Integrated Emotions, Cognition, and Language

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Abstract—**Recent developments in neural and cognitive sciences resulted in appreciation of emotions as inseparable part of intelligence. Emotions evaluate conceptual contents of cognition for instinctual satisfactions. This paper describes aesthetic emotions related to the knowledge instinct. It analyzes the role of emotions in language, develops a hypothesis that aesthetic emotions integrate cognition and language within a wholeness of psyche, and discusses possible brain mechanisms.**

I. INTRODUCTION

EMOTIONS refer to both exaggeratedly expressive communications and to internal states related to feelings. Love, hate, courage, fear, joy, sadness, pleasure, and disgust can all be described in both psychological and physiological terms. Emotion is the realm where thought and physiology are inextricably entwined, and where the self is inseparable from individual perceptions of value and judgment toward others and ourselves. Emotions are sometimes regarded as the antithesis of reason; as is suggested by phrases such as "appeal to emotion" or "don't let your emotions take over." A distinctive and challenging fact about human beings is a potential for both opposition and entanglement between will, emotion, and reason.

An essential role of emotions in working of the mind was analyzed in philosophy [1,2,3], psychology [4], neuro-psychology [5,6,7], linguistics [8], neuro-physiology [9], and from the learning and cognition perspective by the author [10,11,12]. Descartes attempted a scientific explanation of passions. He rationalized emotions, explained them as objects and related to physiological processes. According to Kant, emotions are closely related to judgments about which individual experiences and perceptions correspond to which general concepts and v.v. The ability for judgment is a foundation of all higher spiritual abilities, including beautiful and sublime. Kant's aesthetics is a foundation of aesthetic theories till this very day (we will continue this discussion later). Sartre equated emotions, to significant extent, with unconscious contents of psyche; today this does not seem to be adequate. Jung analyzed conscious and unconscious aspects of emotions. He emphasized undifferentiated status of primitive fused emotion-concept-behavior psychic states in everyday functioning and their role in neuroses. He also emphasized rational aspect of conscious differentiated emotions. Ortony explains emotions in terms of knowledge representations and emphasizes abductive logic as a mechanism of inferencing other people's emotions. Ledoux analyses neural structures and pathways involved in emotional processing, especially in fear. Griffiths considers basic emotions and their evolutionary development within social interactions. According to Damasio, emotions are primarily bodily perceptions, and feelings of emotions in the brain invoke "bodily markers." Grossberg and Levine consider emotions as neural signals that relate instinctual and conceptual brain centers. In processes of perception and cognition, emotions evaluate concept-models of objects and situations for satisfaction or dissatisfaction of instinctual needs.

This paper concentrates on aesthetic emotions and analyzes their role within joint functioning of cognition and language. Some aspects of the mathematical theory developed in the following sections closely follow ideas of Kant, Jung, Grossberg and Levine. The main mechanisms of this theory includes the following. Concepts are similar to internal models of the objects and situations in the world. They evolved for satisfaction of the basic instincts, which have emerged as survival mechanisms long before concepts. Instincts operate as internal sensors indicating the basic needs: for example, when a sugar level in blood goes below a certain level an instinct "tells us" to eat. Instincts are connected to cognition and behavior by emotional neural signals. Whereas in colloquial usage, emotions are often understood as facial expressions, higher voice pitch, exaggerated gesticulation, these are outward signs of emotions, serving for communication. A more fundamental role of emotions within the mind system is that emotional signals evaluate concepts for the purpose of instinct satisfaction.

The knowledge instinct is a special inborn mechanism responsible for cognition [13,14]. Clearly, humans and animals engage into exploratory behavior, even when basic bodily needs, like eating, are satisfied. Biologists and psychologists discussed various aspects of this behavior, calling it "the drive for positive stimulation," "curiosity," or "the drive to reduce cognitive dissonance," [15,16,17]. Until recently, however, it was not mentioned among 'basic instincts' on a par with instincts for food and procreation. The reasons were that it was difficult to define, and that its fundamental nature was not obvious. The fundamental nature of this mechanism is related to the fact that our knowledge always has to be modified to fit the current situations. A mathematical formulation of the mind mechanisms makes obvious the fundamental nature of our desire for knowledge. In fact virtually all learning and adaptive algorithms (tens of thousands of publications) maximize correspondence between the algorithm internal structure (knowledge in a wide sense) and objects of recognition. Knowledge is not just a static state; it is in a constant process of adaptation and learning. Therefore, we have an inborn need, a drive, an instinct to improve our

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knowledge. I call it *the knowledge instinct*. Mathematically it is described as a maximization of a similarity measure between concept-models and the world.

Emotions evaluating satisfaction or dissatisfaction of the knowledge instinct are not directly related to bodily needs. Therefore, they are 'spiritual' or aesthetic emotions. Ortony and Turner (1990) summarized views of fourteen contemporary psychologists about basic emotions. They all emphasize a few basic emotions. Three authors mentioned emotions that I consider aesthetic (Frijda, Izard, and McDougall mentioned interest and wonder). Despite of the fact that most of us experience an infinite manifold of emotions every time we listen to songs and music, psychologists have not recognized this and have no words for this sea of emotions. In this I see a hangover from Descartes, who described a few basic emotions as physiological objects. Already Spinoza mentioned that every emotion is different, depending on object it is associated with [18]. But contemporary psychologists do not recognize this basic fact of our psychology. The reason, I think, is that mechanisms or purposes of this diversity of emotions have not been known. This mystery is the subject of this paper.

II. MODELING FIELD THEORY (MFT)

The mathematical development in this paper is based on the theory of neural modeling fields (MFT) [19], briefly summarized below. The mind involves a hierarchy of multiple levels of concept-models, from simple perceptual elements (like edges, or moving dots), to concept-models of objects, to complex scenes, and up the hierarchy… toward the concept-models of the meaning of life and purpose of our existence. At every level of the hierarchy MFT associates lower-level signals with higher-level concept-models; a result is an understanding of signals as concepts. MFT is a multi-level, hetero-hierarchical system. Bottom-up signals $\{\mathbf{X}(n)\}$ is a neuronal field of input synapse activations. In the process of cognition they are matched to top-down concept-model signal-representations $\{\mathbf{M}_h(n)\}$. Computationally, it maximizes a similarity measure between the sets of models and signals, $L(\{\mathbf{X}(n)\},\{\mathbf{M}_h(n)\})$, over the model parameters, $\{\ \mathbf{S}_h\ \}$,

$$L(\{\mathbf{X}\},\{\mathbf{M}\}) = \prod_{n \in N} \sum_{h \in H} r(h)\, l(\mathbf{X}(n) \mid \mathbf{M}_h(n)); \qquad (1)$$

here, $l(\mathbf{X}(n)|\mathbf{M}_h(n))$ (or simply $l(n|h)$) is a conditional partial similarity between one signal $\mathbf{X}(n)$ and one model $\mathbf{M}_h(n)$; (1) accounts for all possible combinations of signals and models. Parameters $r(h)$, the "weights" of concepts h, are proportional to the number of signals $\{n\}$ associated with the model h. The similarity maximization is a mathematical description of the knowledge instinct. Changes in similarity values are aesthetic emotional signals.

Cognition consists in associating signals with concepts and estimating model parameters $\mathbf{S}_h$ by maximizing

similarity (1). Note, that (1) contains a large number of combinations of models and signals, a total of H^N items; this was a cause for the combinatorial complexity of the algorithms and neural network training procedures in the past. MFT solves this problem using the mechanism of fuzzy dynamic logic (DL) [20,19]. A fundamental aspect of DL is that the initial state of model similarities, $l(n|h)$, is fuzzy and corresponds to uncertainty in the knowledge of model parameters. In the course of learning, knowledge improves, and similarities converge to low-fuzzy, probabilistic, or crisp functions. When new data appear, which do not correspond well to existing models, similarity (1) becomes low and the esthetic emotion is negative. During learning, knowledge improves, similarity (1) increases, and the aesthetic emotion is positive.

MFT describes language similar to cognition . During language learning, input signals are sounds of language, and language models are models of words as composed of phonemes, or models of phrases as composed of words, and similarly up the hierarchy of the mind to models of paragraphs composed of phrases... to the models of text, like "Romeo and Juliet", or "Anna Karenina."

Integration of language and cognition in MFT is attained by characterizing objects and situations in the world with two types of models, cognitive and language models; so that

$$\mathbf{M}_h(n) = \{\mathbf{MC}_{hC}(n),\ \mathbf{ML}_{hL}(n)\}. \qquad (2)$$

Here **MC** stands for cognitive and **ML** for language models. Indexes hC and hL innumerate cognitive and language models; but it is not necessary to consider combinations of hC and hL, because initially all models are same, fuzzy blobs, just placeholders for future knowledge.

Such integrated MFT system learns similarly to human, in parallel in three realms: (1) language and cognitive models are learned jointly, when language data are present in association with perception signals, like during mother talking to a baby: "this is a car" (perception-models and word-models), (2) language models are learned independently from cognition, when language data are encountered for the first time with no association with perception and cognition (most of language learning during the age 2 to 7); (3) similarly, cognitive models are learned independently from language, when perception signal data are encountered for the first time without association with linguistic data. Cognitive and language learning always depend on each other to some extent. The original, inborn models are fuzzy structures equally and poorly matching any sensory or language data. In the process of learning fuzziness decreases, crisp models get associated with specific situations and phrases, and cognitive models always remain associated with language models. Because the integrated (cognitive, language)-model structures are inborn, association between language and cognition begins at a "pre-conceptual" fuzzy level, inaccessible to consciousness. Child learns a large number of language models, which association

with real life is fuzzy; throughout later life they facilitate learning of corresponding cognitive models; similarly, cognitive (say visual) models facilitate learning of language models; eventually h1 and h2, cognitive and language models are properly associated (that is similar across a society, so that people understand each other).

III. HIERARCHY OF LANGUAGE AND COGNITION

Integrated models (2) combined with hierarchical MFT organization lead to integrated cognitive and language hierarchies as illustrated in Fig. 1. An amazing aspect of the human mind is that these two hierarchies are integrated in such a way that relationships among constituent models are preserved. For example, a cognitive model of a situation and the corresponding phrase model are constituted from lower-level models: objects and words. Correspondence between these objects and words in the object-word level is the same as between them, when they become constituent parts of the phrase-situation level model. And this holds true across tremendous number of the phrase-situation level models, using various combinations of the same words from the lower level, and this correspondence is preserved throughout the hierarchy. This amazing property of our mind seems so obvious, that nontrivial complexity of the required mechanism was noticed only recently [21].

Let us elaborate a bit. A dog can learn to bring shoes on command. The dog can associate shoes with a word "shoes." Does it mean dog's mind possesses models (2)? Try to teach a meaning of a word "rational" to a dog. Apparently, a dog can associate sounds with objects, which it sees in the world. A dog treats sounds just like other objects. But it does not possess a hierarchy of integrated models. In dog's mind, cognitive models are "grounded" in objects and situations in the world. But abstract concepts require grounding in other concepts, a hierarchy of concepts is required. According to [21], smartest apes after years of training, could possibly learn 2 levels of a hierarchy. Why is it so difficult? Higher levels of a hierarchy in the ape mind have no "ground." In the human mind, higher level language models are grounded in conversations with other people: Mutual understanding "assures" our mind of the reality of language hierarchy. A cognitive hierarchy is supported by a language hierarchy. Possibly, an essential inborn difference between human and animal minds is that we possess structures similar to eq. (2) and Fig.1. This might be sufficient for evolution of symbolic culture.

Dawkins [22] called concept-models of the mind "memes" and emphasized that model selection will overtake gene selection because models are more efficient replicators. A mathematical description of this process is a subject of this paper. Cognitive models that proved useful in life and evolution cannot be directly transferred to the minds of the next generation. Only language models are transferred to the next generation. This separation between cognitive models and language models can be compared to separation between phenotypes and genotypes. In some ways this comparison could be deep and inspiring, in other ways, it is superficial and wrong. According to the current knowledge of genetics,

acquired properties of phenotypes are not incorporated into genetic information and are not transfer directly to the next generation (as proposed by Lamarck). Nobody knows why this is so, why genetic mechanisms avoid using a potentially more efficient Lamarckian accumulation of experience. One hypothesis is that it would result in a too fast adaptation to a local environment, so that if environment changes, Lamarckian species would not survive. I will attempt to identify mechanisms speeding and decelerating cultural evolution, and identify potential benefits and dangers of these mechanisms.
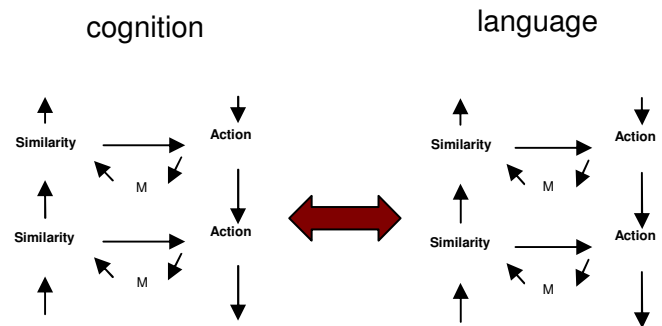

Fig.1. Hierarchical integrated language-cognition MF system. At each level in a hierarchy there are integrated language and cognition models. Similarities are integrated as products of language and cognition similarities. Initial models are fuzzy placeholders, so integration of language and cognition is sub-conscious. Associations depend on both language and cognitive models and signals. Therefore language model learning helps cognitive model learning and v.v. Abstract cognitive concepts are grounded in abstract language concepts.

Cognitive models created by each generation are accumulated in culture due to language. Cultural evolution selects useful models. Language accumulates cultural knowledge at all levels in a hierarchy of the mind. Due to integration of language and cognition, language provides a foundation for developing abstract high-level cognitive models in every human being. But, this requires that individual minds in each generation connect language and cognitive models. Every generation has to learn differentiated conscious *cognitive* models corresponding to the level of differentiation accumulated in language and culture. (In the far from perfect analogy between genetic and cultural evolution, language is transferred to the next generation with little changes, like DNA, and cognitive concept-models are developed by individuals, like phenotypes.

IV. EMOTIONS: DIFFERENTIATION AND SYNTHESIS

The only emotion that is inseparable from human cognition, as we discussed in section 2, is the aesthetic emotion. We are capable of separating other emotions related to bodily instincts from thinking processes. We can discuss dangerous situations without fear, we can discuss food without being hungry. This ability for differentiating concepts and emotions is closely related to our ability for

deliberate thinking. It is uniquely human. Animals cannot separate conceptual thinking about food from the emotion of hunger, from the instinctual need to eat.

This is also true about animal communications. Animals cannot deliberately control their vocal tract. Even our closest relatives, chimpanzees, cannot separate vocalizations and emotions [23]. Animal voice tract is governed from an ancient emotional center in the limbic system. Conceptual and emotional systems in animals are less differentiated than in humans. Sounds of animal cries engage the entire psyche, rather than concepts and emotions separately. An ape or bird seeing danger does not think about what to say to its fellows. A cry of danger is *inseparably* fused with recognition of a dangerous situation, and with a command to oneself and to the entire flock: "Fly!" [24]. An evaluation (emotion of fear), understanding of situation (concept of danger), and behavior (vocalization and wing sweep) – are not differentiated. Conscious and unconscious are not separated: Recognizing danger, crying, and flying away is a unified situational-behavioral fused form of thought-action. Animals can not control their larynx muscles *voluntarily*.

Human vocal tract is governed by two emotional centers, ancient less-conscious and less-voluntary, in limbic system, and recent cortical emotional centers, more conscious and voluntary. Language evolved toward differentiation of psyche. Language differentiates concepts, as well as concepts from emotions [25]. Differentiation between emotions and concepts, as mentioned, is a foundation for our thinking ability. This differentiation, however, is not entirely "good" for cognition. The *meaning* of concepts is not limited to relationships among words and phrases in language, but requires connections between language and cognitive models, eq. (2), connections among cognitive models within the cognitive hierarchy, Fig. 1, and connections of cognitive models to instincts, including the instinct for knowledge, eq. (1). Animal vocalizations are not as differentiated as human, but directly wired to their instinctual needs. Animal cries, therefore, are directly meaningful to animals. Not so for humans. Human languages give us an ability to talk conceptually about tens of thousands or millions of various topics, but conversations and texts are not automatically related to our instinctual needs, *meanings* of language expressions requires instinctual grounding, which mechanism includes emotional signals. Jung called this mechanism *synthesis* [26,27]. Although our ability for differentiated conceptual thinking is enabled by differentiation between concepts and emotions, the other side of this differentiation is that the meaning of even highly differentiated conceptual thoughts might disappear. Dispassionate arguments are among the foundations of cultured and scientific discourse, but dispassionate thinking may lead to an entire culture loosing its meanings. This might have been the reason for the death of many old civilizations [25].

Preserving the meanings of language, culture, and cognitive concepts requires emotional connections to instinctual needs. Let us look into the nature of these emotions preserving synthesis or unity of psyche in the face of differentiated knowledge. The knowledge instinct, as formulated in section 2, results in a single aesthetic emotion, related to a single measure of similarity between all models and all sensor data (all experience). This is certainly a great simplification. When trying to understand the complexity of surrounding world we do not maximize a single measure uniformly over all conceptual knowledge and all experiences. This would not do justice to the diversity of our experiences. Certain concepts are more important for us than others. This is true even within purely scientific domain; for example, the law of energy conservation will not be casually questioned based on some unproven measurements; a first reaction would be to question measurements. Certain moral, political, or religious concepts accumulate cultural experience of many generations and become more important than individual percepts of the reality. Strong emotional feelings usually intervene, when high value concepts are questioned.

When one's material well-being is directly involved, the nature of his emotions is relatively simple to understand due to direct involvement of bodily instincts. This understanding of emotions was discussed in section 1: Emotions evaluate concepts with respect to satisfaction or dissatisfaction of instincts. But when emotions involve correspondence between different abstract concepts, a new explanation is required. Let us look from this vantage point at the hierarchical structure in Fig. 1. Every level in the hierarchy involves a similarity measure, the knowledge instinct operating at this level. Only at the lowest level, the knowledge instinct involves sensor signals and models. At each higher level, a similarity is between bottom-up sets of models and top-down sets of models. Does it provide the necessary structure for understanding emotions that involve high value models?

The hierarchy with a single aesthetic emotion at each level is not rich enough to account for the discussed emotions and their role in cognition. Each valuable concept emotionally affects our recognition and understanding of many other concepts. In other words, concepts act similarly to instincts: They emotionally evaluate other concepts. Therefore, the cognitive hierarchy in the left of Fig.1 involves multiple sub-hierarchies associated with valuable concepts. Each sub-hierarchy produces its own emotional signals, which measure correspondence of the sub-hierarchy to the valuable concept that spawns it. Since the designation "valuable concept" is a matter of degree, all concepts are interrelated by a web of mutual emotional correspondence-evaluations. A similar view on emotions was formulated by Spinoza [18]; he emphasized that every emotion is different depending on the object (model-concept) it is associated with.

These aesthetic emotions unify the total knowledge within mutual interrelationships. The number of aesthetic emotions therefore is combinatorial in terms of the number of concepts, resulting in practically uncountable manifold of emotions. As discussed later, we hear these emotions in music, which makes us aware of many of them. Most of these emotions are below the threshold of awareness, unconscious. The more these emotions become conscious

the more a person is aware of the diversity of knowledge, while preserving synthesis or the unity of one's psyche.

Synthesis is an essential aspect of meaning. If psyche is torn apart by diversity of knowledge, the meaning disappears. One aspect of creating meanings is the discussed synthesis of language and cognition. Another aspect is synthesis of knowledge at the top levels of the hierarchy. General and abstract models near the top of the hierarchy encompass all the diversity of knowledge at the intermediate and lower levels. The gain is synthesis, the "price" is that general models are less specific, vague-fuzzy, and unconscious. Their conscious aspects are developed in cultural evolution, their unconscious aspects are fused with the instinctual bases of the psyche, archetypes, fuzzy models which conceptual and emotional contents are undifferentiated.

There is not enough psychological or neural data at this time to determine uniquely the mathematical structure of sub-hierarchies. They could be similar to eq. (1) with every sub-hierarchy endowed with its own measures of similarity, or they all might share the same structure (Fig. 1), with concept values being represented by weight-parameters, r(h), in eq. (1). These parameters thus acquire the meaning of emotional signals; and their values are not determined simply by empirical evidence (the number of signals corresponding to concept h in the experience of a single agent or person), but are also influenced by culturally accumulated experience preserved in language.

V. LANGUAGE, EMOTIONS, AND CULTURES

Abstract and general cognitive models are grounded in language. The language provides conceptual structures for the models, but also their emotional connections to emotional centers in the brain. Evolutionary recent emotional centers in the cortex are responsible for differentiation of emotional and conceptual contents in languages. Evolutionary old emotional centers in the limbic system are responsible for synthesis. As we discussed, mechanisms connecting language to old emotional centers are closely related to the sound of language. Since Saussure [28] many linguists subscribe to the view that sounds of languages are arbitrary notations for meanings. Different languages use different sounds for the words with similar meanings. Nevertheless, some recent results in language evolution suggest that meaning-sound pairing may not be completely arbitrary [29], especially, when the entire language and cognition are considered as a joint evolving system [30].

Sound of languages changes in their evolution. English today sounds differently from English of Chaucer. Before Great Vowel Shift in the 15th and 16th century English sounded similar to continental German languages and words were pronounced as spelled. Today English is a partly hieroglyphic language, sound departed from writing. This change in sound followed changes in English grammar. In Old English nouns had complex declensions, with affixes

for different numbers and 4 cases (nominative, accusative, genitive, dative), personal pronouns also changed by gender and had a dual number, word order was not fixed, verbs were conjugated. Words were pronounced as spelled. Middle English, nouns had 3 cases (nom., gen., dat.), personal pronouns kept 4 cases; verbs were conjugated by person and number. Words were still pronounced as spelled, and vowel pronunciation was similar to European languages.

Relationships between English sound and grammar seem to be a case of "fusion" between sounds of the word roots and inflectional affixes. Sounds of affixes is "a tail that wags the dog." Pronunciation of inflectional structures is fixed by grammar, which usually remain stable over many generations; stable sounds of the word endings, to an extent, stabilize the sound of the entire word. This property of inflectional languages is responsible for what Humboldt called "inner firmness of words" [31]. In highly inflectional languages (like Russian) sounds and therefore emotions are closely related to meanings. In modern English, sounds and therefore emotions are dissociated from meanings. It would be an interesting topic for psycholinguistic research to compare emotionality of speech of native speakers in various Indo-European languages. A theory developed here predicts positive correlation between emotionality and flectivity (the number and variability of affixes).

The advantage of simplified English grammar is an ease of forming new conceptual structures. Virtually any two words can be combined to form a new meaning. This is not so in highly inflective languages, like Russian. To form a new meaning, a combination of words should "sound right"; that is, an emotional content should correspond to a conceptual content. Because of that, forming new meanings in Russian is much more difficult than in English. English is a pragmatically powerful language. Let us not forget that advancement of pragmatic capitalistic culture, which pushed aside many old cultural emotional encumbrances, occurred soon after English changed from Middle to Modern. This might have been more than just a coincidence.

The other side of powerful differentiating capacity of English is that synthesis lags behind differentiation. This might be the cause of some crisis like phenomena in English-speaking countries. Weakened emotional connections between language and meaning may lead to a loss of synthesis, weakened self identity. Popular songs, by connecting words with emotional sounds, restore synthesis in contemporary Western psyche [32]. This might be the reason for explosion in consumption of popular songs.

The proposed connections between language sounds and emotionality on the one hand, and differentiation vs. synthesis in cultural collective consciousness on the other, were developed for Indo-European (IE) languages [33]. It might seem amazing that these connections also explain the well-known differences between English-speaking and Arab-speaking cultures. Arab language is an inflectional language, but the structure of inflections is different from IE languages. Whereas in IE, word affixes are changed according to situations, in Arabic, the entire word sound changes. Sounds are therefore much more closely fused with meanings than in IE. It follows that the emotionality of

Arabic is much stronger than in IE. Culture is less pragmatic, development of new meanings is difficult, synthesis and a feel of self-identity is strong. Of course, these general characterization of cultures do not necessarily apply to individuals. Less educated and less conscious part of population is more affected by general properties of languages. An individual person striving for conscious cognition of the world can use advantages offered by his or her language and overcome language limitations.

Theoretical connections between sound of language (prosody) and emotions discussed in this paper can be studied in psycholinguistic laboratories [34,35]. These studies can be extended to multiple languages to test the proposed effects of grammar. Current research in evolution of languages and cultures uses mathematical simulations of communities of interacting agents and related statistical models [36,37,38]. Joint evolution of cognition and language was initiated in [39,40,41,42]. The proposed mechanisms of differentiation and synthesis, their interactions with emotionality of language and their effects in cultural evolution can be incorporated into future studies of evolution of languages and cultures.

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