Any Words in the Brain's Language?
Does Mind Really Work That Way?

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Abstract

The paper discusses specificity of linguistic competence, brain imaging data, mental lexicon in language acquisition and pathology. Connectionist and modular approaches are observed in the context of origins of language and in the cognitive framework.

Introduction

Nobody doubts that language is a set of conventions, some of them more or less explicit, some hidden within the brain in the form of the algorithms that we hope to reveal. Chomsky and his followers hold that generative rules go all the way down, and that they are universal and genetically based. It is evident that there is something that we store in the brain and something that we compute. However, what do we store: lexemes (tens of thousands) or concepts? In what form and by what means interconnected? And rules too, at least some of them, hundreds of such, not consciously operated and not reflected - in case of the native language.

It is evident, that languages differ in the way they code semantic or functional relations. The notion that all languages are somehow equal in complexity and expressiveness is often thought to be scientific truth. However, language diversity becomes evident and realized by the majority of brain and language scholars.

Language Origins and Specificity

Origins of language is the problem that until recently both linguists and representatives of other anthropological sciences were feared to consider, as, strictly speaking, the answer to the question as to how and when the human language appeared can be based only on reconstructions. Chomsky and Bickerton consider the "grammatical explosion" a result of macromutation, whereas Pinker — a result of natural selection of small mutations, i.e., of much slower process (Bickerton, 1990; Bloom, 2002; Chomsky, 2002; Fodor 2001; Pinker, Bloom,1990). The scientific community is divided into two camps - those who think the human language to be although very complex, but nevertheless a successor of communicative systems of the nearest biological ancestors and those who adhere to the unique system that performs not only communicative, but also peculiar thinking function and has a structure completely lacking in any other biological codes: 'digital' and hierarchical (phonemes - morphemes - words - phrases - discourse) structure, productivity governed by the linguistic rules, differences in the superficial order of constituents, the use of null elements, the use of sub-categorical argument structure for verbs, mechanisms for expansion of utterances, embedding, etc. At the same time, researchers are divided into the so-called oralists claiming that our language has appeared from the acoustic communication of higher primates and into the manualists thinking that the gesture language was the first to appear and already on its cognitive base the vocal language appeared later developing to the form that exists at present on Earth in more than 6000 variants.

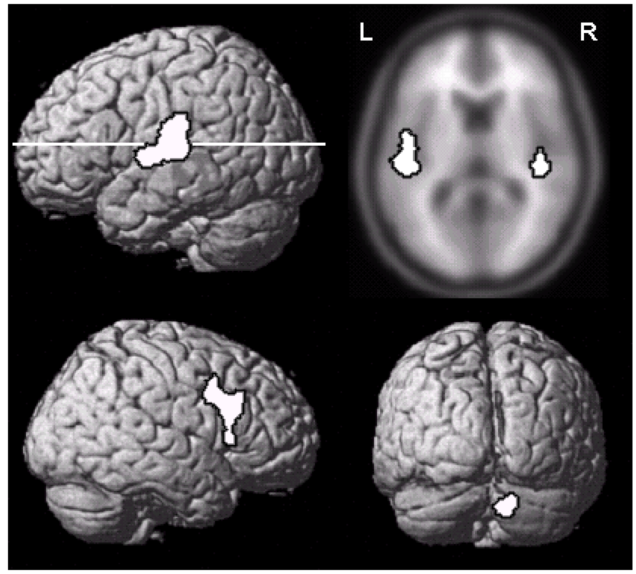
Jackendoff discussing Universal Grammar as a set of attractors causing the Human capacity to learn any language on the basis of the assumption that 'everything is already there, and the learner has only to set the options to suit the environment', argues and that 'it is hard to imagine all this structure emerging in the brain prior to experience, much less being coded genetically... Moreover, inheritance is not absolute: it tolerates partial violations, for instance in irregular verbs and idioms' (2002, p.190-191). The debates based on experiments with L1 and L2 acquisition, with normal adults and children and on clinical observations continue and become more and more technical, and not just theoretical. However, a novel and much more flexible view has appeared from the unexpected address (Hauser, Chomsky and Fitch, 2002) and it argues that distinction should be made between the faculty of language in the broad sense (FLB) and in the narrow sense (FLN): FLB includes a sensory-motor system, a conceptual-intentional system, and the internal computational mechanisms, providing the capacity to generate an infinite range of expressions from a finite set of elements. Most of FLB is shared with other species. FLN only includes recursion and is the only uniquely human component of the faculty of language... Human system of recursion operates with broader range of elements than in other animals and we can apply it *to all cognitive tasks*.

All these features are traditionally believed to be subserved by the speech zones of the left cerebral hemisphere. While the right hemisphere is responsible for a large part of the lexicon, global/Gestalt recognition, for revealing the relevant components of a situation (or a scene), for relatively higher speed of decision making, classification of colors and odors, orientation in space and time, evaluation of gestures, face expressions and verbal prosody, metaphoric thinking, etc. (Chernigovskaya, 1994,1999).

Localizationistic and Holistic Approaches: Brain Imaging Data

However, functional brain imaging and clinical data show that localization problem is not as clear any longer: not only we do not reveal any neuronal basis for the 'language module', but we have to accept that in any complex activity to say nothing of language we see numerous brain regions involved. Neuroanatomical basis for syntactic parsing, as an example, is believed to include the left perisylvian associative cortex, with some possible contribution of the homologous contralateral cortex, as suggested by brain lesion studies (Caplan et al., 1996; Grodzinsky, 1995;). The activation level of Broca's area correlated with syntactic complexity in some PET studies for both visual (Just et al., 1996) and auditory (Caplan et al., 1999) sentence presentation. Just et al. (1996) also reported an increase in rCBF in both Broca's and Wernicke's areas, as well as in the homologous regions of the right hemisphere. Other fMRI studies of natural and pseudo-word sentence comprehension suggested a substantial functional overlap of the brain structures involved in semantic and syntactic language functions within the left perisylvian region, including the inferior frontal, superior and middle temporal gyri (Röder et al., 2002). Humphries et al. (2001) found bilateral activations in the anterior temporal cortex well as in the left posterio temporal area during speech processing, but not during listening to environmental sounds. Friederici et al. (2000, 2002) also showed that syntactic processing of speech influences *bilaterally* the anterior temporal cortex activation, as well as Wernicke's area activation, with an additional activation in the left frontal operculum when syntactically plausible non-word pseudosentences were processed. According to the other fMRI study (Homae et al., 2002), activation in the left inferior frontal gyrus, relevant to sentence processing, appears to be sensory modality independent. Studies of the prosodic processing have suggested the involvement of either the right or both hemispheres (Kotz et al., 2003). These structures, therefore, might be a part of the syntactic analysis network, being involved into pause segmenting and pitch processing. Artificial grammatical violations also activates Broca's region as shown by Petersson et. al. (2004). in event-related brain imaging, among other issues, discussing differences between human and animal learning to be relevant to the narrow faculty of language (Hauser et al., 2002). Similarities between language and music processing and it's localization is currently widely discussed (Hauser & McDermott, 2003).

One of the prosodic cues, important for segmenting spoken phrases is a position of the semantic pause. Therefore, the present study was planned to investigate the brain mechanisms of such prosodic segmentation in spoken samples. PET technique was used to see the brain areas recruited in this mechanism. Subjects were adult volunteers native speakers of Russian instructed to appreciate the meaning of auditory presented phrases that critically depended on the position of a segmenting pause.



The data revealed activation areas in the right dorsolateral prefrontal cortex and in the right cerebellum. These structures, therefore, might be a part of the syntactic analysis network, being involved into pause segmenting and pitch processing.

Comparisons in both directions between the "segmented, passive" and the "non-segmented, passive" conditions when a subject was instructed to press the button with a distracting task while listening to not segmented or segmented phrases did not demonstrate any significant difference in brain activation. The "segmented, active" condition elicited significantly higher activation, than the "non-segmented, active" in the right dorsolateral prefrontal cortex (DLPFC) with its peak approximately on the junction of Brodman's areas (BAs) 44, 45, 9. Another activation was found in the medial posterior part of the right cerebellum. Areas of CBF decrease in the "segmented, active" condition in relation to the "non-segmented, active" condition were found in the deep posterior Sylvian cortex bilaterally close to primary auditory cortex with extension to BA 40 on the left side. The present study demonstrates that the right posterior prefrontal cortex and the right medial cerebella area participate in the brain network of the spoken speech syntactic parsing, being involved in the segmenting pause and pitch processing.

Though the right frontal cortex does not seem to play a crucial role in the syntactic analysis, we suppose, that the involvement of the right DLPFC might take place while perceiving prosodic cues..

The problem of cerebral lateralization of prosody perception remains far from being solved: though primarily believed to be totally subserved by the RH neural systems (e.g., Blumstein, Cooper, 1974), later on it was shown that such RH prevalence is more evident only for emotional prosody while the LH was shown to be involved in linguistic prosody (Pell, Baum, 1997). Further studies revealed that some aspects of the linguistic prosody are more related to the LH and some - to the RH (Chernigovskaya, 1994, Chernigovskaya et al., 1995)

The earlier studies associated the right posterior inferior frontal gyrus activation with pitch perception and the right cerebellum activation with verbal fluency and semantic prediction. Thus, this localization reflects the perception of pitch boundaries of the semantic pause and the right cerebellum activation is due to the semantic disruption in sentences, caused by the pause. The left perisylvanian cortex, earlier reported to be involved in visual syntactic processing, in our study was considerably more activated in control conditions rather than in the test ones. Dependence of brain activation on different presentation modalities supports the idea of syntactic processing being not strictly localized in the brain (Strelnikov, Vorobjov, Rudas, Chernigovskaya, Medvedev, 2004).

Mental Lexicon: Modularity vs. Connectionism?

Research of mental lexicon organization gives platform for the discussion between the two competing parties – modular-approach advocates vs. connectionists. Some argue that mental lexicon structure is based on declarative memory, and the mental grammar - on rules using procedural memory (Ullman, 2004): the first – advocates of the *dual processing* approach (Pinker, Prince,1994) - claim that irregulars are lexically represented while regulars are derived by a rule to form a complex surface word. *Single, or parallel distributed processing*, proposed by connectionists (Bybee, 1995), claims that memory is not a list but is partly associative, where features are linked to features, so we also see rules but different from symbolic and more complex and covering all kinds of processing both regular and not.

Our study explores the processing of verbal morphology in Russian, a language with numerous verb classes, which vary in size, and numerous conjugational patterns. It assumes that since Russian verb classes differ 'gradually' in 'regularity' and size, a sharp division into regular and irregular processing could hardly be expected. It focuses on the role of morphological cues and explores the hypothesis that the complexity of paradigm plays a role in native processing. The complexity of paradigm is understood as the number and type of rules shaping the conjugational pattern of individual verb classes.

The study addressed the following issues:

- ✓ What is the default pattern for Russian? Which conjugational patterns are more likely to be generalized to other verb classes?
- ✓ Are generalizations influenced by type frequencies of the verbal classes involved and/or by the complexity of paradigm factor?
- ✓ What is the role of morphological cues in verbal processing?
- ✓ Are the rules shaping the conjugational pattern for a particular verb class applied in a set, or they may be disassociated in verbal processing?

Our experimental data show that the complexity of paradigm factor overrides the frequency factor and that the overall pattern of responses suggests that the subjects favor the isolated 'default' rule. Overall, the results suggest that conjugational patterns for different verb classes consist of discrete *"rules,"* and are not necessarily applied as one bloc. The type frequencies of the verb classes influenced verbal processing. Thus, high frequency conjugational patterns were more readily generalized to other classes. Also, the morphological cues worked better in the processing of high frequency classes. However, in the task, which required generating forms of nonce verbs, the complexity of paradigm overrode the frequency factor.

It is demonstrated that the paradigm is acquired gradually by children with normal language development and in a different manner with individual patterns in SLI and adult aphasic agrammatic patients. The roles of rules and frequency factors and cross-linguistic aspects should be discussed in comparing the results from languages of different structural types: individual language specificity is now evident to make the picture much more complex than it used to be predicted; there are stages and hierarchy in verbal paradigm acquisition by young children with normal language development, and SLI children develop language more slowly and in a different way (cf. Chernigovskaya, Gor, 2000; Gor, Chernigovskaya, 2001, 2004). Neither one-system nor dual- system approach is adequate for explaining mental lexicon structure and functioning in all the categories if subjects at least in languages with developed morphology.

It should again be stressed that experimental research should not underestimate a large set of factors, among them not only language diversity, prohibiting to extrapolate the data in one or close languages to human linguistic capacity in general, but also the possibility of using different algorithms of processing, e.g. templates and Gestalts of different kinds in one procedure or task and sequential in the other; difference in cognitive styles and psychophysiological profiles; fuzziness of a 'norm'; multi-factorial basis of behavior both in life and in an experiment (memory, attention, emotions, associations, parallel processing of all kinds, etc.); nonstability of behavior, caused by exo- and endogenic (neurochemical) fluctuations etc. So, the puzzle of localization is far form being solved.

Discussion

As long ago as in 1949, Donald Hebb (however, the idea decades before discussed by A. Ukhtomsky and P. Anokhin), proposed a model that reconciled the localizationistic and holistic approaches of cerebral control of the higher cognitive functions, specifically of the verbal ones. According to this model, cell assemblies in the brain cortex can be arranged in neurobiological groups to form cognitive units of the type of words or Gestalts of different kind, for instance, of visual images. Such point of view differs fundamentally from the localizationistic approach, as it implies that neurons from different cortex areas can be simultaneously united into the single functional block. It also differs from the holistic approach, as it denies determination of everything everywhere, but emphasized principal dynamics of the mechanism and a constant reorganization of the entire pattern depending on the cognitive task. This means that we deal with a finely tuned orchestra, in which location of conductor is unknown and unstable and possibly is not occupied at all, as the orchestra is self-organized with taking into account many factors and is tuned to the dominant.

When discussing constant debates of nativists and adepts of the primacy of learning, it is worth recollecting that all biological systems are characterized by the capability for self-regulation and among those of the self-regulation in ontogenesis there should be noted three main factors: (i) development according to genetic program; (ii) development depending on the role of environment (for instance, the negative result of sensory deprivation leads to brain underdevelopment, the absence of adequate verbal surrounding — to the lack of language development , etc.; (iii) the own conscious self-regulation is the property that increases with a rise of the range of biological objects on the evolutionary ladder as a result of the increasing role of individual, rather than group behavior. The sign of evolution is a rise of independence of the environment. Astonishingly, some general principles of evolution (as we understand them nowadays) reflect such different processes as evolution of living creatures and of natural and artificial languages. Karl Pribram notes that the organism external behavior is determined by a complexly organized mechanism formed by *competent* structures, whose functions depend on experience in a given environment. In theories of learning, by competence the sum of knowledge is understood, which determines limits of success of performance of a task. If the competence, including the genetic one, is equal to zero, no incentives are able to cause performance of a given task.

Of course, the hierarchy of syntax is necessary for such a complex, self-organizing system as language, in the same way as the hierarchy and dynamics of neuronal patterns are necessary for such a most complex system as the brain. The adept of the idea of macromutation and, therefore, actually an anti-Darwinist Chomsky and his opponents Pinker and Bloom insisting on the natural selection that has led to formation of the language capacity could have to be conciliated in the same way as Hebb's model gives a possibility of conciliation of the modular and holistic paradigms. Is it worth adhering to centrism of syntax, if we live in the world of concepts? Is it worth keeping to be as before in captivity of the binary way of thinking, with necessity of choosing between polar viewpoints: mutation or selection, modularity or neuronal network?

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