Advanced e-Learning by Inducing Shared Intentionality:

Foundation of Coherent Intelligence for Grounds of e-Curriculum

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***Abstract*— How is initial social knowledge acquired? The primary data entry (PDE) problem provides an understanding of the modality of social interaction between organisms disabled to communicate. The paper proposes the Model of Coherent Intelligence (MCI) and its neural foundation. The MCI shows how interpersonal dynamics shape shared intentionality in intimately related individuals. This hypothesis postulates two ideas: (1) cognition begins from a separation of sensory cues: Long Term Potentiation (LTP) can only be induced in neurons of particular Modality Specific (M-S) gateways (not all)–selective induction promotes selective sensitivity to the chaos of stimuli. (2) Neurons can learn Spike Timing Dependent Plasticity (STDP) by repeating the timing code of other organisms' mature neurons to modulate certain synaptic strength, which triggers either LTP or Long Term Depression. The paper suggests that shared intentionality in humans is the evolution outcome. Social animals demonstrate the quality of goal-directed coherence. The paper defines it as the ability of organisms to select only one stimulus for the entire group instantly. The manuscript shows the candidate for triggering the mechanism of goal-directed coherence and shared intentionality. The protein molecules contribute to animals' interaction ability, from essential motility organs in simple organisms (by presenting in receptors) to neural circuit assembly regulation and STDP in humans (by presenting in neurons). The study shows a direction for developing e-learning through stimulating learners' shared intentionality. An actual application of this approach is e-curriculum for children from 2 years of age.**

Keywords-coherent intelligence; goal-directed coherence; shared intentionality; e-learning; embodied cognition

I. Introduction

This article is an extension of the conference presentation “New findings in education: primary data entry in shaping intentionality and cognition” [1]. The academic knowledge on the study of mind historically and conceptually has settled three main approaches within cognitive science: cognitivism, connectionism, and embodied dynamicism [2]. Many theories of mind combine all three approaches, where they co-exist in various hybrid forms. The more interesting of them are the Embodied dynamic system [2], the theory of innate intersubjectivity and innate foundations of neonatal imitation [3], the theory of natural pedagogy [4], and the theory of sensitivities and expectations [5]. All these theories are plausible; the current paper observes different views to engage a gap in knowledge.

According to Thompson [2], cognitivism (the metaphor is the mind as digital computer) and connectionism (the mind as neuronal network), in different ways, appeal to the same computational principle of cognition. This principle based upon processing a signal within neuronal networks. This computational principle certainly requires the primary data entry as a necessary initial condition to launch processing. None algorithm and/or a sequence of instructions may perform the computation of any process without corresponding to the specific situation inputs, that should substitute variables and parameters of the formulas. The algorithm remains just a set of mathematical variables without this input. This argument may mean the necessity to input an initial set of social phenomena of the specific community to trigger this system – the Primary Data Entry (PDE) problem [6].

According to embodied cognitivists, the mind is an autonomous system by its self-organizing and self-controlling dynamics, which does not have inputs and outputs in the usual sense, and determines the cognitive domain in which it operates [2][7][8]. This approach is grounded on the dynamical hypothesis [9]. However, this interpretation of a dynamic system is not accurate [1]. Why does the dynamic system need PDE:

Argument A. According this approach embodied features of cognition deeply depend upon characteristics of the physical body. If the agent's beyond-the-brain body plays a significant causal role, then the primary data yet makes sense [1].

Argument B. In mathematics, a dynamic systems model is a set of evolution equations. It means that entering primary data is required. The dynamic system may not begin its life cycle without introducing initial conditions corresponding to specific situation inputs and parameters [1].

Argument C. The dynamical system hypothesis [9] has not claimed the lack of initial conditions. Dynamicists track primary data less than dynamic changes inside. However, it does not mean that primary data do not exist and do not necessary [1].

Given these above arguments, the PDE problem must be considered in the onset of cognition. The embodied dynamic system approach tends to solve the above-noted gap by introducing the notion of dynamically embodied information [2]. Although, to introduce this concept, it is necessary to explain the categorization of reality through intentionality. According to embodied cognition approach, symbols encode the local topological properties of neuronal maps [2], a dynamic action pattern. The sensorimotor motor network yields pairing of the binary cue stimulus with the particular symbol saved in the structures and processes that embody meanings. 'Representational “vehicles” are temporally extended patterns of activity that can crisscross the brain-body-world boundaries, and the meanings or contents they embody are brought forth or enacted in the context of the system’s structural coupling with its environment [2, p.36].' This idea requires introducing the nature of intentionality. In a multi-stimuli environment, the stimulus-consequence pair is unpredictable due to the many irrelevant stimuli claiming to be associated with the embodied dynamic information randomly. The bond of stimulus-consequence pair of a social phenomenon in the sensorimotor network requires categorizing reality by the nervous system before applying the innate reflex about this social phenomenon to a specific case. Therefore, dynamically embodied information can be useful if intentionality is already in place. However, the embodied dynamic system introduces intentionality without a biological and / or physical basis. The theory of natural pedagogy [4], and the theory of sensitivities and expectations [5], as well as many others may not solve the problem of PDE [9].

According to Trevarthen and Delafield-Butt [11], primary consciousness develops in embryogenesis and is the first operative in early fetal life. 'Consciousness as "acting with knowledge" requires a nervous system that regulates prospective perception in intentional engagement with the world [11, p. 22]’. In the first trimester, patterns of sensory regulation of movements of the fetus' body and limbs gain affective evaluation and sensitivity for sounds and rhythms of other human presence [11]. It means that the pure nervous system should already possess intentionality as well as initial knowledge about social reality: human sounds and rhythms also yield meanings. Even if fetuses can hear different sounds and feel rhythms from outside of the womb, this does not mean that they alone (independently) can process their meanings.

Searle et al. [12] argued that intentionality is the mental power of minds to represent or symbolize things, properties, and states of affairs. According to Crane [13], mental states or events or processes which have objects in this sense are traditionally called 'intentional,' and 'intentionality' is, for this reason, the general term for this defining characteristic of thought. The meaning of directed action implies the purpose of the action, which first requires the categorization of reality. It is a dichotomy of what happens first. Current knowledge does not solve it.

Tomasello [14], through the study on ontogenesis and phylogenesis, introduced the hypothesis of gradually increasing social bond development in children referred to time slices: (1) emotion sharing from the birth, (2) joint intentionality from the nine-month revolution, (3) collective intentionality at around three years of age, (4) reason and responsibility. Tomasello [14] introduced the beginning of cognition through the newborns' basic motive force of sharing intentionality. However, the mechanism of such emotion coordination is not clear because it is grounded on emotion sharing [14]. Whether or not protoconversations imply understanding emotional states. Many researchers, including the authors, believe that the hypothesis about the universality of emotional expressions is formed by limited experimental methods, since other research designs show the opposite outcome [15]-[19]. There is no evidence of a genetic mechanism that can link meaning in mind with certain social reality to apply an appropriate emotional pattern to a specific situation. Even if one assumes that the hypothesis of universal emotional expressions proves innate emotional patterns together with their meanings; even if newborns may alone recognize the basic facial expressions of caregivers and the specific situation to apply them; but in this case, newborns do not have time for such a "training course", because they demonstrate their achievements already in the first hours of life [20]. If there is no innate mechanism, then, apparently, emotional contagion can occur between individuals without their awareness [10][20][22]; it can happen even without awareness of the emotional stimuli existence [22]. Section II discusses the hyperscanning studies' outcomes, showing brain-to-brain synchronization. Section III presents the hypothesis of the neuronal foundation of shared intentionality. Section IV discusses the physical ground of goal-directed coherence–a forerunner of shared intentionality. Section V elaborates all findings.

II. Problem: How Does Social Interaction Encourage Cognition

Brain-to-brain relationships shape the mind during moment-to-moment interactions [23]. The dichotomy of newborns' succeed in beginning knowing and their communicative disability challenges our knowledge on social interaction modalities [20]. We believe that understanding the problem of the intentionality emergence in an organism at the beginning can explain the problem of PDE and the onset of consciousness. This knowledge can contribute to the study of cognition because obviously if and as soon as this implicit modality occurs it continues the whole rest of life. We believe that the caregivers' intentionality forms the intentionality in newborns. Fetuses and newborns are not able to behave intentionally on their own due to the lack of meaningful (informative) sensory interaction at the beginning [6][20][24]. We predict an implicit modality of social interaction that provides shared intentionality at the beginning. Cooperation in a group enhances intentionality, providing categorization.

According to Valencia and Froese [23], their review of studies based on EEG- and fNIRS hyperscanning methodologies shows evidence of inter-brain synchronization in the fastest frequency bands, supporting the possibility of extended consciousness. Among hyperscanning studies, we have chosen 4 studies conducted without explicit interaction between subjects. These studies compared differences of brain-to-brain synchronization in subjects when participants solved tasks together as confronting to the condition in which: (i) the subjects solved them individually [25][26]; (ii) the same task when interacting with a machine [27]; (iii) the individuals from another team solved the same problem [28]. These studies declared an exclusion of sensory interaction between subjects. However, it should be noted that the subjects of all these studies knew about social encounters during the experiments. Therefore, instead of mental collaboration their results may simply mean an increase of brain activity due to similar emotional arousal in participants stimulated by the social encounter.

The near-infrared spectroscopy study (non-hyperscanning) on asleep newborns shows an increase of the neural response to a familiar (English language) versus unfamiliar language (Tagalog, a Filipino language) spoken by strangers in both conditions [29]. The language stimuli (the identical low-pass filtered sentences) were played through two speakers approximately 1.5 m from the infants' head. According to May et al. [29], these findings show that the newborn's neural processing of language is influenced by early language experience due to neonate brain responds to familiar versus unfamiliar language. To our mind, this outcome may lead to evidence of another inference. This experiment was not a hyperscanning technique. However, subjects were in pairs with their caregivers. Neonates classified these sound stimuli without the ability to perceive them. Sleeping newborns' brains reacted to sound stimuli that their sensing could not provide due to their brains' sensory isolation to meaningless and unfamiliar sounds. Sleepers seem to enter a standby mode, allowing them to balance the monitoring of their surroundings with sensory isolation [30]. Sleepers are sensitive to the semantic content of an auditory stream [30]-[32] and amplify relevant, meaningful stimuli [30][32]. The sleeping brain retains some residual information processing capacity, which, however, does not form enduring memories [33]. Neonates are not able to understand even Mother's speech although her sound is familiar. Given all these, any speech for neonates is meaningless, and asleep newborns may not be sensitive to the sounds even their native tongue (the language spoken by the mother during pregnancy) in experiments when these sounds were pronounced by outsiders. However, they were sensitive to them. Sleeping newborns' brains reacted to sound stimuli that their sensing could not provide due to their brains' sensory isolation to meaningless and unfamiliar sounds. We believe that this outcome may mean the implicit modality of newborns' interaction with caregivers since any other explanation of this outcome is excluded.

Recent hyperscanning shows an increase of coordinated neuronal activities in subjects during collective efforts without communication via sensory cues [34]. What are the neurobiological grounds of coordinated neuronal activities?

III. Foundation of Coherent Intelligence

A. *Experiments on Problem-Solving in Groups*

Recent research of 24 online experiments presented that unprimed participants show a more significant accuracy level when they complete the thought task simultaneously with confederates who are primed with the correct answer; if they were emotionally stimulated and completed the tasks without communication [10]. Primary groups [35] show empirical evidence of a more significant accuracy in problem-solving in the coherent intelligence state. In specific, we conducted 13 experiments in dyads (116 subjects) with *P*-value < 0,001 (probability-value in null hypothesis significance testing), and 7 experiments in primary group adults (41 subjects) with the *P*-value < 0,002. Experiments with 43 secondary group subjects (unfamiliar adults, M=20) show the effect only with the task of unfamiliar language translation. Non-semantic tasks–with synthetic language and two-color round symbols–did not stimulate the effect in 2 experiments with 207 secondary group subjects (unfamiliar). These results are consistent with research Danilov et al. [36] [37].

B. *The Model of Coherent Intelligence*

According to Danilov and Mihailova [24], a supranormal environmental case–e.g., first hours after birth–stimulates supranormal sensation in dyads. This can push the inherited mechanism of social entrainment of infants to the rhythm of the mother. Both the supranormal sensation and social entrainment may stimulate the common emotional arousal. The latter is increased by the ongoing supranormal sensation and the occurring rhythm of arbitrary movements of the infant. The continuing supranormal sensation and ever-increasing arousal of the infant and the mother along with the rhythm of the infant's unintentional movements stimulate early imitation and emotional contagion. The problem is how the infant capture and reproduce the kinematic of movements.

The MCI proposes that common emotional arousal together with the identical rhythm create coherent mental processes in dyads–Coherent Intelligence (Figure 1). At Sensorimotor Stage (by Piaget, or Stage 3 of the Model of Hierarchical Complexity MHC [38]), organisms do not maintain bilateral communication. According to Danilov and Mihailova [24], individuals are able to interact by distinguishing perceptual signals of identical modality by their significance. This ability can contribute to ostensive cues. After all, this meaningless interaction modifies into communication when individuals imbue perceptual impulses with mutually implied meanings, cascading their signals in response to the history of relations between them [24].

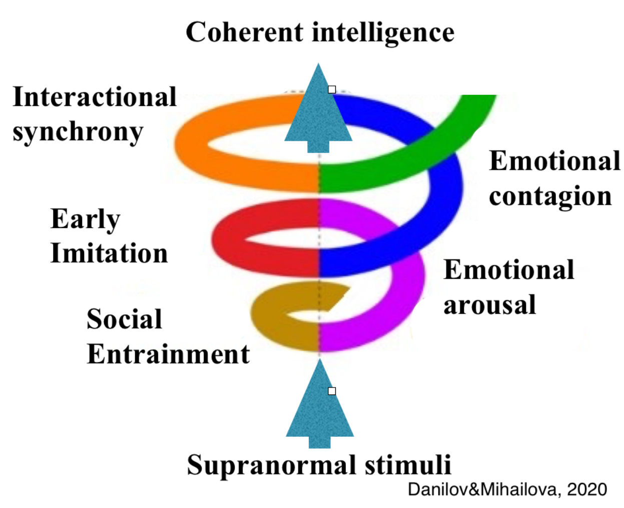

Figure 1. Interpersonal dynamics in Model of Coherent Intelligence[24]

C. *Neuronal Foundation of the MCI*

It seems consistent to say that intention arises from conscious intentionality, or intentionality shapes intention if intentionality becomes conscious. Specific brain regions may be engaged in shared sensory/cognitive processes irrespective of the feedback's valence and in encoding the subjective relevance of the feedback [39][40].

Outside areas involved in this processing, additional brain areas are specifically engaged according to the particular communicative modality [41]. According to Tettamanti et al. [42], Intention Processing Network (IPN) involves the medial prefrontal cortex, precuneus, bilateral posterior superior temporal sulcus, and temporoparietal junctions. Depending on different social interaction modalities, the IPN is complemented by activation of additional brain areas, reflecting different Modality-Specific (M-S) input gateways to the IPN [42]. The M-S gateways mediate the structural and semantic decoding of stimuli and provide M-S information [42]. Sensory inputs of a specific modality can activate the precise association of certain sensorimotor networks with specific brain emotion circuits [42].

We believe that this emotion-motion dynamics can involve the particular cognitive process of a high order. When two or more organisms are in common emotional arousal and simultaneously in the interactional synchrony, then these two different experiences may meet each other in high-order cognitive processing. Emotional arousal can trigger evolutionarily old brain circuits, which interact with high-order cognitive and linguistic processing [43]. It seems uncontroversial to say that infants' pure nervous system may experience emotions, but only primitive ones related to survival, such as those associated with hunger and pain. However, newborns cannot express emotions themselves appropriately to a specific social case on their own, even though they possess inherited neuronal patterns of primitive emotional impressions. They also cannot understand the expression of others' emotions (as is discussed above). They are only capable of experiencing primitive emotions, not correctly expressing them independently. Research on insects–organisms in stage 3 of MHC [38] like human newborns–assumes that they also experience emotions [44]. Researchers argued that agitated honeybees exhibit pessimistic cognitive biases: 'Whether animals experience human-like emotions is controversial and of immense societal concern. The next reason is that animals cannot provide subjective reports of how they feel, emotional state can only be inferred using physiological, cognitive, and behavioral measures. In humans, negative feelings are reliably correlated with pessimistic cognitive biases, defined as the increased expectation of bad outcomes. Recently, mammals and birds with poor welfare have also been found to display pessimistic-like decision making, but cognitive biases have not thus far been explored in invertebrates [44].'

In parallel, interactional synchrony stimulates a sensorimotor network engaging neural networks responsible for communicative intention processing (including high-order cognitive and linguistic processing)[41]. Neural networks of emotional excitation and the sensorimotor networks are separately connected to many different M-S gateways. Meanwhile their coherence intersects in certain M-S gateways of each organism depending on (i) pattern of neural circuit engaged through emotional excitation and (ii) pattern of the sensorimotor network [41].

We propose a rough hypothesis of how Long-Term Potentiation (LTP) can be induced only in particular M-S gateways, retaining information about the certain received stimulus [1]. Different areas of the brain exhibit different forms of LTP, their types depend on a number of factors, such as age and the neuron's anatomic location. However, the common processes are the same for all. The simple nature of Hebbian learning, based only on the coincidence of pre- and post-synaptic activity, LTP is persistent, lasting from several minutes to many months, and it is this persistence that separates LTP from other forms of synaptic plasticity [45]. Spike-timing-dependent plasticity (STDP)–that involves the pairing of pre- and postsynaptic action potentials (APs)–causes a variation of LTP or Long-Term Depression (LTD) [46]. The timing between pre- and postsynaptic APs modulates synaptic strength, triggering LTP or LTD [46]. The sign and magnitude of the change in synaptic strength depend on the relative timing between spikes of two connected neurons (the pre- and postsynaptic neuron) [46]. The structural organization of excitatory inputs supporting STDP remains unknown [46]. Even though the ensemble of emotion-motion integrated networks weakly stimulates the intersected neurons in their junction with M-S gateways. If all M-S gateways also simultaneously receive weak stimulation from the receptors (due to the chaos of stimuli received by the pure nervous system), then this multi-signal contributes to LTP in the neurons of particular M-S gateway at the junction of this emotion-motion ensemble due to the effect of the synaptic cooperativity, because of the following. LTP can be induced either by strong tetanic stimulation of a single pathway to a synapse, or cooperatively via the weaker stimulation of many. Neurons from the gateways in the connections of these networks receive cooperative stimulation [1]. Induction of cooperativity can ensure LTP.

According to Tazerart et al. [46], the synaptic cooperativity of only two neighboring synaptic inputs onto spines in the basal dendrites of L5 pyramidal neurons extends the pre–post timing window that can trigger potentiation. The engaged M-S gateways retain a certain stimulus, while other M-S gateways (also of the same sensory modality) remain depressed without keeping information of other stimuli. Therefore, specific M-S gateways are sensitive, and all these organisms respond to specific sensory modalities. Figure 2 shows a very rough schematic picture of this process. The induced emotion and sensorimotor networks (they are red in the picture) together activate certain M-S gateway even with weak stimulation of sensory input. The different colors of M-S gateways refer to different sensory modalities. At this point, the analysis encounters the ground of the PDE problem of how immature neurons learn the timing code to modulate certain synaptic strength, which triggers either LTP or LTD. Because the structural organization of excitatory inputs supporting STDP remains unknown [46].

The study of the PDE problem leads to the analysis of the axiomatic foundations of Psychology, Sociology, and Neuroscience–the basic notions that form these sciences–from the perspectives of the actual scientific paradigm.

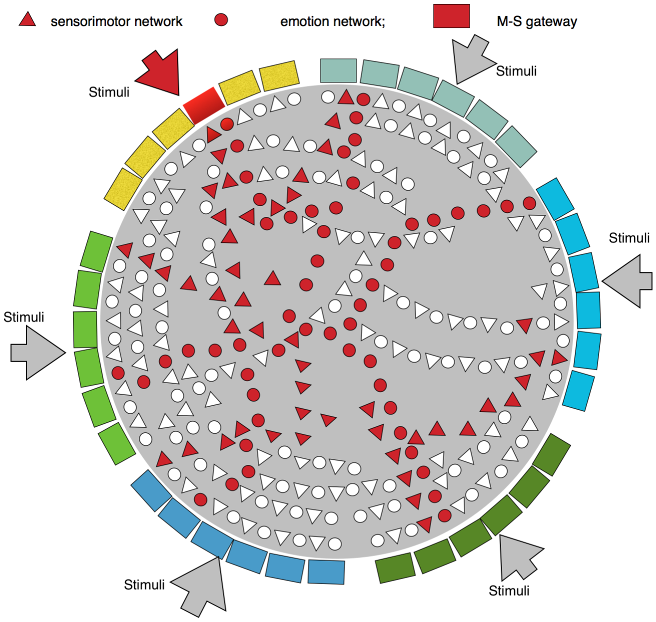

Figure 2. The very schematic picture of M-S Gateway Activation [1].

The question of "how can the blank mind begin to learn from social interaction" is reduced to "how immature neurons learn the timing code to modulate certain synaptic strength, that triggers either LTP or LTD"[1]. The sign and magnitude of the change in synaptic strength depend on the relative timing between spikes of two connected neurons (the pre- and postsynaptic neuron) [1]. How can neurons of an immature organism (even a newborn) learn the structural organization of excitatory inputs that support STDP? The further arguments show why we believe that the entanglement state of neurons can contribute to simultaneous LTP in neurons.

The daily routine develops neuronal patterns of primitive emotions and sensorimotor neuronal patterns in infants. Their everyday coherency with the social world forms various integrated neuronal patterns of different emotions from the existing ensemble of emotion scripts in their community. We believe that caregivers contribute to the formation of emotion scripts and, consequently, shaping of specific neuronal patterns in infants [1]. Obviously, adults experienced intentionality before their coherent mental process began with newborns. Life experience taught them particular emotion scripts and defined their precise motion kinematics, that formed more elaborated sensorimotor patterns. In routine cooperation with newborns, a caregiver enters in interactional synchrony with a newborn, under the influence of supranormal stimuli, being in social entrainment. Therefore, the similar M-S gateways are excited in the dyad. Meanwhile, the adult's current intentionality has already triggered a particular network that includes current emotion patterns and sensorimotor patterns. Part of it corresponds to a primitive complex emotion-sensorimotor network in the newborn with similar M-S gateways. This newborn's primitive network is less developed, although it is similar to the part of the adult's integrated complex network. It can be assumed that the neurons in the connections of different excited emotion patterns and sensorimotor patterns of both neural systems receive similar stimulation due to interactional synchrony and emotional arousal of organisms. The neurons of mature organism receive LTP, being induced cooperatively via many stimulations. If simultaneously, neurons of mature and immature organisms are also induced by a single harmonic oscillator, these neurons of specific M-S gateways go into the coordinated state [47]. According to Danilov [46], due to STDP, the precise order and timing of pre- and postsynaptic action potentials trigger LTP or LTD regulating the connection strengths between neurons. These M-S gateways of the neonate begin to react on the high-frequency sequence of stimulation in the same way as those M-S gateways in the caregiver and receive LTP [47]. The relationships of these neurons teach the specific M-S gateway of the newborn to react to the specific stimulation, supporting STDP in responding to a particular emotional and sensorimotor neural pattern [47]. In such a manner neurons of mature organisms train newborns' neurons, being in coherence; because the adult and infant neurons behave as a single unit [1].

Therefore, specific M-S gateways are sensitive in dyads, and these organisms equally respond to specific sensory modalities [1]. The induction of t-LTP and t-LTD in single spines follows a bidirectional Hebbian STDP learning rule [46]. Hebbian theory claims that an increase in synaptic efficacy arises from the learning process. The PDE problem in the chaos of irrelevant stimuli requires a teaching mechanism from the beginning. The coordinated state of neurons is a possible option of their cooperative activity, how infants' neurons learn spike-timing-dependent plasticity [1].

Emotion sharing indicates implicit modality of social interaction. The coordinated state of neurons in the certain M-S gateways is a possible option of how infants' neurons learn STDP [1]. This involvement of similar networks and the sensibility of the certain M-S gateways lasts as long as is necessary to teach the immature nervous system. The coordinated state of these neurons ensures their immediate response to the specific stimulus, regardless of the spatial division of organisms. Therefore, specific M-S gateways are sensitive, and these organisms equally respond to specific sensory modalities. This is an old evolutionary mechanism because interaction without sensory cues should be the primary and archetypal modality in biological systems beginning from bacteria. Section IV shows why we believe so.

IV. GOAL-DIRECTED COHERENCE

Knowledge about a coordinated state of neurons from different organisms can complement the set of social interaction modalities. The manuscript shows two possible options for involving cells into a coordinated state: entanglement of entire cells or their coordinated activity due to an agent (chemical element or compound). In the latter option, the entangled state of the agent leads cells to coordinated cooperation. Three candidates can pretend to become such an agent: they are the atom of hydrogen [48], the Posner molecule [49], and protein. According to Danilov and Mihailova [50], the idea of the protein as the agent seems to be more plausible from the two other above mentioned.

A. Protein as the Agent

Proteins become biologically active only when folded into a three-dimensional structure of amino acids formed into particular, highly complex configurations. A relatively small protein of only 100 amino acids folds into its functional shape in nanoseconds [51]. This high rate of choosing through a vast number of different possible configurations (at least 10 to the power of 100 options!)[50] in forming the precise symmetric configuration corresponds only to quantum mechanisms [50]-[55]. Consequently, it is possible to assume that quantum mechanisms can have a widespread connection mode between protein molecules in nature.

In bacteria, protein takes part in photoreceptors [56]. The review on the photoreceptors in plant-associated bacteria identified common traits such as protein-protein interaction during signal transduction [57]. Even more, these light-sensitive proteins seem to control infectivity and virulence to a level that generates not too much harm to the plant host [57], interacting with plants cells. These facts are relevant to quantum relationships between amino acids of bacteria proteins and between amino acids of bacteria and those from the plant [50]. In humans, protein Reelin is essential for hippocampal integrity and synaptic plasticity. According to Faini et al. [58], this molecule contributes to neural circuit assembly, refinement, and function, as well as axonal guidance, synaptogenesis, and dendritic spine formation. Thus, the entanglement between protein molecules of neurons from different organisms could become a candidate for their connection that leads to neurons' coordinated activity in different organisms [50].

B. Goal-Directed Coherence in Biological Systems

Social animals demonstrate the quality of goal-directed coherence. This quality is defined by the ability of organisms to select only one stimulus for the entire group instantly. It seems that its main features can be defined as follows: a) bypassing sensing (insensitivity to sensory perception), b) independence from a distance, c) instantaneousness in time. There are a few arguments why proposes this definition:

a) Bypassing sensing. Bacteria are the smallest free-living (self-replicating) organisms. They were among the first life forms to appear on Earth. The phenomenon of community phototaxis in bacteria is the concerted movement of an entire colony of cells towards or away from the light source which mechanism is still undefined [59]. According to Danilov [60], by themselves, photoreceptors of bacteria cannot measure the field gradient and show the direction of movement. However, community phototaxis involves direct sensing of the position of a light source [60]. The ability of the single cell to independently determine the direction of movement contradicts the simplicity of its internal structure-organization [60].

According to Zirbes et al. [61], earthworms demonstrate the cooperative ability to choose the same direction of movement as their conspecifics. According to Danilov [60], this earthworms' ability shows the incongruence of the complexity required communication and a set of sensory modalities in earthworms because their simple nervous system and sensory receptors make communication impossible. Therefore, the only possible explanation for earthworms' cooperative achievements with a communicative disability is that these organisms can together separate sensory stimuli according to their significance [60]. For this reason, they need to share the significance of the specific cue.

b) Independence from a distance. Individual ants perform large distance foraging excursions up to 1200 m, from which they return on a direct, shortcut way to their nests and can infer this ground distance when walking over hills [62]. Individual ants successfully perform this task without direct visibility of the goal and changes in the environment (wind, light, etc.). They seem to choose the certain path strategy from different options through interaction with their nest-mates on a case-by-case basis [60]. There is a dichotomy between the perceptual ability of organisms and environmental conditions–such as inappropriate distance, landscape, and weather–that are needed for successful interaction through sensory cues [60].

c) Instantaneousness in time. According to Danilov [60], flocks of birds, schools of fish, and hordes of insects also show the phenotype of the synchronization, performing the cooperative movements. Moreover, these social organisms can instantly change the direction of movement and shape fantastic collective forms in motion at a high rate. These collective movements intend the joint ability of organisms to choose the same direction of movement that required simultaneous information exchange. The high-speed rate of changing movement direction can mean the interaction modality that proceeds instantaneously, bypassing sensory receptors. Furthermore, all biological systems demonstrate instant interaction if they successfully perform the two previous features of bypassing sensing and interacting, overcoming insuperable distance. Indeed, in a multi-stimuli environment, when many organisms are required to instantly choose one stimulus from a dozen irrelevant ones, only simultaneous information exchange (instant) provides the correct solution for choosing the one correct stimulus for the whole group.

Many other biological systems also show two or three features of the quality of goal-directed coherence. Such a quality is presented in the mother-fetus dyads in humans. The intriguing facts of fetal facial expressions, voice recognition, and twin fetuses co-movement highlight the vital role of interaction in mother-fetus dyads in cognitive development [60]. Common sense assumes that this is the way it should be, while biology emphasizes separating these organisms. Fetuses own their autonomous nervous system. There is no communication between these organisms–the mother can not explain to her fetus social meanings using sensory cues. Even the mother's voice is a social cue, unintelligible for her fetus. Indeed, the meaning "mother" begins from self-awareness, from understanding the meanings of "self" and "other" and then understanding many other essential needs–just hearing a sound every minute does not lead to understanding its meaning. Even an undeveloped nervous system of fetuses casts doubt on the possibility of communication, and even more so the absence of abstract thinking at this stage of development. Nevertheless, the above facts show that, during gestation, some social learning succeeds, despite the absence of communication.

According to Darwinism, if inherited valuable qualities appear in every generation, the useful variations become so noticeable that the organism evolves into a new species over several generations. If the quality has been preserved over many generations of a phylogenetic ancestor, it manifests itself in one form or another in different species of its offspring. These arguments mean that quality preserved in simple organisms through many generations should manifest itself in one form or another in more developed animals.

Even in simple organisms, the sustainability of an organism's development in colonies (first of all, increased protection against predators and foraging efficiency) contributes to the propagation of the corresponding phenotypic features. If the quality of goal-directed coherence propagates in different species through an evolution development, this quality's single primary physical mechanism could exist. The entanglement between protein molecules from different organisms could become a candidate for triggering this physical mechanism. Because this molecule contributes to animals' interaction ability, beginning from essential motility organs in simple organisms (by presenting in receptors) to neural circuit assembly regulation and spike-timing-dependent plasticity in neurons of organisms with the nervous system.

Nevertheless, there are three candidates for this coherence mechanism of the organisms' cooperativity. Further research is needed to understand if this physical mechanism exists in all animals and because of what agent.

C. Findings in Physics for Goal-Directed Coherence

In physics, all matter with a temperature greater than absolute zero emits thermal radiation, consisting of electromagnetic fields. Coherence means a fixed relationship between the phase of waves of a single frequency and identical waveforms of two or more waves. Therefore, two neurons can become coherent in the case of features correspondence of their radiation. Quantum coherence appears from the interference of particles' quantum waves with each other.

According to the received view in physics, in short, coherence is converted into quantum entanglement. Streltsov et al. [63] argued that coherence in a system is converted into entanglement with another separate system. Any nonzero coherence in a system can be converted into an equal amount of entanglement between that system and another initially incoherent one [63]. From this perspective, a single harmonic oscillator can induce quantum entanglement in two or more particles of different systems if the properties of this electromagnetic field are such as it induces coherence of these particles.

Marletto et al. [64] argued that they found empirical evidence of entanglement between bacteria and the light (modeled as a single quantum harmonic oscillator). If so, this empirical data is probably the first evidence of quantum entanglement within a colony of one of the most ancient living organisms in nature. However, this result can also be regarded as a coordinated activity of the bacteria colony due to a single harmonic oscillator. That is, even though the experiments by Marletto et al. [64] have shown the entanglement of objects close to quantum scale size, according to the received view in physics, these cells are not the objects of quantum physics. Therefore, the conclusion can be threefold. First, as these authors argued, they induced the entanglement between bacteria. The generation of entanglement between increasingly macroscopic and disparate systems is an ongoing effort in quantum science [65]. Recent studies have shown that the behavior of objects 15 micrometers in size is consistent with the quantum world's laws, such as the phenomenon of quantum entanglement [66]. In comparison, a neuron's nucleus has a diameter of 3 to 18 micrometers, and a neuron has a size of 4 to 100 micrometers. Second, these objects can also be considered systems of atoms. While this is also entanglement however from this point of view, it can be defined as an entangled state between two or more quantum systems. For instance, recent studies showed that it is also possible. An entangled state was generated between a millimeter-sized dielectric membrane and an ensemble of 109 atoms [65]. Third, the experimenters observed the coordinated activity of bacteria due to the entangled state of an agent in these cells. The current article proposes that the amino acids from the protein molecules or the protein molecules themselves can become such an agent of the entanglement.

The article considers protein molecules in photoreceptors of bacteria (and neurons as well) as the agent of this coherence. From this perspective, the single harmonic oscillator can entangle the protein molecules (or amino acids from the protein molecules) from different bacteria receptors. The coordinated states of photoreceptors of different bacteria lead to coordination in their motility. From this point of view, during the experiment by Marletto et al. [64], a single harmonic oscillator with identical frequency and waveform electromagnetic field as in protein amino acids (or the whole protein molecules) induced entanglement of different cells' proteins promoting similar activity of bacteria. Considering the essential role of protein in simple organisms (in the activity of the photoreceptors) and organisms with the nervous system (in neural circuit assembly regulation and spike-timing-dependent plasticity in neurons), the quality of Goal-Directed Coherence might be the ground of biological systems and widely distributed in nature.

Moreover, the properties of quantum entangled systems promote coordinated activity in biological systems overcoming the long distance between organisms. Entanglement is an essential property of multipartite quantum systems, characterized by the inseparability of quantum states of objects regardless of their spatial separation [65]. A recent study tested quantum entanglement over great distances, sending entangled pairs of photons to three ground stations across China—each separated by more than 1200 kilometers. Yin et al. used the Micius satellite, which was launched last year and is equipped with a specialized quantum optical payload. They successfully demonstrated the satellite-based entanglement distribution to receiver stations separated by more than 1200 km [67]. Therefore, goal-directed coherence in biological systems (shared intentionality in humans) should also be possible in a long distance between organisms.

The study shows a possible direction for progress in e-learning by designing an advanced e-curriculum that can stimulate shared intentionality in students. We believe that the ideas mentioned above contribute to an advanced e-learning curriculum for young children. Recent case studies (conducted online) with the educational task to children aged 12 to 33 months show coordinating actions in the absence of communication through sensory cues in the mother-child dyads that promoted numerosity in infants and toddlers in a short course at an age younger than others (before then peers do) [68] [69].

V. CONCLUSIONS

The current study discussed a possible foundation of Shared intentionality for stimulating Coherent Intelligence that can form grounds of advanced e-curriculum. The analysis of recent empirical data yields a hypothesis of beginning cognition–the Model of Coherent Intelligence and its neuronal foundation of how the pure nervous system distinguishes sensory stimuli. This hypothesis postulates two new ideas of the PDE basis: (1) cognition begins from a separation of sensory stimuli: LTP can only be induced in neurons of particular M-S gateways (not all)–selective induction promotes selective sensitivity to the chaos of irrelevant stimuli. (2) Neurons can learn STDP in social interaction by repeating the timing code of other organisms' mature neurons to modulate certain synaptic strength, which triggers either LTP or LTD [1]. We believe that the MCI shapes intentionality in intimately related individuals. Coherent Intelligence is the integration of M-S gateways of particular brain areas, which contributes to different organisms' sensibility to similar sensory inputs [1].

Recent hyperscanning shows an increase in coordinated neuronal activities in subjects during collective efforts in the absence of communication through sensory cues [34]. This finding may mean indirect evidence of the hypothesis about the Model of Coherent Intelligence and its neuronal foundation. In addition, a growing body of literature on increasing the efficiency of cooperative decision-making in groups without sensory cues between subjects [10][24][36] [37] also shows empirical indirect evidence of the MCI.

The paper suggested that this social quality of humans is the outcome of evolution development. Social animals demonstrate the quality of Goal-Directed Coherence. The paper defined this quality as the ability of organisms to instantly select only one stimulus for the entire group. It also argued its main features: a) bypassing sensing (insensitivity to sensory perception), b) independence from a distance, c) instantaneousness in time.

The manuscript showed the candidate for triggering this physical mechanism–entanglement between protein molecules from different organisms (or amino acids from the protein molecules). This molecule contributes to animals' interaction ability, from essential motility organs in simple organisms (by presenting in receptors) to neural circuit assembly regulation and spike-timing-dependent plasticity in organisms with a nervous system (by presenting in neurons). Nevertheless, the paper proposed three candidates for this coherence mechanism of the organisms' cooperativity. Further research is needed to understand if this physical mechanism exists in all animals and what kind of agent it is.

We believe that this approach may contribute to studying the mind and, specifically, understanding the appearance of intentionality. In addition, we believe that these findings may contribute to an advanced e-curriculum, specifically in teaching children from 2 years of age with communication disabilities. Further research can also examine whether the MCI can provide a contactless interaction of the computer with neuronal circuits, in which the computer would become a part of the extended mind. This approach provides a wide range of possibilities for developing advanced intelligence systems, in specific a human-computer interface.

AUTHORS CONTRIBUTION

Igor Val Danilov formulated the hypothesis and wrote the first draft of the manuscript. Igor Val Danilov and Sandra Mihailova improved the text over several iterations.

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