The Effects of Emotionality of Languages on Evolution of Cultures

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***Abstract*-Abstract-Languages convey emotional as well as conceptual information. Conceptual contents of languages mostly reside in words and their semantic meanings. Emotional contents of languages mostly reside in language prosody (sounds). Conceptual contents could be borrowed among languages. Emotional contents are significantly determined by grammar, and cannot be easily borrowed. Conceptual and emotional mechanisms of languages are considered along with their functions in the mind and cultural evolution. Neural mechanisms are suggested as well as their mathematical models. These include neural modelling fields, dynamic logic, the knowledge instinct, the language instinct, and the dual model connecting language and cognition. Mathematical results are related to cognitive science, linguistics, and psychology. We consider an essential contradiction in human evolution: while evolving from animal vocalizations language evolution has required reduced emotionality. Yet, a language without emotions contains just "empty" sounds, disconnected from sensory-motor experience and "irrelevant to life". Too "low" emotionality makes languages "irrelevant", too "high" emotionality makes languages inflexible for acquiring new knowledge. We suggest approaches to quantifying these quoted, difficult to define notions. Experimental evidence and theoretical arguments are discussed. Approximate equations for evolution of human minds and cultures are derived. Their solutions identify just few types of possible cultures and language emotionalities leading to these cultures. We consider evidence and testable predictions. The proposed emotional version of Sapir-Whorf hypothesis suggests that differences in language emotionalities influence differences among cultures no less than conceptual differences. We discuss future research directions.**

Keywords-Language; Cognition; Basic Emotions; Prosodic Emotions; Knowledge Instinct; Language Instinct; Inner Form; Outer Form; Language Firmness; Dynamic Logic; Mind; Hierarchy; Dual model; Sapir-Whorf Hypothesis; Emotional Sapir-Whorf Hypothesis

I. LANGUAGE AND THOUGHT

Language and thought are so closely related that it is difficult to imagine what one without the other would be. Scientific progress beginning in the 1950s toward understanding of language was initiated by Chomsky's idea that language is independent of thought [1]. It explained several mysteries about language, e.g. why learning language takes few years without schooling and is possible by any normal child, whereas learning theory of relativity takes much study and only few people with special abilities can do it. Yet Chomskyan linguistics did not result in a testable mathematical theory. Many linguists rejected the idea of complete separation between language and cognition in Chomsky's theories. Decades of effort by cognitive linguists and evolutionary linguists did not, however, lead to a mathematical theory unifying language and cognition [2-6]. Evolutionary linguistics considered the process in which language is transferred from one generation to the next one [7, 8, 9]. This transferring process was demonstrated to be a "bottleneck," a process-mechanism that selected or "formed" compositional properties of language. As language content evolves in complexity, a non-compositional language could not be transferred to the next generation. Under certain conditions a small number of sounds (phonemes, letters) are aggregated into a large number of words, and this compositional language can be transferred to the next generation. Brighton et al. [10] demonstrated in computational simulations the emergence of a compositional language due to this bottleneck mechanism. Yet, this development lacks in two fundamental aspects. First, its mathematical apparatus leads to fundamental computational difficulty (incomputable combinatorial complexity, CC, [11]), which cannot be scaled up to a realistic complexity of language. And second, objects of thoughts or cognitive concepts are supposed to be known; evolutionary linguistics has not been able so far to demonstrate how cognitive concepts and thoughts emerge in interaction with language [12].

This section summarizes neural and cognitive mechanisms developed in [9, 11-17]. We investigate a hypothesis of joint emergence of language and cognition. Perception of objects does not require language. This ability exists in animals lacking human language. Yet, abstract thoughts cannot emerge without language. The reason is that learning requires grounding. The problem of grounding in learning of language and cognition was discussed in [18-22]. At the lower levels in the hierarchy of thought learning is grounded in direct perception of the world. Learning is grounded in real objects. At higher levels, however, learning of abstract cognitive representations has no ground. Abstract thoughts are called abstract exactly for this reason, they cannot be directly perceived. Language acquisition by an individual, on the opposite, is grounded in the language, which is spoken in the environment; this grounding exists at every level (sounds, words, syntax, phrases, etc.). There is a popular idea that abstract thoughts are learned as useful combinations of simpler objects. Mathematical analysis, however, reveals that this idea is naïve. It is mathematically impossible to learn useful combinations of objects among many more useless ones, because the number of combinations is too large. In every situation there are hundreds of objects, most of which are not relevant to a particular situation, and we learn to ignore them. Combinations of just 100 objects are 100^{100}, an astronomical number exceeding all elementary interactions in the Universe in its entire lifetime. So, how is this learning possible? Learning which combinations are useful and which are useless is not possible during an individual lifetime. Given references proposed a hypothesis that learning abstract ideas is only possible due to language, which accumulates millennial cultural wisdom. The speed of accumulation of knowledge in cultural evolution, likely, is combinatorially fast [23], so one CC cancels the other, which makes emergence of language and cognition mathematically possible only in the process of joint in evolution. Language learning by an individual, as discussed, is grounded in the surrounding language. We learn words, phrases, and general abstract ideas ready-made from the surrounding language. Mathematical models of this process are considered in the following sections.

Cognition as well as language has a hierarchical structure, illustrated in a simplified way in Fig. 1. This hierarchy is not strict. Feedbacks among multiple levels play an important role in language and thinking mechanisms. The fundamental aspect of these mechanisms is an interaction of bottom-up and top-down signals between adjacent levels, also called afferent and efferent signals [24]. Consider first thought and language processes separately. At every level, neural representations of concepts, or internal mind models, receive bottom-up signals from models recognized at a lower level. Models approximately corresponding to these signals are excited and send top-down neural signals to a lower level. Cognition processes consist in matching top-down signals to patterns in bottom-up signals. A successful match results in recognition of an object, a situation, or emergence of a thought. The corresponding models are excited and send neural signals up the hierarchy. At the very bottom of the hierarchy the source of bottom-up signals are sensory organs.

The following sections consider interacting bottom-up and top-down signals, first for cognition, then for interacting cognition and language, and biological drives for these processes.

II. THE KNOWLEDGE AND LANGUAGE INSTINCTS

Matching bottom-up and top-down signals, as mentioned, constitutes the essence of perception and cognition processes. Models stored in memory as representations of past experiences never exactly match current objects and situations. Therefore thinking and even simple perception always require modifying existing models; otherwise an organism will not be able to perceive the surroundings and will not be able to survive. Therefore humans and higher animals have an inborn drive to fit top-down and bottom-up signals. This mechanism is called the knowledge instinct, KI [14, 15, 25-27]. This mechanism is similar to other instincts [14, 15, 28] in that our mind has a sensor-like mechanism that measures a similarity between top-down and bottom-up signals, between concept-models and sensory percepts. Brain areas participating in the knowledge instinct were discussed in [29]. As discussed in that publication, biologists considered similar mechanisms since the 1950s; without a mathematical formulation, however, its fundamental role in cognition was difficult to discern. All learning algorithms have some models of this instinct, maximizing correspondence between sensory input and an algorithmic internal structure (knowledge in a wide sense). According to the instinct-emotion theory [28], satisfaction or dissatisfaction of every instinct is communicated to other brain areas by emotional neural signals, which direct appropriate actions. In case of KI these emotional signals are felt as harmony or disharmony between the knowledge-models and the world. At lower levels of everyday object recognition, these emotions are usually below the threshold of consciousness; at higher levels of abstract and general concepts, this feeling of harmony or disharmony could be strong, as discussed in [15, 30], it is a foundation of human higher mental abilities.

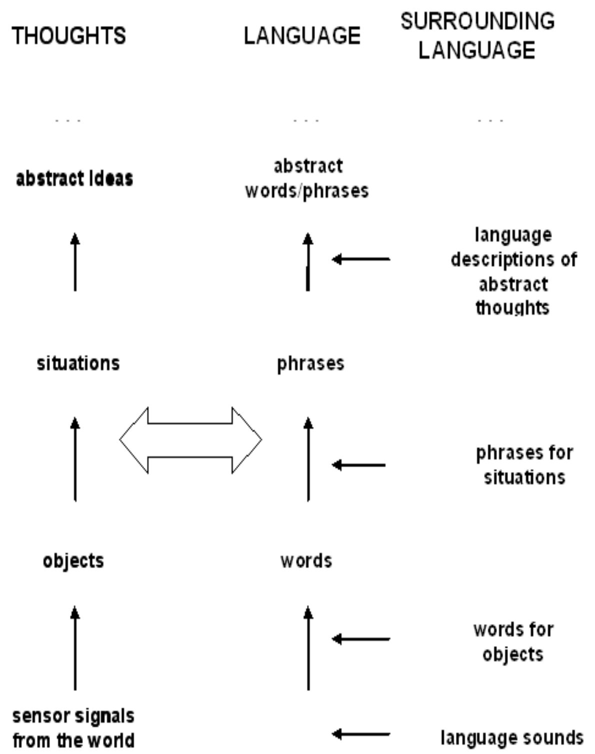

Fig. 1 Parallel hierarchies of cognition and language

Mathematical models of matching bottom-up and top-down signals have been developed for decades. This development met with mathematical difficulty of CC. This CC is related to the fact that in every concrete situation objects are encountered in different color, angle, lighting, etc., but in addition, objects are encountered in different combinations. As discussed, every situation is a collection of many objects. Most of them are irrelevant to recognition of the situation and separating relevant from irrelevant objects leads to CC. The same is true about language. Every phrase is a collection of words, and only some of these words are essential for understanding the phrase. This problem is even more complex for understanding paragraphs or larger chunks of texts. Learning language also requires overcoming CC. Mathematically, CC is related to formal logic, which turned out to be used by all mathematical procedures in the past, even by those specifically designed to overcome logic limitations, such as neural networks and fuzzy logic [27, 31-33, 66]. The mathematics capable of overcoming CC, dynamic logic (DL), which models the process of satisfaction of KI, while overcoming CC has been developed in [15, 25-27, 34-36]. In several cases it was mathematically proven that DL achieves the best possible performance [37-40] in matching bottom-up and top-down signals. The next section describes DL mathematically. Here we discuss DL conceptually.

The fundamental property of DL, which enables it to overcome CC, is a process “from vague-to-crisp” [27, 32, 33]. In this process vague representations-models evolve into crisp ones, matching patterns in bottom-up signals without CC. The DL process mathematically models actual neural processes in the brain. This can be illustrated, based on current knowledge of the brain neural architecture, with a simple experiment. Just close your eyes and imagine an object in front of you. The imagined object is vague-fuzzy, not as crisp as a perception with opened eyes. We know that this imagination is a top-down projection of models-representations onto the visual cortex. This demonstrates that models-representations are vague, similar to models in the initial state of the DL process. When you open your eyes, these vague models interact with bottom-up signals projected onto the visual cortex from retinas. In this interaction vague models turn into crisp perceptions as in the DL process. Note that with opened eyes it is virtually impossible to recollect vague images perceived with closed eyes; during usual perception with opened eyes, we are unconscious about the DL-process from vague to crisp.

Similar experiments were conducted in much more details using neuro-imaging technology [41]. The authors confirmed that the initial state of representations is vague. The process from vague-to-crisp, in which vague models match patterns in retinal signals takes about 160 ms. This process is unconscious. Only in the final state of the process, a crisp perception of an object is conscious. Authors also identified brain modules participating in this perception process.

It has been suggested that not only perception, but all cognitive and language processes at all levels in the hierarchy proceed according to DL, the process from vague-to-crisp [27]. These are processes, in which new cognitions-representations are born when vague cognitions, results of previous cognitive processes, interact with current reality. These processes of creating new thoughts are driven by an inborn mechanism, striving to match thoughts to reality. This mechanism has been called a need for knowledge, curiosity, cognitive dissonance, or KI [27, 42-50]. Mathematical modeling of perception and thinking revealed fundamental nature of this instinct: all mathematical algorithms for learning have some variation of this process, matching bottom-up and top-down signals. Without matching previous models to the current reality we will not perceive objects, or abstract ideas, or make plans. This process involves learning-related emotions evaluating satisfaction of KI [27, 28, 29, 51].

Bar et al. [41] experimentally demonstrated neural mechanisms of DL in visual perception. Experimentally demonstrating neural mechanisms of DL for higher cognitive levels, for language, and for joint operations of learning and cognition is a challenge for future research and we hope that the mathematical theory proposed in this paper will help identifying experimental approaches [52].

This process of creating new knowledge, however, is not the only way of decision making [29, 53, 54]. Most of the time, most people do not use KI and do not create new knowledge corresponding to their circumstances. More often people rely on ready-made rules, heuristics, even if they only approximately correspond to concrete individual situations. This preference for rules, heuristics, instead of original thinking is the content of the Tversky and Kahneman [55, 56] theory that received a Nobel Prize in 2002. This reliance on heuristics, even in cases when correct decisions are easily within the grasp of one’s thinking, psychologists often call the basic irrationality of human thought [54, 57]. The proposal in [13, 14, 17, 29, 35] relates thinking by heuristics and relates irrationality to language, which interacts with cognition according to Fig. 1.

Whereas KI drives learning of cognitive models toward better correspondence to events in the world, a different drive, the language instinct (LI) drives learning of language models [58]. The fundamental difference of LI from KI is that LI drives learning of language models to correspond to the surrounding language. Why these two different instincts are necessary? Cognitive models can be directly compared to events in the world only at lower levels of the mind hierarchy, up to the level of objects. At higher levels of abstract concepts this is not possible; abstract concepts are called this way exactly because they cannot be directly observed in the world. Abstract concepts are first learned in language. Every child by the age of 5 or 7 can talk about much of knowledge existing in surrounding culture. Yet, a child cannot behave as an adult in real life. This early learning of language is possible because language models exist in surrounding language “ready-made,” throughout the entire hierarchy from objects to abstract ideas. LI drives human mind to learn language models in correspondence with surrounding language [59]. Learning language does not require complete understanding how language relates to the world. This early learning of language is necessary for subsequent learning of cognitive representations, especially abstract representations “above” objects. Abstract concepts are learned from experience guided by language. Let us repeat, learning directly from experience is not possible because every abstract concept involves many lower-level concepts in varying degrees; and every experience involves many lower and higher level concepts. The number of possible combinations of lower-level concepts at every level much exceeds all human experiences during the lifetime and results in incomputable CC. One’s own experience would never be sufficient for learning abstract concepts. It is only possible when guided by language, which accumulates cultural wisdom.

III. DYNAMIC LOGIC, MATHEMATICAL FORMULATION

We summarize now a mathematical theory combining the discussed mechanisms of language and cognition as interaction between top-down and bottom-up signals at a single layer in the multi-layer hierarchical system following [15, 60-62]. KI and LI maximize a similarity measure L between top-down signals M and bottom-up signals X, at every level of hierarchy h,

$$L = \prod_h L_h. \quad L_h = \prod_n \sum_m l_h(n|m) \qquad (1)$$

Here h denotes hierarchy levels; we omit this index below; l(n|m) is a shortened notation for $l(X_n|M_m)$, a partial similarity of a bottom-up signal in pixel n given that it originated from model m. Similarity L accounts for all combinations of signals n coming from any model m, hence the huge number of items MN in Eq.(1); this is a basic reason for CC of most algorithms. The models depend on unknown parameter values S, $M_m(S)$.

KI and LI maximize the similarity L over model parameters S. Dynamic logic maximizes similarity L while matching the vagueness or fuzziness of similarity measures to the uncertainty of models; this process overcomes. It starts with any unknown values of the parameters S and defines association variables f(m|n),

$$f(m|n) = l(n|m) / \sum_{m'} l(n|m') \qquad (2)$$

Initially, parameter values are not known, and the uncertainty of partial similarities is high. So the fuzziness of the association variables is high. In the process of learning, the models become more accurate, and association variables more crisp, as the value of the similarity increases. The dynamic logic process always converges as proven in [29].

Earlier formulations of using dynamic logic for joint learning of cognition and language were considered in [63-66]. Here we consider a more powerful model. For concreteness, we discuss a child learning to recognize situations (upper level), assuming that objects constituting situations (lower level) are known. This is a simplification, in real life multiple hierarchical levels are learned in parallel. We use this simplification for an ease of presentation, it is not essential for the mathematical method. For the hierarchical system of cognition (or language) the partial similarities are defined according to [61] using binomial distribution,

$$l(n|m) = p_{mi}^{xni} (1 - p_{mi})^{(1-xni)} \qquad (3)$$

Here, Do is the total number of objects that the child can recognize; n is the index of an observed situation encountered by the child; m is the index of a model (of a state in the child's brain); and i is the index of an object; pmi are model parameters, they are the probabilities that object i is present in situation-model m; xni are data indicating presence (x=1) or absence (x=0) of object i in observed situation n. In every situation the child perceives Dp objects. This is a much smaller number compared to Do. Each situation is also characterized by the presence of Ds objects essential for this situation (Ds < Dp). Normally nonessential objects are present and Ds is therefore less than Dp. There are situations important for learning (Ds>0) and many clutter situations, composed of random collections of objects, which the child should learn to ignore.

The joint learning of language and cognition is achieved by using

$$l(n|m) = l^C(n|m) * l^L(n|m) \qquad (4)$$

where C and L denote cognitive and language parts of the partial similarity; data, models and their parameters are separate for cognition and language and all have these indexes. Below we usually omit these indexes. LI drives learning of language models from language data, and KI drives learning of cognitive models from sensory data.

The DL process is an iterative estimation of the model parameters, pmi. First it starts with all probabilities set randomly within a narrow range around 0.5; this corresponds to a vague initial state, in which all objects (words) have approximately equal probabilities of belonging to any situation-model (phrase model). Second associations f(m|n) are computed. Third, parameter values are updated according to [61],

$$p_{mi} = \sum_n f(m|n)\, x_{ni} / \sum_{n'} f(m|n') \qquad (5)$$

The iterative DL process is defined as follows. After initiation, association variables f(m|n) are defined according to (2). An intuitive meaning of this equation is that probabilities are weighted-averages of the data. Upon convergence, associations f(m|n) converge to 0 or 1, and probabilities for each situation are average values of data for this situation. The DL iterations are defined by repeating the second and third steps until convergence.

This formulation of joint learning of language and cognition models actions of LI and KI. As analyzed in details in given references, this is the only computable model of learning of either of them. This model includes conceptual and emotional mechanisms. (Let us emphasize that we use word "model" in two different ways: for mathematical modeling of the mind mechanisms, and for inner mind models-representations, Mm. Conceptual mechanisms are modeled by models-representations, and emotional mechanisms are modeled by satisfaction of KI and LI, which increase at every step of the DL iterations. This mathematical process of the joint language-cognition learning models conceptual-emotional processes in mind, and forms a basis for the following discussions.

IV. EMOTIONAL SAPIR-WHORF HYPOTHESIS

Benjamin Whorf [67] and Edward Sapir [68] in a series of publications in the 1930s researched an idea that the way people think is influenced by the language they speak. Although there was a long predating linguistic and philosophical tradition, which emphasized influence of language on cognition [69-71], this is often referenced as Sapir-Whorf hypothesis (SWH). Linguistic evidence in support of this hypothesis concentrated on conceptual contents of languages. For example, words for colors influence color perception [72, 73]. The idea of language influencing cognition and culture has been criticized and "fell out of favor" in the 1960s [74] due to a prevalent influence of Chomsky's ideas emphasizing language and cognition to be separate abilities of the mind [1]. Recently

SWH again attracted academic attention, including experimental confirmations (see the previous references) and theoretical scepticism [75]. Interactions between language and cognition have been confirmed in fMRI experiments [76]. Brain imaging experiments by Franklin, et al [77] demonstrated that learning a word "rewires" cognitive circuits in the brain, learning a color name moves perception from right to left hemisphere. These recent data address in particular an old line of critique of SWH: whether the relationships between cultures and languages are causal or correlational; and if causal, what is the cause and what is the effect. Franklin et al. [77] experiments have demonstrated that language affects thinking, not the other way around. This discussion will be continued later but first I would like to emphasize that all arguments and experiments about SWH referenced above concentrated on conceptual effects of language.

Emotional effects might be no less important [78, 79]. In particular indicative are results in [78]: whereas the mother tongue is usually perceived as more emotional, Spanish-English bilinguals reported more intense emotions in psychological interviews conducted in Spanish than in English, irrespective of whether their first language was English or Spanish. Still, experimental evidence of interaction between the emotional contents of languages and cognition is limited, the neural mechanisms of these interactions are not known, and no computational models have existed prior to our publications [14, 15, 80-89].

This paper has summarized neurally motivated computational models of how conceptual and emotional contents of language affect cultures. The next section reviews conceptual and emotional mechanisms of language and its interaction with cognition. We briefly review existing theoretical ideas and experimental evidence on language evolution, conceptualizing possible mechanisms, and emphasizing directions for future research. Section 5 summarizes previously developed neuro-mathematical theories of interaction between language and cognition [14, 15, 80, 81, 82, 83, 84, 85, 86, 87, 88, 88, 89, 90, 91], which have been partially proven experimentally. Section 6 derives neurally motivated cultural evolutionary models and demonstrates that different cultural evolutionary paths are favored by differences in emotionally driven interactions between cognition and language. Conclusion discusses future theoretical and experimental directions.

V. LANGUAGE AND COGNITION. PHYSIOLOGY AND PSYCHOLOGY OF THE SECTION 3 MODEL

Language is widely considered as a mechanism for communicating conceptual information. Emotional contents of language are less appreciated and their role in the mind and evolutionary significance are less known. Still their roles in ontology, evolution, and cultural differences are significant [92]. Whereas much research concentrates on language-computation, sensory-motor, and concept-intention interfaces [93], this paper emphasizes that the primordial origin of language was a unified neural mechanism of fused voicing-behavior, emotion-motivation, and concept-understanding [94-96]. It is likely that differentiation of mechanisms involved in language, voicing, cognition, motivation, and behavior occurred at different prehistoric times, in different lineages of our ancestors. This may be relevant to discussions of evolution of language and cognition [97, 98] (Botha, 2003; Botha & Knight 2009).

The paper addresses the current differentiated state of these abilities in the human mind, as well as unifies mechanisms of interfaces-links, which make possible integrated human functioning. The paper concentrates on mechanisms of existing interfaces and their cultural evolution. On the basis of mechanisms of language, concepts, and emotions modeled mathematically in the previous section, here we summarize these mechanisms conceptually in correspondence with general knowledge documented in a large number of publications emphasizing certain aspects that have escaped close scientific attention in the previous research.

A. *Undifferentiated Animal's Psyche*

Muscles of animals' vocal tract are controlled from the ancient emotional center [95, 96] summarized the state of knowledge about vocalization by apes and monkeys. Emotional-behavioral meanings of calls are not differentiated; primates vocalization is closely related to their emotional-behavioral situations; this is one reason they cannot have language [94- 96].

Sounds of animal cries engage the entire psyche, rather than concepts and emotions separately. An ape or bird seeing danger does not have voluntary control about what to say to its fellows. A cry of danger is *inseparably* connected to recognition of a dangerous situation, and with a command to oneself and to the entire flock: "Fly!" An understanding (concept of danger), evaluation (emotion of fear), and behavior (cry and wing sweep) are not differentiated. Recognizing danger, crying, and flying away is an inseparable concept-emotion-behavioral *synthetic* process of cognition-action. Animals can not control their larynx muscles *voluntarily*.

B. *Language and Differentiation of Emotion, Voicing, Cognition, and Behaviour*

Emergence of language required freeing vocalization from uncontrolled emotional influences. Undifferentiated unity of emotional, conceptual, and behavioral-(including voicing) mechanisms had to separate-differentiate into partially under volitional control [95, 96]. This volitional emotional mechanism evolved in parallel with language computational mechanisms. In contemporary languages the conceptual and emotional mechanisms are significantly differentiated. Languages evolved conceptual contents, while reducing their emotional contents. Cognition, or understanding of the world, consists of matching mental concept-models with patterns in sensor data; according to [99] this involves simulator-processes re-enacting past experiences. Mathematical models of these processes are similar to models in Section 3 [60]. Representations-models generate top-down signals that are matched to bottom-up neural signals coming from lower levels [24, 13]. In this simulation process vague mental models-representations are modified to match concrete objects or situations [13, 14, 25, 32, 41].

Cognitive processes in humans are strongly affected by language [14, 15]. Cognitive abilities in primates are independent from language. A mathematical model of language guiding cognition have been discussed in [12, 14, 19, 51, 63-66, 81-88, 100, 101]. This is called the dual model: every concept-model has two parts: language and cognitive. The language models (words, phrases) are acquired from surrounding language by early age. They contain cultural experience accumulated through generations. The language models guide the acquisition of cognitive models.

C. Instincts and Emotions

Below we conceptually discuss the mathematical model of Section 3. The word emotion refers to several neural mechanisms in the brain [102]; as discussed previously, this paper always refers to instinctual-emotional mechanism described in [28]. Instinct in correspondence with this reference denotes a simple inborn, mechanism of internal "sensor," measuring vital body parameters, such as sugar level in blood, and indicates to the brain when these parameters are out of safe range. More details could be found in [103] and references therein. Our organisms have many such sensors, measuring body temperature, pressure at various parts of the body, etc.

Mental representation-concept mechanisms evolved for instinct satisfaction. According to [28], communicating instinctual needs from instinctual "sensors" to decision making brain organs is performed by emotional neural signals. Processes of understanding of objects or situations that potentially can satisfy an instinctual need receive preferential attention and processing resources in the brain.

D. The Knowledge Instinct

As discussed in Section II, understanding the world requires matching top-down signals from concept-models to bottom-up signals coming from sensory organs. It is required for survival. Therefore high animals have an inborn drive to fit top-down and bottom-up signals, the knowledge instinct, KI, [14, 26, 51, 104-106]. Specific emotions related to satisfaction or dissatisfaction of KI are related purely to knowledge, not to bodily needs; this type of emotions are called aesthetic emotions [107]. They are inseparable from perception and cognition, while at the top of the mental hierarchy they are the foundation for emotions of the beautiful and sublime [105, 108-113].

Various aspects of this mechanism have been discussed by many scientists under various names: a need for positive stimulations, curiosity, a motive to reduce cognitive dissonance, a need for cognition [28, 43, 114-116]. This drive however was not mentioned among 'basic instincts', it has not been recognized as similar to instincts for food and procreation. The mathematical modeling of workings of the mind clarified the fundamental basis of this mechanism. Knowledge has to be modified to fit surrounding situations. Objects are never exactly same as in the past: angles, distance, and surrounding contexts are different. Therefore, mental representations have to be modified; learning is required [24, 117]. Higher animals and all learning and adfaptive algorithms maximize correspondence between the internal structure (knowledge in a wide sense) and objects of recognition; the psychological meaning of this mechanism is KI [29] discussed the mind-brain mechanisms of KI. It is a foundation of higher cognitive abilities, it defines the evolution of cognition and cultures.

E. The KI and Aesthetic Emotions at Higher Levels of the Hierarchy

At lower levels of the mental hierarchy, Fig.1, KI acts autonomously and aesthetic emotions could be below the level of conscious registration, whereas conceptual parts are accessible to consciousness. Near the top of the hierarchy mental representations unify entire life experience and their conceptual contents are perceived as the meaning of life. Aesthetic emotions associated with learning-adaptation of these representations are perceived as emotions of the beautiful and sublime. Language parts of these representations are conscious and have evolved in cultural evolution. Cognitive parts of these representations are mostly below the level of conscious [87, 105, 106, 109, 110, 121, 122]

F. Language and Differentiation

Language part of voice began separating from emotional centers more than two millions years ago. Still, languages contain emotions. Most of them originate in cortex and are controllable aesthetic emotions. Emotional centers in cortex are neurally connected to limbic centers, so old and new influences are present. Language sounds, so-called prosody of voice, carry emotional contents of languages. Human voice therefore affects us emotionally, which is most pronounced in songs [81, 119, 123 -129].

Emotional contents of speech usually are low, unless it is specifically intended. Emotionality of everyday "non-affective" speech may not be noticed. Yet, "the proper level" of emotional contents is crucial for developing cognitive mental models. If language is "too" highly emotional, any conversation turns into fights and there is no room for deliberate discussions. If language is non-emotional at all, there is no motivation for conversations, for developing high cognitive models. Higher cognition would not be developed. Models of situations and higher cognition, as discussed, are developed based on language models [12, 14, 15, 81-85, 87-91, 100, 130]. Interactions between cognitive and language models require emotional motivations.

Animal's integrated voice-cognition-emotional models, have differentiated in humans long ago. The involuntary ties between voice, emotion, and cognition have dissolved with emergence of language. They have been substituted by habitual connections. All languages have changed their sounds. Sounds, emotions, and meanings in languages could disconnect. However, if language sounds change slowly the connections between sounds and meanings persists and the emotion-meaning connections are maintained. This is a foundation of meanings because, as discussed, meanings require motivations. If language sounds change too fast, the cognitive models loose motivations, and meanings disappear. If the sounds change too slowly emotions nail the meanings to the old ways, and culture cannot evolve.

Cognitive models may contain meanings separate from language [12], but transmission of cognitive models from generation to generation cannot be accomplished without language. Cognitive models do not jump from one head to another, but language models can. Language models are major vehicle of cultural knowledge shared among individual minds and collective culture. Mathematical models in Section III suggest that language guides cognitive contents. Existing experimental evidence supports the idea that language affects brain, and therefore cultures [77].

These arguments suggest that for understanding cultural evolution it is needed to identify mechanisms of changes of the language sounds. As we will demonstrate, changes in the language sounds depend on grammar. Affixes, endings, and other inflectional devices in inflectional languages are fused with sounds of entire words. Pronunciations of affixes are controlled by few rules, persisting over entire language. These few rules are used in every phrase. Therefore every child learns to pronounce them properly. Vocal tract and mouth muscles for pronunciation of affixes (etc.) are preserved throughout population and are conserved through generations. Correspondingly, sounds of whole words are preserved, and language sounds change slowly. Therefore inflections literary are "tails that wag the dogs," they fix language sounds and preserve meanings. Humboldt [70] likely meant this by "firmness" of inflectional languages. When inflections disappear, this anchor does not exist, and the sounds of language become fluid and change with every generation.

In English language this occurred after transition from Middle English to Modern English [131]. Most of inflections have disappeared and sounds of the language were changing within each generation; this process continues today. English lost excessive emotionality and evolved into a powerful tool of cognition. English spreads democracy, science, and technology around the world. This has been made possible by conceptual differentiation empowered by language, which overtook emotional synthesis. But the loss of synthesis has also lead to ambiguity of meanings and values. Current English language cultures face internal crises, uncertainty about meanings and purposes. Many people cannot cope with diversity of life. Future research in psycholinguistics, anthropology, history, historical and comparative linguistics, and cultural studies will examine interactions between languages and cultures. Initial experimental evidence suggests emotional differences among languages are consistent with our hypothesis [78, 79].

Neural mechanisms of grammar, language sound, related emotions-motivations, and meanings hold a key to connecting neural mechanisms in the individual brains to evolution of cultures. Studying them experimentally is a challenge for future research. It is not even so much a challenge, because experimental methodologies are at hand; they just should be applied to these issues. The following sections develop mathematical models based on existing evidence that can guide this future research

VI. DIFFERENTIATION AND SYNTHESIS

Let us recollect that mental representations are stored in memory as vague and distributed; they do not remind images of objects or situations. In the process of matching top-down and bottom-up signals, these vague representations are matched to sensory images and become crisp. This however is only possible at lower levels of concrete object perception. Object perception, in other words, is grounded in sensor data. At higher cognitive levels there is no concrete sensor data to ground cognition of abstract concepts. Higher level cognition is only possible due to language. Mental language representations are acquired from surrounding language, where they exist "ready-made." Learning of language does not require understanding of real life. For this reason language can be acquired early in life. This is why children learn language by 5 years of age, but cannot act like adults. The part of language instinct related to language learning is specific to humans; Pinker called it "the language instinct" [58]. The language instinct, however, does not connect language learning to real life. Cognitive representations connected to sensor and motor data are developed from life experience; the development of the hierarchy of these representations, far removed from direct sensor data, is only possible due to guidance by language. Cognitive representations connect language to life. This process (as any other mental process) could only move due to emotional motivations. Therefore, emotionality of language is crucial for connecting language to life [12, 14, 51, 82, 84-91].

We would emphasize this fundamental contradiction of the human mind mechanisms. Human cognition requires language. Evolution of language is only possible due to reduced emotionality of vocalization. Reduced emotionality constitutes the very possibility of language evolution and enables human cognition. However, if emotionality of a language becomes "too low," it is not connected to real life, and becomes void of meaning. Human thinking exists in this contradiction: abstract concepts that do not steer emotions are weakly connected to life experience.

The fundamental contradiction of human mind described above affects the hierarchical dynamics of KI manifested as differentiation and synthesis. In interaction of top-down and bottom-up signals, at every layer of the hierarchy KI drives more crisp and detailed development of lower representations. At the same time KI drives higher representations toward more general and abstract ideas. Development of concrete and specific concepts is called differentiation, and creation of general concept-models, unifying differentiated signals is called synthesis.

Differentiation and synthesis are in complex relationships, at once symbiotic and antagonistic [51, 82, 87-91, 123-126, 132-134]. Synthesis creates emotional value of knowledge, it unifies language and cognition, and in this way it creates conditions for differentiation; it leads to spiritual inspiration, to active creative behavior leading to fast differentiation, creativity, knowledge, to science and technology. At the same time, a “too high” level of synthesis, “too” high emotional values of concepts stifles differentiation, as in traditional consciousness: every notion is so valuable emotionally that its differentiation becomes impossible. These considerations along with the above mathematical model of language-cognition interaction have been used to derive a mathematical model of cultural evolution [82, 89, 133].

Solutions of these equations result in several types of cultural evolution, which we describe here conceptually. Synthesis leads to growth of general concept-models and to growth of the hierarchy. This is counterbalanced by differentiation. Differentiation leads to the growth of the number of concepts approaching “precise knowledge about nothing”. When acquiring knowledge the growth of synthesis is limited psychologically since the emotions of KI satisfaction “spread” over large number of concepts cannot sustain the growing number of concepts. Thus, whereas emotional synthesis creates a condition for differentiation (high emotional value of knowledge, efficient dual model connecting language and cognition, conceptual differentiation undermines synthesis (emotional value of knowledge).

“Too high” level of synthesis stifles differentiation by creating too high emotional value of concepts. By creating emotional values of knowledge, it sustains differentiation. However, differentiation by spreading emotions among a large number of concepts destroys synthesis. At moderate values of synthesis the number of concepts grows until certain level, when it results in reduction of synthesis; then the number of models falls. As a number of models falls, synthesis grows, and the growth in models resumes. The process continues with slowly growing, oscillating number of models. Oscillations affecting significant part of knowledge indicate internal instability of knowledge-accumulating consciousness and cultures. This type of solution corresponds to “conceptual-differentiating” or “knowledge accumulating” culture.

Another type solution corresponds to initially high level of synthesis. Synthesis continues growing whereas differentiation levels off. This leads to a more and more stable society with high synthesis, in which high emotional values are attached to every concept. However, differentiation stagnates. This type of solution corresponds to “emotional-traditional culture.”

These two solutions defining two types of cultures can be compared to Humboldt’s [70] characterization of languages and cultures. He contrasted inert objectified “outer form” of words vs. subjective, culturally conditioned, and creative “inner form”. Humboldt’s suggestion continues to stir linguists’ interest today, yet seem mysterious and not understood scientifically.

Our analysis suggests the following interpretation of Humboldt’s ideas in terms of neural mechanisms. “Inner form” corresponds to the integrated, moderately emotional neural dual model [12, 14, 15, 81, 82, 87- 91, 100, 104, 124-126, 132, 133]. Contents of cognitive models are being developed guided by language models, which accumulate cultural wisdom. “Outer form” of language corresponds to inefficient state of neural dual model, in which language models do not guide differentiation of the cognitive ones. This might be due to either too strong or too weak involvement of emotions. If emotional involvement in cognition or language is too weak, learning does not take place because motivation disappears. If emotional involvement is too strong, learning does not take place because old knowledge is perceived as too valuable, and no change is possible. The first type of culture corresponds to low-inflected languages, when sound of language changes “too fast”, and emotional connections between sound and meanings are severed. The second type of culture might be characteristic of “too strongly” inflected languages, in which sound changes “too slowly” and emotions are connected to meanings “too strongly”. A brief look at cultures and languages certainly points to many examples of this case: highly inflected languages and correspondingly “traditional” stagnating cultures.

English is a typical language corresponding to “knowledge accumulating culture”. English lost most of its inflections relatively recently, during transition from Middle English to Modern English, which led to “Great vowel shift,” and its sounds was continuously changing since [131]. Arabic with its fusion grammar has a strong connection between sounds and meanings, and correspondingly to emotions and meanings; all words have strong emotional connotations. Arabic corresponds to “emotional-traditional culture”. This corresponds to Humboldt’s ideas. The integrated dual model assumes “moderate” emotional connection between language and cognitive models, which fosters the integration and does not impede it. Humboldt suggested that this relationship is characteristic of inflectional languages (such as Indo-European), inflection provided “the true inner firmness for the word with regard to the intellect and the ear” (today we would say “concepts and emotions”). The integrated dual model assumes a moderate value of synthesis, leading to interaction between language and cognition and to accumulation of knowledge. This accumulation, however, does not proceed smoothly; it leads to periodic cultural calamities; this characterizes significant part of European history from the fall of Roman Empire to recent times.

Much of contemporary world is “too flat” for an assumption of a single language and culture, existing without outside influences. When cultures interact, eventually they stabilize each other, both benefit from fast growth and reduced instabilities.

VII. DISCUSSION AND FUTURE RESEARCH

Models of neural mechanisms, language, emotions, and cultural evolution described here are initial steps requiring much experimental evidence and theoretical development. Influence of language on culture and the Bhartrihari-Humboldt-Nietzsche-Sapir-Whorf hypothesis formalized by the discussed mechanisms give new directions to this old idea. The emotional contents of languages could be more important in influence on cultures than their conceptual contents.

Chomsky's assumed independence of language and cognition denied scientific foundations for the Sapir-Whorf hypothesis (SWH). Today it is rejected by many linguists and psychologists, yet accepting evolution of languages and cultures will take more research. Consider the following statement challenging conclusions of this paper:

"This… challenges the possibility of perfectly representing the world with language, because it implies that the mechanisms of any language condition the thoughts of its speaker community" [74].

A naïve view of language "perfectly representing the world" is considered as a scientific possibility in Wikipedia. Psychological linguistics clearly has much to learn. [5] characterizes this unscientific view as "the prevalent commitment to uniformitarianism, the idea that earlier stages of languages were just as complex as modern languages". With the development of cognitive and evolutionary linguistics, diversity of languages are considered in their evolutionary reality. Neural mechanisms described in this paper and models inspired by these mechanisms are but an initial step in this line of research. It will be necessary to verify concrete predictions relating language grammars and types of cultures.

Future theoretical research should address continuing development of simulations, connecting neural and cultural mechanisms of emotions and cognition and their evolution affected by language. KI theory should be developed toward its differentiated forms explaining multiplicity of aesthetic emotions in language prosody and music [58-60, 90, 104, 119, 125, 126, 133]. The theoretical development should go along with experimental research [29, 41, 135] and the dual language-cognitive model [12, 14, 15, 81, 82, 87-91, 100, 123-126, 132, 133].

Experimental results [76, 77] support the mechanism of the dual model: learning language rewires the brain. Brain imaging can directly verify the dual model. Experimental studies should be expanded to interactions of language with emotional-motivational, voicing, behavioral, and cognitive systems.

Proposed correlation between grammar and emotionality of languages can be verified in direct experimental measurements using skin conductance and fMRI neuro-imaging. Emotional version of Sapir-Whorf hypothesis should be evaluated in parallel psychological and anthropological research. More research is needed to document cultures stagnating due to "too" emotional languages; as well as crises of lost values due to "low" emotionality of languages.

Anthropology could address the hypothesis that the primordial system of fused conceptual cognition, emotional evaluation, voicing, motivation, and behavior differentiated at different prehistoric time periods. Are there data to support this hypothesis, can various stages of prehistoric cultures be associated with various neural differentiation stages? Can different humanoid lineages be associated with different stages of neural system differentiation? What stage of neural differentiation corresponds to Mithen's hypothesis about singing Neanderthals [76]? Social, anthropologic, and psychological research should go in parallel documenting various cultural evolutionary paths and correlations between cognitive and emotional contents of contemporary and historical cultures and languages.

A parallel study should address differences between Indo-European (IE) and Chinese languages. There are significant differences in several respects affecting connections between sounds and meanings. Future research should address how these differences might affect evolution of language and cultures. Inflections have disappeared in Chinese languages more than two millennia ago. Great achievements of classical Chinese culture might correspond to initial centuries of simplified language grammar (similar to cultural flourishing in England that followed initial centuries of Modern English). It is possible that in later centuries Chinese culture did not play the role of the world cultural leader because the language emotionality did not support effective balance between emotions and meanings. Old Chinese writing was pictographic; providing a direct connection between pictograms and meanings. Pictographic languages, however, are not convenient for expressing abstract concepts. Phonetic elements were added with time, and pictograms were simplified and became characters with less direct connections to their meanings. Chinese languages are tonal languages. Whereas in most IE languages tone of voice is used exclusively for emotional language content, tone of voice in Chinese may convey also semantic content. This mixes emotions and meanings, contrary to the fundamental development of languages toward separation of emotional and semantic contents.

In addition there has been a significant historical cultural difference related to religions. In Near Eastern languages, inflections have led to very strong connections between sounds and meanings. This facilitated emergence of a monotheistic religion, in which morals and daily life were directly connected to the mystery of human spirit and the highest goals of human existence. Unification of human soul in monotheistic religions creates conditions for striving toward higher goals and creativity. When monotheistic religion was later combined in Europe with less inflected languages, this combination of everyday and the highest in human psyche led to significant increase in cultural creativity. In classical period Chinese culture created two teachings, acquiring religious significance over time. Lao Tse directed thinking toward the mystery of human soul, and Confucian teachings directed everyday work and morals. These two essential aspects of human psyche have not been connected in Chinese culture until the 20th century. It is possible that the current flourishing of Chinese culture is related to this unification of human soul, which has led to conditions for increased cultural creativity.

A similar process of cultural flourishing began in the 6th century in Islamic cultures due to emergence of Islam. It is possible that a slowdown of Islam cultures occurred several centuries later due to influence of a "too strong" inflection and emotion-meaning connections in Arabic language. “Too strong” connections nail thinking to the old ways.

The neural mechanisms of grammar, language sound, related emotions-motivations, and meanings hold a key to connecting the neural mechanisms in the individual brains to the evolution of cultures. Studying them experimentally is a direction for future research.

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