarities in their mental abilities, particularly in the realm of advanced cognitive processing that is surprising due to the vast difference in sizes and structure of avian and primate brains. Moreover, chimpanzees, gorillas, and orangutans have not some cognitive abilities of jays, crows, ravens, magpies, and parrots [15]. Even insects possessing miniature brain exhibit a sophisticated behavioral repertoire with unexpected cognitive capabilities such as attention modulation and conceptual learning that go beyond of the simple associative learning [16], i.e. a living thing is cognitive on definition, and a life is a process of cognition. This statement is valid for all organisms with and without the nervous system, which does not create cognition but only serves its carrier [17] like liquid water that is informational medium in living things [18].

This paper considers an opportunity of liquid water to be a basic carrier of working memory for living things because water plays an active role in communication of cells with receiving and sending vital information. Accumulated evidence supports the notion that hydration state of brain affects cognitive ability and mood. Severe dehydration causes cognitive deficits in working memory and visual perceptual abilities [19].

Distributed Working Memory

Attention is a basic biological component given us at birth. One can best describe it as the stable concentration of cognitive resources of working memory on given information with filtering the extraneous one. Attention is a basic function that often is a precursor to all other functions (behavioral or cognitive) [20]. Therefore, attention can regulate intensity of information signals from sensory neurons that compete for access to working memory, i.e. the selectivity of attention maintains a coherent course of action in competition between mutually exclusive information streams. On the other hand, sensory signals as positive emotions can strongly affect the attention due to using cognitive resources and can impede filtering out distractions so the momentary content of working memory will influence the selection of new information for long-term storing [21]. At the same time, we distinguish actions that are in our attention from those that we do not attend. For example, breathing is not in our attention because that occurs naturally. We do not pay attention to riding a bicycle because, though we learnt how one is to ride, it has become our second nature.

Thus, attention, learning, and working memory are highly related cognitive functions. Skills involving motor activation and procedural learning stored in long-term memory can access to facilitate ongoing cognitive operations without focusing attention. However, when new information is processed, working memory is active process, which provides the base for distributed associative memory involving of rehearsal and attention executive control as a short-term activation (plasticity) of special neurons distributed over brain with their phasic modifications that are different from short sensory activation and from changes in long-term memory [7].

In neuronal ensembles of brain, synchronized activity of large number of neurons rises to macroscopic oscillations in an electroencephalogram (EEG). Such oscillatory activity of neurons in brain arises during sensory and cognitive processes from feedback between them, which results in the synchronization of their oscillations in different frequency bands: delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (13–30 Hz), and gamma (30–150 Hz) linked to cognitive processing in consciousness.

The studies have shown that many cognitive functions of groups of specialized neurons have a genetically predetermined role in performing these functions and other neurons cannot substitute of them in this cognitive activity [22]. Therefore, we solve a cognitive task by activation of a set of neuronal areas in the brain identified by specific mental operations in working memory. These operations are in local brain areas because a brain damage in there produces the corresponding behavioral effect. However, the remarkable resistance of cognitive functions to such damage allows thinking that many different neuronal areas can support the same function [23].

For performing an integrated task, the brain organizes a distributed network of such areas but each mental operation works locally with controlling by the executive attention that synchronizes the activity of all these areas [24]. In this, the input attention and central attention operate at different times of processing and at different brain areas. This supports to the existence of many attention processes continuously distributed on a neuronal substrate [25, 26]. Moreover, senses serve as the interface between the mind and the external environment receiving stimuli and translating them into nervous impulses for transmitting to the brain. The brain processes this information in working memory and uses the relevant pieces to create thoughts, i.e. the mind integrally synthesizes information from emotions and memories so that mapping finite areas of the brain for cognition is unfeasible. One can map the brain just in terms of general concepts of cognition. Fig. 1 demonstrates how one can split up the brain into five distinct areas having different principle responsibilities.

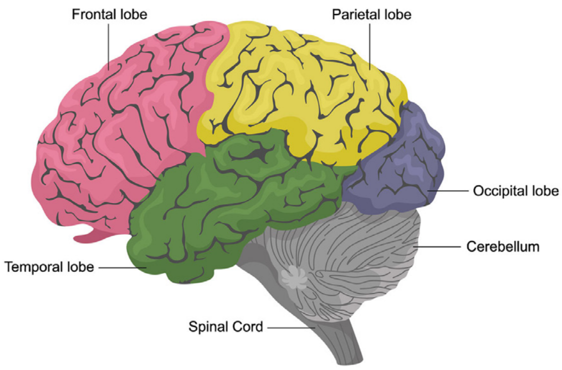

Figure 1: The anatomy of the human brain [27]

It appears that neurons in lateral prefrontal cortex play a critical role in working memory and cognitive strategies. These neurons do not fix responses but flexibly adjust to cognitive demands that distribute information between them in an ensemble [28]. Many facts indicate that glial cells and, particularly, astrocytes, also participate in signal transmission and information processing at cellular and network levels. Such complicated dynamics of the excitatory synaptic current can lead to non-trivial changes in individual postsynaptic neuronal activity and, hence, in the cooperative activation of neuronal groups linked by the astrocyte-mediated bridge [29].

Thus, the elementary building blocks of cognitive architecture of living things are neuronal networks of different brain areas but not individual neurons [30]. Such expanded networked structure of brain is to have a biological basis in a matter carrier capable to maintain these blocks for recalling and integrating phonological, visual, and other information from a broad range of behavioral cues of sensory neurons and emotions [4]. It is necessary also to take account of the attention as selective awareness, which is not under control but governs moving of these information cues [31]. Liquid water in the cerebral tissue (see fig. 1) can be a carrier of these functions embodied in synchronized clusters of oscillators having the given phase shift of proton vibrations in helixes of hydrogen bonds out of different number of water molecules [18].

Only such general carrier in microbes can generate collective working memory of “past experience” in any colonial organization of more than 99% bacteria on earth living in cell masses. In these conditions, bacteria utilize communication capabilities of liquid water [18] in self-organizing colony with high adaptability to environment [32, 33]. For example, underwent the same antibiotic action a second time they cope better with this stress by building an appropriate colony structure shown in fig. 2.

Figure 2: The colony of E. coli cells generated by auto chemotaxis during in 3 days from a single inoculation made in the center of a plate [32]

In the result, microbes have developed a quick and effective way to exchange genetic information, in particular, the coding of antibiotic resistance that they did not inherit from parents. This exchange occurs even between bacteria different each other as a human is from yeast [34]. Now obviously, why there has been a rapid diversification of bacterial lineages up to 27% of modern gene families in the brief Archaean period of genetic innovation. A functional analysis of these genes reveals that they increase usage of oxygen and transition metals (sensitive to the redox-potential) due to the oxygenation of biosphere in the period of Archaean expansion [35].

The Essence of Thinking

A strong adaptive sensitivity of living things to numerical properties is likely in their neuronal structure and an elementary number system constitutes a start-up tool of development of symbolic numerical thinking, i.e.

living things possess an abstract non-modal representation of a number [36].

Decomposing of the world into things is the essence of thinking in working memory and its distinction from perception, which gives knowledge as an unbroken essence [37]. The working memory holds only active (conscious) information and manipulates these elements under the control of attention. As selective attention is, by definition, a dynamic process, its basis is a modulation of neuronal activity and of neuronal communication by perceptive signals defining the priority of items with relevant features [38]. It means that the working memory encodes information of items, coherence, and representations duration as oscillations with different frequencies [39].

The visual-spatial selective attention modulates the signals incoming into the neurons of the sensory systems by altering their excitability and sensitivity to sensory stimulation [40]. Usually, one equates visual consciousness to what is in the focus of attention. Opposite, psychological and neurophysiological findings separate the attention and visual consciousness. The first is a sensory-motor processing in working memory. The second is a repeating this activity in the cortical areas. Therefore, all sensory-motor activity is conscious and more of common features are between awareness and working memory than between attention and awareness [41]. For example, a burst of high gamma synchronization contributes to explicit awareness of the content in working memory [42]. Moreover, one can determine consciousness as getting of meaningful representations so that a living thing can carry out adaptive behavior. Neuronal clusters implement these transformations in the multidimensional space of representations (thoughts, visual images, emotions, and intentions) outside the specific neurons that synchronize spikes with internal states as if they are independent entities [17, 43]. This second-order phase transition in human brain dynamics shows the mental essence goes out of the physical one [44].

There can be different material substrates for the mind and its operations to function [45]. As a carrier of such process, there can be also an aqueous medium distributed over brain cells for representations of consciousness and working memory by electromagnetic signals of synchronized proton oscillators [18]. They in bulk water act as a quantum system because have coherent properties that are quantum mechanical in origin. These properties can give rise to memory of frequencies and long-range effects as a phase coherence phenomenon [46]. NMR method based on quantum coherence can manifest such brain dynamics reminding the heartbeat potentials. These signals have no correlates with the classical NMR contrast and appear only with decreasing the local magnetization of tool, i.e. the found signals are generated by the consciousness that cannot be classical [47]. Indeed, coherence is a means of neuronal communication in living things and coherent waves have a constant phase relationship with peaks and troughs always similarly placed. Just the phase bears direct connection with the quantum nature of consciousness [48].

Synchronous Mechanism of Working Memory

Phase synchronization is the cyclic repetition of rhythmic signals of neurons when relative phase leads neuronal coding motif to coordinating spatial-temporal neuronal activity [49]. Therefore, synchronized rhythms control neurophysiological dynamics to facilitate precise and flexible communication between neurons necessary for goal-directed action and cognitive functions (information transfer, perception, motor controlling, and working memory). They link feed forward and feedback interactions between brain regions where the phase coherence of neuronal oscillations express cognition processes and increasing synchrony of these spike trains becomes the neuronal correlate of selection attention [50, 51].

The neuronal synchronization has initially discovered in the visual system and conceptualized as a possible mechanism for dynamically binding perceptual elements into coherent object representations [52]. This system represents image features in a distributed manner over different brain regions. The binding of them into coherent representation occurs when the neurons in these areas synchronously enhance the rate of spikes due to attention to these features [53].

Obviously, sensory information (in spikes) can undergo such associative processing (in frequency spectrum of synchronous oscillations) with attention modulation for incorporating into the context of cognition. This process occurs in zones of synaptic hierarchy in the cerebral cortex. Connections from one zone to another are reciprocal and allow higher synaptic levels to exert a feedback influence upon earlier levels of processing. The resulting synaptic organization allows each sensory event to generate multiple cognitive and behavioral outcomes. The highest synaptic levels of sensory processing are in inter-modal and limbic cortices. They form multi-modal representations distributed on many neurons for transforming perception into recognition, word-forms into meaning, scenes and events into experience, and spatial locations into studying [54]. In this, the oscillatory brain activity is a prominent feature of neuronal transmission of information when the ability to modulate signal transmission in frequency function gives an additional regulation. For example, the neuromodulator (dopamine) changes frequency of signal transmission in controlling information flow from the entorhinal cortex to the hippocampus [55].

Thus, the brain processing depends on an interaction between neuronal groups governed by the cognitive mechanism that modulates the effective strength of a given connection, and the mutual influence of neuronal groups depends on the phase relation between their activities within the groups that precedes this interaction. Therefore, the synchronization of these activities flexibly determines the character of neuronal interaction [56].

Although synchronization plays a vital role in the brain functions, it is not the only mechanism for the neuronal communication. For example, a period of spikes and coding of frequencies act together during movement control, i.e. both factors should be accounted for interpreting movement-related activity [57]. In addition, neuronal activity in the auditory system synchronizes with sound rhythms that are fundamental to successful auditory perception. For example, the music evoked strong neuronal synchronization in 37 participants listening to music modulated by rhythm (1–4 Hz). Moreover, familiar easily perceived music with slow rhythm elicited the strongest neuronal response. These results show the importance of spectral and temporal fluctuations for driving neuronal synchronization, and highlight its sensitivity to predictable stimuli [58].

Another example is the conscious recognition of familiar objects, which induces a transient inter-hemispheric electroencephalographic coherence in the alpha-band that does not occur with meaningless objects or with passive viewing. These data expect a close link of inter-regional synchronization and conscious recognition of objects [59]. Moreover, transient global increase of phase synchronization of oscillatory activity in the gamma-range stimulates the conscious perception [60].

Studies from recordings of events in animals to electroencephalography in humans have demonstrated the pivotal role of phasic synchronization of oscillations (in different brain regions) for the working-memory functioning [61]. Therefore, the base of consciousness is the connection between synchronization of neurons and their functional integration. Such phasic synchronization appears in brains during social interaction, i.e. one should consider the mind in line with the social nature of human experience. These findings challenge the standard view to human consciousness as about the unique and private one [62].

Discussion of Results

3Ma, precursors of the genus Homo made first stone artifacts. 2Ma, early Homo erectus has left traces of technological innovations though their accurate copying and social transmission between generations was rare up to 1Ma. After that, Pleistocene Homo underwent evolutionary adaptation of neuronal propensity (as working memory) for accurate copying which defined social transmission of technologies inside and between generations [63]. Indeed, an observer response is more important for the cultural accumulation of an innovation than innovator product itself because just the observer registers and copies unusual behavior of innovator in the horizontal and vertical transmission between generations.

Human cognitive abilities have grown with evolutionary cortical expansion. In addition to increasing of neuronal number, this cortical expansion has increased the number of glia-cells and, hence, a volume of water in the white and grey matter of cortex that occupies 75% of the entire brain mass and volume though contains only 20–25% of all brain neurons. The cortical layers with pyramidal neurons have shown the maximal expansion at the human brain evolution. Just this evolutionary adaptation of cortex apparently defines the multiplicity of human cognitive abilities [64]. Therefore, the brain functions are inextricably associated with aqueous homeostasis because the most of volume between neurons is water (of 75%) in glial cells and between them (in small extracellular space) is aqueous solution for ions exchange to excite neurons [65, 66].

Thus, the overall result of human brain evolution is not only the increasing of cortical volume but a diversity and complexity in the structure and function of cortical neurons with the highest number of synapses per neuron and with complex connections by means of glia-cells. The human brain contains at least five anatomically distinct networks (see fig.1). Sensory cells give rise information streams into each of these networks. Attention, motivational and emotional modulations, mental imagery, all emerge in working memory where they create a highly edited subjective version of the world. In this, the human working memory prolongs the neural impact of mental events in enriching the texture of consciousness, which helps to loosen the rigid bonds between stimulus and response that dominate in the behavior of animals [54].

In a "clot" of glia-cells full of wrinkles expanding their surface area (the conventional point of view), the brain contains a branched neuronal structure (schematically shown in fig. 3) including 10% of fat and 8% of proteins in 100 billion neurons for processing and transmitting information. Up to 5 trillion of glial cells (7% of dry mass) support this structure and provide goal-directed information streams as well as form a long-term memory in the brain for long storing information. The remaining mass of brain (about 75%) is aqueous solution that can serve as a basic working memory because large coherent domains of liquid water (double helical clusters of hydrogen bonds) generate electromagnetic waves that naturally provide the synchronization for data processing and informational transduction in the quantum brain dynamics [18, 67]. These properties of liquid water play a key role in receiving, storing and passing on information in the form of electromagnetic signals for the regulation of its exchange within the self-organized structure of living things and carrying from outside environment for prolongation of their life [68].

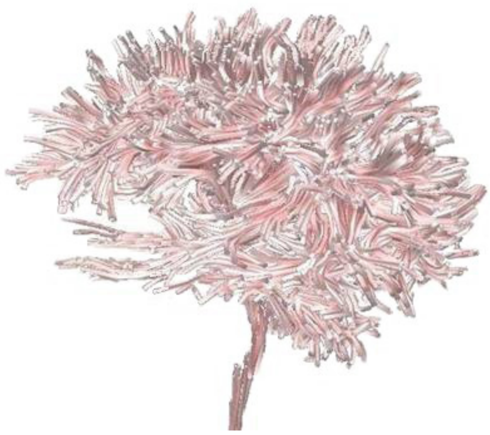

Figure 3: The conjectural texture of branched neuronal network in the human brain [69]

Thus, in the living cell, the plasmas oscillations in the GHz–THz range (frequency spectra of spikes) interact with electromagnetic fields of water coherent domains with relatively large de Broglie wavelengths and such naturally-generated waves support intercellular correlations at long distance in an organism and its cognitive processes [70]. Therefore, cognition is nothing than an oscillational function. Data obtained from pyramidal cells in sensory, motor, association, and executive cortex show that without these specializations in the structure of pyramidal cells and without growth of dendritic spines, human cognitive capabilities would not have evolved to its present state [71]. A higher intelligence quotient (IQ) correlates with a thicker temporal cortex (more of glial cells) per one pyramidal neuron, which has more elaborate dendritic network and activates faster. A lower IQ correlates with a thinner temporal cortex per one pyramidal neuron having less complex dendritic networks and activates slower [72].

One can identify various cognitive functions or cognitive “frequency domains”, responsible for regulation of specific behavior or action. These functions often operate synergistically and arise by processes occurring within certain parts of the brain but only some of them enter in our consciousness as higher-level functions of the brain. They encompass language and imagination, perception and planning that are an embodied realizing in contrast to the computational one. For example, intention is central item in the concept of voluntary action because an action is voluntary if and only if has intention. When testees attended to their intention rather than their action, the pre-supplementary motor area (pre-SMA) became active according to data of magnetic resonance imaging, i.e. the activity of the pre-SMA reflects the momentary realization of intention [73].

Just therefore, the research of artificial intelligence has foundered because it has considered the intelligent system consisting of independent information processing units that interface each other via representations. Opposite, the intelligent system of living things consists of independent and parallel activity units that interface directly with the outside things by perception and action. The attention controls this activity by specialized mechanisms (activation and inhibition). They serve for maintaining information through activation of relevant brain circuitry and inhibition of the irrelevant information [74]. Therefore, intelligence is the ability to adapt to the environment and the society where embodied cognition implicates the body (liquid water) as the important factor of cognition and as development of cognitive capabilities along with classic symbolic architectures and neuronal nets regulating our thoughts and behavior [75, 76].

Thus, one can represent a hierarchic structure of cognitive processes in living things by the scheme in fig. 4. Here liquid water filling the branched neuronal network (see fig. 3) is a basic carrier of working memory as a useful tool for bridging the gap between neurons and cognition because the naturally coherent frequency domains in liquid water can spontaneously generate an intention of voluntary action as an interaction between individual neurons [18]. Such oscillations can appear as rhythmic patterns of action potentials in post-synaptic neurons. Synchronized oscillatory activity of large number of neurons can arise from feedback between them [77]. The transmission of glial-cells contributes this synchronization. Particularly, calcium elevations in astrocytes lead to the synchronous excitation of clusters of pyramidal neurons. Thus, astrocyte signaling can contribute significantly in the maintenance of synchronized activity patterns in the neuronal networks [29].

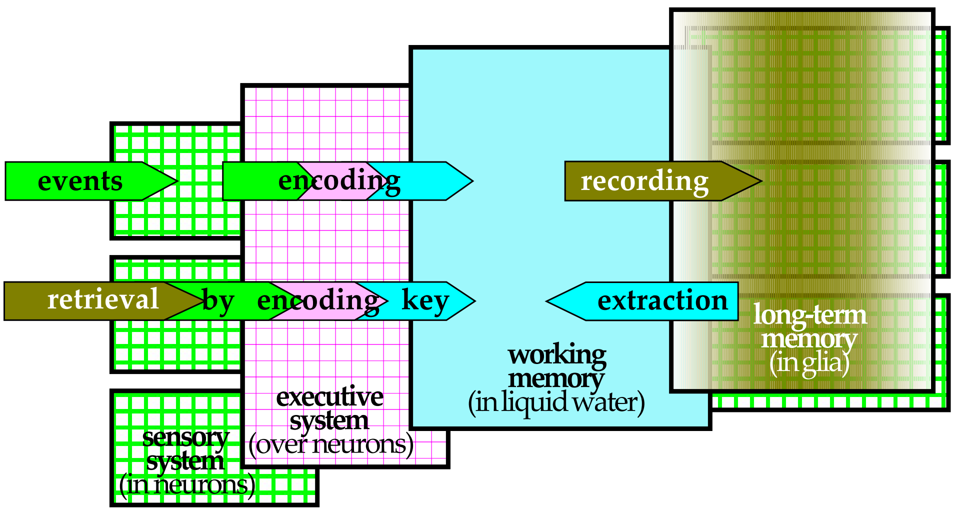

Figure 4: The hierarchic structure of information carriers in living things

It is important to remember that "increased neuronal synchrony" can mean 1) flexible and long-range (due to liquid water) phase synchronization of information carriers in the gamma-band associated with consciousness, and 2) inflexible and persistent phase synchrony in the alpha-band associated with unconsciousness, for example, due to anesthesia [78].

Taking into account the role of phasic synchronization, one can presume that recording information into the long-term memory (in glia) is like the holographic one, which fundamentally differs from all other ways recording the image by distributing that on the all registration elements by means of interferometry [79]. Then, a partial damage of the elements with reducing their number does not lead to loss of the image. Its quality only decreases just by loss of a clearness when the reference wave illuminates the interferometry pattern for extracting the image. This follows from results of investigations of memory place in the brain of rats trained to seek a food reward in the maze. Indeed, the removing of parts of rats' brain did not eliminate the memory of the maze, i.e. they have distributed the information about the maze over the all brain [80].

Thus, the sensory system encodes an initial information about any event in the working memory (liquid water) that temporally lies there as a set of electromagnetic vibrations [81]:

$$I_s(t) = Re \sum_{k=k^s_{\min}}^{k^s_{\max}} n^s_k e^{i(\omega_k t + \delta^s_k)}$$

excited by k-pairs of proton oscillators $H_3O^+(H_2O)_{2k-2}OH^- \leftrightarrow OH^-(H_2O)_{2k-2}H_3O^+$ in the corresponding double helixes (of hydrogen bonds) with k water molecules [18]. Here, $I_s(t)$ is the temporal sequence of spikes (schematically shown in fig. 5) as a set of brief electrical impulses (~1 ms) generated into the axon of tonic receptor in the sensory system (see fig. 4); n^s_k is the number of *k*-th oscillators, ω_k is their angular frequency, δ^s_k is its shift of phase, and i is the imaginary unit. Re denotes the real part of exponential function.

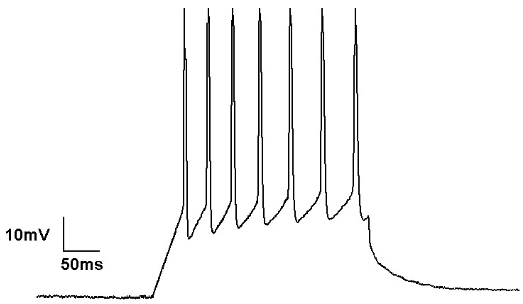

Figure 5: Tonic firing pattern of individual neuron of sensory system as a specific spiking activity

Now, one can represent any thought or intention in working memory as a coherent superposition of synchronous vibrations

$$T_{sev}(t) = \mathrm{Re} \sum_{k=n^{sev}_{\min}}^{n^{sev}_{\max}} n^{sev}_k e^{i(\omega_k t + \delta^{sev}_k)}$$

as a result of action by neurons of sensory system (*s*), inhibitive and stimulating signals by executive system (*e*), and voluntary virtual (*v*) impulses of the brain memory. The multicolored arrow in fig. 4 shows this for recording such information over the branched neuronal network (see fig. 3) by glial-cells. They grow as the long-term memory (see fig. 4) because 3D snapshots of electromagnetic vibrations in liquid water are short-term.

Indeed as soon as information encoding cuts out, the water immediately goes back to its normal chaotic because is an adaptive information medium with the volumetric working memory up to 8.5 PB/l [18].

Conclusions

One can determine consciousness as getting of meaningful representations so that a living thing can carry out adaptive behavior in the multidimensional space of representations (thoughts, visual images, emotions, and intentions) outside the specific neurons that synchronize spikes with internal states as if they are independent entities, i.e. their mental essence goes beyond the physical one. As a carrier of such transformations, there can be an aqueous medium in brain cells having electromagnetic signals of synchronized proton oscillators as the content of working memory. They act as a quantum system because have macroscopic phase-coherent properties directly connected with the quantum nature of consciousness.

Human cognitive abilities have grown with evolutionary cortical expansion. In addition to increasing of neuronal number, this cortical expansion has increased the number of glia-cells and, hence, a volume of water in the cortex that occupies 75% of the entire brain mass and volume though contains only 20–25% of neurons. The cortical layers with pyramidal neurons have shown the maximal expansion at the human brain evolution that apparently defines the multiplicity of human cognitive abilities. Therefore, the brain functions are inextricably associated with water content.

Motivational and emotional modulations, mental imagery emerging in working memory create a highly edited subjective version of the world and prolong the neural impact of mental events in enriching the texture of consciousness, which helps to loosen the rigid bonds between stimulus and response that dominate in animals. For this, large coherent domains of liquid water (double helical clusters of hydrogen bonds) can generate electromagnetic waves that naturally provide the synchronization and informational transduction in the quantum brain dynamics.

Thus, in the living cell, the plasmas oscillations in the GHz–THz range (frequency spectrum of spikes) interact with electromagnetic fields of water coherent domains and such naturally-generated large waves support intercellular correlations in an organism at long distances. Therefore, cognition is nothing than an oscillation function. Then, one can identify various “frequency domains” of the brain synchronous oscillations as cognitive functions responsible for regulation of specific behavior or action. These functions encompass language and imagination, perception and planning that are an embodied realizing in contrast to the computational one because the intelligent system of living things interfaces directly with the outside things by perception and action. The attention controls this activity by specialized mechanisms (activation and inhibition), i.e. intelligence is the ability to adapt to the environment and the society where embodied cognition implicates the body (liquid water) as its own basis.

In the hierarchic structure of cognitive processes of living things, liquid water filling the branched neuronal network as a basic carrier of working memory can be a useful tool for bridging the gap between neurons and cognition because the naturally coherent frequency domains in liquid water can spontaneously generate an intention of voluntary action. Such oscillations can appear as rhythmic patterns of action potentials in post-synaptic neurons, and the synchronized oscillatory activity of large number of neurons can arise from feedback between them by means of proton oscillations in liquid water.

Acknowledgements

Author is very glad of opportunity to thank his colleagues for useful discussion of principally new information aspects of liquid water as a basic carrier of working memory of living things.

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