

*T. V. Chernigovskaya*

### **FACTORS DETERMINING «FUNCTIONAL CEREBRAL ASYMMETRY» IN HOMO LOQUENS<sup>1</sup>**

The last few years of research in functional cerebral asymmetry has brought a reconsideration of a number of crucial issues (cf. Efron 1990). 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, etc. really measures what we hope they do. It is evident that asymmetries under observation could be:

- central (cerebral hemispheres) or peripheral (sensory input)
- cortical or subcortical (involving cerebellum, striatum, basal ganglia, hippocampal system, limbics, etc.)
- morphological, chemical or functional
- stable or is under voluntary and involuntary control of a subject
- 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

It looks like neuronal activity governing language functions is spread over both cerebral hemispheres, beyond the areas traditionally associated with language processing. Functional brain imaging demonstrates flood of activation from area to area, starting, as an example, from frontal attention areas and coming to right-hemispheric areas homologous to Wernicke (Schwarz a. o. 1996); inner speech was PET-imaged to be guided by the right parietal cortex. Moreover, motor-perceptual components involved in the cognitive activity can determine to a certain extent results of the functional neuronal mapping (Muller 1996). 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 1993–2000). It has been shown that children under 10 and representatives of traditional, or ar-

chaic, cultures demonstrate right-hemispheric type of mentality proved by EEG monitoring (Chernigovskaya 1994;1996; Rotenberg, Arshavsky 1997). The book of R. Davidson and K. Hugdahl (1995) gives us a remarkable and reliable insight into the state of the art.

Most brain mapping studies of asymmetries in the central nervous system have centered on regions located in the neocortex, like *planum temporale* — the most highly materialised cortical area in the human brain, governing phonology. As an example, Steinmetz et al. demonstrated that right-handers typically have much larger left *planum temporale* in comparison with the right-sided homologous area (Steinmetz a. o. 1991). LeMay (1976) has shown that the *left occipital pole* is wider and protrudes more posteriorly than the right. Witelson (1986) demonstrated anatomical variations in *corpus callosum* in relation to hemispheric specialisation and integration. MRI asymmetry of *pars triangularis* (a portion of Broca's area) was shown to be relevant for language dominance (Foundas a. o. 1996). Anatomical — as well as functional — difference in cerebral organisation of males and females has been demonstrated by many authors. Moreover, cerebral lateralisation in females is probably modulated by the menstrual cycle diminishing with an increase of the steroids estrogen and progesterone during the follicular and luteal phase and enchanting with steroid decrease during the menstrual phase (Rode a. o. 1995). Thatcher a. o. (1987) have shown that different regions within the cerebral hemisphere exhibit different rates of maturation (see also Molfese, Sagalowitz 1988). Neuroembriologic model of hemispheric specialisation (developmental gradients as associated with asymmetries in adulthood) was developed by Best (1988) and describes three main gradients of influence: (I) anterior-to-posterior gradient; (II) ventro-dorsal gradient and (III) gradient from primary to secondary to tertiary neocortices. It is evident that plasticity slowly decreases with age: we know that the ability to sprout new dendritic connections and synaptic branches as well as myelination is best before 5.

Analogous to LeMay's model there appeared studies measuring asymmetry of cerebellum both in right- and left-handers, in males and females (Snyder 1994). Morphometric procedures using MRI have shown the same types of asymmetry for dextral subjects at metencephalic level as previously demonstrated at the neocortical level and roughly analogous to data on *planum temporale*. It is stressed that neocerebellar cortex, which evolved together with the frontal lobes in mammals, plays important role in memory, emotion, coordination of certain functions associated with fluent language processing. The study examines relationship between asymmetries in metencephalon and hand preference.

It is shown that there is cytoarchitectonical argument for anatomical cerebral asymmetry not only in *homo sapiens* but already in *homo erectus* and *homo habilis*. Broca area seems to have been found in archaic *homo*. However, does it indicate that archaic 'owners' of the region had used it in the same way we do? Is it enough to declare they could speak? No doubt they could have had associ-

ation areas corresponding to Broca (and Wernicke, and to regions governing reading and writing, arithmetic and singing, etc.) — is it a relevant information? Moreover, rhesus monkeys (*Macaca mulatta*) have been shown to have anatomically as well as functionally asymmetrical brain (D. Falk). The data and considerations on our biological origins are so contradictory that I do not have the courage to explore them (see as an example P.Fleming's review of the two 'cross-ocean' contradictory publications by Ch. Stringer, C. Gamble of 1992 and by E. Trinkaus, P. Shipman of 1993, in which — one group argues that Neanderthals were the ancestors of some of us and were like ourselves in anatomy and behaviour, while the other considers them to be quite different from us in all the aspects and in no way our ancestors). However, attempts to find genetic blueprints underlying language functions, i.e. hypothetical 'linguistic' genes on a certain chromosome, seems to be most intriguing and facing another set of problems concerning cerebral asymmetries.

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 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 SLA or caused by pathology) you tend to use more pragmatic (i.e. right-hemispheric) language (Paradis 1993; 1996).

Meanwhile, the shift from perceptual to conceptual distinctions (Bichakjian 1988; 1996; 1997) is evident to characterise cognitive and language evolution from primates to humans and within the human development (see also Donald 1993; Liska 1994; Ragir 1994). Our data in neurological patients with lateral focal lesion, psychiatric patients observed after unilateral therapy, as well as in normal individuals subjected to non-invasive instrumental examination (monaural and dichotic listening) and a battery of lateral perceptual, cognitive and motor testing (Chernigovskaya 1993–1999), 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 poles in 'mythological' and 'logical' antithesis in association with cerebral lateral mechanisms. Both ontogenetic and cross-cultural data demonstrate semiotic evolution from the right-

hemispheric 'archaic' mentality towards the left-hemispheric. 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.

### Notes

<sup>1</sup>*Acknowledgements:* The research was supported by grant No. 00–15–98855 from Russian Foundation for Basic Research

### References

- Best 1988: *Best C. T.* The emergence of cerebral asymmetries in early human development: A literature review and a neuroembryological model // *Brain Lateralisation in Children: Developmental Implications* / Ed. by D. L. Molfese, S. J. Sagalowicz. New York: Guilford Press, 1988.
- Bichakjian 1996: *Bichakjian B.* Evolution: From Biology to Language // *Darmstadter Beiträge zur Naturgeschichte*. 1996. Heft 6.
- Bichakjian 1997: *Bichakjian B.* Language evolution and the shift to features characteristic of the left hemisphere // *Semiotische Prozesse und natürlische Sprache* / Ed. by A. Gather, H. Werner. Stuttgart: Steiner, 1997.
- Chernigovskaya 1993: *Chernigovskaya T. V.* Die Heterogenität des verbalen Denkens als Cerebrale Asymmetrie; Die Lateralisierung von Sprachen bei Bilingualen // 'Psychosemiotik-Neurosemiotik' Dr. N. Brockmeyer / Ed. by P.Grzybek. Bochum, 1993.
- Chernigovskaya 1994: *Chernigovskaya T. V.* Cerebral lateralization for cognitive and linguistic abilities: neuropsychological and cultural aspects // *Studies in Language Origins* / Ed. by J. Wind, A. Jonker, R. Allott, L. Rolfe. Amsterdam; Philadelphia, 1994. Vol. 3.
- Chernigovskaya a. o. 1995: *Chernigovskaya T., Svetosarova N., Tokareva T.* Hemispheric contributions to processing affective and linguistic prosody // *Proceedings of XII International Congress of Phonetic Sciences*. Stockholm, 1995.
- Chernigovskaya 1996: *Chernigovskaya T. V.* Cerebral asymmetry — a neuropsychological parallel to semiogenesis // *Acta Colloquii. — Bochum publications in Evolutionary Cultural Semiotics, «Language in the Wurm Glaciation»* / Ed. by U. Figge, W. Koch. 1996. Vol. 27.
- Chernigovskaya 1997: *Chernigovskaya T. V.* Lateralization for Auditory Perception of Foreign Words // *EUROSPEECH'97*. Rhodes, Greece. 1997. Vol. 5.
- Chernigovskaya 1999: *Chernigovskaya T. V.* Neurosemiotic Approach to Cognitive Functions // *Journal of the International Association for Semiotic Studies — SEMIOTICA*. 1999. Vol.127, № 1/4.

- Chernigovskaya a. o. 2000: *Chernigovskaya T., Natochin Y., Menshutkin V.* Principles of evolution of natural and computer languages and physiological systems // «Becoming Loquens» – Bochum Publications in Evolutionary Cultural Semiotics / Ed. by B. Bichakjian, T. Chernigovskaya, A. Kendon, A. Moeller. Frankfurt am Main; Berlin; Bern; Bruxelles; New York; Oxford; Wien, 2000. Vol. 1.
- Davidson, Hugdahl 1995: *Brain Asymmetry* / Ed. by R. Davidson, K. Hugdahl. The MIT Press, 1995.
- Donald 1993: *Donald M.* Origins of the Modern Mind: Three Stages of Culture and Cognition. Cambridge, Mass.: Harvard Univ. Press, 1993.
- Efron 1990: *Efron R.* The decline and the fall of hemispheric specialisation. Hillsdale, N.J.: Erlbaum, 1990.
- Flemming 1993: *Flemming P.* Review of Ch. Stringer and C. Gamble. In search of the Neanderthals. London: Thames and Hudson, 1992 and E. Trinkaus and P. Shipman. The Neandertals: Changing the Image of Mankind. London: Jonathan Cape, 1993 // LOS Forum. 1993. № 17, Fall.
- Foundas a. o. 1996: *Foundas A. L., Leonard C. M., Gilmore R. L., Fennell E. B., Heilman K. M.* Pars triangularis asymmetry and language dominance // Proc. Natl. Acad. Sci. USA. 1996. Vol. 23, № 93 (2).
- Hugdahl 1995: *Hugdahl K.* Classical conditioning and Implicit Learning: The Right Hemisphere Hypothesis // *Brain Asymmetry* / Ed. by R. Davidson, K. Hugdahl. The MIT Press, 1995.
- LeMay 1976: *LeMay M.* Morphological cerebral asymmetries of modern man, fossil man, and nonhuman primates // Ann. New York Acad. Sci. 1976. Vol. 280.
- Liska 1994: *Liska J.* Sign arbitrariness as an index of semiogenesis // Studies in Language Origins / Ed. by J. Wind, A. Jonker, R. Allott, L. Rolfé. Amsterdam; Philadelphia. 1994. Vol. 3.
- Molfese, Sagalowitz 1988: *Brain Lateralisation in Children: Developmental Implications* / Ed. by D. L. Molfese, S. J. Sagalowitz. New York: Guilford Press, 1988.
- Muller 1996: *Muller R.-A.* Innateness, autonomy, universality? Neurobiological approaches to language // Behavioural and Brain Sciences. 1996. № 19.
- Paradis 1993: *Paradis M.* Linguistic, psycholinguistic, and neurolinguistic aspects of 'interference' in bilingual speakers: the activation threshold hypothesis // International Journ. of Psycholinguistics. 1993. Vol. 9, part 2, № 26.
- Paradis 1996: *Paradis M.* Selective deficit in one language is not a demonstration of different anatomical representation / Comments on Gomez-Tortosa et al. // Brain and Language. 1996. Vol. 54, № 1.
- Ragir 1994: *Ragir S.* Vocal/auditory cognitive mapping, shared meaning and consciousness // Studies in Language Origins / Ed. by J. Wind, A. Jonker, R. Allott, L. Rolfé. Amsterdam; Philadelphia, 1994. Vol. 3.
- Rode a. o. 1990: *Rode C., Wagner M., Guuturkun O.* Menstrual cycle affects functional cerebral asymmetries // Neuropsychologia. 1998. Vol. 22, № 7.

- Rotenberg, Arshavsky 1997: *Rotenberg V. S., Arshavsky V. V.* Right and left brain hemisphere activation in the representatives of two different cultures // *Homeostasis*. 1997. Vol. 38, № 2.
- Schwarz a. o. 1996: *Schwarz T. H., Ojeman G. A., Haglund M. M., Lettich E.* Cerebral materialisation of neuronal activity during naming, reading and line-matching // *Cognitive Brain Research*. 1996. № 4.
- Snyder a. o. 1995: *Snyder P. J., Bilder R. M, Wu H., Bogerts B., Lieberman J. A.* Cerebellar Volume Asymmetries: A Quantitative MRI Study // *Neuropsychologia*. 1995. Vol. 33, № 4.
- Steinmetz a. o. 1991: *Steinmetz H., Volkmann J., Jancke L., Freund H.-J.* Anatomical left-right asymmetry of language-related temporal cortex is different in left- and right-handers // *Ann. Neurol.* 1991. № 29.
- Stringer, Gamble 1992: *Stringer Ch., Gamble C.* In Search of the Neanderthals. London: Thames and Hudson, 1992.
- Thatcher a. o. 1987: *Thatcher R. W., Walker R. A., Giudice S.* Human cerebral hemispheres develop at different ages // *Science*. 1987. № 236.
- Trinkaus, Shipman 1993: *Trinkaus E., Shipman P.* The Neanderthals: Changing the Image of Mankind. London: Jonathan Cape, 1993.
- Witelson, Kigar 1988: *Witelson S. F., Kigar D. L.* Anatomical development of corpus callosum in humans: A review with reference to sex and cognition // *Brain Lateralisation in Children: Developmental Implications* / Ed. by D. L. Molfese, S. J. Sagalowitz. New York: Guilford Press, 1988.