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## **Evolutionary Perspective for Cognitive Function: Cerebral Basis of Heterogeneous Consciousness**

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*'...The name of the song is called "Haddogs' Eyes", [said the White Knight.]  
'Oh, that's the name of the song, is it?' Alice said, trying to feel interested.  
'No, you don't understand,' the Knight said, looking a little vexed. 'That's  
what the name is called. The name really is "The Aged Aged Man".'  
'Then I ought to have said "That's what the song is called"?'  
Alice corrected herself.  
'No, you oughtn't: that's another thing. The song is called  
"Ways and Means": but that's only what it's called, you know!'  
'Well, what is the song, then? said Alice,  
who was by this time completely bewildered.  
'I was coming to that,' the Knight said. 'The song really is  
"A-sitting On a Gate": and the tune's my own invention.'*

Lewis Carroll

'Through the Looking-Glass  
and What Alice Found There'

*The idea of semiotic evolution from the right-hemispheric 'archaic' mentality towards the left-hemispheric 'modern' is presented in neuropsychological, developmental and cross-cultural aspects..*

In his paper of 1992 'Ecogenesis and Echogenesis : An Echo of Umberto Eco' Walter Koch (1992) formulated two theorems for bio-semiotic disciplines: (1) everything coheres with everything else (ECOgenesis) and (2) phylogenetic processes tend to be echoed in processes of other geneses (ECHOgenesis). Associated with this he writes later that 'ecogenesis is to refer to innumerable eco-taxa which made up the complex and simultaneous environment of the specific part of evolution under focus'; 'echogenesis is a cover term for possibly correlative types of genesis: phylogenesis, ontogenesis, etc'. Our attention will focus here mainly on anthropological aspects of

cognition, i.e. on cerebral 'dialogues', or 'polylogues', providing specific semiotic behavior, as expressed in human biological and cultural evolution.

The specific character of human cognition is its semiotic heterogeneity, its duplicity based on hemispheric organization. Brain structure itself causes formation of different mental realities - left- or right hemispheric and to a certain extent 'virtual' with its own language, priorities and rules. These two 'interlocutors' *Ego* and *Alter Ego* in their ever-lasting discussions create the basis of intellectual activity. As Yu. Lotman puts it, bi-polarity is a minimal structure necessary for semiotic construction. Moreover, he argues that intelligence evolves only when there are inner non-uniformities of structure (1983). Lotman was witty enough to suppose the formation of contrasting psychological poles, or 'personae' both within a society or an individual in the course of cultural development - with all possible communicational problems (see publications of Lotman, Uvanov and our group in *Acta et Commentationes Universitatis Tartuensis, Semiotica* 16, 17 and 19: 1983- 1986 - in Russian).

Neuropsychological and neurological data provide important evidence on cerebral organisation of various types of mentality - both verbal and nonverbal - in identifying hemispheric involvement in cognitive processes.

In spite of the long history of the research, there is still quite a lot of uncertainties in cerebral asymmetry of higher functions. The problem has an important evolutionary aspect associated with the perspective of human cognition discussed in different aspects by M. Donald (Donald, 1991). What kind of knowledge do we have? How is it organised? Are we able to reflect all types of our knowledge? Are we humans - becoming more reflective in our evolution? What brain areas are responsible for the reflective and conceptual thinking? Are we still changing?

Reliable experimental data indicate that reflective thinking seems to be provided by the left cerebral (LH) hemisphere. In this case, do we need the right hemisphere (RH) capacity to process information? especially nowadays, where the life seems to be completely "digitised"?

Human thinking is fundamentally heterogeneous - we see it in different cultures, modes of education and in cerebral hemispheric organisation of higher cortical functions (Chernigovskaya, 1994,1995). The problem of hemispheric lateralisation of cognitive and linguistic facilities is still being debated (Efron 1990; Davidson and Hugdahl 1995; Paradis 1996). However, it is widely accepted that the thinking provided by the LH is formal, analytic. The thinking provided by the RH is metaphoric, Gestalt-like, mosaic (Chernigovskaya, et al.1983, 1986, 1989; 1994-1997). It was shown that the RH is a winner in speed when isolating relevant features from the mosaics of all the features, including irrelevant. It can operate with several types of uncertainties: inexactness, incompleteness, probabilities, fuzziness, observation errors, etc. (Chernigovskaya et al., 1989, 1991, 1993).

Our data in neurological patients with lateral focal lesions, psychiatric patients observed after unilateral therapy, as well as in normal individuals subjected to non-invasive instrumental examination (monaural and dichotic listening, tachistoscopic presentations of visual stimuli) and a battery of lateral perceptual, cognitive and motor testing, reveal linguistic and cognitive features specific of the left and the right cerebral hemispheres in humans. The data show cardinal differences in hemispheric mentality (cognitive styles) - both in verbal and non-verbal procedures, like metalinguistic abilities, perception of speech sounds, rhythms, understanding metaphors and idioms, syllogistic reasoning, animistic thinking, retention abilities, etc. Cultural and gender differences are also evident.

It allows us to discuss two main semiotic oppositions of ‘mythological’ and ‘logical’ antithesis in association with cerebral lateral mechanisms. Both developmental and cross-cultural data demonstrate semiotic evolution from the right-hemispheric ‘archaic’ mentality characteristic of traditional societies towards the left-hemispheric ‘modern’ -‘eurocentric’ guided by Aristotelian logic. Cerebral asymmetry characterising - in spite of all the contradictory arguments - specifically human neuronal mechanisms of cognition and language was ( and probably is) the basis of a tremendous evolutionary break-through. Increasing motor and anatomic asymmetry in animals - as seen in evolution - and all kinds of asymmetries in humans provide growing adaptation abilities in the ever-changing world. Evolutionary Physiology gives us evidence of the older age of the right hemisphere function in comparison to the left hemisphere. It is also shown that small children (up to 10 years of age) are in the majority much more right-hemispheric than the adult: the older they are the more left-hemispheric components they gain. Therefore, we argue that in this sense both phylo- and ontogenesis have a certain vector. The shift from perceptual to conceptual distinctions (as stated already by Lev Vygotsky) (1965) associated with the RH-to-LH direction is evident to characterise evolution from primates to humans and within the human development of cognition and language (Bichakjian 1988, 1996, 1997; Cronkhite 1990; Chernigovskaya 1995; Donald 1991; Liska 1994; Ragir 1994; Tulviste 1978).

The last few years of research in functional cerebral asymmetry has, however, brought, a reconsideration of a number of crucial issues. The full range of data, therefore, should be discussed in the new perspective as well as further studies based on routine experimental paradigms do not seem to be promising. What is not clear, moreover, is whether all the functional monitoring including fMRI, EEG, PET, SPECT\*, etc. really measure what we hope they do. It is evident that we have under observation a whole set of asymmetries:

- central (cerebral hemispheres) or peripheral (sensory input)
- cortical or subcortical ( involving cerebellum, striatum, basal ganglia, hippocampal system, limbic, etc.)
- morphological, chemical or functional
- ‘independent’ or controlled
- motor, sensory or cognitive
- individual or populational
- innate or culturally and developmentally dependant
- specifically linguistic or of a more general cognitive nature
- depending on individual abilities and styles
- specifically human or common with other species

From the up-dated point of view neuronal activity governing language functions is spread over both cerebral hemispheres, beyond the areas traditionally associated with language processing. Functional brain imaging demonstrates floods of activation from area to area, starting, as an example, from frontal attention areas and coming to right -hemispheric areas homologous to Wernicke (Schwarz, Ojeman et al.,1996); inner speech was PET-imaged to be guided by the right parietal cortex. And of course, the results ARE task-driven - that is being shown by dozens of experiments revealing all kinds of perceptual and cognitive processing - from pure tones

discrimination to syllogistic reasoning and understanding metaphors (cf. Chernigovskaya, 1993-1997).

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\*Methods of brain- mapping : fMRI (functional magnetic resonance imaging); EEG (electro- encephalography), PET (positron emission tomography), SPECT (single photon emission computer tomography)

It has been shown that children under 10 (Thatcher et. al. 1987; Sagalowicz 1988; Molfese, Sagalowicz 1988; Rotenberg, Arshavsky, 1997) and representatives of traditional, or archaic, cultures demonstrate right hemispheric type of mentality proved by different kinds of monitoring. The book of R. Davidson and K. Hugdahl (1995) gives us a remarkable and reliable insight into the state of the art. Of special interest are also research of LeMay (1976), Witelson, Kigar (1988), Steinmetz et. al. (1991), and Snyder et. al. (1995).

Discussing specific linguistic role of cerebral mechanisms, M. Paradis argues that linguistic 'competence' (knowing 'how') and 'knowledge' (knowing 'what') are mostly guided by different cerebral hemispheres. Procedural competence is automatic, not conscious, acquired incidentally, and stored implicitly in the left cerebral hemisphere, diffuse cortical areas involving also cerebellum, striatum and basal ganglia. Declarative knowledge is to a certain extent controlled, associated with and the right-hemispheric functions, and depends on the integrity of the hippocampal system. As M. Paradis puts it 'we have no control of how we use grammar, but we have control of what we want to say'. Therefore, we deal with the right-hemispheric pragmatics and diffuse or left-hemispheric linguistic knowledge. So, according to Paradis, if you are less linguistically proficient (in second language acquisition or caused by pathology) you tend to use more pragmatic (i.e. right-hemispheric) language. It is noteworthy that amazingly early - in 1868 - in a discussion on aphasia J. H. Jackson (1958) subdivided language function into two separate forms - 'intellectual' expressing propositions and 'emotional' expressing not only emotions but also jargon, cursing, idioms, facial and sound mimicking, etc. Quite a few examples from Jackson show us that in his view the RH in this or that way provides pragmatic aspects of communication while the LH role is to lineally organize linguistic rules. Experimental proofs for these statements were to come over a hundred years later.

Some examples of our experimental research demonstrating hemispheric differences are presented further.

One of the most effective RH ways to process information is 'metaphoric thinking'. The majority agrees that without metaphorical transfer each possible object would require a separate denomination and, consequently, mental storage for a tremendous stock of words. There is a vast linguistic, psycholinguistic and neuropsychological literature on the subject: here we shall only mention here such well-known scholars as Wittgenstein, Chomsky, Katz, Fodor, Bever, Billow, Tversky, Whorf, Jakobson, Halle, Gardner, Pollio, and others. One can also point to Tourangeau & Sternberg (1978) and the experimental paper of Marquise, Glass & Corlett (1984) who in EEG brain mapping showed that speed of metaphor understanding was higher in the right than in the left hemisphere. Strangely, there are not much experimental data proving RH involvement into metaphoric processing.

The method we used was to examine psychiatric patients after a therapy, that caused temporal inactivation of the left or the right hemisphere. The procedure gave the possibility to juxtapose the behaviour of one and the same patient with either the left or the right hemisphere being active and the other depressed as well as in control conditions when both hemispheres were normally functioning. The findings demonstrated the right hemisphere superiority for interpreting metaphors as well as for recalling idioms that could not be interpreted literally. Contrary to it, the left hemisphere was apparently unable to perform the tasks. It appears that this kind of right hemispheric ability is the most relevant and adaptive cognitive behaviour in a novel situation. Meanwhile, our findings have close analogies in cross-cultural and developmental research. Opposite to it, the LH is bright in syllogistic reasoning expressing the capacity for formal logical deduction (Tulviste 1978; Chernigovskaya 1994).

'Nominal realism', or 'word magic', depicts a lack of reflective abilities and scientific concepts in young children and in some groups of adults (Piaget and Vygotsky). Such individuals do not realize the conventional nature of denomination. Arbitrariness of this kind could be vividly illustrated by an elegant and witty idea of Rene Magritte expressed in his "Der Traumschlüssel" - the idea amazingly similar to tokens used to teach language to nonhuman primates and in Lewis Carroll's verbal chef d'oeuvre cited above.

In our experiments it appeared that for subjects with intact RH and depressed LH the distance between a word and its referent was not evident, and in this they were very much similar to young children and to individuals from archaic societies as shown by Tulviste (1978). They could easily tell us that the Sun was named so because it is shining, and 'bread' - because 'it is so tasty and fresh', or 'spaghetti' - because 'they eat it with cheese', etc. They would definitely deny the possibility to rename objects and many of them have even told us that names appeared earlier than objects. LH-intact patients, contrary to it, had no doubts concerning the arbitrary nature of nomination.

The same tendency was seen in 'animistic thinking' or 'retention abilities', again quite similar to what have been shown earlier by developmental and cross-cultural psychologists. Patients with intact RH performed the tasks like young children

or representatives of archaic societies and demonstrated inability to retain quantity, number and volume, as well as they were often unable to identify animate objects from inanimate, saying that 'watch is alive because it goes', or 'the Moon is alive because it moves on the sky', or 'a stone is alive because electrons rotate within it'.

The above examples show that reflectivity definitely is a left-hemispheric characteristics. However, hemispheric specialization was shown not only to characterize higher functions but also some kinds of 'lower-level' sensory perception. As an example, we demonstrated that the LH much more rapidly and accurately recognizes amplitude changes in high frequency (3kHz) acoustic signals with high rhythms of tonal bursts (60 Hz), while the RH prefers low frequency (0.25 kHz) and low rhythms (20Hz) (Vartanian, Chernigovskaya 1992)

In apparent contrast to numerous research in other sensory functions the role of the hemispheric functions in chemoreception, evaluation and verbalisation of odours is scantily known. Olfactory information is known to be complex, uncertain (fuzzy) and extremely difficult to verbalise. Special attention was paid in our research to social, cultural, educational and professional characteristics of subjects. The influence of odour on human behaviour is evident, though it is only a part of the

Gestalt stimulating complex presented to the individual in nature or in an experiment: the same flavour may be pleasant or unpleasant, depending on individual experience, associations and memory (Ugolev, Chernigovskaya, 1989; Chernigovskaya, Arshavsky, 1994). We studied (i) memory, associations and verbalisation of odours in subjects representing different cultures and languages. A group of normal adults tested for lateralities and cognitive styles was accessed for voluntary free associations concerning individual memory for odours. Associations were later evaluated by the subjects as neutral, negative or positive and according to different semantic fields.; (ii) reactions to fragrances - their rejection or preferences - presented to the right- and the left hemispheric normal adults, professional tasters included; (iii) preferences, classifications and verbalisation of colours and complex visual images in normal adults and in patients with temporal left- or right hemisphere inactivation.

In our experiments subjects with RH type of reactions (i.e. preferably guided by the right hemispheric dominance for cognitive functions) demonstrated reliable correlation of biopotentials in the RH when stimulated by odours preferable for them. Individuals of the LH type (i.e. preferably guided by the left hemispheric dominance for cognitive functions) demonstrate correlation of biopotentials in the LH when stimulated by the odours rejected by them before. The choice of preferable odours and colours of Lusher set - depended on individual levels of anxiety. Classification and verbalisation of colours show significant difference in the types of strategies used by RH vs. LH subjects.

The data suggest that most RH individuals demonstrate specific memory and verbalisation of odours and that most professional tasters of odours appear to be RH personalities. It also shows the important role of social and cultural as well as of linguistic background. Right hemispheric visual, auditory and olfactory processing seems to correlate with certain behavioral characteristics showing successful adaptation and resistance to stress and psychic or somato-psychic diseases adoptive behaviour in general.

#### CONCLUSION.

Experimental data, therefore, demonstrate more general than linguistic distinctions in hemispheric function. The LH mentality can be correlated with thinking in terms of scientific notions, acquired in the 'western' type of education. The RH mentality is correlated with children's pre-operational thinking, heterological thinking in archaic cultures and with creative thinking of modern humans. Semiotic preferences of the hemispheres could be illustrated by a scheme (Fig.1), where the LH role is to connect signs and concepts while the RH role is to connect signs and denotates.

Human evolution, therefore, seems to be the evolution of signs from iconic resemblances (Gestalt-like), characteristic to semiotic abilities in nonhuman primates and in early hominids as well as in young children and archaic societies, towards complex arbitrary signs, conceptual symbols - the mentality, characterized by analytical reasoning and manipulating with scientific concepts. Humans' ability to voluntary control semogenesis and memory, their reflective skills, have evolutionary gained neural basis - the left-hemispheric structures. Mental activity is a play of these opposing systems, attempts to examine an object in different perspectives and with different range of accuracy. Therefore, I argue again that the RH and the LH

'realities' are both 'virtual', based on at least two semiotic systems, and only a kind of their synthesis gives us something more or less 'real'.

However, in spite of an overall 'left -oriented' vector we probably face the next stage of mental development - a tendency to evaluate the world and to process information in a Gestalt, global, right - hemispheric way. So, we still have quite a long way to go before we master our own potential skills. However, new cognitive experience causes neural changes itself...(Donald 1991). Shall we be able to cope with it and with quick environmental changes? Or Alice is right announcing as ever 'curiouser and curiouser' together with Mirab Mamardashvili's 'knowledge about the object of our vision undoubtedly prevents us to see the visible'( 1988, 1990)? Shall we be able to overcome anthropological catastrophe and the collapse of Frege Triangle so evidently demonstrated by European history of the XX century? Or shall we finally develop into *der letzte Menschen* ('Was ist Liebe? Was ist Schöpfung? Was is Sehnsucht? Was ist Stern?... Wir haben das Glück erfunden'- sagen die letzten Menschen und blinzeln) (Nietzsche 1966) ?

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#### REFERENCES

- Bichakjian B. (1988). Evolution in Language. Ann Arbor, MI:Karoma  
-- (1996) Evolution: From Biology to Language. Darmstadte Beitrage zur Naturgeschichte, Heft 6,153-163, Darmstadt  
-- (1997)Language evolution and the shift to features characteristic of the left hemisphere.In: Andreas Gather and Heinz Werner,eds. Semiotische Prozesse und naturlische Sprache, Stuttgart:Steiner, 42-51
- Chernigovskaya T.V., L.J.Balonov, V.L.Deglin. (1983) Bilingualism and brain functional asymmetry.//Brain and Language.20,195-216
- Chernigovskaya T.V., V.L.Deglin. (1986) Brain functional asymmetry and neural organization of linguistic competence.// Brain and Languagev.29,1,141-155
- Chernigovskaya T.V., V.S.Rotenberg, D.I.Shapiro (1989). On identification and presentation of knowlege.// In: Prague Bulletin of Mathematical Linguistics, - Univerzita Karlova,Praha, v.52, 25-33
- Chernigovskaya T.V ., Rotenberg V., Shapiro D. (1991) Knowledge, cerebral asymmetry and neural networks.// Prague Bulletin of Mathematical Linguistics, - Universita Karlova, Praha, v.55, .81 -89
- Chernigovskaya T.V (1993). Die Latelarizierung von Sprachen bei Bilingualen. // In: (Ed. P.Grzybek) 'Psychosemiotik- Neurosemiotik' Dr.N. Brockmeyer, Bochum, 15-36  
-- (1993a). Die Heterogenitat des verbalen Denkens als Cerebrale Asymmetrie. // In: (Ed. P.Grzybek) 'Psychosemiotik- Neurosemiotik' Dr.N. Brockmeyer, Bochum, , 37-54

- (1994) Cerebral lateralization for cognitive and linguistic abilities: neuropsychological and cultural aspects. //In: Studies in Language Origins, Amsterdam-Philadelphia, v.III (Eds. Jan Wind, Abraham Jonker), p.56-76
- (1995) Cerebral asymmetry - a neuropsychological parallel to semiogenesis. //In: Acta Colloquii. - Bochum publications in Evolutionary Cultural Semiotics, "Language in the Wurm Glaciation", v.27, (Eds. Udo Figge, Walter Koch), p.53-64.
- Chernigovskaya T., Arshavsky V. (1994). Hemispheric Asymmetry in Olfaction Processing: Neurophysiological and Cognitive Aspects. Abstracts of 23 Meeting of International Neuropsychological Society, Angers
- Chernigovskaya T., T.Gavrilova. (1996) Modelling hemispheric contribution to language faculty: 'bilingual brain' and learning strategies.// II International Conference on Mathematical Linguistics (ICML'96), Terragona, Spain, 25-26
- Chernigovskaya T. (1997) Semiotic Heterogeneity of Human Mentality: Neuropsychological Evidence from Cerebral Asymmetry. VI International Congress of Semiotic Studies "Semiotics Bridging Nature and Culture", Guadalajara-97, Mexico, July 13-1, p.214-215
- Chernigovskaya T., T.Gavrilova, A. Voinov. (1997) Neuro-cognitive bias for distance and computer-aided learning. The Eighth International PEG Conference PEG-97, ('Meeting the challenge of the new technologies') Sozopol, Sofia, pp.171-177
- Cronkrite G. (1990). Psychosemiotics //In: Sebeok T. and J. Umiker-Sebeok (eds.) The Semiotic Web Berlin: Mouton de Gruyter, 1- 40
- Davidson R. and K.Hugdahl (eds.) (1995) Brain Asymmetry, The MIT Press
- Donald M. (1991) Origins of the Modern Mind: Three Stages of Culture and Cognition. Cambridge, Mass.; Harvard University Press
- Efron R. (1990). The decline and the fall of hemispheric specialisation. Hillsdale, N.J.: Erlbaum,
- Koch W. (1992). Ecogenesis and Echogenesis : An Echo of Umberto Eco' In: Sebeok T. and J. Umiker-Sebeok (eds.) Biosemiotics. The Semiotic Web Berlin: Mouton de Gruyter, 1- 37
- Jackson J. H. (1958) Selected Writings.v.2 (ed.J.Taylor), Stapples Press. London,
- Liska J. (1994) Sign arbitrariness as an index of semiogenesis. In: Studies in Language Origins (J. Wind, A. Jonker, Eds.), Amsterdam-Philadelphia, III, 161-178
- LeMay M. (1976) Morphological cerebral asymmetries of modern man, fossil man, and nonhuman primates. Ann. N.Y.Acad. Sci.,280, 349-366
- Lotman Yu. (1983). Asymmetry and Dialogue. Acta et Commentationes Universitatis Tartuensis, Semiotic Studies,vol. 16, 635:15-30 (in Russian)
- Mamardashvili M. (1988) La responsabilité européenne. // In: Europe sans rivage. Symposium international sur l'identité culturelle européenne. Paris, Albin Michel, 201-205
- (1990) Kak Ja Ponimaju Filosofiju (How I Understand the Philosophy), Moscow, Progress Publishers, (in Russian)
- Marquis, F. A., Glass, A., & Corlett, E. N. (1984). Speed of work and EEG asymmetry. Biological Psychology: 19, 3-4, 205-211
- Molfese D.L., Sagalowicz S.J.(eds.) (1988) Brain Lateralisation in Children:Developmental Implications.New York: Guilford Press; 35-57

- Nietzsche F. (1966) Also sprach Zarathustra.//Werke in drei Bänden, 2 band, C.Hanser Verlag Munchen, , 284-285
- Paradis M. (1996). Selective deficit in one language is not a demonstration of different anatomical representation: Comments on Gomez-Tortosa et al.(1995) // Brain and Language, 54 (1),170-173
- Ragir S. (1994) Vocal/auditory cognitive mapping, shared meaning and consciousness . In: Studies in Language Origins (J. Wind, A. Jonker, Eds.), Amsterdam-Philadelphia, III, p.205-219
- Rotenberg V.S., Arshavsky V.V. (1997). Right and left brain hemisphere activation in the representatives of two different cultures. Homeostasis, 38, 2, 49-57
- Sagalowitz S.J.,ed., (1988), Brain Lateralisation in Children: Developmental Implications.New York: Guilford Press; 35-57
- Schwarz,T.H., Ojeman G.A., Haglund M.M., Lettich, E. (1996) Cerebral materialisation of neuronal activity during naming, reading and line-matching. Cognitive Brain Research, 4, 263-273.
- Snyder P.J., Bilder R.M, Wu H., Bogerts B.,Lieberman J.A. (1995) Cerebellar Volume Asymmetries: A Quantitative MRI Study, Neuropsychologia, 33, 4, 407-419
- Steinmetz H.,VolkmanJ., Jancke L., Freund H-J. (1991) Anatomical left-right asymmetry of language-related temporal cortex is different in left- and right-handers. Ann Neurol.,29,315-319
- Thatcher R.W., Walker R.A., Giudice S. (1987). Human cerebral hemispheres develop at different ages. Science, 236, 1110-1113.
- Tourangeau, R., & Sternberg, R. J. (1978). Understanding and appreciating metaphors. Nr. 150-420 ONR Technical Report No.11 New Haven: Department of Psychology, Yale University
- Tulviste, P. (1978). On the origin of theoretic syllogistic reasoning in culture and child. Acta et Commentationes Universitatis Tartuensis, 474, 3-22
- Vartanian I.A., T.V.Chernigovskaya. (1992). Auditory processing of high and low frequencies and rhythms of acoustic stimuli - hemispheric paradigm.//Journal of clinical and experimental neuropsychology, v.14, N1, p.91-92.
- Vygotsky L. (1965). Thought and Culture. Cambridge, Mass.: MIT Press,
- Ugolev D.A., T.V.Chernigovskaya. (1989). Semiochemistry and human behavior (sensory, psycholinguistic and instrumental aspects of the formally defined problem) // Proceed. of the X International Symposium on Olfaction and Taste.Oslo, 17
- Witelson S.F., Kigar D.L. (1988). Anatomical development of corpus callosum in humans: A review with reference to sex and cognition. In: Molfese D.L., Sagalowitz S.J.,eds., Brain Lateralisation in Children: Developmental Implications.New York: Guilford Press; 35-57

