Research article

Language and cognition influence on evolution of cultures

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ABSTRACT

Evolution of cultures is influenced by languages. To understand this influence the paper analyzes how language and cognition interact in thinking. Is language just used for communication of completed thoughts, or is it fundamental for thinking? We review a hypothesis that language and cognition are two separate but closely interacting mechanisms, and identify each of them. Language accumulates cultural wisdom; cognition develops mental representations modeling surrounding world and adapts cultural knowledge to concrete circumstances of life. Language is acquired from surrounding language 'ready-made' and therefore can be acquired early in life. Cognition can not be acquired directly from experience; language is a necessary intermediary, a "teacher." This model is consistent with recent neuroimaging data about cognition, remaining unnoticed by other theories. The proposed theory explains a number of properties of language and cognition, which previously seemed mysterious. It suggests mechanisms by which language grammars influence emotionality of languages and directs cultural evolution. This theory may explain specifics of English and Arabic cultures. We review theoretical and experimental evidence and discuss future directions

Keywords: language, cognition, thinking, concepts, emotions, knowledge instinct, dynamic logic, mind, hierarchy, cultural evolution

THE DUAL MODEL OF LANGUAGE AND COGNITION INTERACTION

Languages affect cultures. Let us first look into how language is related to thinking. Do we use phrases to label situations that we already have understood, or the other way around, do we just talk with words without understanding any cognitive meanings? It is obvious that different people have different cognitive and linguistic abilities and may tend to different poles in the cognitive-language continuum, while most people are somewhere in the middle in using cognition to help with language, and vice versa. What are the neural mechanisms that enable this flexibility? How do we learn which words and objects come together? If there is no specific language module, as assumed by cognitive linguists, why do kids learn a language by 5 or 7, but do not think like adults? And why there are no animals thinking like humans but without human language?

Little is known about neural mechanisms for integrating language and cognition. Here we review a computational model that potentially can answer the above questions [1−11].

DUAL MODEL

Consider first how is it possible to learn which words correspond to which objects? Contemporary psycholinguists follow ancient Locke idea, 'associationsim': associations between words and object are just remembered. But this is mathematically impossible. The number of combinations among 100 words and 100 objects is larger than all elementary particle interactions in the Universe. Combinations of 30,000 words and objects are practically infinite. No experience would be sufficient to learn associations. No mathematical theory of language offers any solution. NMF-DL solves this problem using the Dual model [1−3]. Every mental representation consists of a pair of models, or two model aspects, cognitive and language. Mathematically, every concept-model M_m has two parts, linguistic ML_m and cognitive MC_m:

$$M_m = \{ML_m, MC_m\}. \tag{1}$$

This Dual-model equation suggests that the connection between language and cognitive models is inborn. In a newborn mind both types of models are vague placeholders for future cognitive and language contents. An image, say of a chair, and the sound "chair" do not exist in a newborn mind. But the neural connections between the two types of models are inborn; therefore the brain does not have to learn associations between words and objects: which concrete word goes with which concrete object. Models acquire specific contents in the process of growing up and learning, linguistic and cognitive contents are always staying properly connected. Zillions of combinations need not be considered. Initial implementations of these ideas lead to encouraging results [4−9].

DUAL HIERARCHY

Consider language hierarchy higher up from words, Fig. 1. Phrases are made up from words similar to situations made up from objects. Because of linear structure, language actually is simpler than situations; rules of syntax can be learned similar to learning objects and relations using markers, as described in the previous section. The reason computers do not talk human languages used to be the fundamental problem of combinatorial complexity [10].

The next step beyond current mathematical linguistics is modeling interaction between language and cognition. It is fundamental because cognition cannot be learned without language. Consider a widely-held belief that cognition *can* be learned from experience in the world. This belief is naïve and mathematically untenable. The reason is that abstract concepts-representations consist of a set of relevant bottom-up signals, which should be learned among practically infinite number of possible random subsets (their number is much larger than the Universe). No amount of experience would be sufficient for learning useful subsets from random ones.
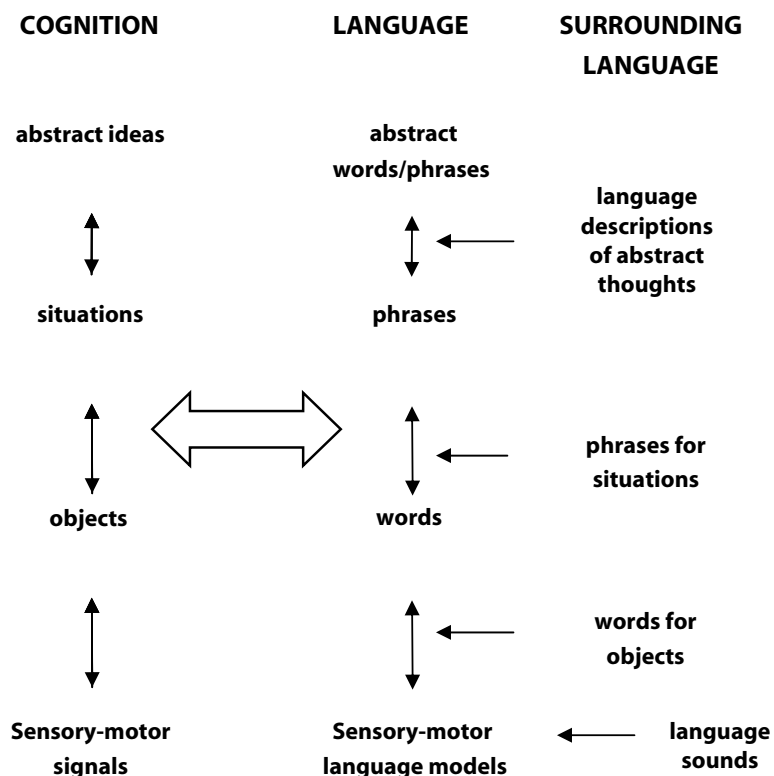
NMF-DL with the Dual model and dual hierarchy suggests that information is coming from language. This is the reason why no animal without human-type language can achieve human-level cognition. This is the reason why humans learn language early in life, but learning cognition (making cognitive representations-models as crisp and conscious as language ones) takes a lifetime. Information for learning language is coming from the surrounding language at all levels of the hierarchy. Language model-representations exist in the surrounding language 'ready-made.' Learning language is thus grounded in the surrounding language.

For this reason language models-representations become less vague and more specific by 5 years of age, much faster than the corresponding cognitive models for the reason that language models are

acquired ready-made from the surrounding language. This is especially true about the contents of abstract models, which cannot be directly perceived by the senses, such as "law," "abstractness," "rationality," etc. While language models are acquired ready-made from the surrounding language, cognitive models remain vague and gradually acquire more concrete contents throughout life guided by experience and language. According to the dual-model, this is an important aspect of the mechanism of what is colloquially called "acquiring experience."

Human learning of cognitive models continues through the lifetime and is guided by language models. If we imagine a familiar object with closed eyes, this imagination is not as clear and conscious as perception with opened eyes. With opened eyes it is virtually impossible to remember imaginations. Language plays a role of eyes for abstract thoughts. On one hand, abstract thoughts are only possible due to language, on the other, language "blinds" our mind to vagueness of abstract thoughts. Whenever one can talk about an abstract topic, he (or she) might think that the thought is clear and conscious in his (or her) mind. But the above discussion suggests that we are conscious about the *language* models of the dual hierarchy. The cognitive models in most cases may remain vague and unconscious. During conversation and thinking, the mind smoothly glides among language and cognitive models, using those that are crisper and more conscious – 'more available.' Scientists, engineers, and creative people in general are trained to differentiate between their own thoughts and what they read in a book or paper, but usually people do not consciously notice if they use representations deeply thought through, acquired from personal experience, or what they have read or heard from teachers or peers. The higher up in the hierarchy the vaguer are the contents of abstract cognitive representations, while due to crispness of language models we may remain convinced that these are our own clear conscious thoughts.

Animal vocalizations are inseparable from instinctual needs and emotional functioning. The Dual model has enabled separation of semantic and emotional contents, which made possible deliberate thinking. Yet operations of the Dual model, connecting sounds and meanings, require motivation.

COGNITION   **LANGUAGE**   **SURROUNDING LANGUAGE**

abstract ideas   abstract words/phrases   language descriptions of abstract thoughts

situations   phrases

     phrases for situations

objects   words

     words for objects

Sensory-motor signals   Sensory-motor language models   language sounds

Figure. 1 Parallel hierarchies of language and cognition consist of lower level concepts (like situations consist of objects). A set of objects (or lower level concepts) relevant to a situation (or higher level concept) should be learned among practically infinite number of possible random subsets (as discussed, larger than the Universe). No amount of experience would be sufficient for learning useful subsets from random ones. The previous section overcame combinatorial complexity of *learning*, given that the sufficient *information* is present. However, theories of mathematical linguistics offer no explanation where this information would come from.

Motivation in language is carried by sounds [11]. Future research will have to address remaining emotionality of human languages, mechanisms involved, emotional differences among languages, and effects of language emotionalities on cultures.

Evolution of the language ability required rewiring of human brain. Animal brains cannot develop ability for deliberate discussions because conceptual representations, emotional evaluations, and behavior including vocalization are unified, undifferentiated states of the mind. Language required freeing vocalization from emotions, at least partially [11,12]. This process led to evolution of ability for music [12].

Another mystery of human-cognition, which is not addressed by current mathematical linguistics, is basic human irrationality. This has been widely discussed and experimentally demonstrated following discoveries of Tversky and Kahneman [13], leading to the 2002 Nobel Prize. According to NMF-DL, the "irrationality" originates from the discussed dichotomy between cognition and language. Language is crisp and conscious in the human brain, while cognition might be vague. Yet, collective wisdom accumulated in language may not be properly adapted to one's personal circumstances, and therefore be irrational in a concrete situation. Possibly Adam was expelled from paradise because he refused original thinking using his own cognitive models, but ate from the tree of knowledge and acquired collective wisdom of language.

The dual-model also suggests that the inborn neural connection between cognitive brain models and language brain models is sufficient to set humans on an evolutionary path separating us from the animal kingdom. Neural connections between these parts of cortex existed millions of years ago due to mirror neuron system, what Arbib called "language prewired brain" [14].

The combination of NMF-DL and the dual hierarchy introduces new mechanisms of language and its interaction with cognition. These mechanisms suggest solutions to a number of psycholinguistic mysteries, which have not been addressed by existing theories. These include fundamental cognitive interaction between cognition and language, similarities and differences between these two mechanisms; word-object associations; why children learn language early in life, but cognition is acquired much later; why animals without human language cannot think like humans. These mechanisms also connected language cognition dichotomy to 'irrationality' of the mind discovered by Tversky-Kahneman, and to the story of the Fall and Original sin [15].

The mathematical mechanisms of NMF-DL-Dual model are relatively simple (see details in the given references). These mathematical mechanisms correspond to the known structure and experimental data about the brain-mind. In addition to conceptual mechanisms of cognition they also describe emotional mechanisms and their fundamental role in cognition and world understanding, including role of aesthetic emotions, beautiful, sublime, and musical emotions [16,17].

EXPERIMENTAL DATA

An experimental indication in support of the Dual model has appeared in [18]. That publication has demonstrated that the categorical perception of color in prelinguistic infants is based in the right brain hemisphere. When language is learned and access to lexical color codes becomes more automatic, categorical perception of color moves to the left hemisphere (between two and five years) and adult's categorical perception of color is only based in the left hemisphere.

This provides evidence for neural connections between perception and language, a foundation of the Dual model. It supports another aspect of the Dual model: the crisp and conscious language part of the model hides from our consciousness the vaguer cognitive part of the model. This is similar to what we observed in the close—open eye experiment: with opened eyes we are not conscious about vague imaginations.

Another experimental evidence for the Dual model is Mirror neuron system (MNS) [19]. In humans, primates, and some other social animals there are neurons that are excited when manipulating objects, and the same neurons are excited, when observing another animal making similar gestures. MNS involves areas of brain near Broca area, where today resides human language ability. M. Arbib suggested that language system was built on top of the MNS; he called it "language prewired brain" [20,21]. The Dual model proposed here models this hypothesis: before language evolves there are already connections between language and perception/cognition brain areas.

LANGUAGE EMOTIONALITY, GRAMMAR AND CULTURAL EVOLUTION

Every complex functioning neural mechanism requires motivation, correspondingly, functioning of the Dual model, requires motivations, or emotions, connecting language and cognitive sides of the Dual model, as illustrated in Fig. 2.

Emotionality of languages resides in their sounds, like the sound of music moves us emotionally. Animal voicing is fused with emotions; animals lack volunteer control over voice muscles, and therefore cannot develop language. Evolution of language required rewiring the brain, so that automatic connection of voice and emotions severed. Language and voice started separating from ancient emotional centers possibly millions of years ago. Nevertheless, emotions are present in language. Most of these emotions originate in cortex and are controllable aesthetic emotions. Emotional centers in cortex are neurally connected to old emotional limbic centers, so both influences, new and old are present. Emotionality of languages is carried in language sounds, what linguists call prosody or melody of speech. This ability of human voice to affect us emotionally is most pronounced in songs (Perlovsky 2010).

Emotionality of everyday speech is low, unless affectivity is specifically intended. We may not notice emotionality of everyday "non-affective" speech. Nevertheless, "the right level" of emotionality is crucial for developing cognitive parts of models. If language parts of models were highly emotional, any discourse would immediately resort to fights and there would be no room for language development (as among primates). If language parts of models were non-emotional at all, there would be no motivational force to engage into conversations, to develop the Dual model. Dual model is fundamental for developing representations of situations and higher cognition (Perlovsky, 2004; 2006a,c; 2007b; 2009). The motivation for developing higher cognitive models would be reduced.
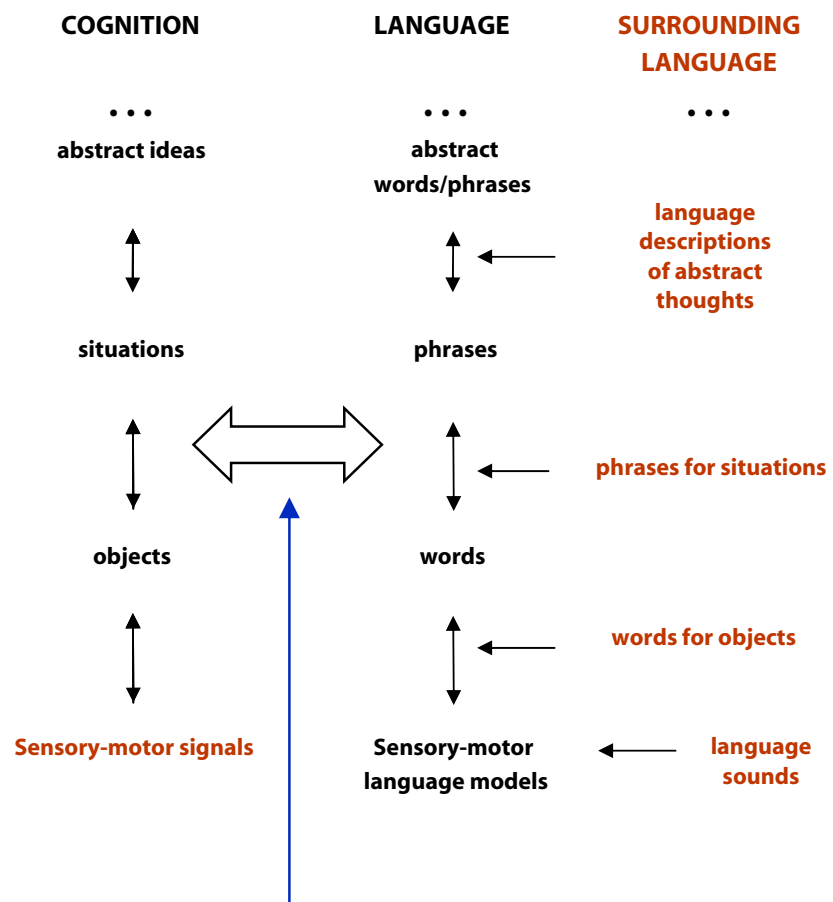
Figure. 2 Developing meanings by connecting language and cognition requires motivation, in other words, emotions. If language emotionality is too weak, language is disconnected from the world, meanings are lost, and cultures disintegrate. If language emotionality is too strong, connections could not evolve, cultures stagnate. Is it possible to keep the balance?.

Primordial fused language-cognition-emotional models, as discussed, have differentiated long ago. The involuntary connections between voice-emotion-cognition have dissolved with emergence of language. They have been replaced with habitual connections. Sounds of all languages have changed in history and sound-emotion-meaning connections in languages could have severed. However, if the sounds of a language change slowly the connections between sounds and meanings persist and consequently the emotion-meaning connections persist. This persistence is a foundation of meanings because meanings imply motivations. If the sounds of a language change too fast, the cognitive models are severed from motivations, and meanings disappear. If the sounds change too slowly the meanings are nailed emotionally to the old ways, and culture stagnates.

These arguments suggest that an important step toward understanding cultural evolution is to identify mechanisms determining changes of the language sounds. These changes are controlled by grammar. In inflectional languages, affixes, endings, fusion, and other inflectional devices are fused with sounds of word roots. Pronunciation-sounds of affixes and other inflections are controlled by few rules, which persist over thousands of words. These few rules are manifest in every phrase. Therefore every child learns to pronounce them correctly. Positions of vocal tract and mouth muscles for pronunciation of inflections are fixed throughout population and are conserved throughout generations. Correspondingly, pronunciation of whole words cannot vary too much, and language sound changes slowly. Inflections therefore play a role of "tail that wags the dog" as they anchor language sounds and preserve meanings. This, I think is what Humboldt [22] meant by "firmness" of inflectional languages. When inflections disappear, this anchor is no more and nothing prevents the sounds of language to become fluid and change with every generation.

This has happened with English language after transition from Middle English to Modern English near the 15th c. [23], most of inflections have disappeared and sound of the language started changing within each generation, this process continues today. English evolved into a powerful tool of cognition unencumbered by excessive emotionality. English language spread democracy, science, and technology around the world. This has been made possible by conceptual differentiation empowered by language, not constrained by emotional mechanisms. But the loss of emotionality has also led 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 consistent with this hypothesis [24,25].

Arabic language is highly inflected. Inflection mechanism called fusion affects the entire word sounds, the meaning of the word changes with changing sounds; also suffixes control verbs and moods. Therefore sounds are closely fused with meanings. This strong connection between sounds and meanings contributes to beauty and affectivity of Classical Arabic texts including Quran. On the other hand, creation of new meanings in Classical Arabic is difficult because of this strong connections, remaining unchanged for centuries, and also because of religious restrictions. Arabic language leads to a culture, where meanings and values are strong, but conceptual culture development is slow. There are significant differences between Classical Arabic and street Arabic languages, however, this topic requires separate study.

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.

FUTURE RESEARCH
The Dual model implies a relatively minimal neural change from the animal to the human mind. It could emerge through combined cultural and genetic evolution and this cultural evolution might continue today. DL resolves a long-standing mystery of how human language, thinking, and culture could have evolved in a seemingly single big step, too large for an evolutionary mutation, too fast and involving too many advances in language, thinking, and culture, happening almost momentarily around 50,000 years ago [26,27]. DL along with the Dual model explains how changes, which seem to involve improbable steps according to logical intuition, actually occur through continuous

dynamics. The proposed theory provides a mathematical basis for the concurrent emergence of hierarchical human language and cognition.

Initial neuro-imaging evidence supports the DL mechanism proposed in this paper, still much remains unknown. DL was experimentally demonstrated for the visual perception; these experiments should be extended to language and interaction of language and cognition. Evolution of languages can be studied using the developed theory and societies of intelligent agents [28].

Cognitive models of some of the mechanisms of evolving languages and cultures have been discussed in [1–3,10,11]. Future research should address evolutionary separation of cognition from direct emotional-motivational control and immediate behavioral connections. The suggested here relations between grammar and language sound should be further verified experimentally and theoretically. Relative roles of religions and languages in cultures should be understood. The cultural role of street Arabic languages should be studied. Emotionalities of different languages and their effects on cultural evolution shall be addressed.

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