Cerebral lateralization for cognitive and linguistic abilities
Neuropsychological and cultural aspects

Tatiana V. Chernigovskaya

Summary

Human thinking is fundamentally heterogeneous, i.e., given the fact that it is associated with various types of culture and with modes of education as well as with brain organization of higher cortical functions. The heterogeneity is manifested as differently oriented cognitive styles of processing information. Empirical data — although contradictory — reveal the possibility to relate different types of mentality with sensory functions which are associated with cerebral specialization. The thinking provided by the left hemisphere (LH) is formal, analytic and characterized by probability laws. In contrast, the thinking provided by the right hemisphere (RH) is metaphoric, Gestalt-like and mosaic. LH thinking can be correlated with thinking in terms of scientific notions, acquired in secondary schools of the western type. It constitutes the basis for acquiring natural languages and for the majority of traditional systems of artificial intelligence. RH thinking is correlated with preoperational thinking of children, with metaphoric, pre- and hetero-logical thinking of archaic cultures and with creative thinking of modern adults; it provides for a holistic grasp of the highest possible number of connections.
1. Introduction

It has become common practice to associate different types of mental activities and of sensory functions with cerebral asymmetry. Though the analogy is quite trivial the aspect of the mind-body problem related to language origins studies is still being debated and has so far not become any clearer. Moreover, the more neurophysiological data we have acquired and the more sophisticated our research methods have become, the more complex the whole problem has seemed to become.

Using this kind of negative introduction one should also take into account peculiarities of clinical research, psychophysiological characteristics of normal subjects, their sensory/motor — and not only cerebral — organization, their emotional, motivational status, the character of the subjects’ presuppositions and the previously learned templates, their creativity, etc. Also very important is their way of responding to the test presented, e.g. vocal or manual. There is also strong evidence for gender differences and hormonal influences on the manner and speed of processing. There is the anatomical basis of cerebral asymmetry as proved by cytoarchitectural data and found already in *Homo habilis* (Tobias, 1991). There is also reliable evidence that left and right hemispheres (LH and RH) are characterized by different chemical qualities (Vartanian and Klementiev, 1991).

Cerebral asymmetry appears not to be restricted to humans: there is handedness in monkeys and apes (MacNeilage, Studdert Kennedy and Lindblom, 1987), and there are hemispherically different ‘modes of information processing’ in cats and rats (Bianki, 1985) as well as hemispherical specialization for singing in birds (Nottbohm, 1979), etc. Interestingly, also newborn human infants show brain asymmetry, according to Molfe and Molfe (1979) although the data are contradictory. There is a vast literature concerning the evolutionary aspects of brain asymmetry (Walker, 1980; Calvin, 1982; LeDoux, 1982; Levy, 1976; Bradshaw and Nettleton, 1981; Marshall, 1976; Campbell and Hodos, 1970).

We know that cerebral asymmetry is considered to be functional and that it depends on the levels of perception and information processing, its complexity, its novelty, etc. (cf. Moscovitch, 1979; and Zeidel et al., 1990). One of the crucial questions then is: is cerebral asymmetry revealed in cognitive processes only, thus depicting modes of consciousness, or is it also a result of differences in sensorimotor resolution capacities? The answer would lead to a possible revision of current investigation procedures, like tachystoscopic, dichotic and monaural testing. Asymmetry of what is ‘cerebral asymmetry’? Is it asymmetry of phenomenal experience, of attention, of memory, or of cognitive styles? Moreover, as Sergent (1982) has discussed, most hypotheses that seek to explain cerebral asymmetry imply that cortical hemispheres behave as two separate units with the corpus callosum as a go-between. A large body of research with brain-damaged and healthy subjects is interpreted as based on these ideas (see for example Bradshaw and Nettleton, 1981; Moscovitch, 1979; but cf. Efron, 1990).

Cerebral asymmetry is usually described as either depending on the type of stimuli presented — the verbal/visuospatial dichotomy — or the type of processing, i.e., cognitive styles, e.g. analytic or holistic. However, a large body of data reveals that this interpretation is insufficient in recognizing the fundamental differences between the hemispheres: it has been established nowadays that the right hemisphere is quite able to process language while visuospatial stimuli can be successfully processed by the left hemisphere.

Similarly, both hemispheres can use various strategies, depending on a number of factors including individual differences caused by genetically programmed lateralization of cognitive functions as well as by those resulting from some specific training. Recent data, to be discussed in this paper, show that predominant left or right hemisphere involvement in information processing can be determined by the task factor — either experimental or real — and consequently by the necessity of cognitive style choice. Thus, not only qualitatively different information can be processed by either the left or the right hemisphere, but the same stimulus can be described by different hemispheric paradigms depending on the task.

It is also becoming clear that the level of analysis is a very important factor: not all the stages of processing imply hemispheric involvement, i.e., higher cortical functions. Speaking of this question, Roman Jakobson stated in 1980: “It looks as if the joint efforts of linguists and neurologists are combined to suggest and open ever deeper insights both into the structure of language with reference to the brain and to the structure of the brain with the help of the language. The necessary initial step on this path has been the delineation of the set of internal functional convergences which specify each of cerebral hemispheres…” He supposed that the most compelling differences in hemispheric abilities are probably those of semiotic systems. Here, I will make an attempt to consider some additional data in favor of such a view.
2. Methods

Our investigations are based on many dozens of experiments in normal subjects using special techniques, and on dozens of clinical observations of patients after unilateral electroconvulsive therapy (ECT) as used in psychiatry. This treatment results in a situation where the activity of one hemisphere is inhibited, making it incapable of normal functioning, while the other is intact and even appears to be reciprocally stimulated. The course of the therapy includes both right- and left-sided seizures administered to patients suffering from various types of depression. It is possible therefore to juxtapose the suppression effects of the hemispheres in one and the same patient. Continuous EEG monitoring shows asymmetric characteristics — the stimulated hemisphere showing delta rhythms while the intact one shows alpha rhythms.

The subjects were given several types of tests aimed at examining the ability to perform cognitive operations and at demonstrating hemispherically differentiated modes of processing. The group consisted of healthy subjects composed of normal listeners between 20-50 years of age, all native speakers of Russian and right-handed.

The stimuli were taped-recorded speech samples, i.e., CVC syllables with Russian or French vowels, and Russian phrases of different prosodic quality, as well as rhythmical trains of tonal bursts. All the stimuli were presented monaurally, and the type of answer together with reaction time were registered.

3. Syllogistic versus metaphoric mentality

3.1 Syllogistic reasoning

In recent years a concept has emerged of the brain as a system uniting opposite 'personae' which are in the state of continuous dialogue with one another. The dialogue results in the generation of new 'texts', i.e., in mental activity. The possibility of such a view has been explicitly stated in the works of such prominent Russian scientists as L. Vygotsky (1965), Yu. Lotman (1983), and V. Ivanov (1979). In their remarkable paper 'Myth-Name-Culture,' Lotman and Uspehskiy (1973) postulate two poles of mythological and non-mythological thinking. They contrast the mythological language of proper names (and groups of words functionally equivalent to them) with descriptive language of science. This contrast being similar to the 'poetry-science' antithesis. This is in keeping with the theory of heterogeneity of thinking which defines the concept of thinking as a homogeneous process characteristic of Homo sapiens as a species, and postulates a variety of its types.

The above hypothesis raises a wide spectrum of problems here — ranging from ontogeny and the typology of mental processes up to the types of cultures — that are tackled by various branches of humanities and natural sciences such as anthropology, ethnology, history of culture, semiotics, psycholinguistics and physiology. The most valuable contributions to the study of these problems have been made by Spencer, Lévy-Bruhl, Lévi-Strauss, Bruner, Piaget, Scribner, Cole, Jakobson, and Luria.

The results achieved by neurolinguists and cognitive psychologists show the processes in connection with cerebral asymmetry. The fundamental semantic characteristics of obvious differences in 'hemispheric thinking' were formulated by R. Jakobson (1980). He brought the specialization of the right hemisphere in correlation with the immediate character of signal meaning, and the specialization of the left hemisphere in correlation with the mediate character thereof. For example, the mediate character of phonological means — such as distinguishing high and low pitches in polytonic languages like Thai — contrasts with the understanding of high pitch as an indication either of interrogation, or emotional coloring, or of female voice. According to Jakobson, immediate signals are processed by the right hemisphere and mediate ones by the left.

A. Luria in his 1974 book outlined an experimental psychological approach to the problem of culture and thought. The main ideas that have had a pronounced effect on Luria's work and along with Piaget's concepts became the basis for most of contemporary research, were formulated by Lev Vygotsky as early as in 1934 (Vygotsky, 1965). He emphasized the difference between everyday and scientific concepts and stated that most of these correspond to differences in empirical findings in word definition, classifications, units and modes of verbal/nonverbal problem solving, animistic thinking, etc.

It was Levy-Bruhl (1975) who discussed the nature and determinants of cross-cultural changes in thinking. One of his most important ideas was that thinking is heterogeneous within any individual and within any culture. These ideas are being studied now by Cole and Scribner (1974) and by Peter Tulviste
(1978) (at Tartu University, Estonia). Since it seems that none had ever tried to deal with psychophysiological aspects of these propositions we made an attempt to bridge this gap.

The capacity for formal logical deduction is traditionally believed to provide the basis for human mentality. There are many psychological conceptions of syllogistic reasoning. The question of cerebral organization of syllogistic reasoning has not been approached until very recently. The only paper I could find was that of Caramazza, Gordon, Zurif and DeLuca (1976). The problem they treat is the extent to which language comprehension depends upon imaginal processes. Their findings suggest that verbal reasoning requires the formation of right-hemispherically based imagery at either visual or general cognitive level.

In our research project, the patients, after ECT treatment, were given 10 syllogisms: five of them were in line with the subjects' empirical experience, five were 'abstract'. The examples of the first type are: (a) At the latitude of St. Petersburg, nights are white in June. The town Primorsk is at the latitude of St. Petersburg. Are the nights white in Primorsk in June or not? (b) In all the rivers where one sets fish-net there is fish. One sets fish-net on the Neva river (Note: the river is in St. Petersburg). Is there fish in the Neva river or not? The examples of the second type are: (c) All squares have sides of equal length. A girl has drawn a square on the blackboard. Are its sides of equal length or not? (d) All numbers ending in 5 are divisible by 5 without remainder. 705 ends in 5. Is 705 divisible by 5 without remainder or not? (e) Molybdenum is a precious metal. Will molybdenum ever rust or not?

The patients were subjected to the examination before the treatment and after the R-sided and the L-sided seizures. Our results provide convincing evidence that the hemispheres play essentially different roles in the neural organization of syllogistic thinking. Patients with an intact LH solve syllogisms by not taking into account the pragmatic validity of the question; rather they use the rules of formal logic. In contrast, patients with an intact RH are not guided by formal rules, but use their individual empirical experience. The type of patients' reasoning appeared to be dependent on the type of syllogism presented to them: when a subject dealt with abstract problems the likelihood of his using the empirical types of answers was small. The theoretical type is characteristic of the LH properly functioning while the empirical one is of RH. The RH cannot be 'misled' by a formally ideal, but pragmatically absurd

situation. It should particularly be emphasized that opposite contrasting types of answers were given by one and the same person depending on which hemisphere was functioning.

I shall give some examples of answers given by the subjects. First, LH functioning.

(a) - Yes, it is said so.
(b) - Yes, there is, because that is just what we read here.
(c) - Yes, it is said so.
(d) - Yes, it is because it is said that all numbers ending in 5 are divisible by 5 without remainders.
(e) - No, it will not, as it is said here.

Second, RH functioning (the same subjects):

(a) - How should I know where on earth that Primorsk is and what nights are there in June?
(b) - No, there is not, now the water in the Neva is so dirty, there is a lot of engine oil in it, there can't be any fish there.
(c) - No, I don't know that the girl has drawn anything and I have never seen her.
(d) - I don't know, I have to make computations. The subject takes a pen and begins to divide 705 by 5. It should be noted that this man had got a degree in technical sciences and when his LH was properly functioning he didn't have any doubts as to the right answer.
(e) - I don't know any molybdenum and whether it will rust or not.

<table>
<thead>
<tr>
<th>Type of syllogisms</th>
<th>Type of answer</th>
<th>Control</th>
<th>LH intact</th>
<th>RH intact</th>
</tr>
</thead>
<tbody>
<tr>
<td>concrete</td>
<td>theoretical</td>
<td>94%</td>
<td>92%</td>
<td>49%</td>
</tr>
<tr>
<td></td>
<td>empirical</td>
<td>6%</td>
<td>8%</td>
<td>51%</td>
</tr>
<tr>
<td>abstract</td>
<td>theoretical</td>
<td>98%</td>
<td>100%</td>
<td>89%</td>
</tr>
<tr>
<td></td>
<td>empirical</td>
<td>2%</td>
<td>0%</td>
<td>20%</td>
</tr>
</tbody>
</table>
Juxtaposing the results of theoretical reasoning capacities within the hemispheric paradigm with ontogenetic and cross-cultural data we may conclude that right hemisphere reasoning is very much like solving logical problems in the pre-operational stage of a child’s thinking — as Piaget put it — and like problem solving by adults of traditional archaic communities. This leads us to assume that Vygotsky’s ideas about the coexistence of different modes of thinking in one and the same person have a neurophysiological basis, namely the difference in the hemispheric structures. Cross-cultural research also shows that the pensee savage is not the immanent neurophysiological characteristic of humans in traditional cultures, but it is the result of cultural factors like education.

3.2. Understanding idioms and metaphors

There is a vast linguistic, psycholinguistic and neuropsychological literature on metaphoric thinking. We need only mention here such well-known scientists as Wittgenstein, Chomsky, Katz, Fodor, Bever, Billow, Tversky, Whorf, Jakobson, Hallé, Gardner, Pollio and many others. One can also point to a paper of Tourangeau and Sternberg (1978). While I am not in a position to review the present state of the problem, I can only point out that in spite of multi-dimensional research into the problem, I did not come across aspects revealing RH and LH peculiarities of metaphorical abilities. The only paper I could find was that of Marquis, Glass and Corlett (1984) studying EEGs. They came to conclusion that the speed of metaphor understanding was higher in RH than that in LH.

The methods we used in our second project were similar to the ones we used when examining syllogisms. The stimuli consisted of 20 sets of phrases. Each set consisted of three cards — the first containing a metaphor or an idiom, the second — a phrase with the same key word but having a completely different meaning; the third card provided an interpretation of the metaphor (idiom). The subject was asked to choose two of these cards. Here are the examples of some sets.

**Metaphors**

(a) 1. A storm in a teacup. 2. A spoon in a teacup. 3. A great fuss about something trivial.

**Idioms**

(b) 1. Rats desert a sinking ship. 2. Rats can be dangerous. 3. The scoundrels are the first to betray a cause in times of trouble.

(c) 1. The wind returns again according to its circuit. 2. The wind is strong today. 3. All things repeat themselves.

(d) 1. To sit on one’s own hands. 2. To sit on a bench. 3. To sit idly.

(e) 1. To loose one’s temper. 2. To lose one’s bag. 3. To become angry.

(f) 1. Time flies! 2. A bird flies. 3. Time is passing very quickly.

Patients with inhibited RH could make an adequate choice only in half of all the tasks while the same patients with normally functioning RH could manage 90% of the idiomatic tests and 68% of the metaphoric ones. The examples of such typical answers are as follows.

With preferably LH functioning the choice is usually phrases 1 and 2, while with preferably RH functioning they are 1 and 3. The reaction time appeared to be shorter with RH ‘normally’ functioning than with LH.

Table 2

<table>
<thead>
<tr>
<th>Idioms</th>
<th>Normal conditions</th>
<th>LH intact</th>
<th>RH intact</th>
</tr>
</thead>
<tbody>
<tr>
<td>adequate answer</td>
<td>7.2 sec</td>
<td>12.5 sec</td>
<td>9.8 sec</td>
</tr>
<tr>
<td>wrong answer</td>
<td>16.3 sec</td>
<td>14.7 sec</td>
<td>15.2 sec</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metaphors</th>
<th>Normal conditions</th>
<th>LH intact</th>
<th>RH intact</th>
</tr>
</thead>
<tbody>
<tr>
<td>adequate answer</td>
<td>9.7 sec</td>
<td>15.8 sec</td>
<td>10.05 sec</td>
</tr>
<tr>
<td>wrong answer</td>
<td>16.5 sec</td>
<td>17.8 sec</td>
<td>16.5 sec</td>
</tr>
</tbody>
</table>

Interesting is the extent of adequate answers to some of the idioms in different conditions:

<table>
<thead>
<tr>
<th>To lose one’s temper:</th>
<th>normal</th>
<th>LH</th>
<th>RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90%</td>
<td>0%</td>
<td>70%</td>
</tr>
<tr>
<td>To sit on one’s own hands:</td>
<td>80%</td>
<td>20%</td>
<td>90%</td>
</tr>
</tbody>
</table>

The percentages of different types of answers can be seen in Table 3.
We interpret these findings as the RH superiority for Gestalt-like processing required for understanding such tasks and for recalling idioms that cannot be interpreted literally. The LH is apparently unable to perform this task. It appears that RH ability for metaphorical thinking is the only effective reaction in such a novel situation. The majority of researchers agree that metaphorical polysemy would require mental storage of a tremendous stock of separate words for each possible subject. Our findings have direct analogies in cross-cultural and ontogenetic research.

4. Nominal realism as the RH manifestation

'Nominal realism' of Vygotsky and Piaget depicts an absence of reflexive abilities and scientific concepts in young children and certain groups of adults. These subjects do not realize the conventional nature of nomination (see also Rosenbaum and Rinker, 1983). The problem is, from another point, brilliantly discussed in the above paper of Loizand and Uspensky (1973). Our empirical data show the hemispheric basis of the phenomenon. Moreover, our study of educated adults suggested the 'nominal realism' underlying the answers. It appeared that psychological awareness of the difference between word and referent is not as evident. The reaction of normal, well-educated adults was very much like that of the patients after left hemisphere inactivation. So the right hemisphere type of consciousness was once again shown to be quite common in normal adults.

Some results of our research of cerebral involvement in language awareness could be summarized as follows. Our subjects were asked several questions. For example: (a) Why was the sun named "the sun"? (b) Can it be given any other name? (c) Can it be given the name ‘the moon’? (d) Can it be given the name ‘gag’? (e) Which appeared earlier: the sun or its name? (The testword could also be ‘bread’, ‘brother’, ‘spaghetti’, etc.).

Individuals whose LH was functioning normally usually answered that (a) ... because people have given it such a name; (b) ... Yes, of course; (c) ... yes, it is possible, but you better don’t do it; (d) ... yes, it can; (e) ... Naturally, the sun itself appeared earlier.

The same subjects, after unilateral treatment (ECT) when the RH was intact, gave other types of answers. These were: (a) ‘It is called so because it is shining’ (or ... ‘because the bread is tasty and fresh’; ‘... because spaghetti are long and thin and they eat it with cheese’; (b) No, why should we call it differently? (c) No, there is no need to do it, it has its name; (d) No, of course not; (e) (!) The name appeared before the sun.

Most amazing is the continuing existence of this type of consciousness in well-educated adults, who often gave the answers very similar to those given by LH-damaged patients.

5. Conservation abilities and animistic thinking

As to conservation abilities, the essence of the concrete operational level of thinking is the child’s ability to solve a variety of problems in a systemic fashion. Research on the onogeny of thinking highlights the experimental facts showing the inability of young children to conserve quantity, number, and volume (an amount of liquid) (see Piaget and Inhelder, 1941; Elkind, 1961; Lowell and Ogilvie, 1961).

Our experimental procedure was as follows. After unilateral treatment, the patients were shown two vessels. One was high and narrow, the other was low and wide. Water was poured from one of them into the other in the presence of the subjects, and they were asked if the total amount of water was constant all the time. Patients with intact RH reacted like young children and subjects of traditional, 'archaic' societies, while the same subjects with intact LH performed like adults with scientific concepts developed. I have read only two papers dealing with cerebral involvement in conservation concepts understanding. Kraft et al. (1980) interpreted the inability of children under 8 years old of Piagetian conservation as lack of interhemispheric integration as shown by EEG studies, and the associated incomplete cortical myelin development.

Table 3

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>LH intact</th>
<th>RH intact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idioms:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adequate</td>
<td>87%</td>
<td>46%</td>
<td>90%</td>
</tr>
<tr>
<td>wrong</td>
<td>13%</td>
<td>54%</td>
<td>10%</td>
</tr>
<tr>
<td>Metaphors:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adequate</td>
<td>79%</td>
<td>44%</td>
<td>68%</td>
</tr>
<tr>
<td>wrong</td>
<td>21%</td>
<td>56%</td>
<td>32%</td>
</tr>
</tbody>
</table>
The other paper is of Gallagher and Joseph (1982) who equally think that the explanation is to be found in the immature corpus callosum of young children and the inability of their RH to express their knowledge of conservation concepts.

As to animistic thinking, the ability to distinguish animistic objects and living things has equally been a part of our research. The phenomenon has been shown to characterize categorical organization of mentality (Klingberg, 1957). There have been suggestions that this organization can be associated with certain neural substrates. Warrington and Shallice (1984) discussed four case histories of neurological patients with clinical observations of selective impairment of categorization processes: the lesions concerned were diffuse, but would generally be accepted as having mainly been localized in the LH. These authors concluded that identification of animate objects appeared to be selectively impaired and that of inanimate objects selectively preserved.

We asked our patients to identify whether the object was living or not and to provide comments. A set of ten words was presented to the patients. It contained several clearly animate items like ‘a bird’, and several clearly inanimate items such as ‘a stone.’ Furthermore, items like ‘a flower,’ ‘a tree’ and like ‘a watch,’ ‘a river,’ ‘a cloud,’ etc.

The results can be summarized as follows (Table 4). The LH appears to search rationally for characteristics of ‘alive,’ while the RH rather demonstrates animistic (archaic, metaphorical) thinking. It is interesting to note that such animistic thinking is also often demonstrated even by well-educated normal adults in everyday life (one can hear answers like ‘Watch is alive because it goes’ or ‘River is alive because fish lives there, or because it runs’). For similar phenomena see Dennis (1957).

6. Language faculty and hemispheric peculiarities

The relation between lexical and grammatical skills and cerebral asymmetry led to the discussion between Chomsky and Piaget. They addressed the question: To what extent do all natural languages share universal neuro- psychological representations in spite of different performances? There are two contrasting points of view: (i) the innate language acquisition device of Chomsky; and (ii) language faculty as part of more general cognitive ability, such as abstract symbolic representation of analytic combinatorial competence, etc., reflecting cultural and developmental influences on developing linguistic behavior (Piaget and some others).

Our experiments provide convincing evidence that the hemispheres play essentially different roles in the neural organization of linguistic competence. The problem has been discussed in our 1983 and 1986 publications. Our research project aimed at revealing lexical and grammatical skills of the patients after ECT procedures, i.e., with ‘normal’ functioning of either the LH or the RH. We asked the subjects (i) to classify several adjectives which could be done using formal principles or extra-linguistic concepts; and (ii) to classify and identify with corresponding pictures several grammatical items, i.e., reversible active and passive constructions (see Chernigovskaya and Deglin, 1986).

The results were as follows. The experiments revealed that the RH deals mostly with extra-linguistic reality. In classifying words it ignores possible formal principles. In grammatical testing it is guided by the first name in the sentence and ignores grammatical forms and even the meaning of the phrases. We can give two possible explanations. The first one calls our attention to the
rules of deep syntax where the pattern ‘noun - verb - noun’ represents the relation ‘agent - action - patient’. Such an interpretation is characteristic of the early stages of children’s syntactic development and, probably, of the simplest language-type skills in the primates. All these data lead us to believe that the first nominal position in the sentence is always understood as the ‘agent’ irrespective of either grammar or semantics.

The other explanation is based on the rules of functional sentence perspective, the ‘given - new’ strategy, that is, marking the topic and the comment of the sentence. In written Russian the functional sentence perspective is provided by the definite word order: normally the noun-topic irrespective of its case is placed in the first position. We may assume that the right hemisphere interprets all sentences according to this rule.

In any case, we see that word order plays the most important role in the linguistic competence of the RH, which is of special interest here because Russian (the testing was in Russian) is a highly inflected language and the word order is not fixed as in other languages like English. (In Russian the subject of the sentence is unambiguously marked regardless of its position by the nominative case ending, while the object is marked by the accusative case ending; the verb is marked by tense, number, and voice, etc. Thus in Russian there are many aids in finding the agent besides the word order).

It should be emphasized once again that there seems to be a clear similarity of the RH and child linguistic competence. This enables us to formulate a theory of “contextual generalization”, summarized as “what is learned primarily is the proper locations of words”. The child focuses his/her attention on a particular position of a word and classifies all words together that occur in that position. With increasing age more refined positions are utilized. The left hemisphere deals with lexical and grammatical material quite differently. In lexical testing, a formal, metalinguistic tendency is observed. Classifying sentences causes no difficulty with separating passives and actives, and a subject is never guided by nominal position. It appears difficult for the LH to deal with the initial (noninverse active) constructions whereas it has no difficulty dealing with more complicated ones.

We do not know how this paradox should be explained. Nevertheless, it once again shows the inadequacy of the Miller-Chomsky hypothesis. According to this hypothesis, the ‘speaker’ begins with forming basic structure and proceeds to the surface by using T-rules; conversely, the ‘listener’ has to de-transform the surface structure to arrive at the deep structure. Every step of the transformation would then be a separate operation. Also, our results suggest that the analysis of the complicated structure does not consist of reducing transforms to initial sentences taken as syntactic.

The data obtained in our project and summarizing our previous results suggest the following outline of the linguistic competence of each of the two hemispheres. The RH is responsible for the deep semantic level. It relates the sign to its referent. Its syntax is the word order; each position has its specific meaning (agent - patient, or topic - comment). For the LH, the relation of the sign to its referent is of less importance than for the RH; the LH deals with the interrelation of signs. Our earlier findings (Chernigovskaya, Bulonov and Deglin, 1983; Chernigovskaya, in press) convincingly show that the LH and the RH perform principally different roles in the neural organization of the native language, i.e., a language acquired through the use of the direct natural method, on the one hand, and a different language acquired later, e.g., at school, on the other. We suppose that the RH is concerned with the formation of deep semantic structures of the native language while the LH is responsible for the formation of second language deep structures and of surface structures of both languages. The effect of language learning method on cerebral organization of bilingualism was demonstrated to be very important.

7. Music, vowels and prosody perception

Numerous investigations of the problem of creativity agree that musical and, generally, artistic capacities are strictly correlated with right hemisphere activation (Ivanov, 1979; Gowan, 1978; McCallum and Glynn, 1979; Rubenzer, 1979; Katz, 1983; Sinatra, 1984; Beaumont, 1985). The perception and production of music is shown to be more finely grained in subjects whose hemisphericity is ‘shifted towards the right half of the brain’. It is usually associated with an ability to process rhythm and tonal differences as first shown in the 70s. Since then rhythm is described as the basis of music and speech abilities and to be associated with the right hemisphere function.

There are contradictory data, however, that in professional, i.e., analytical listening, the same musical samples can be processed in a left-hemisphere style.

Our own empirical findings show that different types of rhythms are controlled by different hemispheric mechanisms. It was shown that the left
hemisphere rapidly and accurately recognizes the amplitude changes of high frequency signals with high rhythms of tonal bursts (3 kHz - 60Hz). In contrast, the right hemisphere controls low frequency stimuli with low rhythms of tonal bursts (0.25kHz - 20Hz) (Chernigovskaya and Vartanian, 1989).

As is well recognized, speech processing involves the rapid decoding and the construction of meaning from a transient acoustic signal. It has been shown that the LH mechanisms provide for correct phonemic analysis (see Studdert-Kennedy and Shankweiler, 1970), enabling the reduction of a sound continuum to functionally relevant segments; the role of the RH is to realize global template recognition and to discriminate the pitch, individual voice qualities and prosodic features (Deglin, Trachenko and Chernigovskaya, 1987). Our research shows that LH mechanisms secure the accuracy of processing unfamiliar, novel acoustic stimuli, while those of the RH provide for quick orientation in familiar information.

We have also shown the difference in hemispheric involvement in the perception and production of sounds of native and nonnative languages (Chernigovskaya and Vartanian, 1991). Our subjects were right-handed, normal listeners, native speakers of Russian. The stimulus sets were CVC syllables made up of natural speech sounds produced by a male Russian–French bilingual. Russian stop consonants and French and Russian vowels were used to construct syllables on a computer and to record the set. The stimuli were presented monaurally to the right and the left ear in turn. Reaction times and the types of answers were registered automatically. Subjects were asked to give a vocal response, to imitate the stimulus most accurately, to produce or write the Russian syllable similar to the target one.

The results demonstrate two main types of sensor-motor organization of the brain, the dependence of lateralization on the experimental conditions, i.e., the side of stimulation, type of task, type of answer (vocal/manual). It should be emphasized that perception is language-specific and depends on individual acoustic and language background. It is probable that in the central regulation of speech, all high level processing of new and complex information is a function of the LH, while familiar information engages both hemispheres or the RH preferably. Speech processing, therefore, most probably uses higher levels in interpreting lower levels of perception. Our results suggest that RH and the LH control different aspects of syllable processing in different languages: categorization versus imitation, native versus slightly familiar versus unknown language.

Cerebral lateralization

Prosody processing — both comprehension and production — has, for many years, been associated with the functions of the right hemisphere, in the same way that the left hemisphere had been credited with specialized processing of speech. This association was based on an analysis of affective prosody disorders after right hemisphere lesions, the results being extrapolated to the right hemisphere specialization for all types of prosody, both affective and linguistic.

There are, however, a lot of contradictory data concerning comprehension and production of linguistic prosody and quite a few of them definitely prove the existence of right hemisphere involvement in the process (see Behrens, 1988; Blumstein and Cooper, 1974; Emmory, 1987; Heilman et al., 1984; Ross, 1981; Chernigovskaya and Vartanian, 1991). In fact, there is no adequate explanation for laterality of any prosody yet.

Our project dealt with the neural representation for perception of prosody in normal listeners. Different kinds of linguistic material were used for the demonstration of a prosodic features’ continuum. Experimental subjects were adults (right-handed postgraduates) who were asked to analyze the stimuli presented monaurally while noise was presented to the other ear. The reaction time and the types of answers were registered. The results show a specialization of different hemispheres for affective and linguistic prosody. Lateralization of linguistic prosody appeared to be a complex domain still remaining largely unexplained; some information types, i.e., ‘analytical ones,’ seem to involve the LH, while the others show a privileged role of the RH. Affective prosody is associated with RH mechanisms.

8. Conclusion

Our study of verbal thinking as a manifestation of cerebral asymmetry shows that LH and RH mechanisms provide for differently oriented cognitive styles of processing information. Thus, human thinking may be considered fundamentally heterogeneous, i.e., to be associated with the two cerebral hemispheres. Thinking provided by the LH is formal, analytic and characterized by probability; that provided by the RH rather is more metaphorical. Gestalt-like, mosaic-like (Chernigovskaya, Rottenberg and Shapiro, 1989). The LH thinking can be correlated with thinking in terms of scientific notions, such as is acquired in the secondary schools of the western type. It constitutes the basis
for natural languages and for the majority of traditional systems of artificial 
intelligence. RH thinking is comparable with children's preoperational 
thinking, and with metaphorical, prelogical or heterologous thinking in archaic 
cultures as well as with creative thinking of modern Western people. It is the 
RH thinking that provides for a holistic grasp of the highest possible number 
of connections, irrespective of their incompatibility, which leads to forming a 
polysemantic context.

Characteristic features of cognitive processes provided by RH and LH 
structures become apparent in completely different tasks studied by us in 
normal subjects as well (by non-invasive methods): in classification and 
imitation of speech sounds, in classification and description of colors, and in 
perception and description of odors. It should be stressed once more that it is 
the type of task a human subject faces that triggers one of the two modes of 
thinking, i.e., that brings into action the adequate brain mechanisms 
responsible for information processing.

Differences in types of tasks are more significant for determining which 
ehemisphere will be active than differences in thinking of people as a conse-
quence of belonging to different cultures and of speaking different languages. 
Translating this finding into the Sapir-Whorf hypothesis, we suggest that the 
operational relativity is more significant for mental activity than the linguistic 
one (see Tulviste, 1978). This suggestion seems to be justified by the findings of 
ontogenetic and cross-cultural research.

The existence of two main modes of consciousness — logical and meta-
orphic/empirical — is likely to have been of great adaptive value: the solution 
of a certain type of tasks requires a strictly formal, logical approach, whereas 
for other tasks much simpler solutions may be found by merely comparing the 
situation with previous ones, i.e., on the basis of one’s personal experience (cf. 

Finally it seems that human cognitive evolution is, somewhat simplified, 
the evolution of the Gestalt type of processing towards complicated conceptual 
symbols. This may well have been characteristic for the semiotic abilities of 
early hominids — like it is for young children in modern societies and for 
adults in archaic societies. It should be emphasized, though, that the earlier 
acquired symbolic abilities of the archaic type — in individual and 
society — never disappear.

The problems discussed in this paper seem to contribute to language 
origins studies in several respects: cognitive and linguistic universals; func-

Cerebral lateralization

ional lateralization of the human brain; differences in its capacities in ontology 
and phylogeny; cross-cultural, cross-language and cross-species communi-
tication, types of information processing; and some others (cf. von 
Raffler-Engel, 1991; Fidelholtz, 1991; Banak, 1980; Wind, 1983; Bichakjian, 
1988; Allott, 1989; Liska, 1986, 1990; Koch, 1992; Smith, 1985; Jonker, 

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